Reconfiguring the Traditional Gas Appliances in Residential Sector of Pakistan

From Gas-Based Appliances to Clean and Efficient Electrification Pathways

Agora Energiewende

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Pakistan’s gas sector in crisis: Introduction and context

Pakistan's residential gas dependence is no longer sustainable

- Natural gas has long been the backbone of Pakistan's residential energy system, but **mounting pressures threaten this foundation**.
- **Reserves crisis**: Domestic gas reserves are declining at 8.6% annually and will be exhausted within 10–12 years at current extraction rates, with no major new discoveries in recent years.
- **Supply shortfall**: Indigenous gas production meets only 65% of demand, with imports rising sharply over the past decade to fill the gap, now representing a significant portion of total supply (Figure 1)
- **Import cost burden**: LNG imports now comprise 25% of total gas supply at USD 10–12/MMBtu, compared to USD 4–5/MMBtu for indigenous gas, adding USD 4 billion annually to Pakistan's import bill.
- **Market volatility and forex risk**: Rising LNG dependence increases exposure to volatile spot markets and foreign-exchange fluctuations, adding uncertainty to energy costs.
- **Winter energy crisis**: Chronic gas shortages trigger routine winter load-shedding when demand peaks, creating a permanent feature of Pakistan's seasonal energy security challenge.

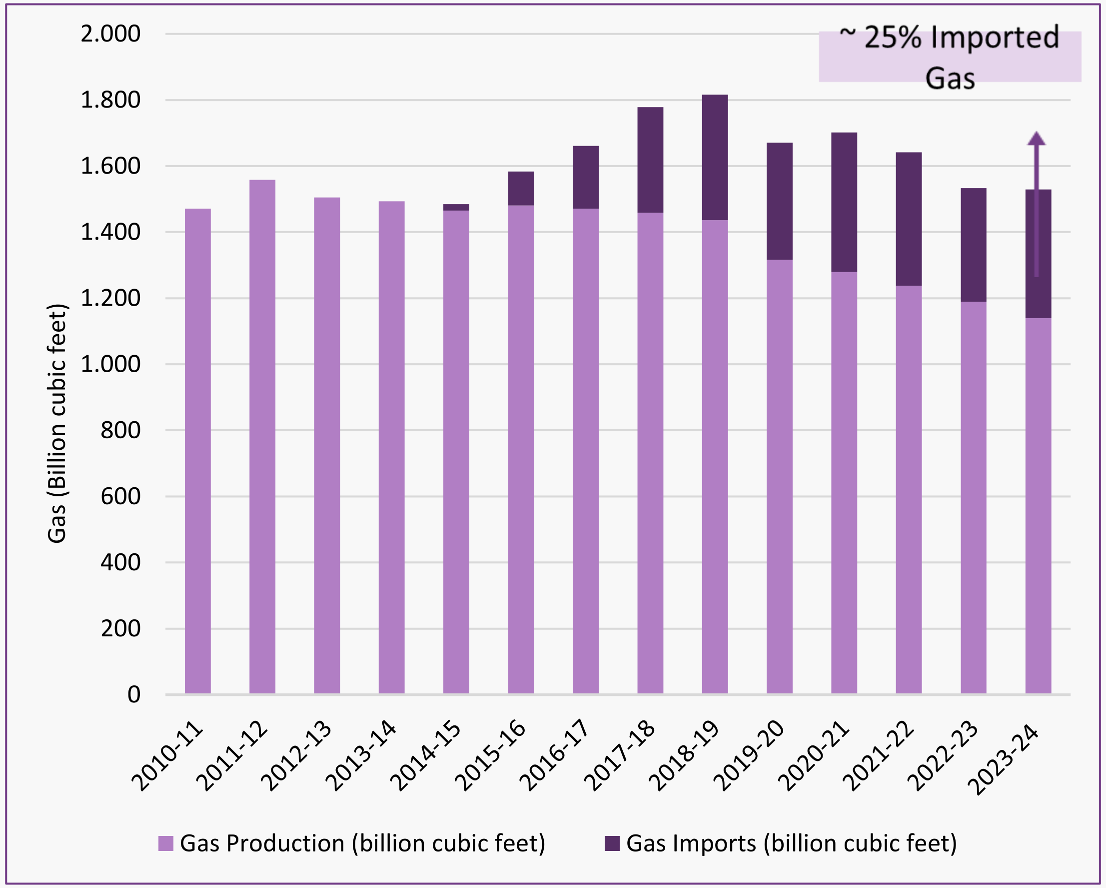

Figure 1.Local gas production and imports. Source: economic survey of Pakistan, 2025

Fiscal unsustainability in gas sector is also deepening due to system inefficiencies and unrecovered costs

- **Utilities struggle with cost recovery**: Pakistan's two state-owned gas distribution companies (SSGC and SNGPL) face compounding structural problems: high technical losses, weak billing systems, and tariffs that fail to recover operational costs.
- **System losses are significant**: Unaccounted-for-gas (UFG) losses in Pakistan's gas network far exceed global standards—16.2% in SSGC and 10.1% in SNGPL. This translates to PKR 2 billion lost per 1% increase in network losses.
- **Subsidies distort consumption patterns**: Artificially low residential tariffs weaken price signals. This encourages inefficient use patterns and accelerates the depletion of an already-scarce national resource.
- **Fiscal burden is unsustainable**: Gas-sector liabilities have exceeded PKR 3 trillion, driven by network losses, delayed payments, and non-cost-reflective tariffs. This magnifies the impact of supply shortages and places sustained pressure on already stressed public finances.

Sources: OGRA Petroleum Industry Report (2024); Abdullah, Fahad Bin, et al. "Addressing unaccounted-for-gas (UFG): Proactive techniques for optimal management and control." *Energy Strategy Reviews* 53 (2024): 101397.

Why residential gas electrification is the logical solution

Residential sector is one of the largest consumers of gas

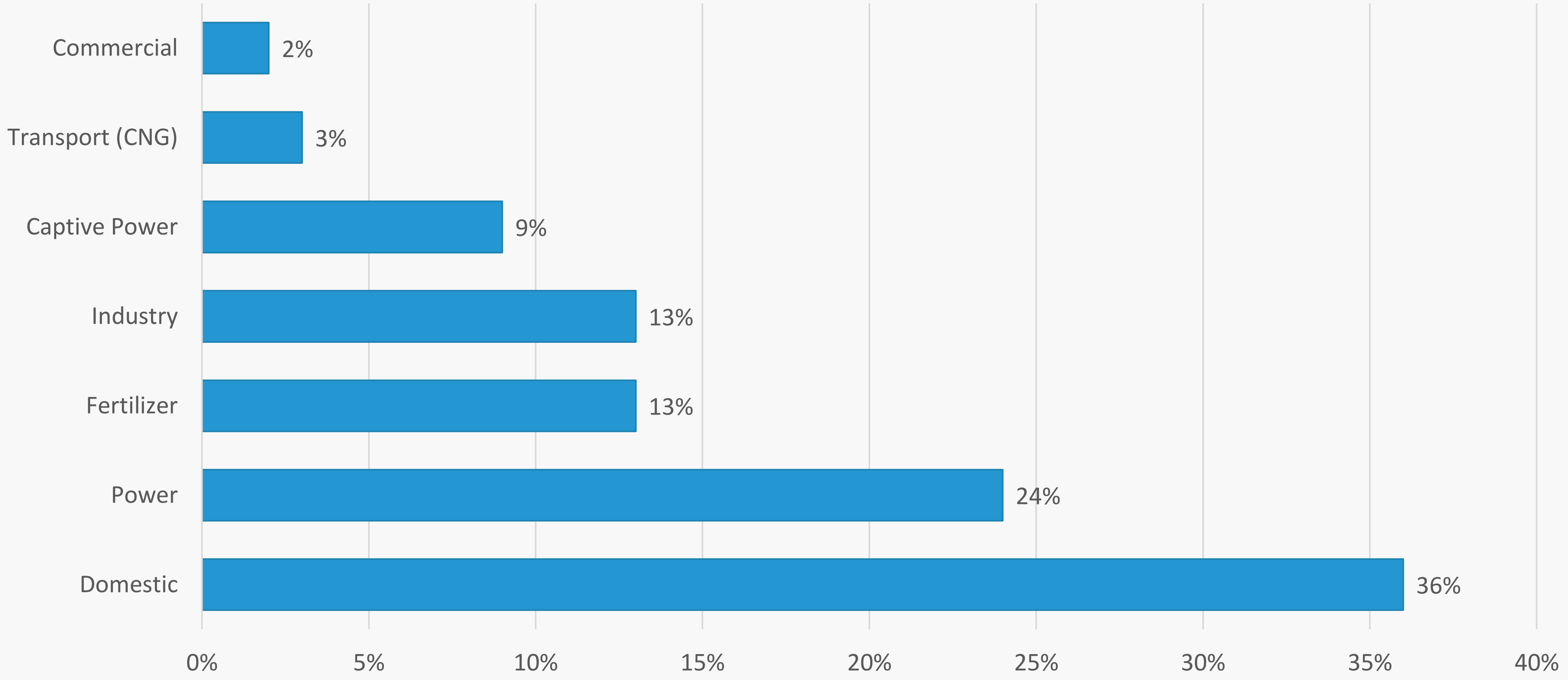

Figure 2.Sectoral gas breakdown. Source: SNGPL & SSGCL Annual Reports, 2023

The power sector has substantial unused capacity

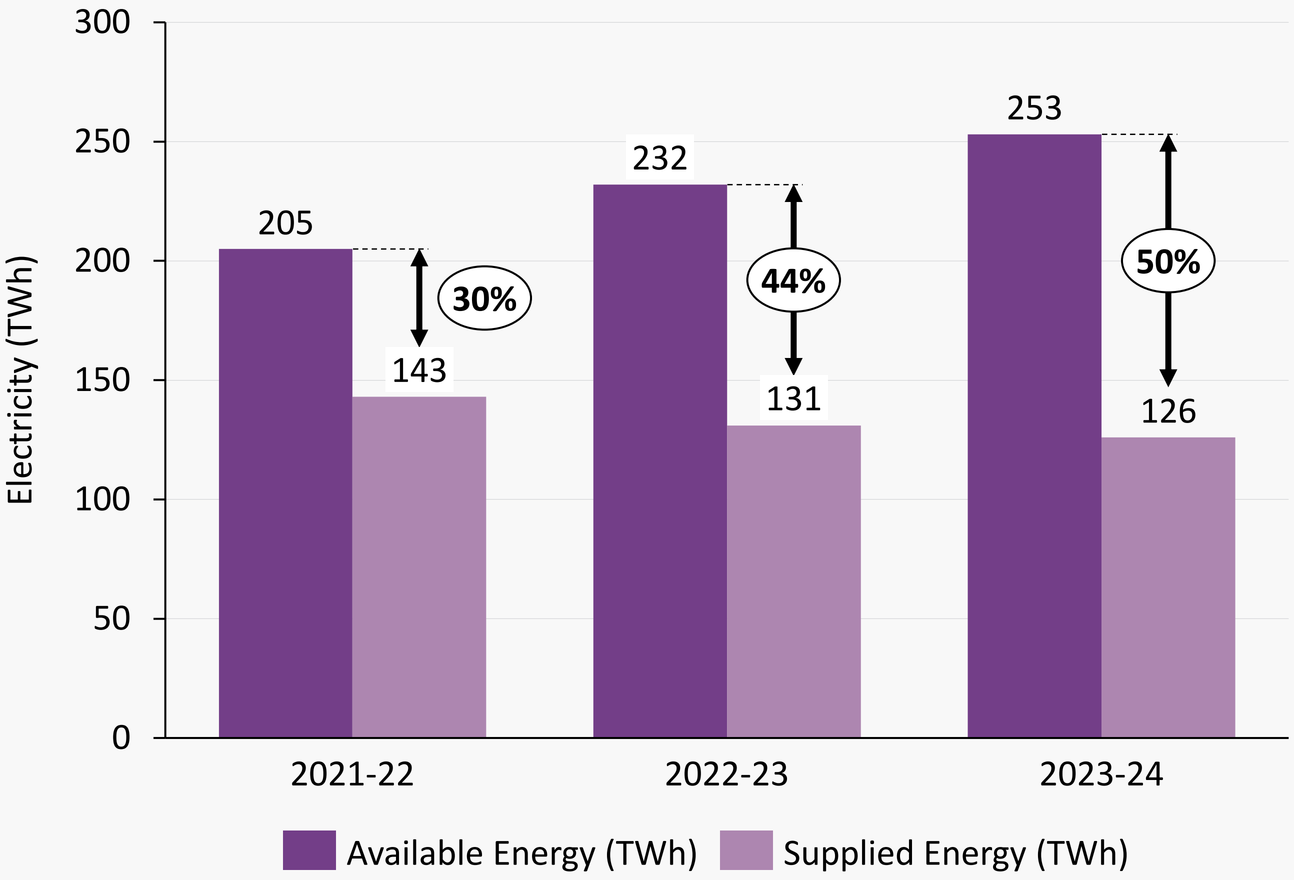

Figure 3. Available energy and supplied energy in power sector (TWh).

- → Pakistan’s current 50% surplus power capacity can readily accommodate new residential electric loads.
- → Also, every winter, Pakistan’s gas system collapses as residential gas demand triples in winter (from ≈ 60 → 190 m^3/household/month).
- → While around the same time, power demand drops, leaving more than 45 % of installed capacity idle.

The seasonal gas opportunity: Gas shortage vs power surplus

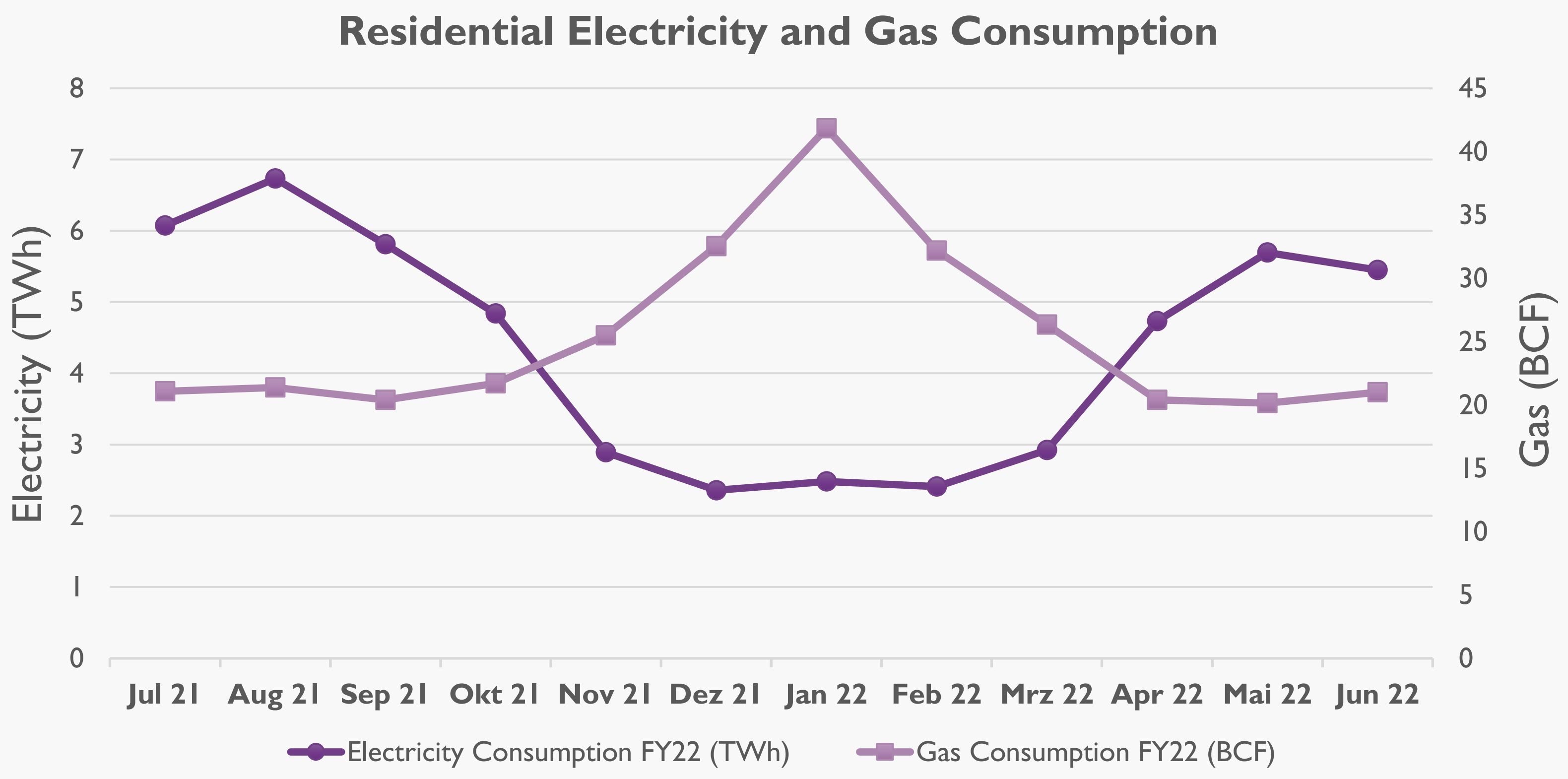

Figure 4.Residential Electricity demand and gas demand. Source. NTDC, SNGPL, and SSGCL .

- Pakistan has a sharp seasonal mismatch between gas demand and electricity demand
- Winter sees a surge in gas demand while electricity demand declines — presenting a perfect swap opportunity.
- This seasonal mismatch creates an arbitrage opportunity to shift heating loads to the electric grid without requiring new generation capacity.

Winter heating forces low-income households into unaffordable tariff slabs.

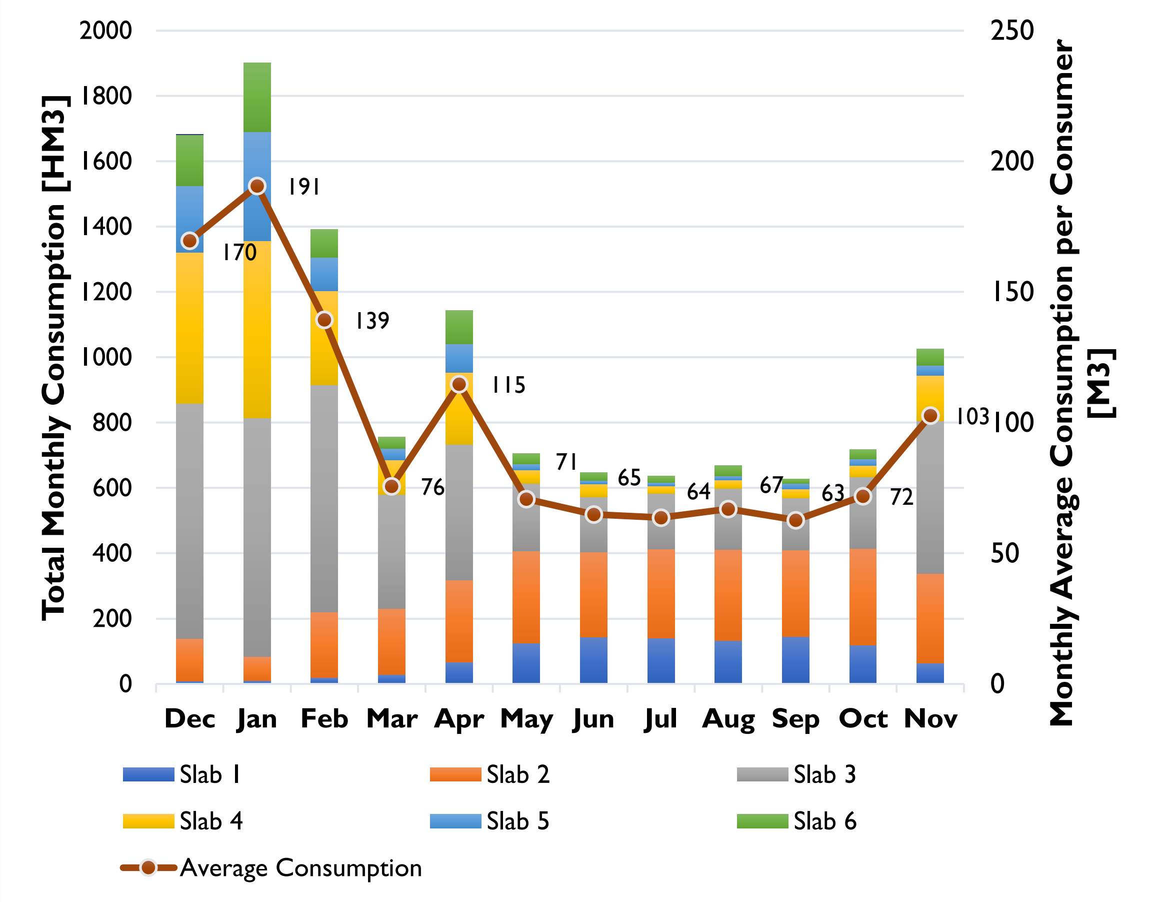

Figure 5.Monthly gas consumption and shift in tariff slabs. Source: OGRA Petroleum Industry Report (2024); Pakistan Energy Yearbook (2022)

- **Consumption Drivers:** Residential gas demand is comprised of baseload cooking consumption and seasonal winter heating peaks.
- **Progressive slab tariffs**: Pakistan's residential gas tariffs follow a stepped structure with lower rates for initial consumption and escalating rates for subsequent slabs, creating non-linear price increases.
- **Winter affordability crisis:** Approximately 68% of households are pushed into higher tariff slabs during winter, driven by increased heating demand.
- **Gas heating burden**: Winter heating turns gas into an unaffordable energy source for millions of middle- and low-income households.

Study objectives and methodology

This study uses data-driven scenario modelling to assess how electrification can provide a cost-effective pathway to reduce Pakistan's gas dependence

This study evaluates the cost-benefit and macroeconomic impact of transitioning residential gas demand to electric and renewable alternatives, assesses system readiness for electrification, and develops a phased implementation pathway for Pakistan.

Methodology: This analysis combines household gas consumption data with market-level appliance comparisons to model electrification scenarios and assess impacts on Pakistan's energy systems and economy.

Specific Objectives

1. Evaluate the cost-benefit and macro-economic impact of transitioning from gas to electric and renewable alternatives
2. Assess system readiness for electrification
3. Develop a phased and actionable pathway for near, medium and long-term.

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Analytical approach and outputs of the assessment

Analytical Approach

Analytical stage	Outputs
Residential gas demand profiling	• Analyzes household gas consumption data and appliance use information • Establishes seasonal demand pattern • Determines household income based on consumption pattern
Market assessment of electric appliance alternatives	• Identifies suitable electric appliance alternatives available in Pakistan market • Compiles retail prices, operation and maintenance cost, and efficiency parameters for each technology
Economics of household electrification	• Construction of affordability-driven electrification bundles by income group • Estimated CAPEX, OPEX and lifecycle costs across grid-only, integrated solar, and gas-based pathways.
Scenario Modelling	• Models Business as Usual (BAU, partial, and full electrification scenarios • Assesses economic implications across the three pathways
Power system impact assessment	• Evaluates power-system readiness and seasonal gas-electric load substitution
Policy recommendations	• Produces a phased implementation roadmap • Proposes policy actions across different phases

To evaluate the capital, operating, and lifecycle costs of residential electrification, three different electrification bundles are used

This analysis defines three household electrification bundles based on income classes and reflecting different levels of upfront cost affordability.

Affordability driven household electrification bundles

Income Classes	Electric appliances bundles
Low income households	Cooking: Hotplate/resistive/infrared (1-2 burners) Space heating: Quartz heater/fan heater Water heating: Instant tankless (<10L)
Middle income households	Cooking: induction cookstop (1-2 burners) Sace heating: Air source heatpump (≤ 1 ton) Water heating: Instant tankless or storage (<50 L)
Upper income households	Cooking: Induction cookstop (2 + burners)/hybrid induction Sace heating: Air source heatpump (1-2 tons) Water heating: Storage electric heater(50-100L)

- The cost of residential electrification transition is calculated by estimating capital, operating and lifecycle costs for income-based electrification bundles.
- Each electrification bundle represents a realistic combination of electric end use technologies that households could potentially adopt

Building electrification: Market assessment and economics of household transition

Market Research: Electric appliances have higher efficiency compared to gas-based alternatives but also higher upfront costs

COOKING	Technology	Retail Cost (PKR)	O&M Cost (PKR/year)	Efficiency
GAS	Gas stove	3,000–8,000	500–1,000	45%
ELECTRIC	Induction stove	15,300–35,000	0–500	95%
ELECTRIC	Induction + hotplate	78,000	0–500	85%
WATER HEATING	**Technology**	**Retail Cost (PKR)**	**O&M Cost (PKR/year)**	**Efficiency**
GAS	Instant geyser	8,000–15,000	500–1,000	60%
GAS	Storage geyser	12,000–20,000	500–1,000	50%
ELECTRIC	Instant geyser	17,500–32,900	0–500	95%
ELECTRIC	Storage geyser	20,000–61,000	0–500	85–95%
SOLAR	Solar water heater	100,000–270,000	2,000–5,000	50–85%
SPACE HEATING/COOLING	**Technology**	**Retail Cost (PKR)**	**O&M Cost (PKR/year)**	**Efficiency**
GAS	Radiant heater	5,000–12,000	500–1,000	60–90%
ELECTRIC	Radiant heater	1,500–19,350	0–500	95%
ELECTRIC	Air-Source heat pump (1.5 ton)	128,000–270,000	2,500–4,000	3–4 COP

- Gas stoves are 3–6 times cheaper than electric options, in parallel they typically operate at very low efficiency
- Electric instant and storage water geysers offer much higher efficiency (80–95%) than gas models (50–60%) at comparable prices.
- The retail price gap between gas and electric space heaters is relatively small, making switching financially feasible for many households.

Electric appliances are more capital intensive compared to gas appliances

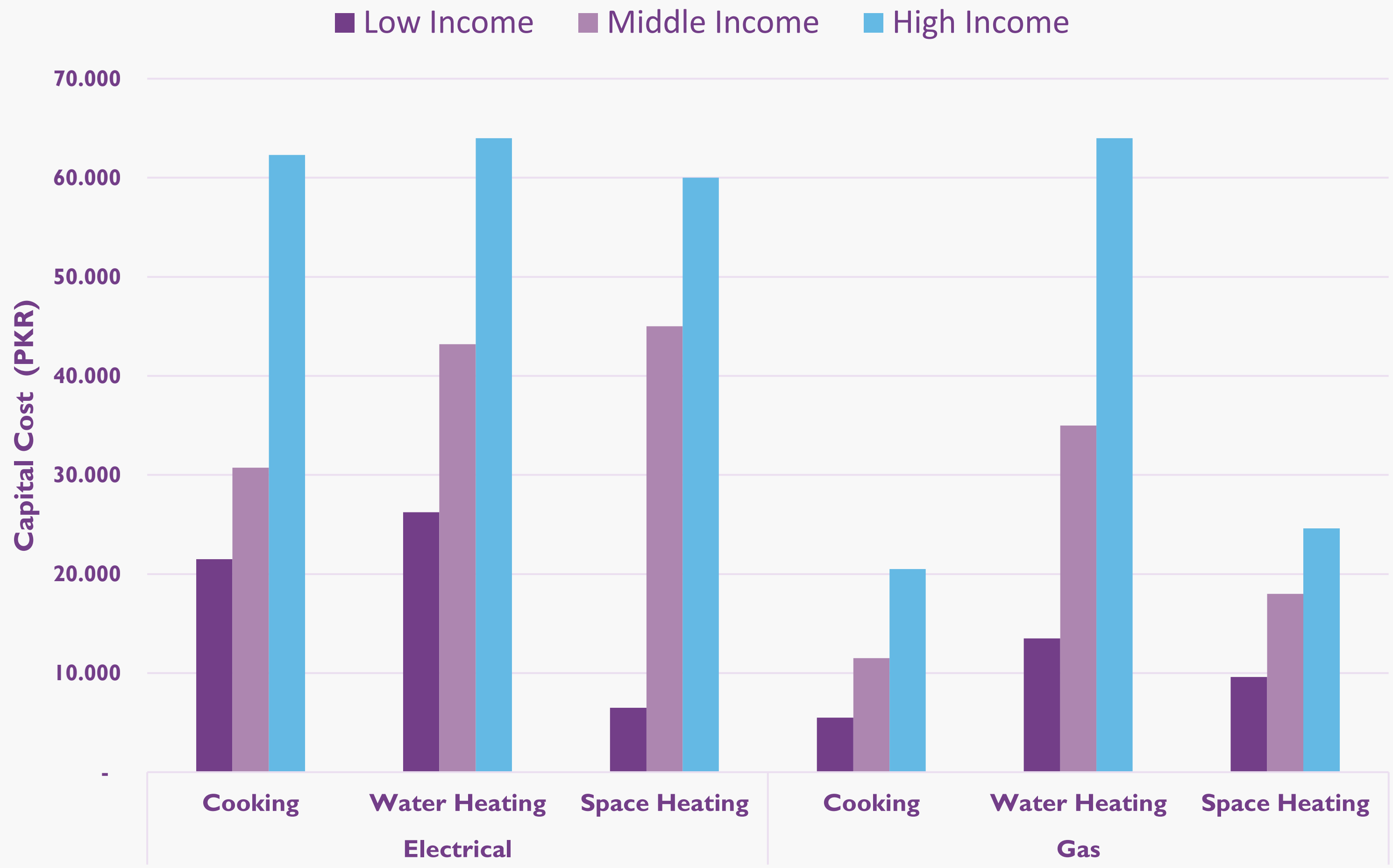

Figure 6. Capital cost comparison across electrification bundles and income groups.

- Gas-based appliances have lower upfront costs across all income groups, making them 3-4 times more affordable than their electric counterparts.
- The largest capital cost appear in air source heat pumps exhibit the highest capital costs posing a significant barrier to adoption.
- Upfront affordability could therefore influence and constraint shift to electric appliances.

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Lower operating costs however offset the higher upfront cost of electrification

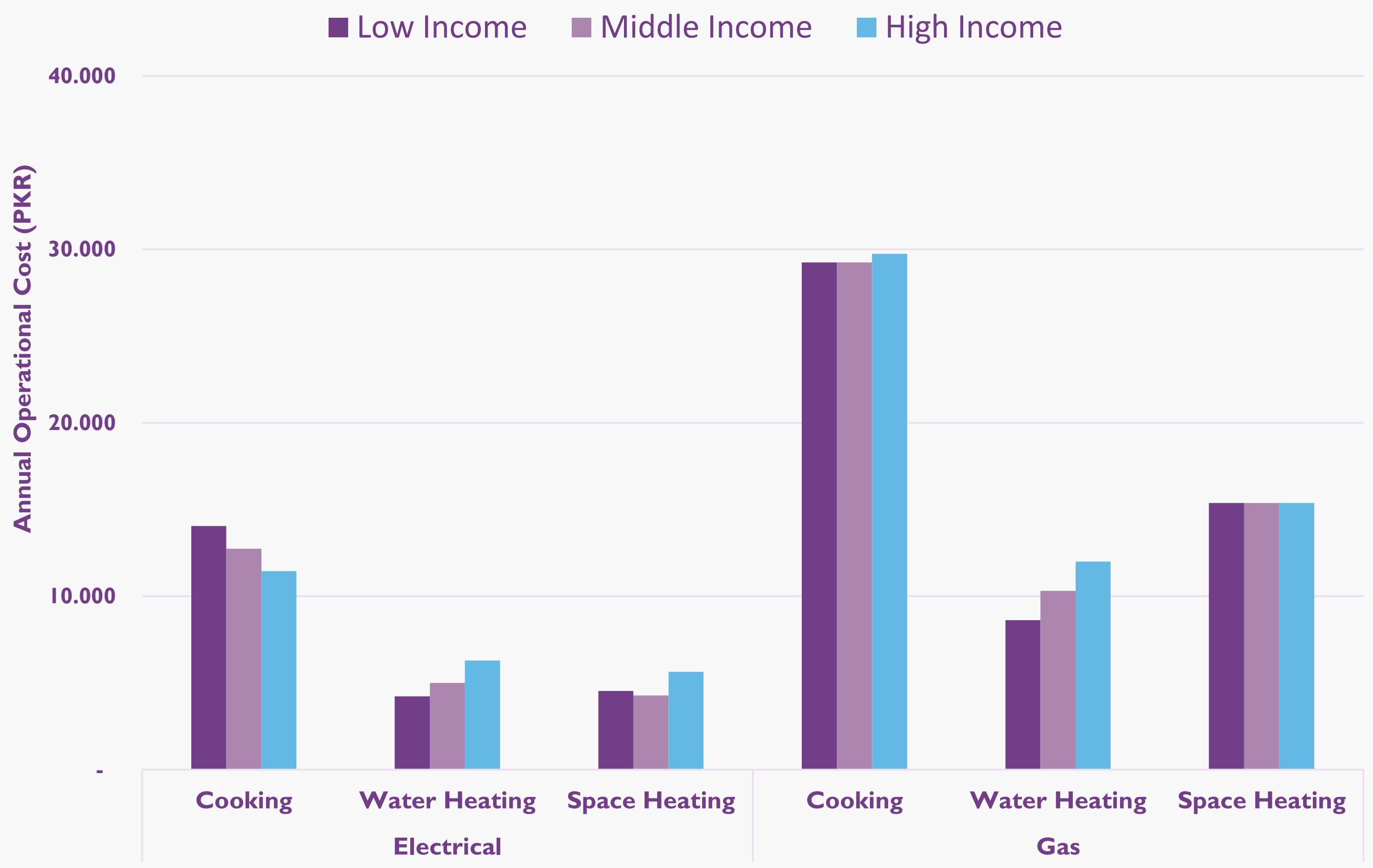

Figure 7. OPEX cost comparison across electrification bundles and income groups.

- Electric appliances show consistently lower operating costs across all income groups and end uses, reflecting higher efficiency.
- For space heating, gas-based systems cost roughly 3-4 times more to operate than electric alternatives across all household groups.
- Overall, electrification delivers **operating cost savings of 50–70%** across income groups, indicating that electrification delivers clear long-term economic benefits despite higher upfront investment

Compared to grid-only electrification, solar integration significantly lowers lifetime electrification costs across income-groups

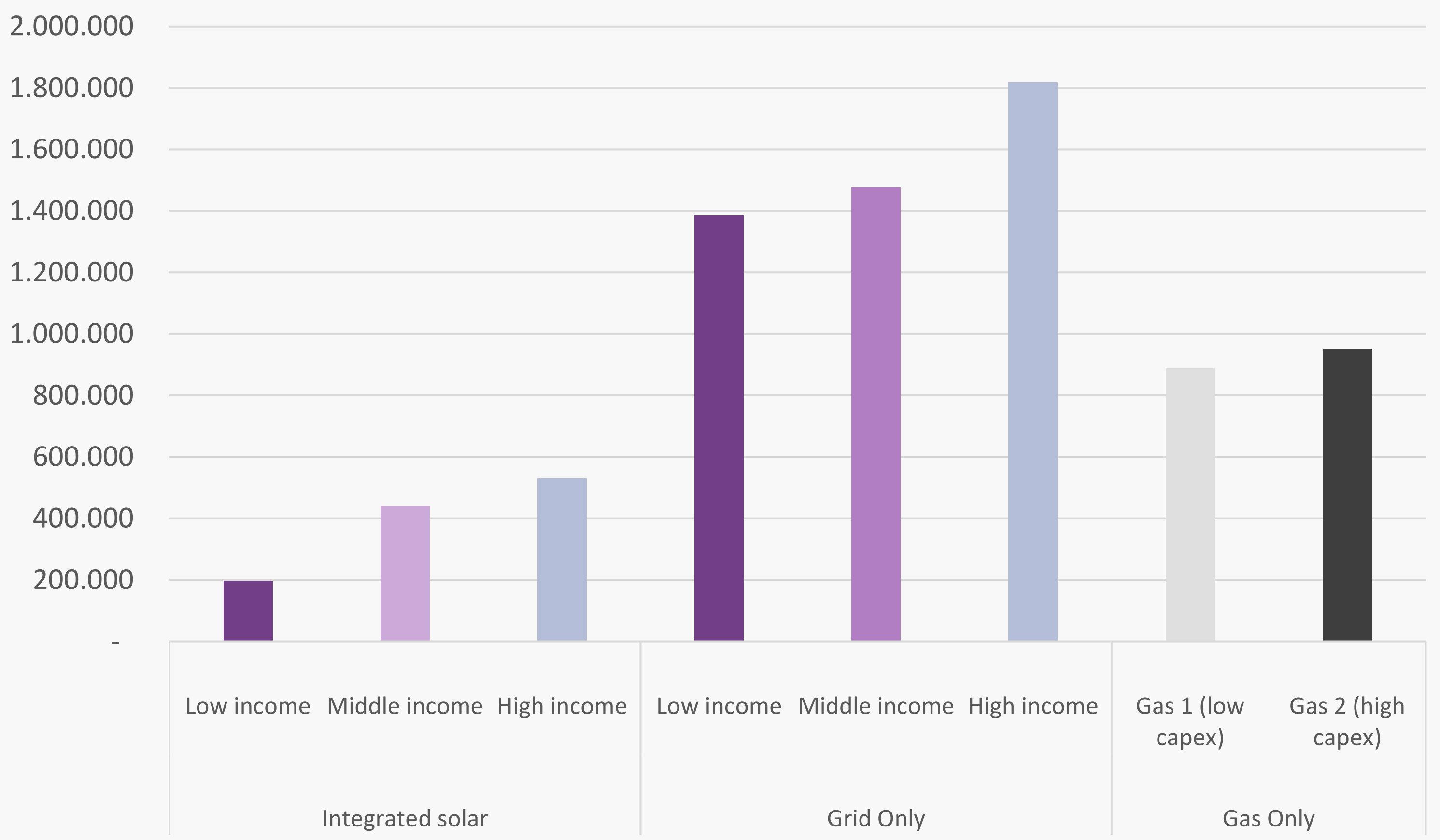

Figure 8. Lifecycle cost over 10 years (PKR).

- **Three configurations are compared**: For lifecycle cost over 10 years, here three system configurations are compared: Integrated solar (solar +grid via net-metering; Grid only , and Gas only use the same electrification bundles.
- Grid only and integrated solar use the same electrification bundle across income-groups. However, in the integrated solar scenario, a 3kW net-metered system has been assumed for low-and middle-income bundles—and a 4kW system for high-income bundle.
- Gas 1 and Gas 2 show two typical gas appliance configurations used to compare costs with electrification options. Gas 1 is relatively low capex, and it assumes a Gas Stove + Gas radiant heater + Instant gas water heater; Whereas Gas 2 assumes Gas stove+ Gas radiant heater+ Gas storage water heater

Scenario modelling

Possible electrification pathways: Business-as-usual, partial, and full electrification

To quantify and compare the economic and environmental impacts of electrification in Pakistan's residential sector, this analysis compares three scenarios:

- **Scenario A — Business As Usual (BAU)**
  - Gas use continues under current trends.
  - Persistent winter shortages, subsidies, and import reliance.
- **Scenario B — Only Space and Water Heating**
  - Space and water heating electrified.
  - Cooking remains gas-based.
- **Scenario C — Full Electrification**
  - All end uses (cooking, water heating, space heating) electrified.
  - Maximum gas, emission, and import savings.

Full electrification unlocks largest macro-economic gains

Gas reduction vs BAU in the residential sector

Indicator	Scenario A (BAU)	Scenario B (Only Space and Water Heating)	Scenario C (Full Electrification)
Gas demand (BCF/year)	299	190	-
Gas reduction vs BAU	–	37%	100%
Added electricity demand (TWh/year)	–	12	37
Import bill (USD bn/year)	3.95	↓ 1.67	↓ 3.59
Emission reduction ($MtCO_2e$/year)	–	6	16
UFG avoided (kt CH_4/year)	–	124.7	340.8
Winter–summer load gap	48.80%	↓ 36%	↓ 43%
Utility cashflow (PKR bn/year)	1930	↑ +380	↑ +1160

Implementation roadmap, power system impact assessment and recommendations

While full electrification delivers the largest economic benefits, achieving it requires a phased implementation sequencing

Phased adoption pathway to full electrification (2025-2050)

	2025-2030 Target (Phase I: Early Adoption Phase)	2030-2040 Target (Phase II: Scaling Phase)	2040-2050 Target (Phase III: Full Transition)
Cooking	~5%	~50%	~90–95%
Water Heating	~20%	~80%	~95–100%
Space Heating	~15%	~70%	~90–95%

- Full electrification delivers the largest macroeconomic benefits and emission benefits across all scenarios analyzed.
- Shifting to full electrification requires sequencing the transition over a realistic timeframe.
- Space and water heating are the primary drivers of winter gas demand spikes. Prioritizing heating electrification could deliver immediate relief to gas system by targeting seasonal gas demand peaks and easing winter gas shortages and tariff pressures.
- Cooking electrification can be scaled later as market penetration improves and behavioral acceptance increases.

A steady and gradual transition from gas to electricity in the residential sector can enable manageable demand growth in the power sector

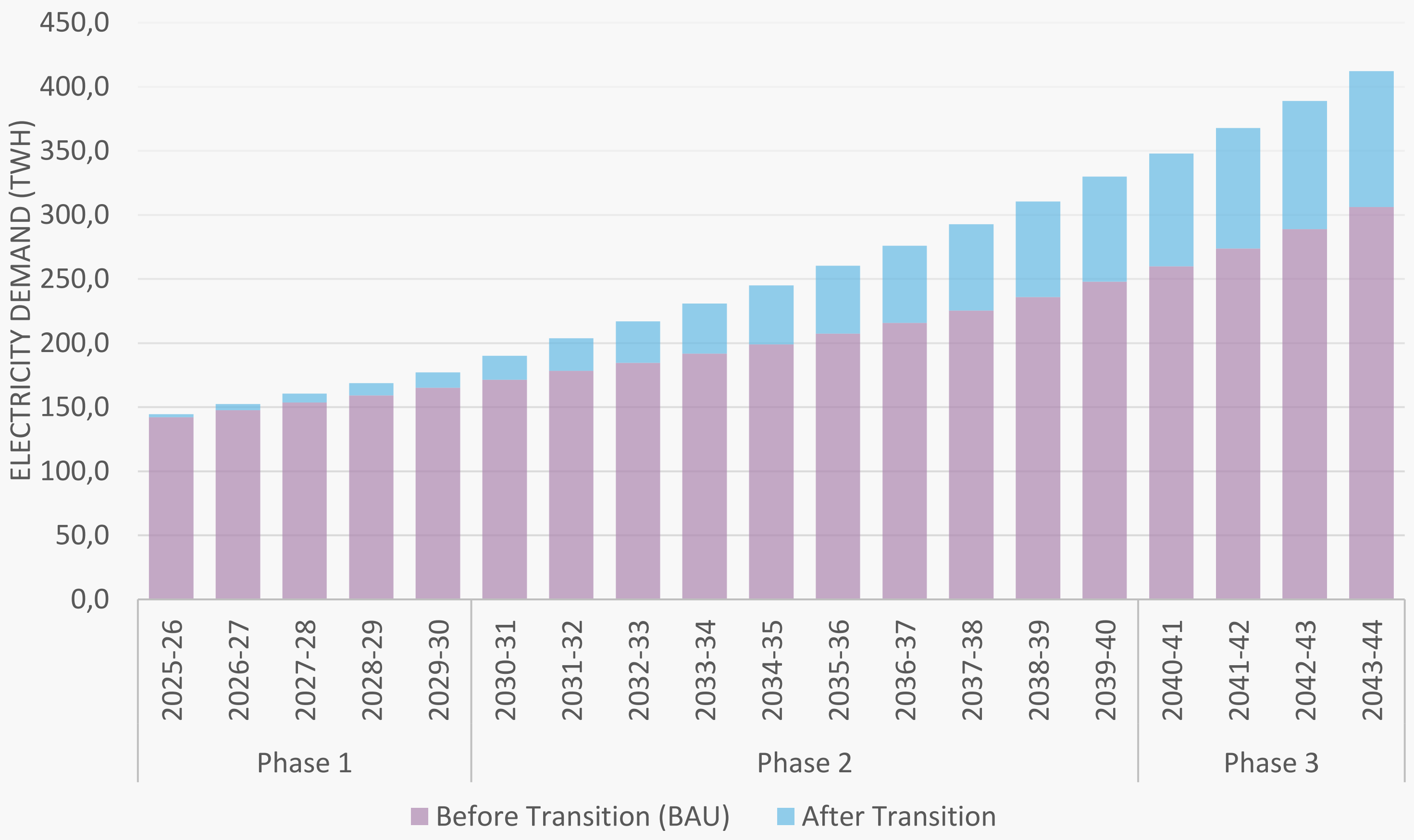

Figure 9. Increase in electricity demand under phased residential electrification

- In **Phase I**, the transition of heating and cooking loads to electricity will easily **utilize existing surplus generation**, particularly during winter months when gas shortages are most acute and power demand is low.
- As electrification expands in **Phase II**, **winter electricity use increases**, narrowing the **summer–winter load gap**, improving capacity utilization, and enhancing overall system efficiency.
- By **Phase III**, electrification remains **technically feasible** if supported through **proactive system planning**, including demand-side management, flexible dispatch, distributed solar integration, and potential generation addition.

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Phase 1: By 2030 electrification increases winter electricity demand by ~2.25 TWh

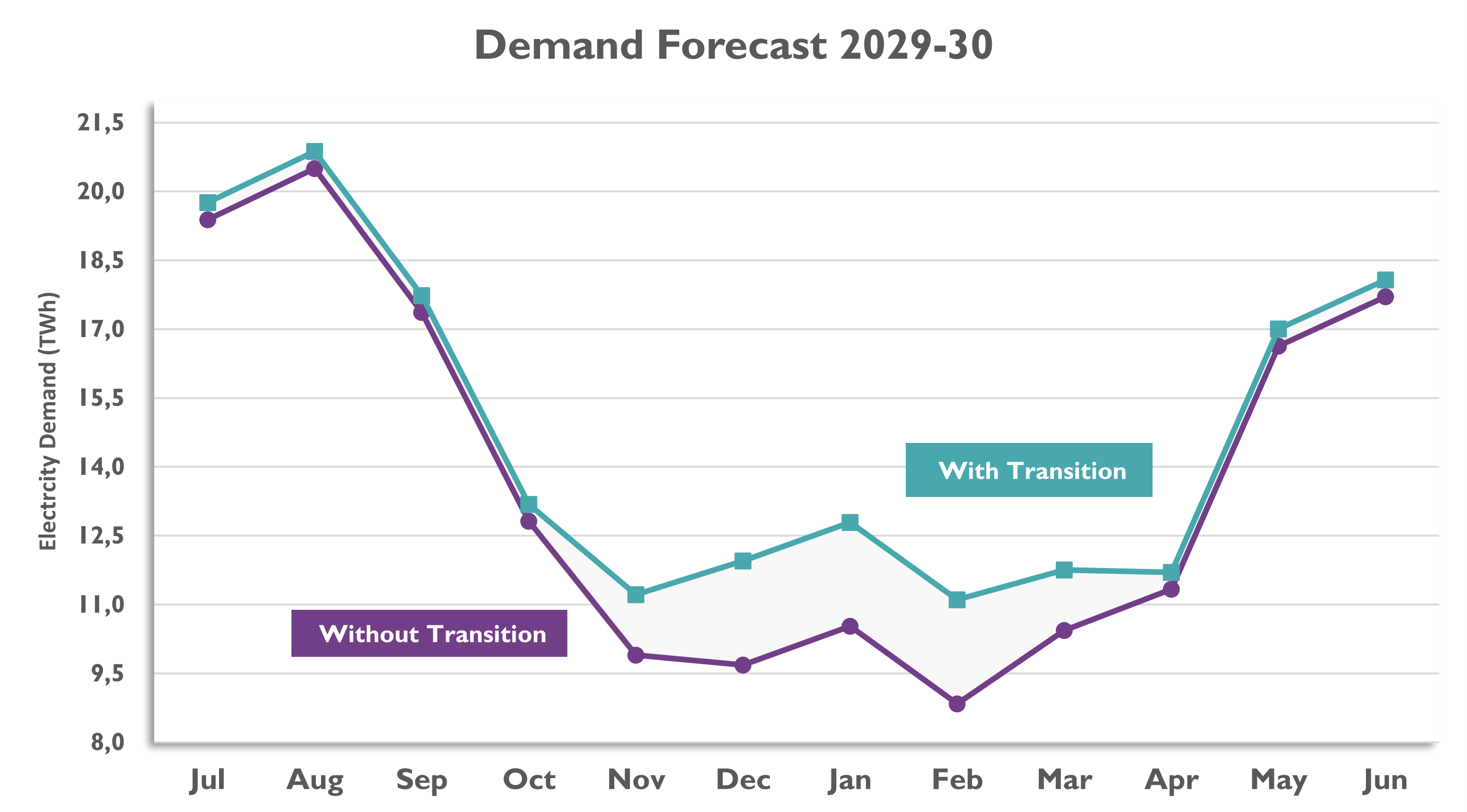

Figure 10. Electricity demand forecast 2029-2030 (TWh).

- By 2029-30 winter demand rises from 9.75 TWh (BAU case) to 12 TWh.
- Heating electrification is the primary driver of the demand growth.
- Summer demand remains largely unchanged, reflecting only slight change in cooking electrification.

Phase-2 By 2040, electrification reduces summer-winter demand gap by 60-70%

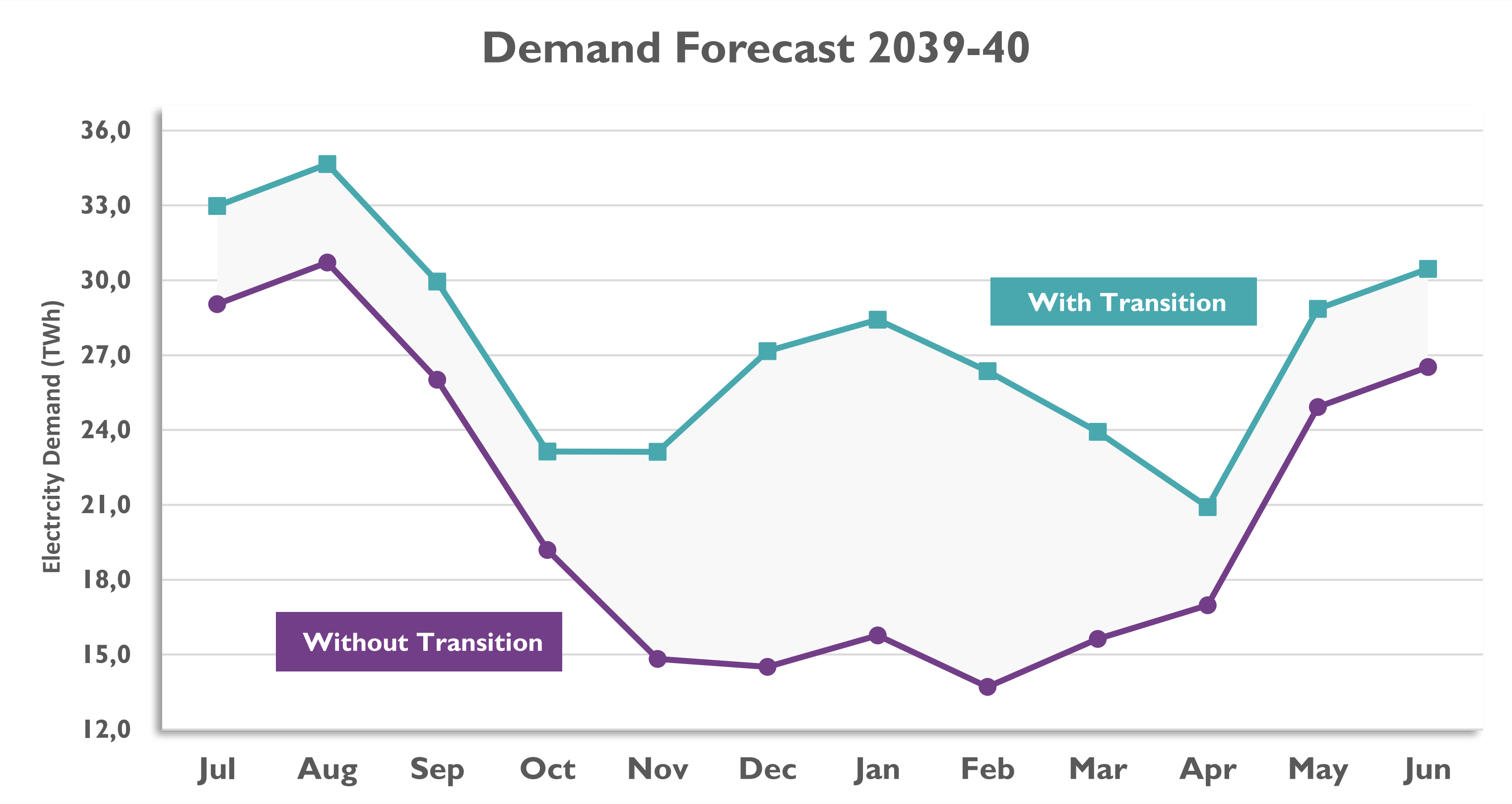

Figure 11. Electricity demand forecast 2039-40 (TWh).

- As electrification scales in Phase II, electricity demand rises in both winter and summer.
- By 2040, Summer demand hits 33 TWh (compared to 30 TWh in BAU case), while Winter demand reaches 27.25 TWh (up from 15 TWh under BAU).
- This shift results in slightly more balanced demand profile across seasons enhancing system efficiency and reducing seasonal underutilization of grid.

Phase-3 Electricity Demand Profile under Full Electrification

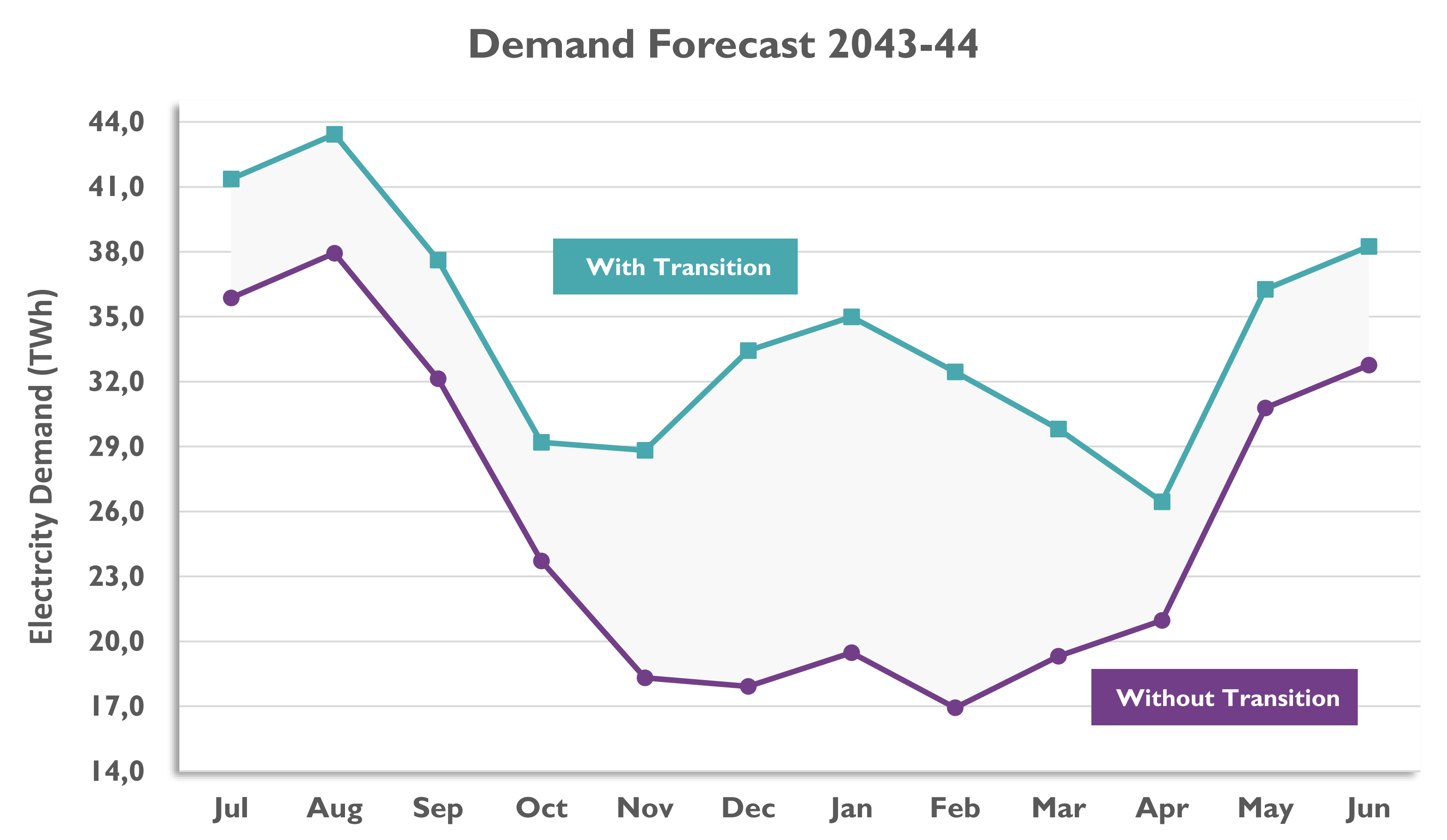

Figure 12. Electricity demand forecast 2043-2044 (TWh).

- By 2044, winter peak demand reaches 34 TWh—while summer peak demand reaches 43 TWh (up by 5 TWh from pre-transition levels.
- Electrification further narrows the seasonal demand gap by 60-65%, promoting year-round balance.
- By Phase III, electrification remains technically feasible if supported through proactive system planning, including demand-side management, flexible dispatch, distributed solar integration, and potential generation addition

Compared to BAU, the power system can absorb the shifting loads from residential gas sector with phased planning

Early-phase electrification is absorbed using existing surplus capacity, while later phases remain feasible with targeted planning and demand-side management

Phase	Additional load impact	Grid absorption capacity	Planning needs	System effect
I (2025–2030)	Minor (≈ 2.25 TWh in Winters)	Easily absorbed (idle winter capacity)	Limited	Utilizes surplus
II (2030–2040)	Moderate (≈ 3 TWh in Summers ≈12.25 TWh in Winters)	Feasible with power sector and grid planning	Tariff rationalization, Demand Side Management (DSM), Distributed solar/storage, distribution system upgrades, grid modernization.	Achieves winter–summer parity
III (2040–2045	High (≈ 5 TWh in Summers ≈14 TWh in Winters)	Feasible with power sector and grid planning	DSM, Distributed solar/storage, distribution system upgrades, grid modernization, potential generation addition, planning of new networks.	Improves capacity factor, grid stability

Recommendations for a residential electrification action plan

	Federal	Provincial
Phase I: **2025–2030** *Enable and De-risk*	• Restructure electricity tariffs to support electrification • Apply energy-only tariffs to incremental winter electric heating demand and rebate capacity charges. • Integrate residential electrification in grid expansion planning • Implement "no new gas connection" rule for residential buildings and housing schemes starting 2026.	• Launch province-led electrification pilots for cooking, water, and space heating. • Enable combined rooftop solar and appliance electrification through concessional finance and targeted appliance support. • Remove provincial taxes and duties on electric appliances and rooftop solar. • Support consumer awareness, training, and after-sales service ecosystems.
Phase II: **2030–2040** *Scale and Lock-in*	• Mandate all-electric standards for new residential buildings through national building codes • Reform gas pricing by reducing subsidies and aligning tariffs toward WACOG to reflect true system costs • Prioritize early upgrades to distribution reliability and voltage quality to ensure consistent winter supply • Establish national electrification funds and blended finance mechanisms • Begin managed phase-down of new residential gas connections and appliances sale	• Implement large-scale retrofit programs in urban and public housing • Design income- and tenure-sensitive support schemes for low- and middle-income households • Expand workforce training for electric appliances, retrofits, and solar integration
Phase III: **2040–2050** *Complete and Manage*	• Legally complete the residential gas phase-out and electrification transition • Manage gas network repurposing and stranded asset risks • Align electrification outcomes with net-zero targets, NDC commitments, and just transition frameworks for affected workers and institutions	• Ensure all inclusive household coverage, including vulnerable, informal and underserved areas • Maintain long-term enforcement, safety, and quality standards • Monitor performance, affordability, and service quality at the local level

Key Findings

1 **Modernising household energy use in Pakistan through electrification can lower costs, strengthen energy security and improve system efficiency.** With declining domestic gas supply and rising import dependence, reducing residential gas demand can ease fiscal pressures on the state while improving affordability for consumers through supportive electricity tariffs and targeted financial support

2 **Fully electrifying household gas appliances by 2050 could deliver around USD 23.8 billion in fuel import savings relative to the current trajectory and avoid nearly 108 million tonnes of carbon emissions.** It would also address Pakistan's seasonal energy imbalance, where winter household gas demand rises sharply for space and water heating while electricity demand falls, leaving significant generation capacity underutilised. Shifting demand from gas to electricity would improve overall system alignment and utilisation.

3 **Widespread adoption of electric cooking and heating requires an integrated institutional architecture that makes grid-connected solutions economically viable.** Distributed solutions are already cost competitive for many households. Scaling quickly requires policy that supports sustainable off-meter deployment while ensuring system-wide efficiency. Aligning regulation, electricity tariff reform and targeted finance can enable system optimisation and lower barriers to household-level distributed energy.

4 **A phased electrification strategy can convert future demand growth into a planning advantage.** Prioritising electrification of heating systems between now and 2040 and gradually transitioning to full electrification by 2050 would allow sufficient time for grid modernization to smoothly integrate new household electricity load profiles in parallel with renewables uptake.

Thank you for your attention!

Do you have any questions or comments?

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