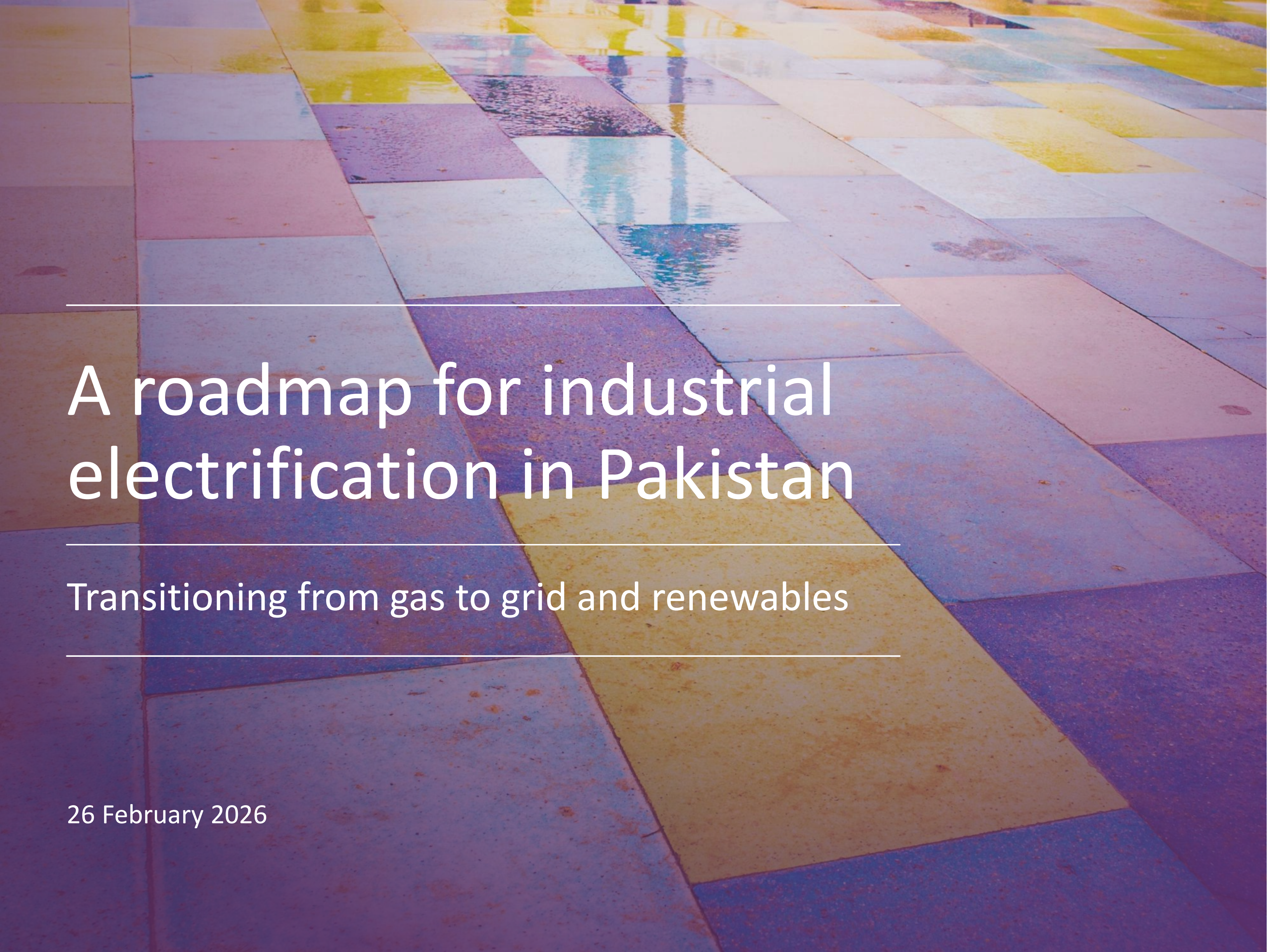

A roadmap for industrial electrification in Pakistan

Transitioning from gas to grid and renewables

26 February 2026

Agora
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Policy Research Institute
for Equitable Development

Key findings

1 **By electrifying industrial heat, Pakistan could cut industrial emissions by up to 50 percent by 2050 compared to the current trajectory, while delivering energy savings of around 36 percent.** This would help close the widening gas supply gap, reduce reliance on costly imported liquid natural gas and ease circular debt by replacing inefficient gas use with more cost-effective electric heat. To maximise benefits, electrification should align with growing renewable capacity – especially on-site solar – and improve utilisation of existing generation assets.

2 **Industrial process heat electrification is economically viable for low- and medium-temperature applications, particularly in food and beverages, textiles, paper and pulp, and fertilisers.** These sectors account for about half of industrial GDP and play a major role in Pakistan’s energy use. Electrification can cut operating costs, improve energy reliability and reduce exposure to volatile gas supply and pricing. As the grid integrates more renewables, especially solar PV, flexible industrial demand can also absorb surplus generation, easing grid congestion.

3 **Boosting electric heat in industry requires supportive electricity tariffs, financing incentives for appliances and regulatory reforms to modernise power grids.** Industrial electrification must go hand in hand with solar integration, coordinated investment in both technologies and grid upgrades to ensure widespread uptake. Stable policy signals and clear regulations can de risk projects, mobilising joint investment in grids, renewables and industry electrification.

4 **A phased national strategy sequenced by technoeconomic readiness can position industrial electrification at the core of Pakistan’s energy transition and industrial modernisation.** This could begin with textiles and food processing this decade, expand to paper and pulp in the medium term and reach energy-intensive sectors like chemicals, fertilisers and steel by 2050. Coupled with coordinated industrial and energy planning, this approach can boost competitiveness and resilience, safeguarding Pakistan’s export access in carbon-regulated markets.

Introduction, scope and method

Greenhouse gas emissions profile in Pakistan’s sector

Fig. 1: Industrial emissions in Pakistan

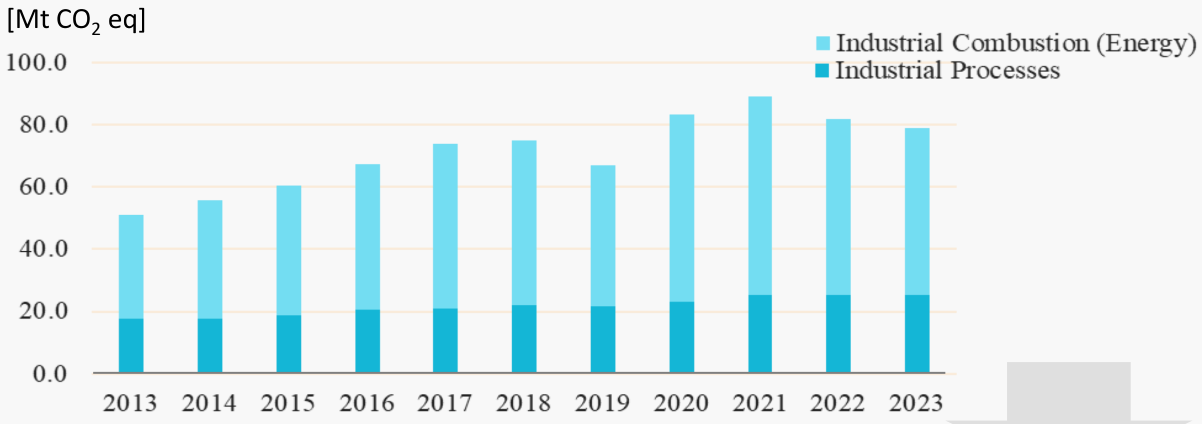


Fig. 3: Industry-wide emissions in Pakistan in 2024

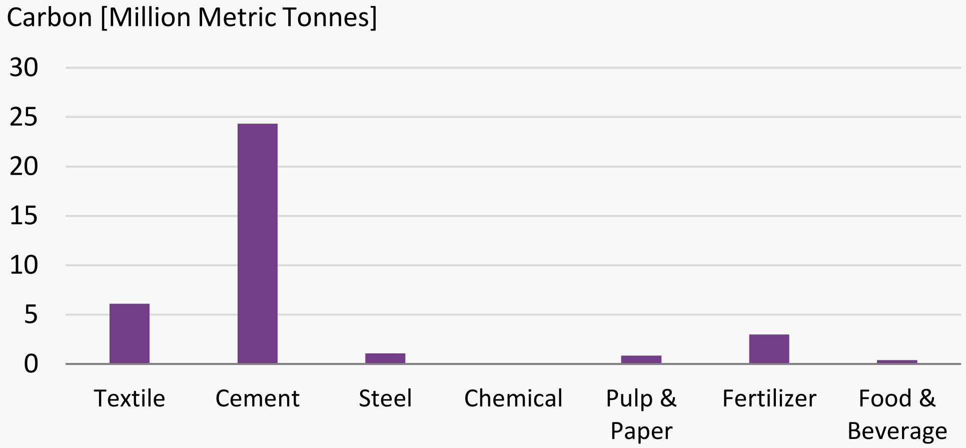
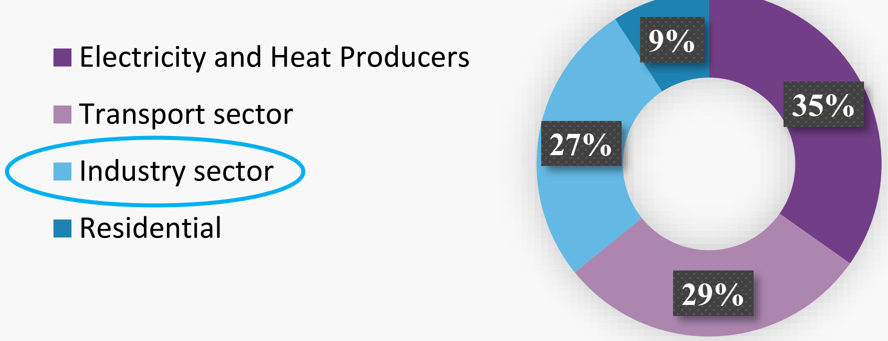


Fig. 2: Sectoral emissions in Pakistan



- **Pakistan's industry sector accounts for a significant share of total final energy use**
- **The cement sector has the highest carbon emissions followed by the textiles and fertiliser sectors**

| Fig. 1: World bank Database; Fig. 2:IEA (2023); Fig. 3: Policy Research Institute for Equitable Development (2026)

Textiles industry has the second highest energy demand and is the highest contributor to export share and industrial GDP share

Figure 4. Fuel mix of the industrial sector.

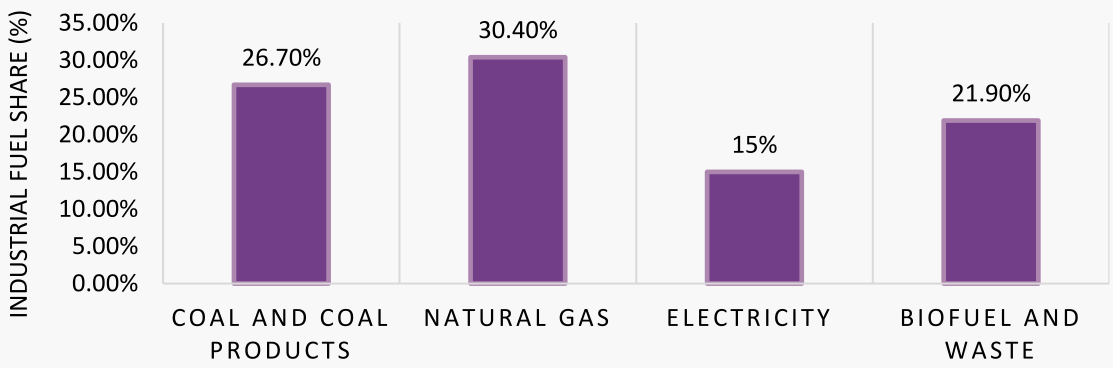


Figure 5. Industrial GDP share.

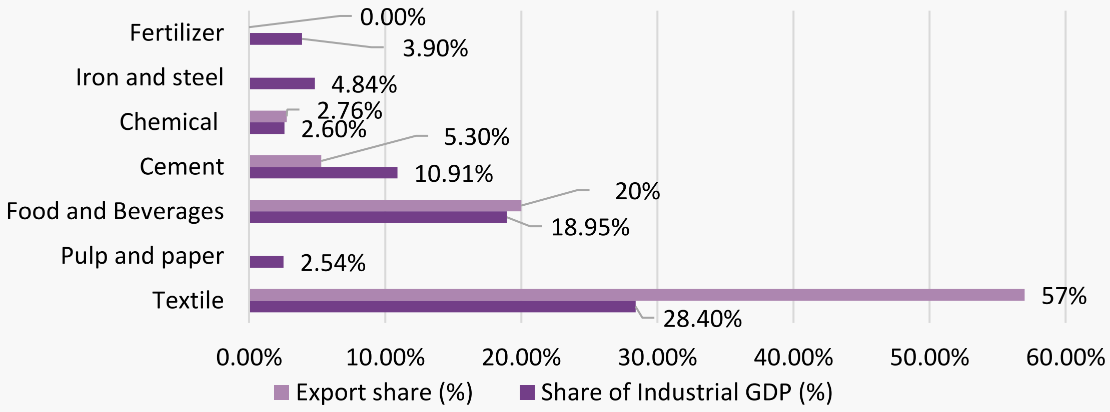


Table 1. Industrial energy consumption

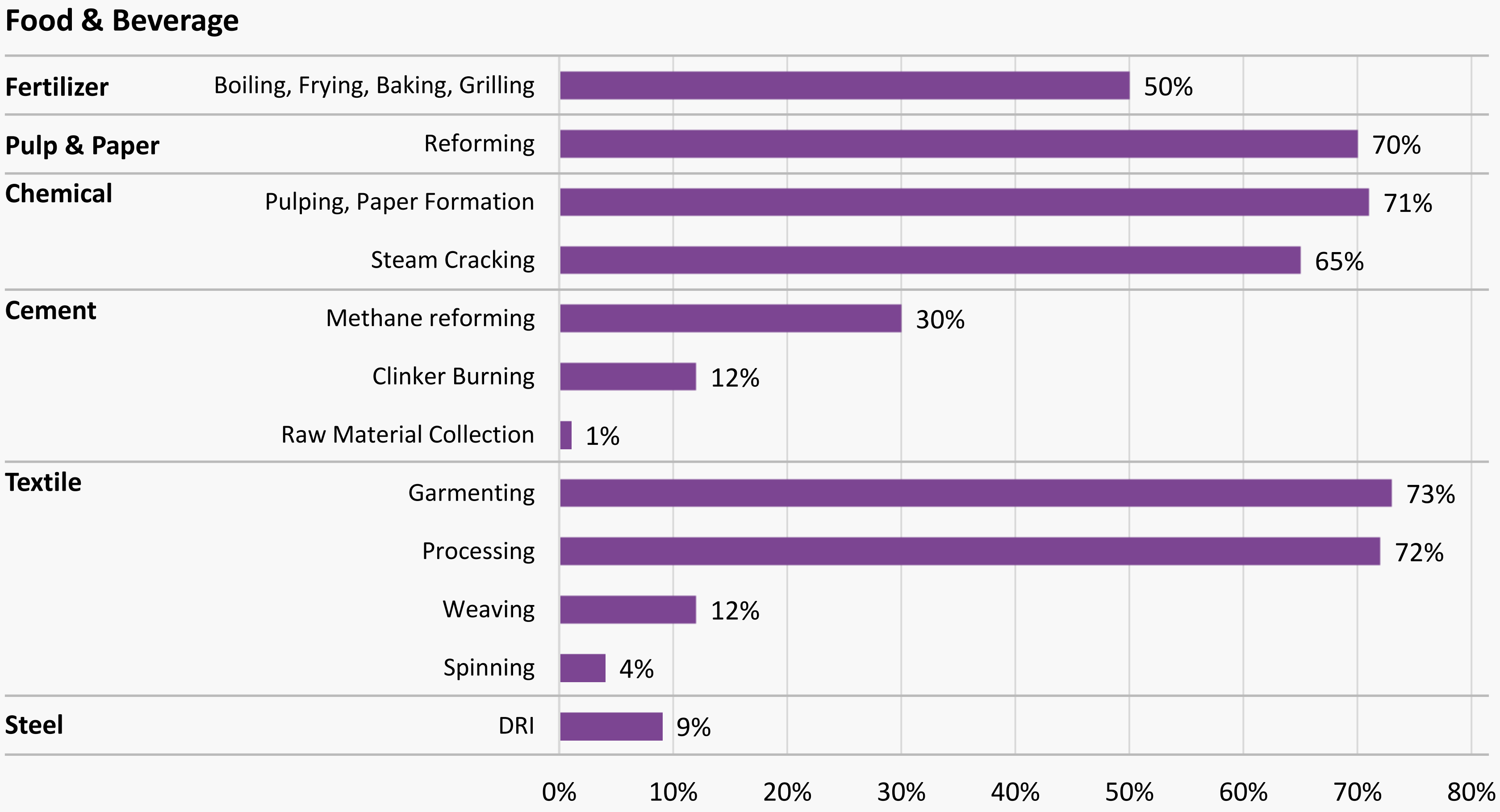
Sector	Energy Demand (kTOE)
Cement, glass and nonmetals	8755
Textile	3235
Chemical and Fertilizer	2930
Iron and steel	1100
Pulp and paper	454
Food and Beverages	132

Table 2. Gas consumption in industrial sub-sectors

Industry	Gas	Electricity	Coal	Oil /Pet.	Biomass	Others
Fertilizer	70%*	0.73%		18%	11%	
Pulp and Paper	60%	13%			27%	
Food and Beverage	50.6%	33.8%	8.8%	6.8%		
Chemical	42%	8.7%		35.7%	13.6%	
Textile	23%	42%	20%			15%
Cement	12%	1.2%	80%			
Steel	9.3%	80%	7%	3.7%		

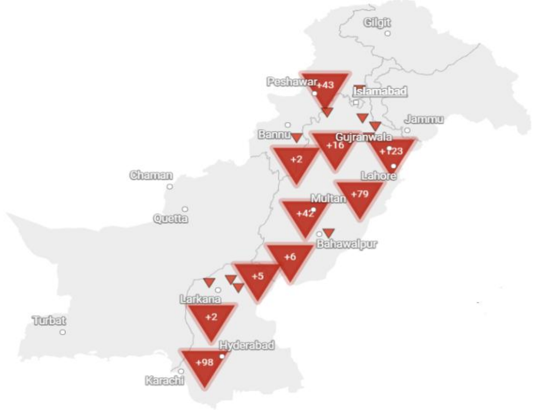
Process-level gas use across industries

Process-wise gas consumption share.



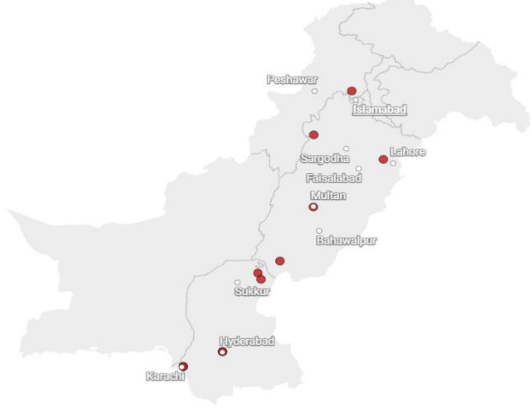
Industrial landscape – where industry is located in Pakistan

Textiles industry

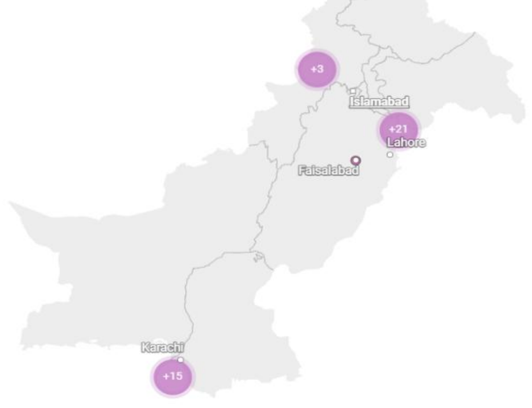


Chemicals industry

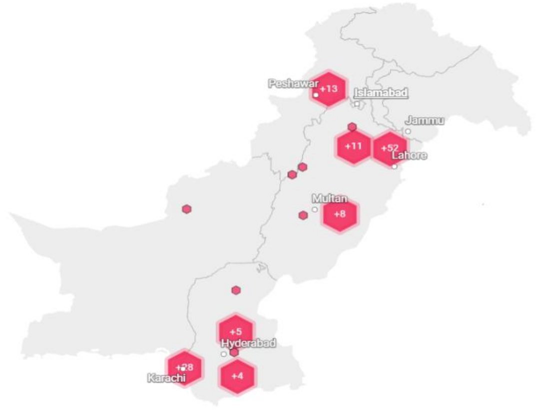
Fertiliser industry



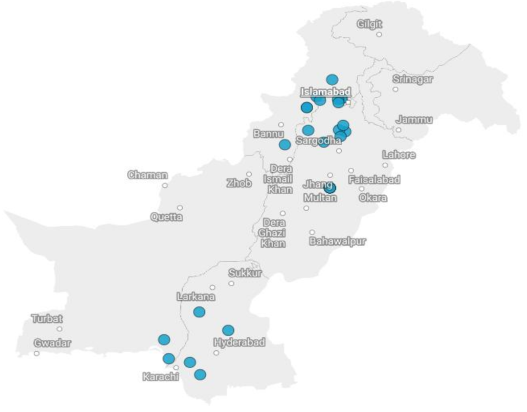
Pulp and paper industry



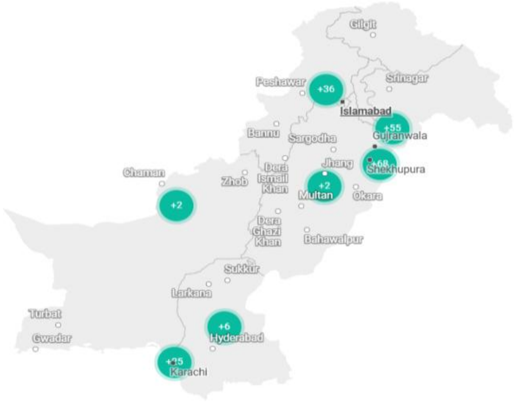
Food and beverages industry



Cement industry



Steel industry



Numbers in the boxes indicate number of industries in that region

Study objectives and rationale

→ Pakistan’s gas sector is increasingly stressed by a widening supply-demand gap, rising reliance on expensive imported RLNG, mounting circular debt, and higher emissions. In contrast, the power sector has surplus generation capacity that could be leveraged to electrify gas using industries and provide cleaner industrial heat.

→ This study aimed to assess electrification potentials of process heat generation across industrial subsectors and processes in Pakistan.

1. To **map industrial gas usage** by process and temperature and **identify feasible alternative electrification technologies**.
2. To **model scenarios** to assess the **environmental, economic, and financial benefits** of replacing gas with **grid electricity or on-site renewables**.
3. To **analyse grid feasibility** for **industrial integration,** while ensuring **grid reliability** through a **phased implementation plan.**

Technology mapping and market readiness

Most gas-based industrial processes in Pakistan already have viable electric alternatives with moderate to high technology readiness

Technology mapping

Industry	Gas-based process	Existing technology			Alternative technology (electricity/RE)				
		Gas-based	Efficiency / COP	Temperature ranges (°C)	Electricity-based	Efficiency / COP	Technology Readiness Index for Pakistan (1 to 10)		
							Low (1 to 5)	Medium (5 to 8)	High (9 to 10)
Steel Industry	Iron making	Direct Reduced Iron (DRI)		>1600	H_2DRI			■	
Textile Industry	Processing	Singeing machine	70%	60	Electric singeing machine				■
		Pre-washing chambers		50	Electric boiler	90%			■
		Steamer	Up to 90%	98	Electric steamer	90%			■
		Main washing steam boiler	94 to 95%	450	Electric main washing boiler	99%		■	
		Dryer	35 to 40%	140	Electric dryer, heat pump	63 to 69%, 1.5 to 6.0			■
		Mercerising (dryer)		140	Electric dryer, heat pump	63 to 69%, 1.5 to 6.0			■
		Pad steam dyeing unit	70 to 80% (Boiler)	50–98	Electric steam pad dying, heat pump			■	
		IR burner	65%	760–900	Electric burner			■	
		Thermosol monforts dyeing		50–98	Electric boiler	90%			■
		Stentering machine	69.37%	170	IR heating	85%		■	
		Sanforising machine		130	Electric sanforising unit		■		
		Calendering machine	95%	200	Induction heated roller	87 to 92%		■	
	Garmenting	Iron machine	93%	200					
		Steam boiler	94 to 95%	100–450	Electric boiler	90%			■
		Dryer	35 to 40%	120–170	Electric dryer, heat pump	63 to 69%, 1.5 to 6.0			■

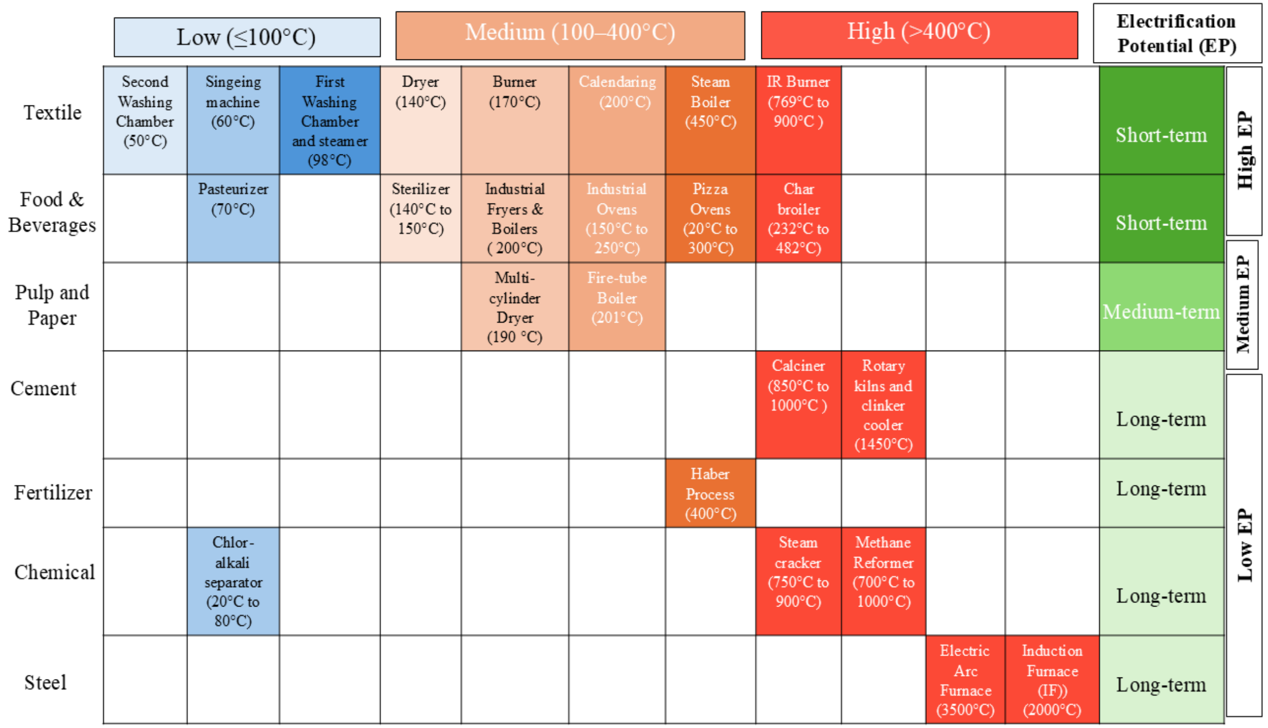
Most gas-based industrial processes in Pakistan already have viable electric alternatives with moderate to high technology readiness (II)

Technology mapping

Industry	Gas-based Process	Existing Technology			Alternative Technology (Electricity/RE)				
		Gas-based	Efficiency / COP	Temperature Ranges (°C)	Electricity-based	Efficiency / COP	Technology Readiness Index for Pakistan (1 to 10)		
							Low (1 to 5)	Medium (5 to 8)	High (9 to 10)
Cement industry	Clinker production	Calciner – partial calcination	90%	850–1,000	Resistive heating, plasma torches	90%, 70%	■		
		Rotary kiln	23–27.5%	1,450	Electrified kilns	40 to 50%	■		
		Clinker cooler	49.2–59.2%	1,450					
Chemical industry	Chlor-alkali separation	Chlor-alkali separator	75%	20–80					
	Reforming	Steam methane reformer	70–85%	700–1,000	Electrified reformers, green H_2	88.9%	■		
	Steam cracking	Steam cracker	67–70%	750–900	Electrified steam cracking	97.1%	■		
Pulp & Paper industry	Pulping	Fire tube water heater	75–80%	201	Electric water heater	90%			■
	Paper formation	Multicylinder dryer	50%	190	Heat Pump	1.5 to 6.0			■
Fertiliser industry	Reforming	Haber process / primary reformer furnace	90%	400	Electric reformer furnace	88.9%	■		
Food & beverages industry	Baking & processing	Gas oven	70–75%	150–250	Electric oven	75 to 80%			■
	Frying	Gas fryer	Up to 70%	200	Electric fryer	75 to 87%			
	Grilling	Char-broiler	51.3%	232–482	Electric char-broiler				
	Cooking	Kettle/boiler	84–89%	200	Electric kettle	70 to 80%			■
	Sterilisation	Steriliser		140-150	Electric boilers, heat pump	90%, 1.5 to 6.0			■

Textiles and food & beverages industries have the highest electrification potential

Electrification potential based on temperature bandwidths of industries



	Low (≤100°C)			Medium (100–400°C)				High (>400°C)				Electrification Potential (EP)	
Textile	Second Washing Chamber (50°C)	Singeing machine (60°C)	First Washing Chamber and steamer (98°C)	Dryer (140°C)	Burner (170°C)	Calendaring (200°C)	Steam Boiler (450°C)	IR Burner (769°C to 900°C)				Short-term	High EP
Food & Beverages		Pasteurizer (70°C)		Sterilizer (140°C to 150°C)	Industrial Fryers & Boilers (200°C)	Industrial Ovens (150°C to 250°C)	Pizza Ovens (20°C to 300°C)	Char broiler (232°C to 482°C)				Short-term	
Pulp and Paper					Multi-cylinder Dryer (190 °C)	Fire-tube Boiler (201°C)						Medium-term	Medium EP
Cement								Calciner (850°C to 1000°C)	Rotary kilns and clinker cooler (1450°C)			Long-term	Low EP
Fertilizer							Haber Process (400°C)					Long-term	
Chemical		Chlor-alkali separator (20°C to 80°C)						Steam cracker (750°C to 900°C)	Methane Reformer (700°C to 1000°C)			Long-term	
Steel										Electric Arc Furnace (3500°C)	Induction Furnace (IF)) (2000°C)	Long-term	

Electrification potential of an industry is identified using three key indicators:

I. Gas share in processes i.e. a high gas share means high opportunity to be electrified/ replaced).

II. Temperature bandwidths where low-to-medium temperature ranges implies high electrification potential and vice-versa.

III. Technology readiness or maturity of relevant alternative technologies available in the market for deployment (i.e., in Pakistan's market context).

Economics and impacts of industrial electrification

Food industry presently offers the highest short-to medium term potential for electrification

Food industry: Process-wise transition analysis

Technology Comparison	Gas Oven	Electric Oven	Gas Fryer	Electric Fryer	Gas Char broiler	Electric Char-broiler
Technology efficiency comparison: Gas equipment Vs electric alternative						
ANNUAL ENERGY CONSUMPTION OF EQUIPMENT (kWh)	292,000	168,192	70,080	58,400	205,568	163,520
ENERGY SAVINGS	42.2%		16.7%		20.5%	
CAPEX COST ($)	7,370	10,000	5,700	7,000	815	1,600
Cost case A: Only grid backed electrification						
ANNUAL ENERGY COST ($)	24,605	33,601	24,605	29,204	24,605	35,243
COST SAVING ($)	**-8,996 (-36.56%)**		**-4,599 (-18.70%)**		**-10,638 (-43.24%)**	
Cost case B: Renewable integrated electrification						
ANNUAL ENERGY COST ($)	24,605	-800	24,605	-5,197	24,605	842
COST SAVING (AFTER SOLAR)	**25,405 (103.25%)**		**29,801 (121.10%)**		**23,763 (96.58%)**	

→ The food industry accounts for ≈19 percent of industrial GDP and relies heavily on natural gas, which supplies ≈51% of its total fuel consumption.

→ Electric ovens, fryers, and char-broilers use 42%, 17% and 20.5% less energy, respectively, but have higher CAPEX.

→ Due to subsidised gas prices ($0.29/m³) and unreliable grid electricity , gas-based equipment remains dominant; grid-only electrification raises operating costs by 18.7-43.2%, resulting in negative savings.

→ When paired with solar PV (CAPEX ≈$0.12/W), electric technologies become highly cost-effective, delivering cost savings from 96-121% making electrification with solar the most viable pathway.

Electric heating and load offsetting to solar PV enables 90% and cost savings with a payback of 2.2 years in the food industry

Food industry: Energy use, cost and investment viability

Parameter	Gas heating	Electric heating-grid only	Electric heating with solar PV integration
Annual Energy Consumption (kWh) – Process	**567,648**	**390,112**	**101,032** (after integrating on-site solar)
Energy Savings (%)	–	31.3% (relative to gas)	82.2% (relative to gas + grid)
Annual Energy Cost (USD) - Process wise	**73,815**	**98,048**	**6,839**
Cost Savings (%)	–	–36.5% (higher cost)	+90–95% (very high savings)
Total CAPEX (USD)	13,835	22,400	41,150 (Electrification + Solar)
Payback Period (Years)	–	>10 years	2.2 years
Benefit–Cost Ratio (B/C)	–	0.8 (Uneconomic)	4.2 (Highly viable)
CO_2 Emission Reduction	–	Moderate	High
Overall Outcome	High fuel cost, inefficient, carbon-intensive	More efficient but higher OPEX	Efficient, low-cost, low-carbon pathway

Paper & pulp industry demonstrates strong medium term (2030-2045) economic viability

Paper and pulp industry: Process-wise transition analysis

Technology Comparison	Gas Based Boiler	Electric Boiler	Multicylinder gas dryer	Electric Fryer	Gas Charbroiler	Electric Charbroiler
Technology efficiency comparison: Gas equipment vs electric alternative						
ANNUAL ENERGY CONSUMPTION (kWh)	166,746	20,843	111,111	100,000	205,568	163,520
ENERGY SAVINGS	87.5%		10%		20.5%	
CAPEX COST ($)	5,600	8000	18,000	25,000	815	1600
Cost case A: Only grid backed electrification						
ANNUAL ENERGY COST ($)	10,458	6,938	10,458	19,498	24,605	35,243
COST SAVING ($)	3,520 (33.7% cheaper)		-9,040 (86.5% more expensive)		**-10,638 (-43.24%)**	
Cost case B: Renewable integrated electrification						
ANNUAL ENERGY COST (AFTER SOLAR)	10,458	-6,822	10,458	5,738	24,605	842
COST SAVING (AFTER SOLAR)	17,280 (165% less than gas)		4,720 (saves energy cost by ~45%)		**23,763 (96.58%)**	

- → The paper and pulp industry is the second-largest industrial consumer of natural gas, accounting for ≈60% of its fuel use and 2.5% of industrial GDP.
- → Electric boilers and dryers deliver the same heat, with 87.5% and 10% lower energy use, respectively, but require higher upfront investment, reflecting an efficiency upgrade rather than a direct cost switch.
- → Given Pakistan's high industrial electricity tariffs, grid-based electrification is mixed: the electric boiler reduces costs by 33.7%, while the electric dryer increases costs by 86.5%, highlighting the risk of electrification without cheap power.
- → When powered by solar PV, electric equipment replaces costly grid electricity, delivering ≈165% cost savings for boilers and ≈ 45% for dryers, while also avoiding gas shortages and load-shedding – making renewable-backed electrification the most cost-effective and reliable pathway.

This analysis examines a representative medium-scale facility with 100 tons/day capacity, operating 16 hours per day.
The analysis compares three gas-based processes with electric alternatives under three scenarios: gas baseline, grid-based electrification, and renewable-powered electrification (solar PV).

Unlocking around 95% cost savings in the paper & pulp industry with a around 4.5-year payback

Paper and pulp industry: Energy use, costs & investment viability

Parameter	Gas Heating	Electric heating-Grid only	Electric heating with Solar PV integration
Total Annual Energy Consumption (kWh)	277,857	120,843	5,211
Energy Savings (%)	—	56.5%	~94.1%
Total Annual Energy Cost (USD) (Scenario Level – Added)	20,916	26,436	1,084
Cost Savings (%)	—	–26% (higher cost)	~95% savings
Total CAPEX (USD)	23,600	37,300	44,800
Payback Period (Years)	—	>10	4.5
Benefit-Cost Ratio (B/C)	—	0.8 (Uneconomic)	2.2 (Highly Viable)
CO_2 Emission Reduction	—	Low (8.2%)	High (87.3%)
Overall Outcome	High fuel cost, inefficient, carbon intensive	More efficient but higher OPEX	Efficient, low-cost, low-carbon pathway

Textile industry also shows a strong potential for electrification in the short term

Textile industry: Process-wise transition analysis

Technology comparison	Thermosol drying – chambers	Electric drying – chambers	Gas steamer	Electric steamer	Gas-based main washing	Electric main washing	Gas-based pre-washing	Electric pre-washing	Gas-based dryer	Electric dryer
Technology efficiency comparison: Gas equipment vs electric alternative										
ANNUAL ENERGY CONSUMPTION (KWH)	512,071	469,303	400,398	327,657	18,000	13,500	18,000	15,000	14,000	11,000
ENERGY SAVINGS	8.4%		18.2%		25%		16.7%		21.4%	
CAPEX COST ($)	150,000	180,000	11,600	20,000	8,000	12,000	35,000	78,000	90,000	105,000
Cost case A: Only grid backed electrification										
ANNUAL ENERGY COST ($)	39,011	77,042	39,011	63,825	39,011	39,972	39,011	40,160	39,011	39,821
COST SAVING ($)	-38,030 (-97%)		-24,814 (-64%)		-961 (-2.5%)		-1,149 (-2.9%)		-810 (-2.1%)	
Cost case B: Renewable integrated electrification										
ANNUAL ENERGY COST (AFTER SOLAR)	39,011	-60,560	39,011	-73,776	39,011	-97,629	39,011	-97,441	39,011	-97,780
COST SAVING (AFTER SOLAR)	99571 (255%)		112,787(289%)		136,640(350%)		136,452(350%)		136,791(351%)	

- → The textile industry consumes **≈23% of its fuel** and contributes ≈**28% to industrial GDP,** making it the largest industrial sector in Pakistan.
- → Electric equipment reduces energy use by **8–25%,** but **higher CAPEX and slower resistance-based heating** increase operating costs when powered by the high-tariff grid (≈97% for drying chambers, 64% for steam, and 2–3% for washing/dryers).
- → On-site **solar PV** largely replaces expensive grid electricity, delivering **annual savings of USD 100,000-137,000 per process** (≈250–350% higher than gas), making electrification **highly profitable and reliable.**

The electric heating and solar PV load offsetting scenario in textile industry demonstrates a strong economic performance with ~6.3-year payback and a B-C ratio of 1.7

Textile Industry: Energy use, costs & investment viability

Scenario	Gas heating	Electric heating-grid only	Electric heating with solar PV integration
Total Annual Energy Consumption (kWh)	962,470	836,461	-319,859
Energy Savings (%) vs Gas	–	13.1%	133%
Total Annual Energy Cost (USD)	195,095	260,820	–427,186
Cost Savings (%) vs Gas	–	–33.7% (cost increase)	+318%
Total CAPEX (USD)	294,600	450,000	525,000
Payback Period (Years)	–	>10	6.3
Benefit-Cost Ratio (B/C)	–	0.7 (Uneconomic)	1.7 (Highly Viable)
CO_2 Emission Reduction	–	Moderate	High
Overall Outcome	High fuel cost, inefficient, carbon-intensive	More efficient but higher OPEX	Efficient, low-cost, low-carbon pathway

The fertiliser industry shows limited electrification potential compared to other sectors due to the extensive use of natural gas as a feedstock rather than solely as a fuel

Fertiliser industry: Process-wise transition analysis

Technology comparison	Gas-based primary reformer	Electric reformer	Gas boiler	Electric boiler
Technology efficiency comparison: Gas equipment vs electric alternative				
ANNUAL ENERGY CONSUMPTION (KWH)	4,391,400	2,823,046	5,644,566	5,055,903
ENERGY SAVINGS	35.7%		10.4%	
CAPEX COST ($)	59,000	230,000	88,000	110,000
Cost case A: Only grid-backed electrification				
ANNUAL ENERGY COST ($)	376,547	556,016	376,547	799,179
COST SAVING ($)	-179,469 (47.7% increase in cost)		-422,632 (112.2% increase in cost)	
Cost case B: Renewable-integrated electrification				
ANNUAL ENERGY COST (AFTER SOLAR)	376,547	-581,031	376,547	-337,868
COST SAVING (AFTER SOLAR)	957,578 (254% cost reduced)		714,415 (189.7% cost reduced)	

- → The fertiliser industry is Pakistan's largest industrial consumer of natural gas, accounting for ≈70% of its total fuel use and contributing ≈8% to industrial GDP.
- → Energy use fell by 35.7% for electric reformers and 10.4% for electric boilers compared to gas-based systems.
- → Grid-only electrification is economically unattractive; annual operating costs rise by 47.7%for reformers and 112.2% for boilers due to high industrial electricity tariffs and operational limitations, despite higher efficiency.
- → Electrification becomes financially viable only when coupled with renewable energy. Integrating solar PV reduces costs dramatically.
- → In Pakistan's fertiliser sector, grid-based electrification raises operating costs, while solar-powered electrification enables both decarbonisation and net economic benefits.

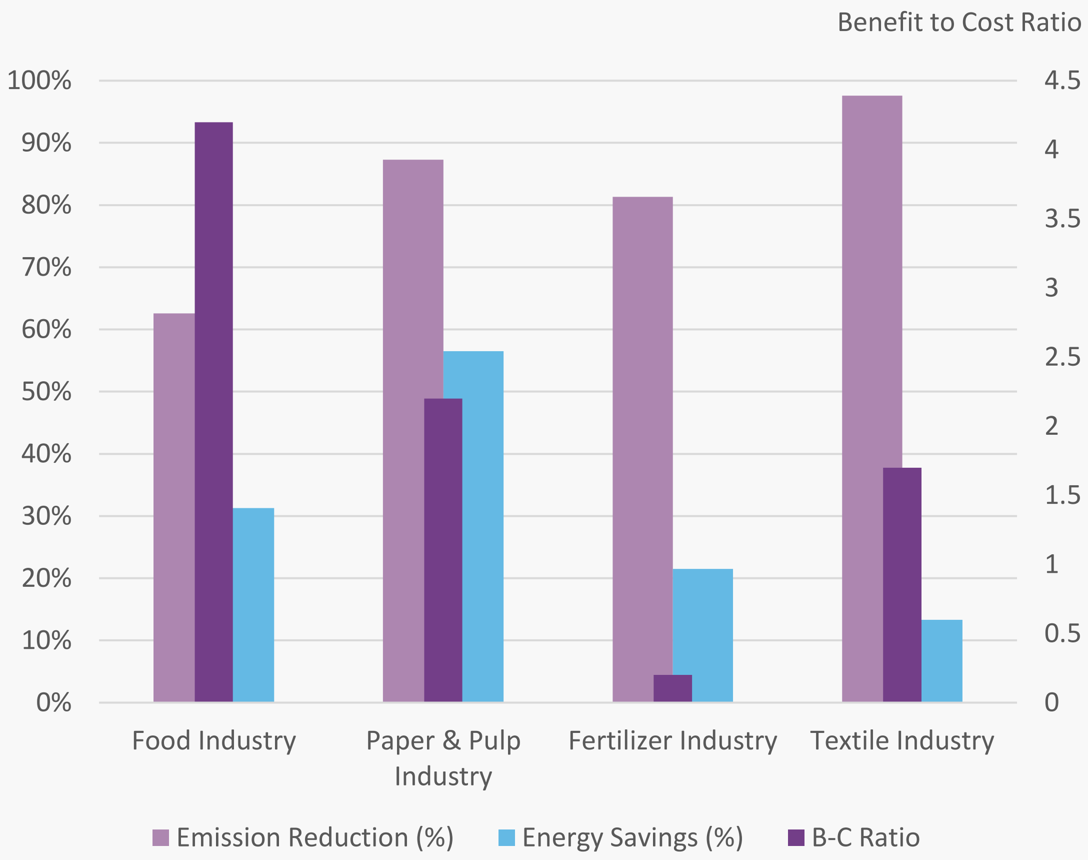
Fertiliser industry achieves high energy savings (92.4%) but low economic returns under electric heating and solar PV load offsetting scenario

Fertiliser industry: Overall energy use, costs & investment viability

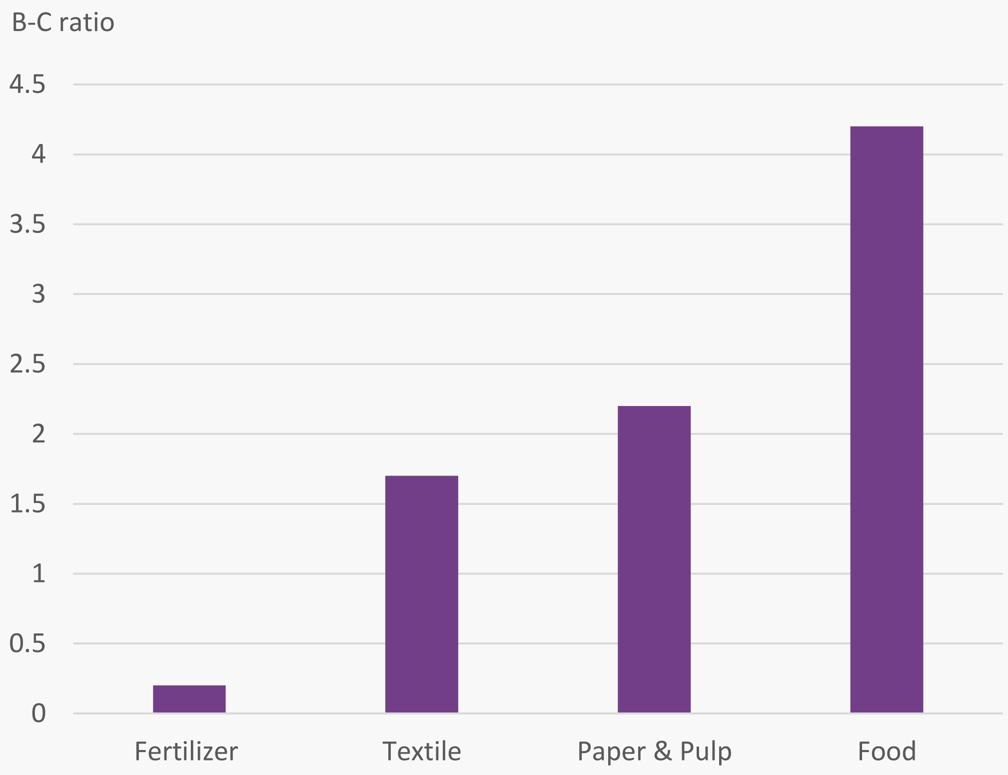
Parameter	Gas heating	Electric heating-grid only	Electric heating with solar PV integration
Total Annual Energy Consumption (kWh)	10,035,966	7,878,951	758,813
Energy Savings (%)	–	**21.5% ↓**	**92.4% ↓**
Total Annual Energy Cost (USD)	753,094	1,175,726	-918,899
Cost Savings (%)	–	**+56.1% ↑ (cost increase)**	**222.0% ↓ (cost reduction)**
Total CAPEX (USD)	147,000	340,000	537,300
Payback Period (Years)	–	> 50 (not viable)	> 20 (long but positive)
Benefit–Cost Ratio (B/C)	–	<1 (uneconomic)	**0.3**
CO_2 Emission Reduction	–	Low	High
Overall Outcome	High fuel cost, inefficient, carbon intensive	More efficient but economically unattractive	**Efficient, costly, high savings, low-carbon pathway**

Comparative insights across industries

Economic & environmental benefits of industrial electrification

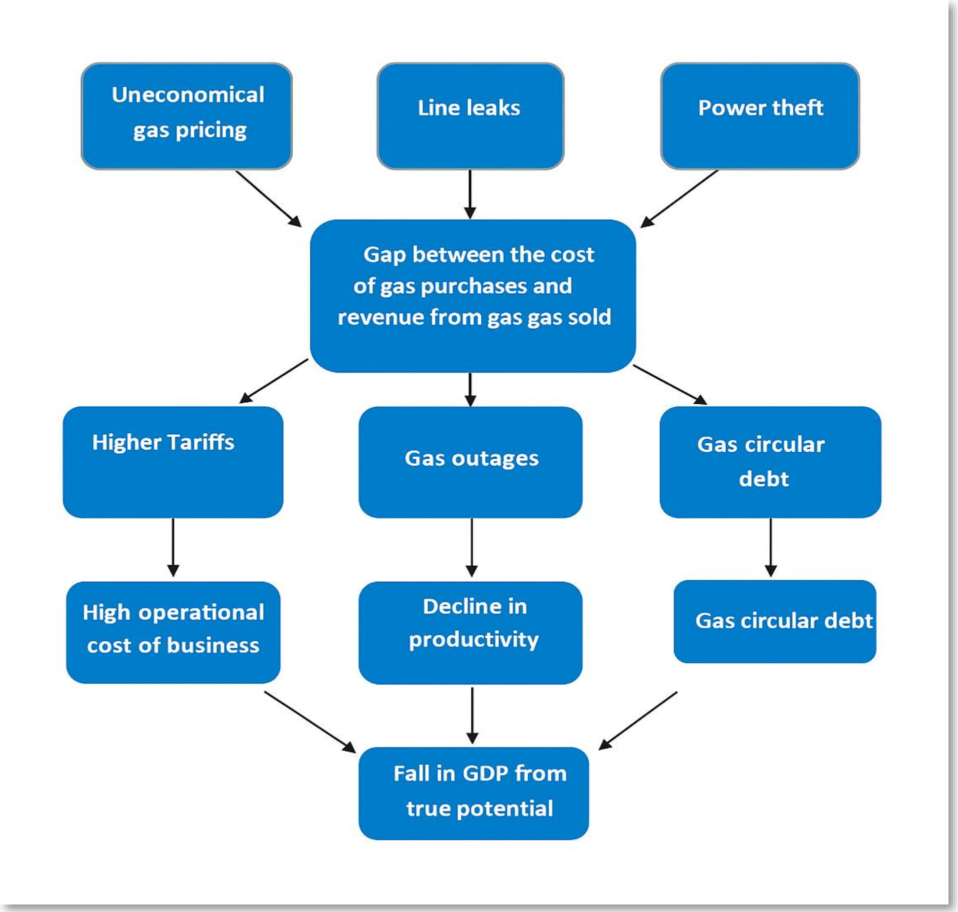


Industries benefit to cost ratio



Source: Policy Research Institute for Equitable Development (2026)

Electrifying just these four major industries could significantly lower Pakistan’s fuel import bills, strengthen the currency and reduce circular debt



Uneconomical gas pricing

Line leaks

Power theft

Gap between the cost of gas purchases and revenue from gas gas sold

Higher Tariffs

Gas outages

Gas circular debt

High operational cost of business

Decline in productivity

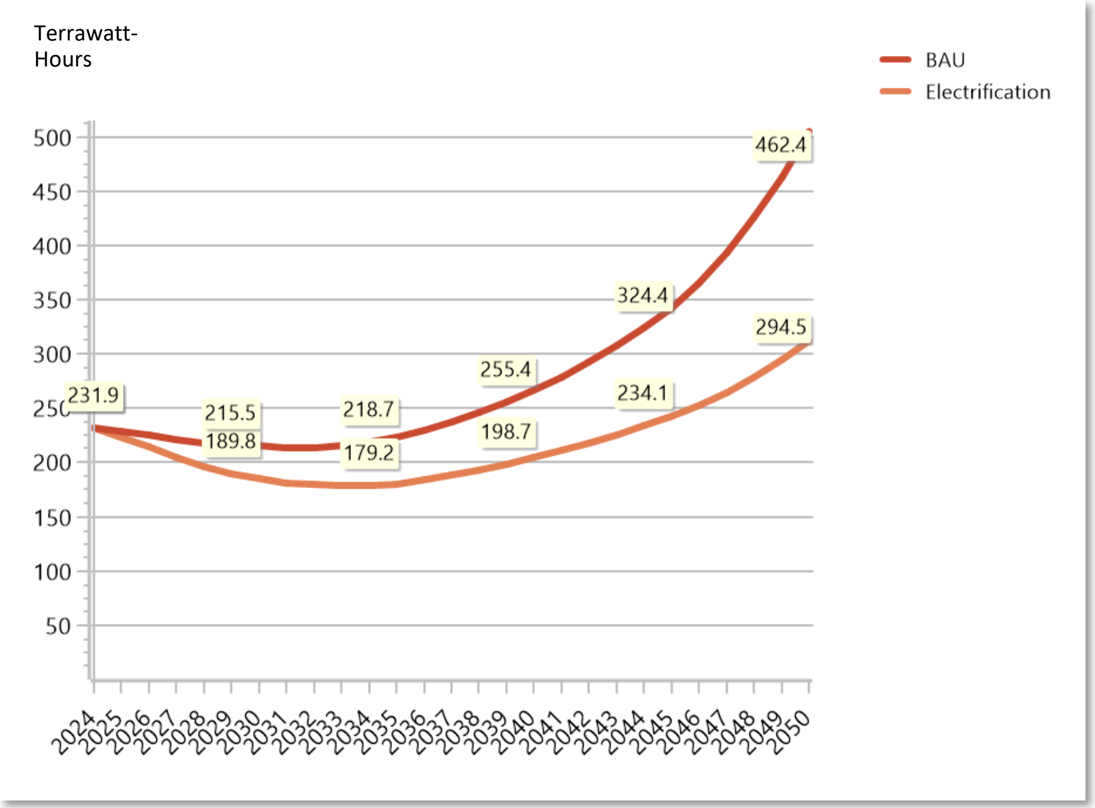
Gas circular debt

Fall in GDP from true potential

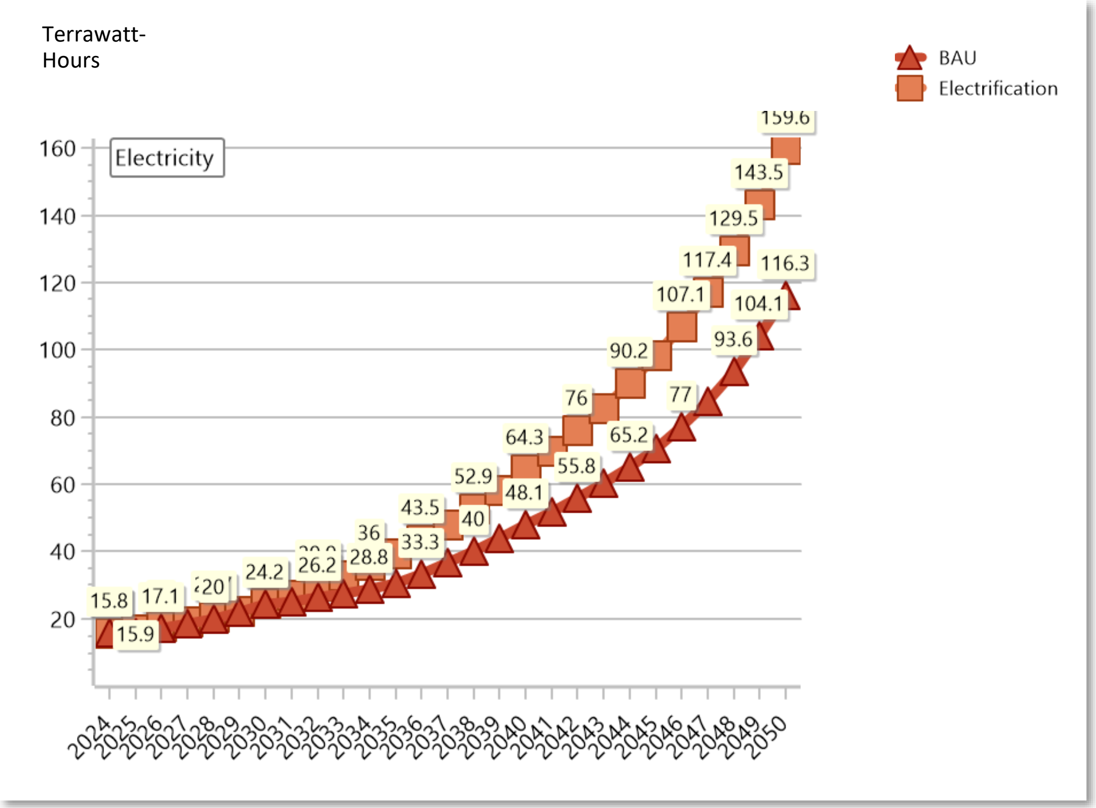
Parameter	Result	Implications
Total Energy Saved	2.4GWh= 2,461,083 kWh/year (as per cost-benefit analysis)	Based on four major industries (fertilizer, textile, paper & pulp, food).
Average Energy Reduction	20.01 percent	Indicates overall efficiency improvement from electrified systems.
National Industrial Gas Consumption	1300 MMCFD	Combined volume for General Industry and Fertilizer (Economic Survey of Pak FY24-25)
Imported RLNG (Industrial sector FY24-25)	288 MMCFD	Current RLNG consumption in Industry (FY24-25)
Equivalent Gas Savings/year	98.460 million MMBtu	Assuming 20.01 percent savings across major gas-consuming sectors.
Avoided Fuel Import Value (USD)	109.01 million MMBtu / year.= 1.199 billion dollars / year	Assuming imported RLNG is fully replaced, Based on imported RLNG gas cost of (11 dollars/MMBTU)
Avoided Fuel Import Value (PKR)	336.95 billion rupees / year.	Using exchange rate of 281 rupees/ US dollars.
Impact on Gas Circular Debt (Reduction)	-12.96 percent	Reduction equivalent to this share of 2,600 billion rupees total gas circular debt.
Macroeconomic Implication	Lower fuel import bill, reduced external pressure on dollar reserves, and improved fiscal sustainability through significant (percent per year) circular debt containment.	

The transition from BAU to industrial electrification provides energy savings of 36.1% by 2050

Final Energy Demand comparison



Electricity Demand Comparison

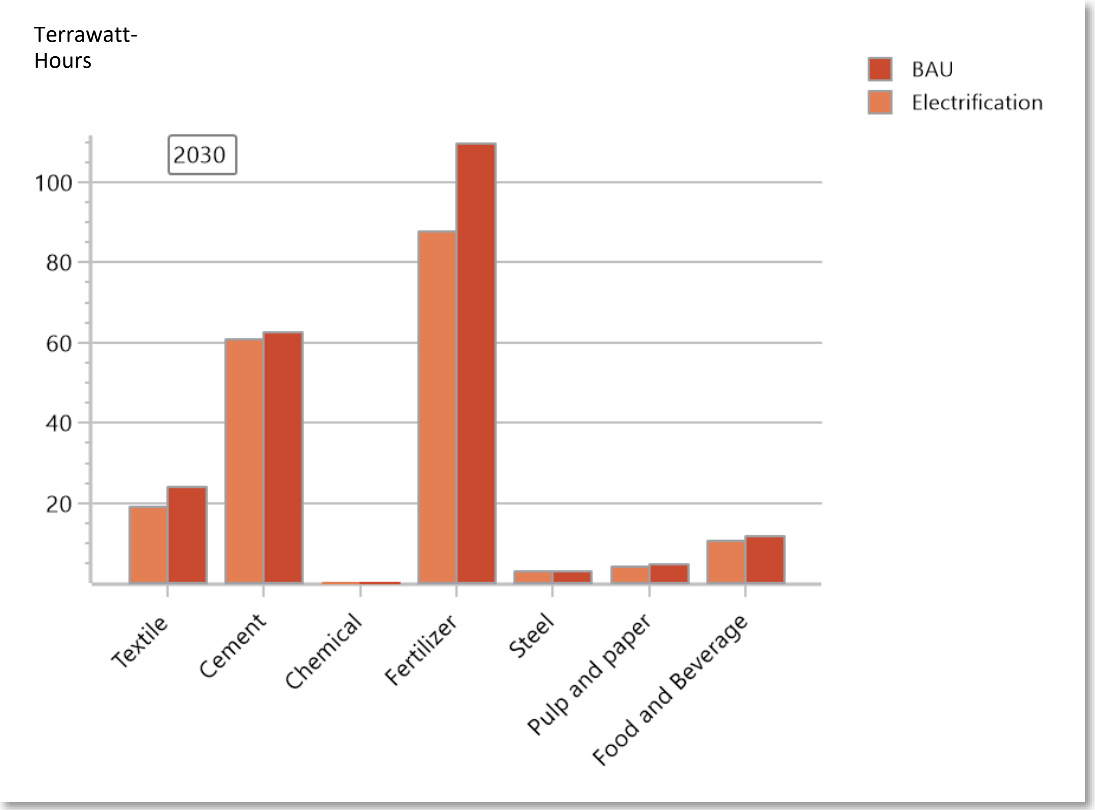


*The electricity demand in the base year (2024) i.e. **15.8 TWh** aligns with the total electricity consumption by the industrial sector as mentioned in the Power System Statistics Report 49th edition.

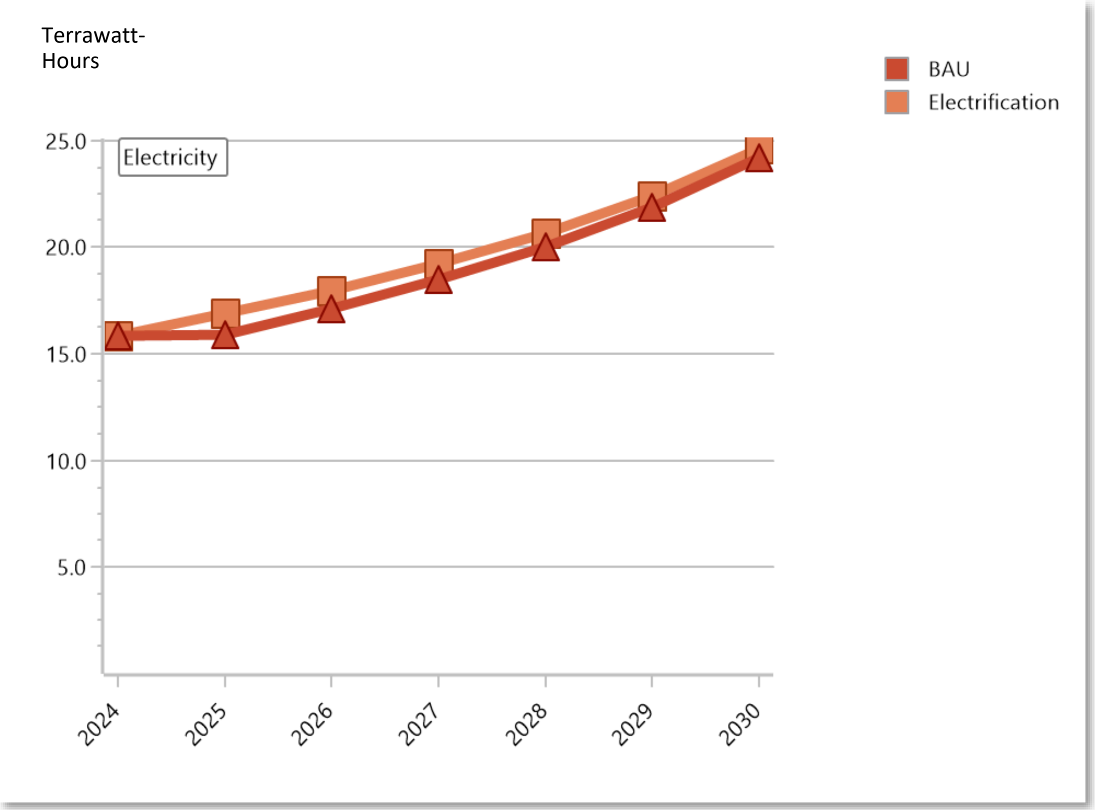
Agora Energiewende
Agora Industry
PRIED Policy Research Institute for Equitable Development

In the short term (2024-2030), electrification cuts total industrial energy use by 19% in 2030, even as electricity consumption increases slightly (by 0.4 TWh) as fossil-fuel processes shift to electric technologies

Industry-wise final energy demand in short-term (2025–2030)



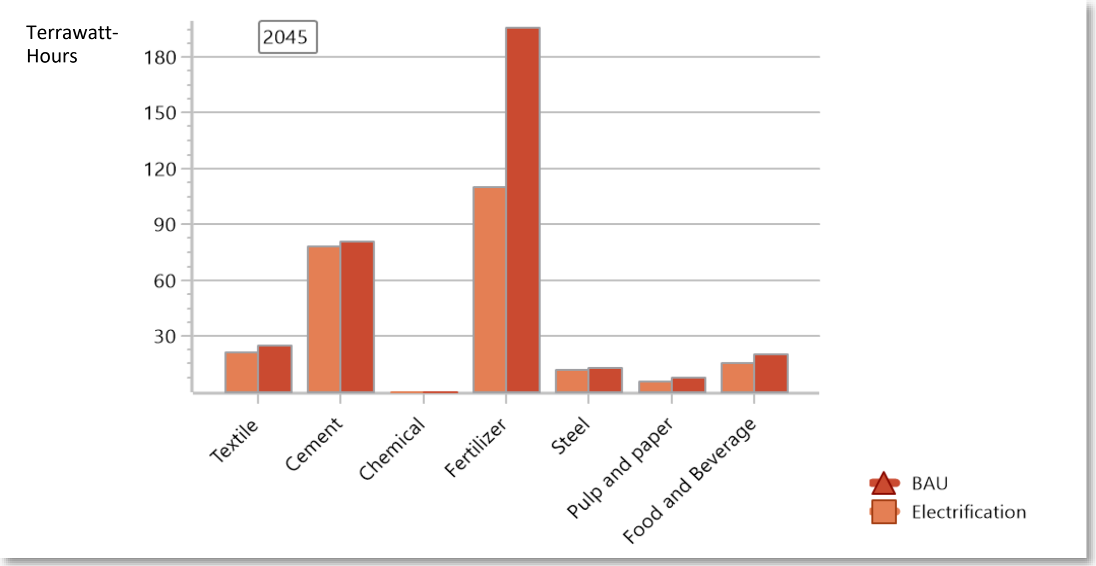
Electricity demand in short-term



| Source: Policy Research Institute for Equitable Development (2026)

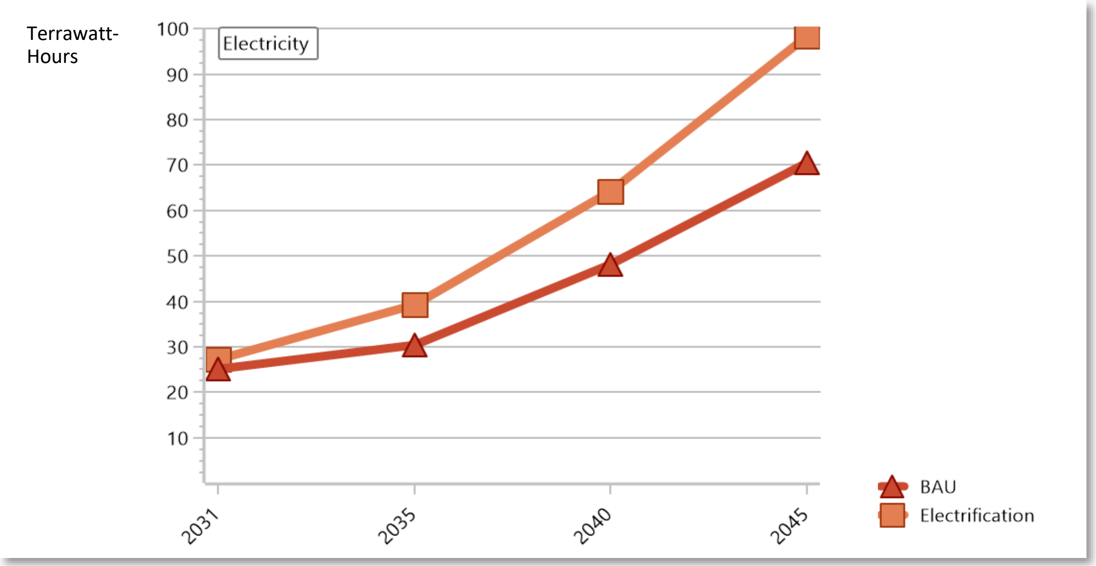
Textiles and food & beverages sectors have the highest electrification potential in medium term (2031-2045)

Industry-wise final energy demand in medium-term (2031–2045)



- → By 2045, total energy demand under the electrification pathway decreases from **342.5TWh in BAU** to about **243 TWh**, representing **29.1% energy savings**.
- → **Pulp & paper** also has medium temperature processes so we assume it can be electrified up to **58% in medium term and 65% in long term (2050).**
- → Textile and Pulp & Paper achieved **4 TWh (16%) and 2.1 TWh (26.25%)** energy savings in **2045**.

Electricity demand in medium-term

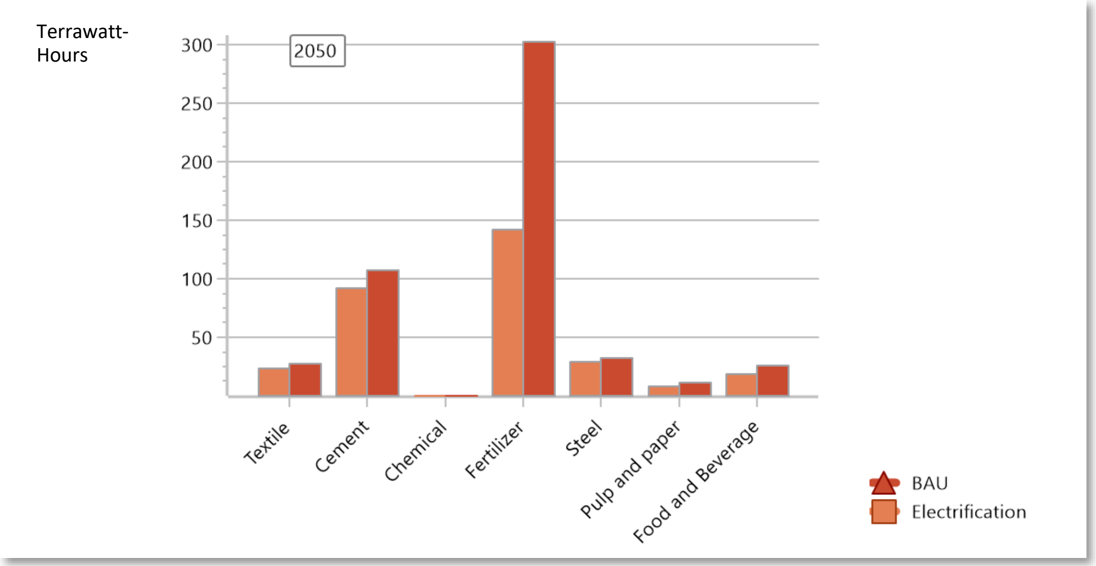


- → In Medium-term (2031 to 2045), the electricity demand increases significantly in electrification scenario.
- → The increase in electricity demand after electrification as compared to BAU is **27.7 TWh** reflecting a **39.2%** addition.

Source: Policy Research Institute for Equitable Development (2026)

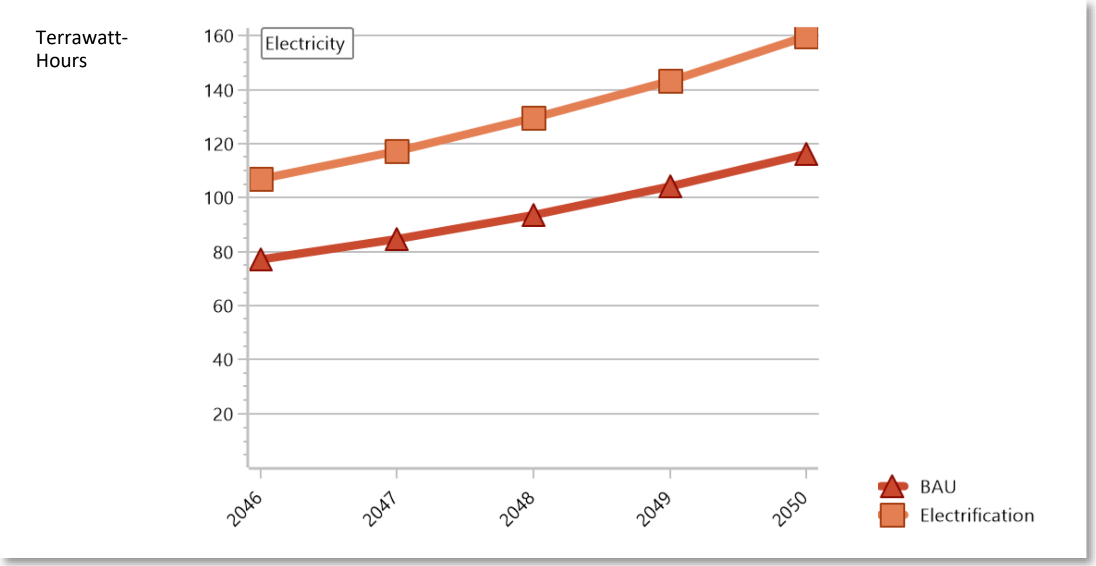
Industrial electrification raises electricity demand by around 37% in the long term (2046-2050)

Industry-wise final energy demand in long-term (2046–2050)



- **System-wide impact:** By 2050, electrification reduces total energy demand from ≈504.7 TWh (BAU) to ≈312.5 TWh, delivering ≈38% cumulative energy savings over 2024–2050.
- **Sectoral potential:** The chemical industry reaches ≈35% electrification by 2050, mainly in low-temperature processes, while cement (20%) and fertilizer (26%) remain constrained by high-temperature requirements and limited technology readiness.
- **Energy savings & limits:** By 2050, cement and fertilizer achieve ≈2.6 TWh (3.2%) and ≈85.3 TWh (43.7%) energy savings, respectively; the steel sector shows limited additional electrification, with energy demand stabilizing after 2040 due to rise in hydrogen-DRI technologies.

Electricity demand in long-term

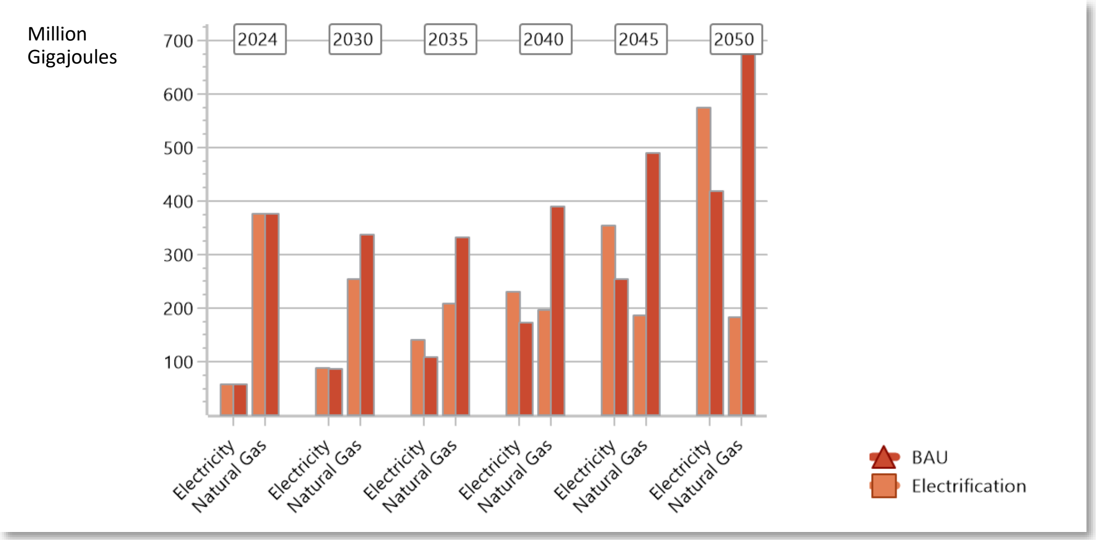


- The electricity demand of the industrial sector increases from 15.8 TWh in 2025 to 159.6 TWh in 2050 in the electrification scenario.
- The increase in electricity demand after electrification as compared to BAU is **43.3 TWh**, reflecting a **37.2%** addition of electrification technologies.

Source: Policy Research Institute for Equitable Development (2026)

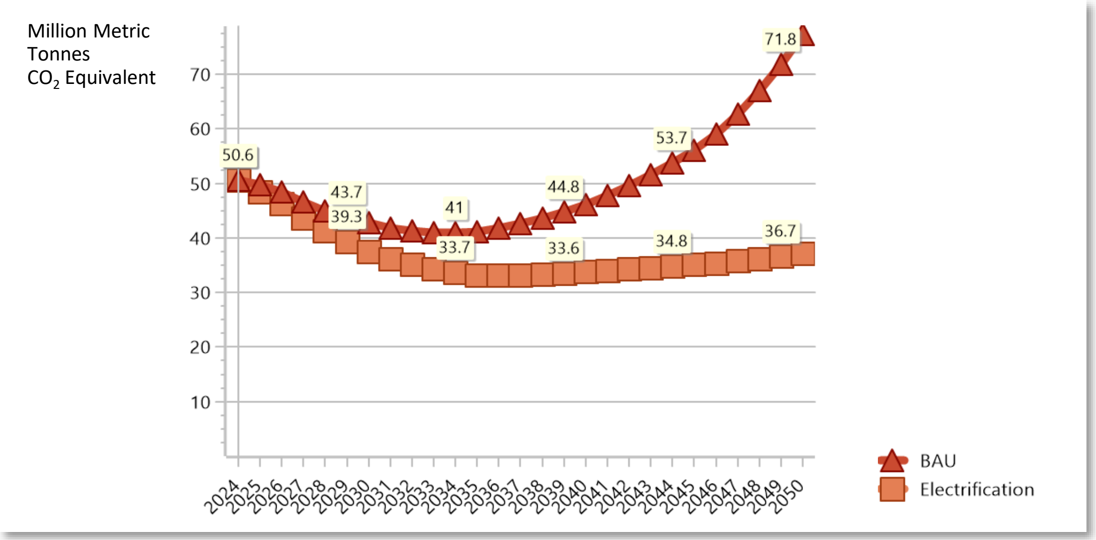
Industrial electrification can cut carbon emissions by up to 52% by 2050

Fossil (natural) gas and electricity trends before and after transition



- → A visible decline in natural gas consumption occurs in the electrification scenario as electricity replaces it for process heating and mechanical drives.
- → Natural gas demand in **BAU** is **716.8 million GJ** by 2050. However, in the **electrification** scenario, it reaches **183.8 million GJ by** 2050.
- → Total natural gas consumption has reduced by **74.4%** after electrification as compared to BAU in 2050.

Carbon emissions from fossil-based energy sources (Scope I emissions)



- → By 2050, total carbon dioxide emissions from fossil fuel-based energy sources, including coal, natural gas, and oil under the **electrification** pathway decrease from around **76.5 million metric tonnes in BAU** to about **36.9 million metric tonnes.**
- → The adoption of electrification technologies can lead to approximately **52% emission reductions** in the industrial sector of Pakistan.

| Source: Policy Research Institute for Equitable Development (2026)

Power system readiness for industry electrification

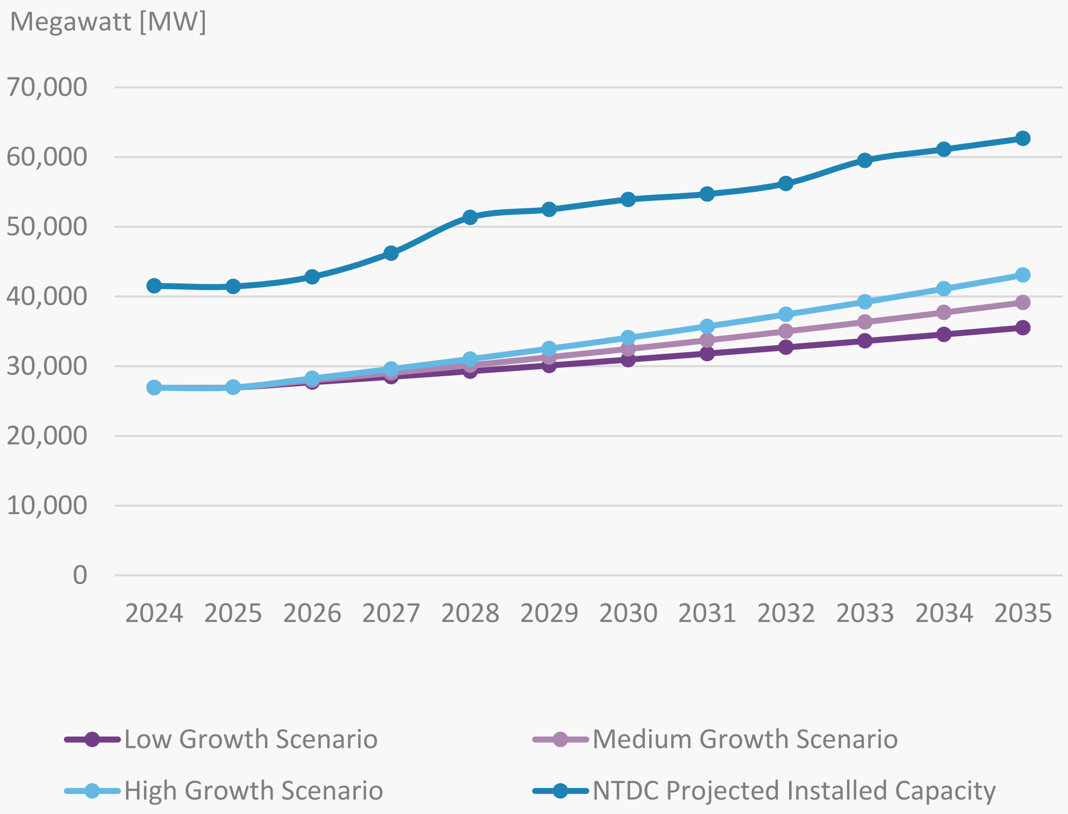
Indicative Generation Capacity Expansion Plan (IGCEP) projections show that national grid has surplus capacity

→ The NTDC's projected installed capacity remains significantly higher compared with demand across all Indicative Generation Capacity Expansion Plan (IGCEP) growth scenarios throughout the projection period (2024–2035).

→ While peak demand in the High-Growth Scenario rises from 26,913 MW in 2024 to 43,069 MW by 2035, the installed capacity expands from 41,516 MW to 62,657 MW over the same period (Source: IGCEP 2025–35).

→ From a system level perspective, electricity supply is sufficient to support industrial electrification.

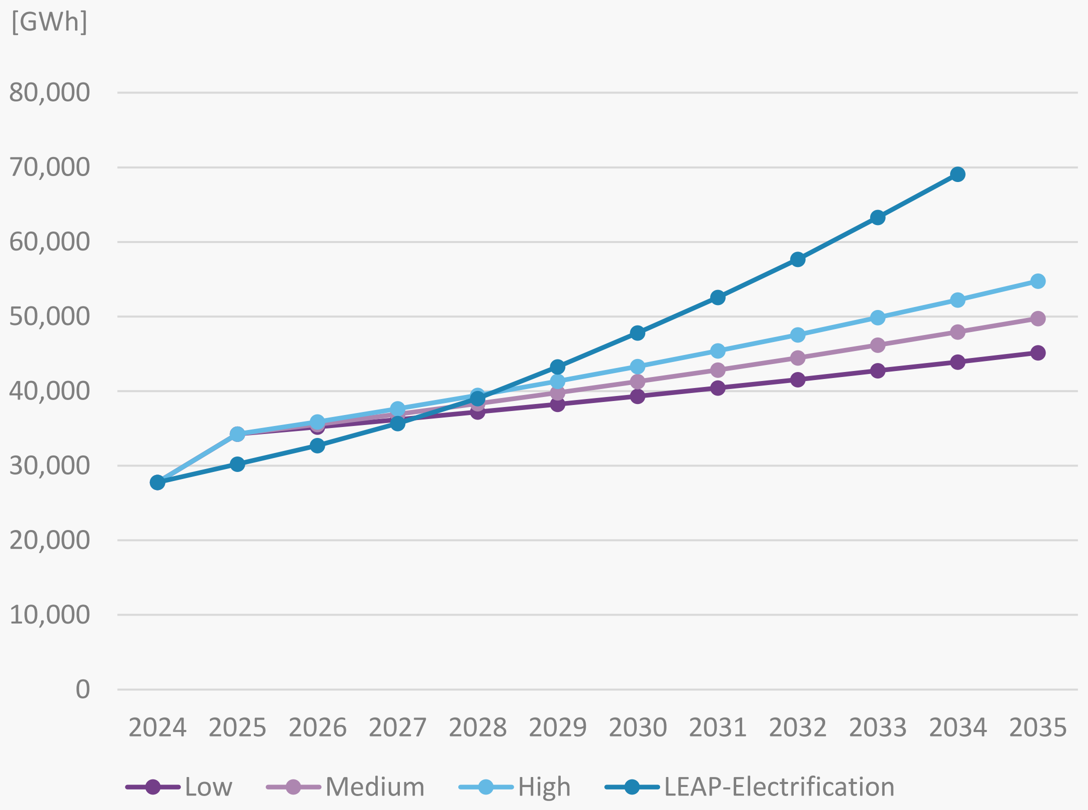
Growth scenario vs. NTDC capacity additions



However, current IGCEP projections underestimate future demand

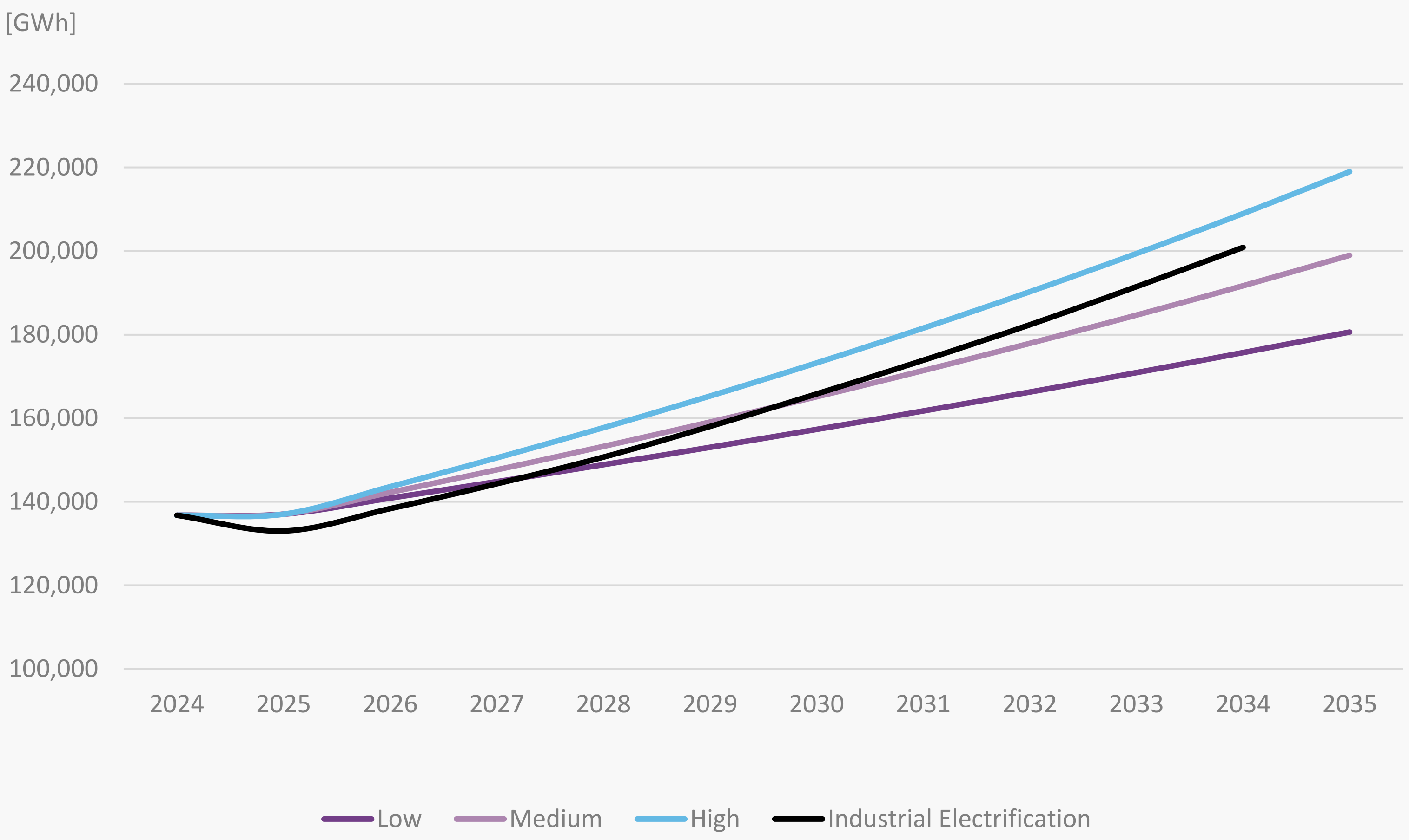
- → Existing IGCEP projections does not fully account for industrial demand projections.
- → In the IGCEP, three long-term load forecast scenarios are developed, i.e., Low (Business-as-Usual), Medium, and High demand scenarios.
- → Our LEAP based demand analysis shows higher electricity demand post 2030 when electrification is included – by 2031, demand (47,718.69 GWh) exceeds even the IGCEP High case (45,384.5 GWh).
- → This creates a mismatch between future demand realities and current planning assumptions.

Industrial demand comparison (IGCEP vs. LEAP)



Source: Policy Research Institute for Equitable Development (2026)

Industrial electrification could push demand beyond the baseline, existing IGCEP demand forecast



- → Under the LEAP-based total demand, electrification exceeds both the Low and Medium growth scenarios by 2031.
- → However, demand growth is gradual, allowing time for planning and system adaptation.

Policy Research Institute for Equitable Development (2026). Note: Country’s peak demand comparison inclusive of all the sectors

The ability to absorb electrified industrial loads will also depend on location specific distribution readiness which presently varies significantly across utilities

- → Most DISCOs have surplus transformer capacity at peak demand, but localised overloading persists, showing that capacity alone does not prevent congestion.
- → Daily tripping's occur across multiple DISCOs; MEPCO and K-Electric experience the highest rates (>300/day), reflecting chronic network stress and reliability issues.
- → These issues impact power quality and supply continuity, and these constraints will worsen with integration of higher load from industrial electrification.

DISCO-wise transmission network statistics

DISCO	Power Transformers, Capacities (MVA)/2024	Required Power Transformer capacity at peak demand/ 2024	% Distributed transformer Overloading percentage at peak demand (sep 2024)	% Power transformer 100% or above Overloaded 2024	Capacity to require-ment ratio 2024	No. of tripping's across all feeders	Duration of tripping's (Minutes)	Avg. tripping's per day
PESCO	7,707	2,732	5	18	2.8	55390	7484171	152/day
TESCO	1,302	601	12	23	2.2	22271	2655576	61/day
IESCO	7,349	2,979	0	3	2.5	86343	8327842	236/day
GEPCO	5,542	2,553	2	0	2.2	50703	4902595	139/day
LESCO	14,094	5,807	11	0	2.4	3658	267761	10/day
FESCO	6,747	3,121	4	0	2.2	57969	2208344	159/day
MEPCO	9,312	4,618	7	0	2.0	135703	8250413	372/day
HESCO	3,189	1,237	0	1	2.6	66578	1616239	182/day
SEPCO	3,096	1,112	9	0	2.8	36989	16622388	101/day
QESCO	4,112	1,135	2	8	3.6	39129	1022167	107/day
K-Electric	7,095	3,640	15	1	1.9	123710	7029701	339/day

Transition framework and implementation plan

Opportunities and barriers for industrial electrification

Barriers	Opportunities
Policy and Regulatory Gaps: Fragmented industrial energy policies and lack of a clear electrification roadmap; limited coordination between Ministry of Energy, NEPRA, and provincial departments.	**Policy Alignment and Mandates:** IMF-driven gas reforms and the National Electricity Plan (2023–2028) push industries toward grid-based and renewable energy adoption.
Financial Constraints: High upfront CAPEX for electric boilers, heat pumps, or solar integration; limited access to concessional finance.	**Access to Climate and Green Finance:** CBAM and global decarbonisation pressures create an investment case for low-carbon technologies, unlocking **green credit lines** and **blended finance**.
Infrastructure Limitations: Weak grid reliability and limited 11–33 kV feeder capacity for industrial clusters; low penetration of distributed solar plus storage.	**Underutilised Grid Capacity:** Pakistan's **falling grid demand** creates an opportunity to utilize surplus capacity through industrial electrification and demand recovery.
Dependence on Captive Gas: Industries reliant on subsidised or dedicated gas supply face adjustment risks under **IMF conditionalities** removing gas concessions.	**Energy Security Transition:** Gas rationalization under IMF reforms incentivizes industries to shift toward **stable, diversified electricity sources** (grid + renewables).
Technology Awareness: Limited knowledge and technical capacity regarding high-temperature electric heat options (e.g., electric boilers, resistance heating, hybrid solar-thermal systems).	**Emerging Technologies:** Rapidly falling costs of **heat pumps, induction heaters, and solar-thermal hybrids** make electrification more feasible and efficient.
Competitiveness Concerns: Industries fear higher production costs during the transition, particularly for export sectors.	**Trade Advantage under CBAM:** Early adoption of low-carbon technologies can protect export access to EU markets and enhance Pakistan's competitiveness.
Institutional Silos: Lack of coordination between energy, industry, and climate ministries in planning and implementing electrification programs.	**Integrated Planning Opportunity:** Aligning **industrial electrification** with **NDCs 3.0**, the **National Climate Finance Strategy**, and the **ARE Policy 2019** ensures cohesive national implementation.

Transition framework and implementation plan

Phase	Strategies	Actions
Short-Term (2025–2030)	• Electrify gas-based processes in the **Textile and Food & Beverage industries**. • Strengthen **CBAM readiness** and the **carbon governance framework**. • Establish foundational **carbon pricing and MRV systems**. • Expand access to **green finance and innovation support.** • Reform **energy market** for **renewable access and affordability**.	**Technology Transition:** • Form a CBAM Taskforce under the Ministry of Commerce & Climate Change for industry coordination. • Textile Industry: Replace the gas-based technologies with feasible and low-cost electrification alternatives including heat pumps, electric steamers etc. • Food & Beverage Industry: Replace the gas-based technologies to feasible electrification alternatives including electric ovens, electric fryers, and electric char-broiler. **Policy Needs and Market Signal:** • Enhance capacity building for industries and regulators on MRV, GHG accounting, and CBAM reporting. • Develop robust MRV and traceability systems for industrial exports. • Launch a Green Innovation Fund (GIF) connecting academia, research, and industry. • Introduce green procurement standards and low-carbon operational benchmarks for industries. **Governance & Institutional Coordination:** • Reduce industrial electricity tariffs to make electrification viable. • Mobilize technical and financial assistance for SMEs to adopt low-cost decarbonization measures. • Strengthen international cooperation for carbon markets, technology transfer, and climate finance investment for industrial decarbonisation projects as a tool. • The government should provide a detailed roadmap with specific targets for each industrial sub-sector for industrial electrification in Pakistan.

Transition framework and implementation plan (II)

Phase	Strategies	Actions
Medium-Term (2031–2045)	• Electrify gas-based processes in the **Paper and Pulp industry.** • Deepen electrification through renewable integration. • Align industrial transformation with Pakistan's NDC 4.0 and net-zero pathway. • Scale innovation, circular economy, and data-driven carbon transparency. • Strengthen institutional, financial, and infrastructural capacity for decarbonization.	**Technology Transition:** • Pulp & Paper Industry: Replace the gas-based technologies with feasible electrification alternatives including heat pumps, electric boilers and electric dryers. • Integrate renewables into industrial processes for low- to medium-temperature needs. • Develop national baseline emission datasets and standardize industrial carbon reporting. • Establish shared utilities and common infrastructure (wastewater, steam, power) to reduce emissions intensity. **Policy Needs and Market Signal:** • Expand sector-specific green financing schemes for emission-intensive industries. • Strengthen CBAM registry systems and exporter-level compliance frameworks. **Governance & Institutional Coordination:** • Foster public-private partnerships (PPPs) to scale decarbonization projects. • Promote regional carbon market collaboration and green hydrogen cooperation in South Asia. • Continue grid modernization and enhance renewable power flexibility. • Support R&D commercialization of local clean technologies through GIF and innovation grants. • Maintain policy coherence between energy, trade, and climate strategies.

Transition framework and implementation plan (III)

Phase	Strategies	Actions
Long-Term (2046–2050)	- Achieve full **industrial electrification** and **deep decarbonisation**. - Transition hard-to-abate sectors to **hydrogen and electrification alternatives and CCUS-based systems.** - Enforce national and global **net-zero compliance standards.** - Institutionalize **low-carbon industry certification** and **international competitiveness.**	**Technology Transition:** - Chemical & Fertilizer Industry: Replace the gas-based technologies with feasible electrification alternatives including electric reformers and electric boilers. Adopt Green H_2 electrolysis to replace natural gas as feedstock. - Steel and cement Industry: Replace the gas-based technologies with feasible electrification alternatives including H_2DRI and electric kilns, respectively. - Electrify hard-to-abate sectors (cement, steel, fertilizer) through hydrogen integration and CCUS deployment. - Transition industrial operations to zero-emission technologies eliminating Scope 1, 2 & 3 emissions. **Policy Needs and Market Signal:** - Establish national low-carbon certification systems for verified products. - Expand shared hydrogen and renewable infrastructure (green hubs, CCUS clusters). - Mandate green procurement and trade standards for domestic and export industries. - Advance circular economy systems (waste recovery, heat reuse, material recycling). **Governance & Institutional Coordination:** - Align all industrial policies with Pakistan’s net-zero and climate resilience frameworks. - Encourage private sector leadership and PPPs in innovation and climate finance. - Replicate global best practices (HYBRIT, Japan’s hydrogen model, Germany’s pilots) to enhance competitiveness. - Ensure just transition by protecting industrial employment and supporting SME adaptation.

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Annex

Comparative analysis of industrial sub-sectors in Pakistan

Table 13. Comparative analysis of industrial sub-sector in Pakistan

Industry	GDP contri-bution	Exports	Production	Energy Intensity	Carbon Intensity	Industrial emissions share	Growth (2024)	Gas Consumption		Temperature Bandwidths
								Gas sector	Fuel mix	
Textile	8.50%	57%	657.9 million square meter	0.130 GJ / sq meter	0.00925 tCO_2 / m^2	5%	-8.27%	14%	23%	Low to Medium
Food & Beverage	>20%	21%	211.5 Million tonne	0.6228 GJ/tonne	0.00189 tCO_2 / tonne	-	-1.74%	27%	51%	Low to Medium
Pulp & Paper	2%	0%	602.1 Thousand tonne	31.15 GJ / tonne	1.43 tCO_2 / tonne	3%	-1.96%	22%	60%	Medium
Steel	2%	0%	8.4 Million tonne	1.425 GJ/tonne	0.13 tCO_2 / tonne	2%	-2.2%	2%	9.3%	High
Chemical	2.60%	2.80%	3 Million tonne	0.0001161 GJ/tonne	0.0000067 tCO_2 / tonne	7%	-3.2%	15%	42%	High
Fertilizer	1.00%	0.00001%	9.1 Million tonne	47.9 GJ/tonne	0.33 tCO_2 / tonne	7%	+16.4	13%	70%	Medium
Cement	1%	5.30%	28.546 Million tonne	10.404 GJ/tonne	0.85 tCO_2 / tonne	75%	+2.4%	2%	12%	High

Note: Low Temperature range (≤100°C), Medium Temperature range (100–400°C) and High Temperature range (>400°C).

Industry-wise final energy demand 2024-2050

- → Under the BAU scenario, demand rises more sharply because of continued reliance on fossil fuels and low efficiency improvements.
- → The Electrification Scenario shows a lower energy demand due to improved efficiency of electric technologies and the substitution of high-loss thermal systems.
- → Cement and fertiliser sectors continue to dominate overall energy consumption due to their energy-intensive, high-temperature processes and heavy reliance on fossil fuels.
- → Despite the introduction of electrification measures, these sectors maintain high energy intensity because electric alternatives remain technologically immature in Pakistan's context.

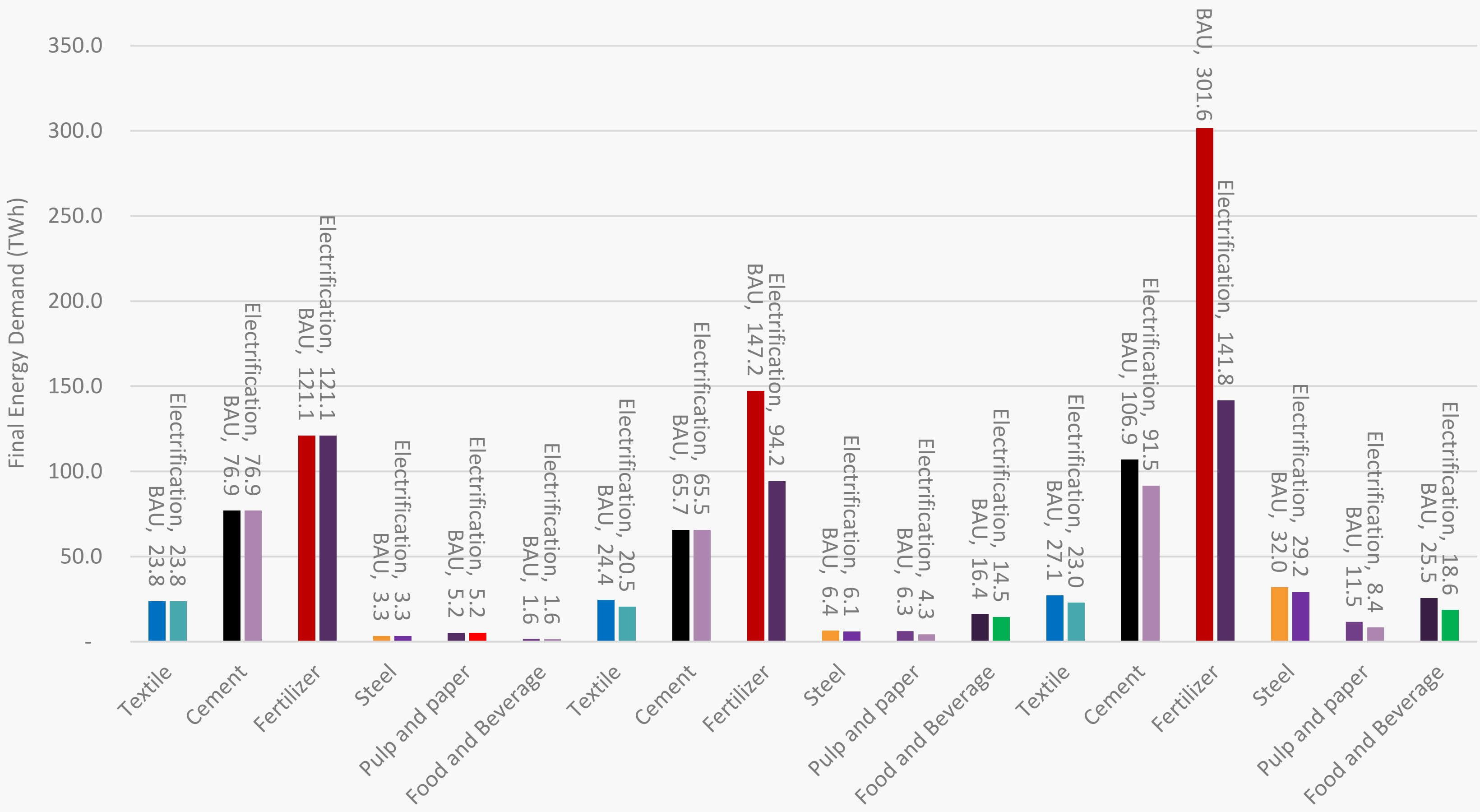

Figure 31. Industry-wise final energy demand

Food industry transition

- The food industry is a large consumer of natural gas in Pakistan, using approximately 50.62% of its total fuel consumption and contributing around 19% to the country's industrial GDP.
- Given that Pakistan primarily comprises medium-scale food industries, this analysis focuses on a representative medium-level, ready-to-cook manufacturing facility with a daily production capacity of 1.2 tons and operating 16 hours per day.
- To identify key electrification opportunities, major gas-consuming processes were evaluated based on their energy intensity and transition potential. From this assessment, three feasible gas-powered cooking equipment types were shortlisted for potential electrification, supported by current market analysis.

Step 1
Baseline Setup: Gas Equipment Characteristics

We first established the existing gas-based process heating baseline by inputting the rated thermal capacities of the installed equipment:

- Gas Oven: **50** kW
- Fryer: **12** kW
- Char-broiler: **35.2 kW**

→ Defined reference fuel consumption and costs in current operations.

Step 2
Transition Scenario: Electric Equipment Using Grid Electricity

We replaced the gas units with efficient electric alternatives powered by the national grid.

- Electric Oven: **28.8kW**
- Electric Fryer: **10 kW**
- Electric Char-broiler: **28 kW electric**

→ Quantified the energy demand (kWh) and cost implications of switching to electric heating.

Step 3
Renewable Energy Integration: Offset Load with solar photovoltaic (PV) systems

To improve feasibility, we introduced solar PV to offset electrical demand:

- PV System size: **150kW**
- Capacity factor: **22 percent**
- Annual offset applied to **390,112 kWh** electricity consumption
- Solar system CAPEX: **$125/kW** (optimistic) → **$18,750** total

→ Determined contribution of renewables in reducing costs, emissions and grid dependence.

Step 4
Process-Level Energy Efficiency Assessment

We analyzed energy performance improvements from electrification:

- Evaluated baking, frying, and grilling processes using different end-use energy efficiency measures, accounting for the higher efficiency of electric heating compared to gas.

→ Estimated energy savings by reducing thermal losses and improving conversion efficiency.

Step 5
Feasibility Analysis: Energy Use, Cost, and Investment Viability

We compared all scenarios: Gas baseline, electric heating using grid only, electric heating with renewable (PV) offset.
Key metrics analysed:

- Annual energy consumption
- Energy cost impacts
- Savings achieved through energy efficiency and PV integration
- Economic viability (CAPEX vs. payback and savings)

→ Determined if gas-to-electric transition is viable for the food processing sector in Pakistan.

Figure 32. Food Industry

Food industry: equipment transition analysis

Table 14. Food industry: equipment transition analysis

Technology Comparison	Gas Oven	Electric Oven	Gas Fryer	Electric Fryer	Gas Char-broiler	Electric Char-broiler
Scenario 1: Gas Equipment to Electric Alternative Transition						
ANNUAL ENERGY CONSUMPTION OF EQUIPMENT (kWh)	292,000	168,192	70,080	58,400	205,568	163,520
ENERGY SAVINGS	42.2%		16.7%		20.5%	
CAPEX COST ($)	7,370	10,000	5,700	7,000	815	1600
Scenario 2: Electrification using Grid Electricity						
ANNUAL ENERGY COST ($)	24,605	33,601	24,605	29,204	24,605	35,243
COST SAVING ($)	**-8,996 (-36.56%)**		**-4,599 (-18.70%)**		**-10,638 (-43.24%)**	
Scenario 3: Shifting to Renewables (PV)						
ANNUAL ENERGY COST	24,605	-800	24,605	-5,197	24,605	842
COST SAVING (AFTER SOLAR)	**25,405 (103.25%)**		**29,801 (121.10%)**		**23,763 (96.58%)**	

This table compares gas-based equipment with electric equipment under three cases:

(1) Gas Equipment to Electric Alternative Transition,
(2) Electrification using grid electricity, and
(3) Electrification powered by renewable energy (on-grid solar).

- Although, electric ovens, fryers, and char-broilers use **42 percent, 17 percent and 20.5 percent less energy,** respectively, than their gas alternatives but their CAPEX cost and energy use intensity (EUI) remains high as compared to the gas-based equipment.
- In Pakistan's food industry, gas-based equipment remains dominant **because gas is cheaper (approx. 0.29 $/m3),** has lower energy use intensity **(EUI),** and fast heating speed in large scale applications, and is considered more reliable than grid electricity. Electrifying ovens, fryers, and char-broilers without solar leads to **18.7–43.24 percent** higher operating costs despite using less energy, resulting in negative cost savings.
- Electric technologies are far more efficient, and when their electricity demand is offset by solar, they become highly profitable—delivering cost savings of up to **121.10 percent** for electric fryers, **103.25 percent** for electric ovens, and **96.58 percent** for electric char-broilers, due to the **low CAPEX** cost **0.12$/W** (existing market price), making electrification with solar the most viable pathway for industries.

Food industry: process-level energy savings from electrification

For a medium ready-to-cook food industry in Pakistan, shifting from gas to electric ovens, fryers, and grills makes baking, frying, and grilling more energy-efficient — less energy in, same food out. This chart proves that electrification cuts energy waste at the process level, helping reduce fuel dependency, improve operational efficiency, and ultimately save money.

- → Electric heating equipment (such as electric ovens, fryers, and grills) can perform the same cooking job using much less energy compared to gas. Gas consumes more units and wastes more energy, while electricity uses fewer units and reduces waste in every process – baking uses 42% less energy, frying uses 17% less 5% and grilling uses 21% less.
- → Gas shortages, variable industrial tariffs, loss of heat through combustion and ventilation increase production costs for food industries in Pakistan, as every wasted unit of gas adds expense. Switching to electric equipment allows the same products to be cooked with less energy, reducing fuel consumption, emissions, and reliance on expensive gas – while improving energy efficiency and operational stability.

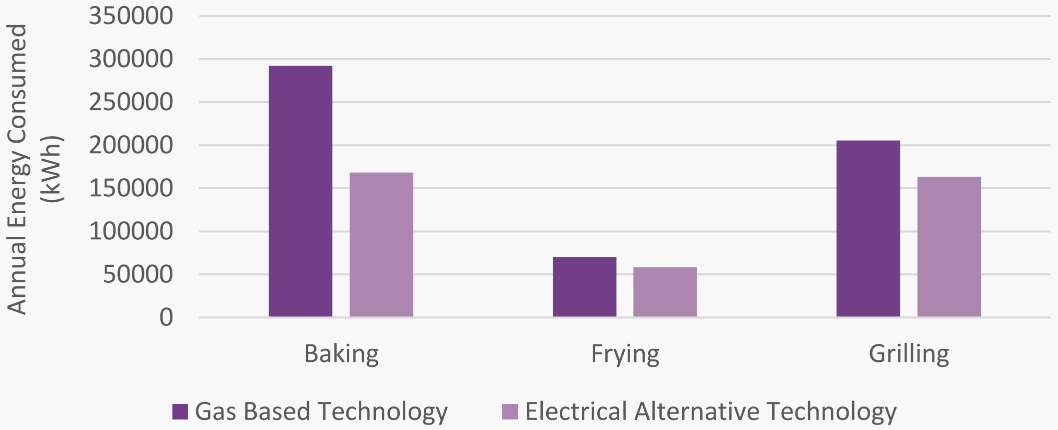

Figure 33. Food Industry: Energy Consumption Analysis

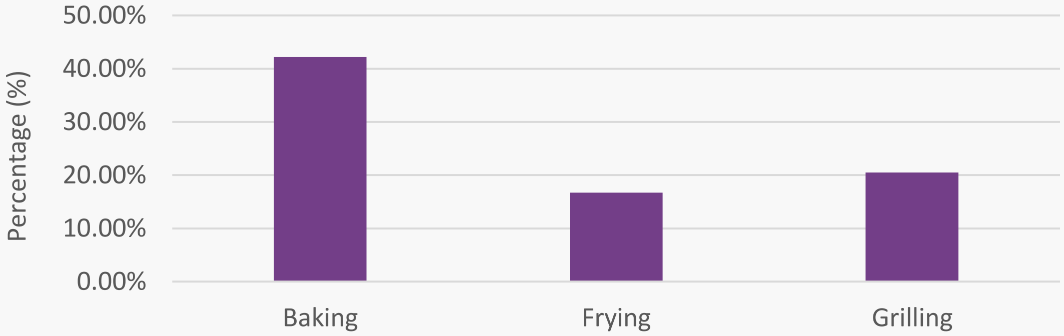

Figure 34. Food Industry: Transition Energy Savings (%)

Paper & pulp industry transition

→ The paper and pulp industry is the second-largest consumer of natural gas, comprising 60% of its total fuel use and contributes around 2.54% to industrial GDP. This analysis focuses on a representative medium-level facility with a daily production capacity of 100 tons and operating 16 hours per day.

→ To identify key electrification opportunities, major gas-consuming processes were evaluated based on their energy intensity and transition potential. From this assessment, two feasible gas-powered equipment types were shortlisted for potential electrification, supported by current market analysis.

Step 1
Baseline Setup: Gas Equipment Characteristics

We first established the existing gas-based process heating and process steaming baseline by inputting the rated thermal capacities of the installed equipment:

- Gas based fire tube water heater: 92 percent heat recovery efficiency
- Multicylinder Dryer (Drying): 111 MWh Heating

→ Defined reference fuel consumption and costs in current operations.

Step 2
Transition Scenario: Electric Equipment Using Grid Electricity

We replaced the gas units with electric alternatives, powered by the national grid.

- Electric water heater: 99 percent heat recovery efficiency
- Heat pump (Drying): 100 MWh Heating

→ Quantified the energy demand (kWh) and cost implications of switching to electric heating.

Step 3
Renewable Energy Integration: Offset Load with PV

To improve feasibility, we introduced solar PV to offset electrical demand:

- PV System size: 60 kW
- Capacity factor: 22 percent
- Annual offset applied to 115,632 kWh electricity consumption
- Solar system CAPEX: $125/kW (optimistic) → $7500 total

→ Determined contribution of renewables in reducing costs, emissions and grid dependence.

Step 4
Process-Level Energy Efficiency Assessment

We analyzed energy performance improvements from electrification:

- Evaluated steaming and drying processes using different end-use energy efficiency measures, accounting for the higher efficiency of electric heating compared to gas.

→ Estimated energy savings by reducing thermal losses and improving conversion efficiency.

Step 5
Feasibility Analysis: Energy Use, Cost & Investment Viability

We compared all scenarios: the gas baseline, electric heating solely powered by the grid , and electric heating with renewable (PV) offset.

Key metrics analysed:

- Annual energy consumption
- Energy cost impacts
- Savings achieved through energy efficiency and PV integration
- Economic viability (CAPEX vs. payback and savings)

→ Determined the feasibility of gas-to-electric transition for the industry

Figure 35. Paper & Pulp Industry

Paper and pulp industry: equipment transition analysis

Technology Comparison	Gas Based Boiler	Electric Boiler	Multicylinder gas dryer	Electric Fryer	Gas Charbroiler	Electric Charbroiler
Scenario 1: Gas Equipment to Electric Alternative Transition						
ANNUAL ENERGY CONSUMPTION (kWh)	166,746	20,843	111,111	100,000	205,568	163,520
ENERGY SAVINGS	87.5%		10%		20.5%	
CAPEX COST ($)	5,600	8000	18,000	25,000	815	1600
Scenario 2: Electrification using Grid Electricity						
ANNUAL ENERGY COST ($)	10,458	6,938	10,458	19,498	24,605	35,243
COST SAVING ($)	3,520 (33.7% cheaper)		-9,040 (86.5% more expensive)		**-10,638 (-43.24%)**	
Scenario 3: Offsetting Load to Renewables (PV)						
ANNUAL ENERGY COST (AFTER SOLAR)	10,458	-6,822	10,458	5,738	24,605	842
COST SAVING (AFTER SOLAR)	17,280 (165% less than gas)		4,720 (saves energy cost by ~45%)		**23,763 (96.58%)**	

This table compares gas-based equipment with electric equipment under three cases: **(1) Gas equipment to electric alternative transition, (2) Electrification using grid electricity, and (3) Electrification powered by renewable energy (mainly solar).**

- → Electric boilers and dryers consume less energy to deliver the same industrial heating output, showing 87.5 percent and 10 percent energy savings respectively. Although transitioning from gas to electric requires a higher upfront investment, it represents a clear efficiency upgrade.
- → Industrial electricity in Pakistan is significantly more expensive than gas. Therefore, switching to electric equipment highly depends on energy savings achieved can outweigh the electricity prices to be paid. The electric boiler, due to its high efficiency, reduces costs (**33.7 percent** saving) whereas the electric dryer becomes **86.5 percent more expensive. This mismatch** – low efficiency improvement combined with high electricity tariffs – makes grid-based electrification risky.
- → By powering electric equipment with solar PV, industries replace expensive grid electricity with much cheaper solar energy, resulting in substantial cost reductions. The electric boiler achieves **~165 percent cost savings,** while the electric dryer achieves **~45 percent cost savings. This approach** also mitigates gas shortages and load-shedding, making **scenario 3** the most cost-effective and reliable transition scenario.

Table 15. Paper & Pulp Industry: Equipment Transition Analysis

Paper and pulp industry: process-level energy savings from electrification

This chart compares energy use in the two major gas-intensive processes of Pakistan's paper and pulp industry – Process Steam (Boilers) and Process Heat (Dryers) – and shows how much energy can be saved by replacing gas equipment with electric alternatives.

- → Electric boilers consume far less energy than gas boilers because they avoid heat losses from combustion, burner inefficiency, and flue gases. In Pakistan, many gas boilers operate at low efficiency due to poor gas pressure and outdated systems. Electrifying process steam eliminates these losses and is a high-impact option, providing substantial energy savings of 87.5 percent and reducing operational issues related to gas shortages or pressure fluctuations.
- → Dryers require large amounts of heat, and both gas and electric technologies consume nearly the same energy for this process. Electric dryers offer only modest efficiency improvements, achieving approximately 10 percent of energy savings. Therefore, electrifying process heat provides limited energy benefits.

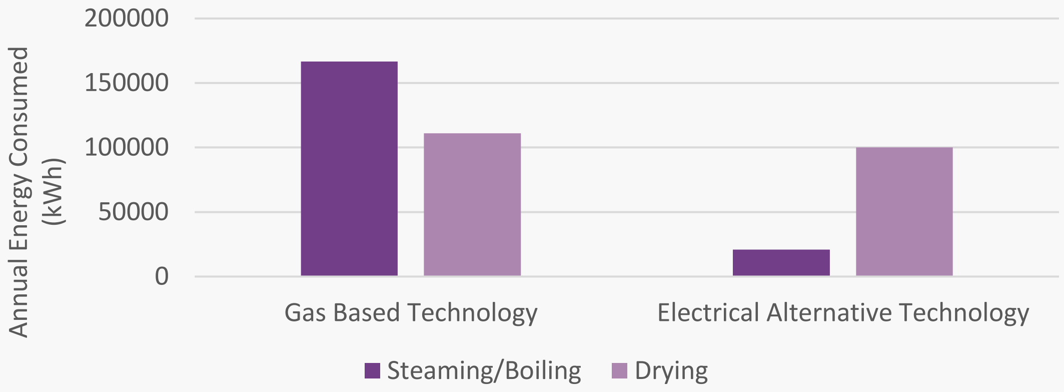

Figure 36. Paper & Pulp Industry: Energy Consumption Analysis

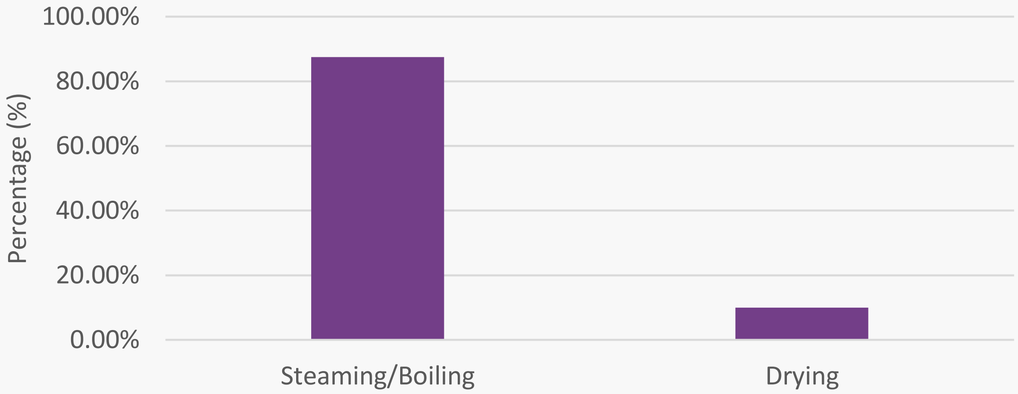

Figure 37. Paper & Pulp Industry: Transition Energy Savings (%)

Fertiliser industry transition

→ The fertiliser industry is the largest consumer of natural gas, comprising 70% of its total fuel. It contributes around 8% to the industrial GDP.

→ Pakistan primarily has medium- and large-scale fertiliser industries. This analysis focuses on a representative medium-level facility with a daily production capacity of 1500 tons, operating 16 hours per day.

→ To identify key electrification opportunities, major gas-consuming processes were evaluated based on their energy intensity and transition potential. From this assessment, two feasible gas-powered equipment types were shortlisted for potential electrification, supported by current market analysis

Step 1
Baseline Setup: Gas Equipment Characteristics

We first established the existing gas-based process heating and process steaming baseline by inputting the rated thermal capacities of the installed equipment:

- Gas based Primary Reformer: 607 kW
- Gas Boiler: For 850 kg/h Steam Flow with Steam Pressure 25 bar

→ Define reference fuel consumption and costs in current operations

Step 2
Transition Scenario: Electric Equipment Using Grid Electricity

We replaced the gas units with electric alternatives, powered by the national grid.

- Electric Reformer: 390 kW
- Electric Boiler: For 850kg/h Steam Flow with Steam Pressure 16 bar

→ Quantified the energy demand (kWh) and operational cost implications of switching to electric heating.

Step 3
Renewable Energy Integration: Offset Load with PV

To improve feasibility, we introduced solar PV to offset electrical demand:

- PV System size: 4 MW
- Capacity factor: 22%
- Annual offset applied to 7,708,800 kWh electricity consumption
- Solar system CAPEX: $125/kW (optimistic) → $500,000 total

→ Determined contribution of renewables in reducing costs, emissions and grid dependence.

Step 4
Process-Level Energy Efficiency Assessment

We analysed energy performance improvements from electrification:

- Evaluated heating and steaming processes using different end-use energy efficiency measures, accounting for the higher efficiency of electric heating compared to gas.

→ Estimated energy savings by reducing thermal losses and improving conversion efficiency.

Step 5
Feasibility Analysis: Energy Use, Cost & Investment Viability

We compared all scenarios: the gas baseline, electric heating solely powered by the grid , and electric heating with renewable (PV) offset.

Key metrics analysed:

- Annual energy consumption
- Energy cost impacts
- Savings achieved through energy efficiency and PV integration
- Economic viability (CAPEX vs. payback and savings)

→ Determine if gas-to-electric transition is viable for the fertilizer industrial processing sector in Pakistan.

Figure 38. Fertilizer Industry

Fertiliser industry: process-level energy savings from electrification

This chart compares energy use in the two major gas-intensive processes of Pakistan's paper and pulp industry – Process Steam (Boilers) and Process Heat (Dryers) – and shows how much energy can be saved by replacing gas equipment with electric alternatives.

→ Electric boilers use far less energy as compared to gas boilers because they do not lose heat through combustion, burner inefficiency, or flue gases. In Pakistan, many gas boilers operate at low efficiency due to poor gas pressure and outdated systems. Electrifying process steam avoid these losses and is a high-impact option as it provides major energy savings of 87.5%, and reduces operational issues related to gas shortages or pressure fluctuations.

→ Dryers require large amount of heat, and both gas and electric technologies consume nearly similar energy for this process. Electric dryers offer only modest efficiency improvements of about 10% savings. Electrifying process heat provides limited energy benefits.

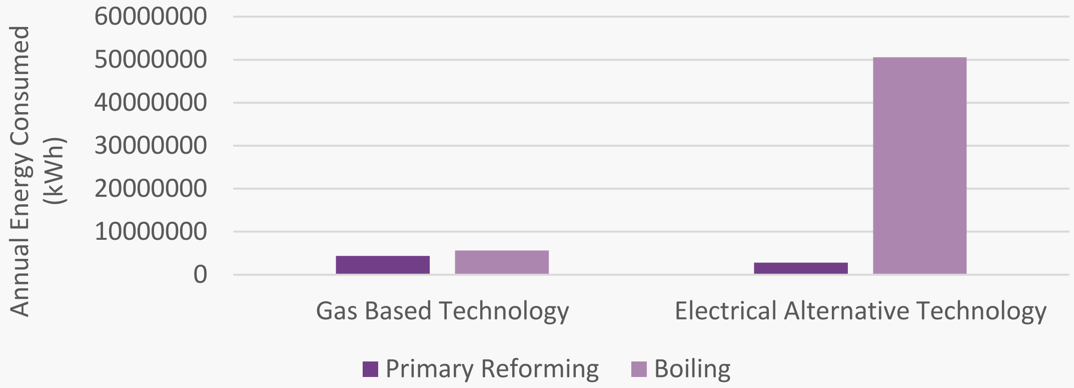

Figure 39. Fertilizer Industry: Energy Consumption Analysis

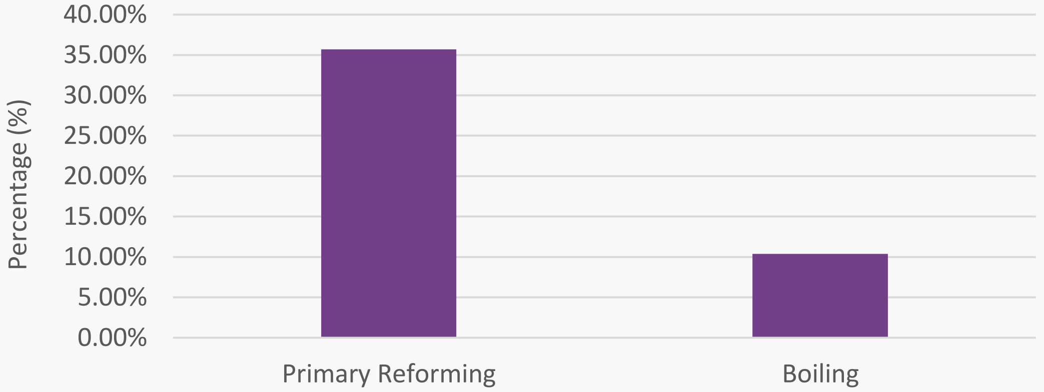

Figure 40. Fertilizer Industry: Transition Energy Savings (%)

Textile industry transition

- → The textile industry is a leading consumer of natural gas, consuming 23% of its total fuel use.
- → It contributes around 28% to industrial GDP, making it the most significant industry.
- → Pakistan mainly has medium and large-scale textile industries. This analysis focuses on a representative medium-level facility operating 16 hours per day.
- → To identify key electrification opportunities, major gas-consuming processes were evaluated based on their energy intensity and transition potential. From this assessment, five feasible gas-powered equipment types were shortlisted for potential electrification, supported by current market analysis.

Step 1
Baseline Setup: Gas Equipment Characteristics

We first established the baseline for existing gas-based process heating and steaming by inputting the rated thermal capacities of the installed equipment:

- Pre-Washing Gas based Boiler: 18 MWh Annual Heating
- Gas based Steamer: Steam Flow Rate 72 kg/h
- Main Washing Gas based Boiler: 18 MWh Annual Heating
- Gas Thermosol Dying Chamber: 98kg/h Steam Flow Rate
- Gas Based Dryer: 14MWh

→ Define reference fuel consumption and costs in current operations.

Step 2
Transition Scenario: Electric Equipment Using Grid Electricity

We replaced the gas units with electric alternatives, powered by the national grid.

- Pre-Washing Electric Boiler: 15 MWh Annual Heating
- Electric Steamer: Steam Flow Rate 62 kg/h
- Electric Main Washing Boiler: 13.5 MWh Annual Heating
- Electric Boiler for Thermosol Dying: 92kg/h Steam Flow Rate
- Electric Dryer: 11MWh

→ Quantified the energy demand (kWh) and operational cost implications of switching to electric heating.

Step 3
Renewable Energy Integration: Offset Load with PV

To improve feasibility, we introduced solar PV to offset electrical demand:

- PV System size: 0.6 MW
- Capacity factor: 22%
- Annual offset applied to 1,156,320 kWh electricity consumption
- Solar system CAPEX: $125/kW (optimistic)
→ $ total 75,000.

→ Determined contribution of renewables in reducing costs, emissions and grid dependence.

Step 4
Process-Level Energy Efficiency Assessment

We analysed energy performance improvements from electrification:

- Evaluated the heating and steaming processes using different end-use energy efficiency measures, accounting for the higher efficiency of electric heating compared to gas.

→ Estimated energy savings by reducing thermal losses and improving conversion efficiency.

Step 5
Feasibility Analysis: Energy Use, Cost & Investment Viability

We compared all scenarios: Gas baseline, Electric heating using grid only, Electric heating with renewable (PV) offset.

Key metrics analysed:

- Annual energy consumption
- Energy cost impacts
- Savings achieved through energy efficiency and PV integration
- Economic viability (CAPEX vs. payback and savings).

→ Determine if gas-to-electric transition is viable for the textile industrial processing sector in Pakistan.

Figure 41. Textile Industry

Textile industry: process-level energy savings from electrification

This analysis shows energy savings (percent) in key textile processes when gas-based equipment is replaced with electric alternatives. These processes are divided into two categories, i.e., process steam and process heat, which together account for the majority of energy use in Pakistan's textile sector.

- → Process steam in textile mills – used for water heating, steaming, main washing, and pre-washing – shows clear efficiency gains with electrification, as energy consumption falls by **18.2% in steaming** due to better temperature control and lower heat losses, **25% in main washing** because electric systems heat water directly without combustion or distribution losses, and **16.7% in pre-washing** by avoiding fuel wastage at lower temperatures, resulting in overall **16–25% energy savings** and demonstrating that electric systems are significantly more efficient for steam- and hot-water-based textile operations.
- → Process heat in textile mills – mainly used for fabric drying and thermal finishing – shows notable efficiency improvements with electrification, as energy consumption decreases by **8.4 percent in thermasol drying** chambers due to reduced heat losses and better control, and by **21.4% in dryers** where electric heating provides more uniform and efficient heat application, resulting in overall energy savings of **8–21%,** with higher gains in controlled drying processes and moderate gains in large thermal chambers.

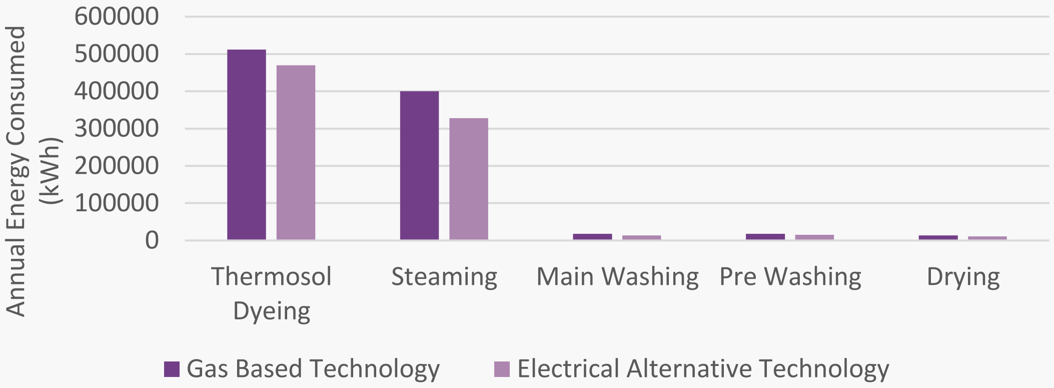

Figure 42. Textile Industry: Energy Consumption Analysis

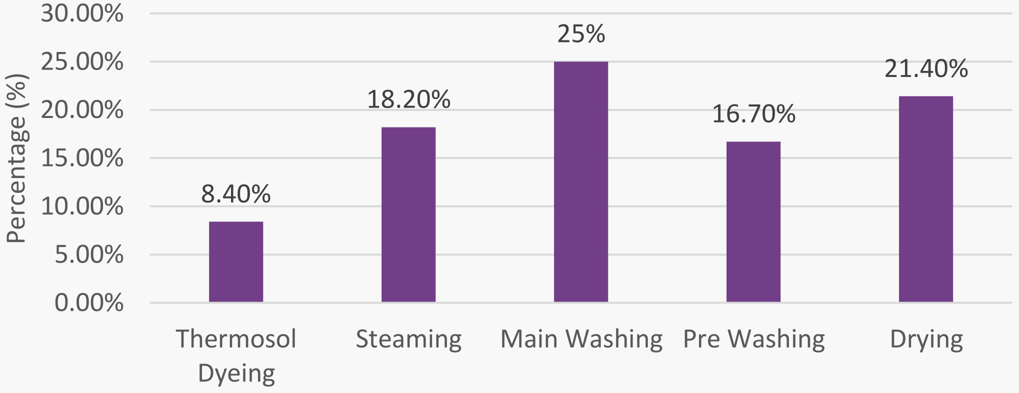

Figure 43. Textile Industry: Transition Energy Savings (%)

Textile industry: equipment transition analysis

Technology Comparison	Thermosol Drying – Chambers	Electric Drying – Chambers	Gas Steamer	Electric Steamer	Gas Based main washing	Electric main washing	Gas based pre washing	Electric pre washing	Gas based dryer	Electric dryer
Scenario 1: Gas Equipment to Electric Alternative Transition										
ANNUAL ENERGY CONSUMPTION (KWH)	512,071	469,303	400,398	327,657	18,000	13,500	18,000	15,000	14,000	11,000
ENERGY SAVINGS	8.4%		18.2%		25%		16.7%		21.4%	
CAPEX COST ($)	150,000	180,000	11,600	20,000	8,000	12,000	35,000	78,000	90,000	105,000
Scenario 2: Electrification using Grid Electricity										
ANNUAL ENERGY COST ($)	39,011	77,042	39,011	63,825	39,011	39,972	39,011	40,160	39,011	39,821
COST SAVING ($)	-38,030 (-97%)		-24,814 (-64%)		-961 (-2.5%)		-1,149 (-2.9%)		-810 (-2.1%)	
Scenario 3: Offsetting Load to Renewables (PV)										
ANNUAL ENERGY COST (AFTER SOLAR)	39,011	-60,560	39,011	-73,776	39,011	-97,629	39,011	-97,441	39,011	-97,780
COST SAVING (AFTER SOLAR)	99571 (255%)		112,787(289%)		136,640(350%)		136,452(350%)		136,791(351%)	

Electrifying 5 major gas consuming processes with efficient technologies

In Scenario 1, replacing gas equipment with electric equipment (without solar) reduces energy use by **8–25%** as electric machines are more efficient, but it requires higher upfront investment since electric systems are newer, more efficient and automated.

In Scenario 2, the electric machines rely on slower, resistance-based heating than gas – leading to longer operating hours – and when powered solely by Pakistan's high-tariff grid, operating costs rise sharply (≈**97%** for drying chambers, **64%** for steam generation, and **2–3%** for washing/dryers), making grid-only electrification economically unattractive for textile mills.

In Scenario 3, when electric textile equipment is powered by on-site solar PV, expensive grid electricity is largely avoided, reducing operating costs drastically – often to near zero – and delivering annual savings of about 100,000–137,000 US dollars per process (around 2**50–350%** higher savings than gas operation), making electrification highly profitable and reliable for Pakistan's textile industry.

Table 16. Textile Industry: Equipment Transition Analysis

Technical constraints: most DISCOs are not ready to serve increased electrification load

We are taking C-R as one of the metrics to analyse the feasibility for the respective DISCOs to absorb the electrification load.

DISCO Transformer Capacity Projections (2030)

- Capacity-to-Requirement Ratios (2030): Under projected load factors, all DISCOs are expected to maintain ratios generally above 1.6 to 2.7, indicating sufficient transformer capacity to meet peak demand.

Technical Insights:

- Despite adequate transformer capacity, network congestion and insufficient system strength remain critical issues.
- Some DISCOs have experienced prolonged blackouts, with recovery times exceeding 24 hours due to the lack of black-start capability.
- Limited reactive power support exacerbates voltage instability and contributes to cascading failures during high-demand periods.
- K-Electric continues to show relatively constrained capacity (1.4–1.8), highlighting the need for targeted network reinforcement.

DISCO	Capacity to requirement ratio 2024	% power transformer 100% or above Overloading percentage 2024	Capacity to requirement ratio-2030 (LF=0.41)	Capacity to requirement ratio-2030 (LF=0.6)
PESCO	2.8	18.00	1.7	2.3
TESCO	2.2	23.47	1.4	2.4
IESCO	2.5	2.81	2.0	2.6
GEPCO	2.2	0.00	2.0	2.5
LESCO	2.4	0.00	2.0	2.7
FESCO	2.2	0.41	2.1	2.3
MEPCO	2.0	0.00	1.6	2.2
HESCO	2.6	0.79	2.3	3.8
SEPCO	2.8	0.00	2.0	4.1
QESCO	3.6	8.41	2.4	3.2
K-Electric	1.9	0.55	1.4	1.8

Table 17. DISCO-wise transformers capacity to requirement ratio

Industry-specific transition roadmap based on our findings

Implementation Plan			
Industry	**Short-term (2024 to 2030)**	**Medium-term (2031 to 2045)**	**Long-term (2046 to 2050)**
Textile	Replace the gas-based technologies with feasible electrification alternatives, including heat pumps, electric steamers and electric main washing ultimately achieving approximately 43 percent energy savings at the plant level.	Replace the gas-based technologies with feasible electrification alternatives including electric pre-washing, electric drying chamber and electric dryer achieving more than 40 percent energy savings at plant level.	Completely cut down gas consumption by transitioning toward renewable electricity.
Food & Beverage	Gradually replace the gas-based char-broiler with feasible electric alternatives i.e. heat pumps, electric char-broiler will help in achieving more than 20 percent energy savings at plant level.	Replace the gas-based technologies with feasible electrification alternatives including electric oven ultimately achieving approximately 40 percent energy savings at plant level.	Fully transition toward renewable electricity to reduce dependence on coal, oil and natural gas as energy sources.
Pulp and Paper	Adopt renewable energy technologies such as biomass boilers to reduce reliance on natural gas.	Replace the gas-based technologies with feasible electrification alternatives including electric boiler and electric dryer ultimately achieving more than 95 percent energy savings at plant level.	Adopt renewable energy such as solar energy and biomass to completely minimize reliance on fossil fuels.
Chemical	Adopt renewable energy such as solar energy to meet the electricity demand.	Start Pilot projects for electrified steam cracking and completely cut down reliance on fossil fuels through renewable electricity.	Adopt electrified steam cracking and electric furnace to fully decarbonize the industry.
Fertiliser	Replace the gas-based captive power plants with solar power plants.	Start Pilot projects to produce green ammonia through Green H_2 Electrolysis replacing natural gas as feedstock.	Replace the gas-based technologies to feasible electrification alternatives including electric reformer and electric boiler achieving approximately 45 percent energy savings at plant level.
Cement	Shift towards Biomass/waste for heat production in a kiln.	Start pilot projects to use green hydrogen for power/heat generation.	Replace the gas-based technologies to feasible electrification alternatives including electric calciner and electric kilns.
Steel	Shift towards biomass-fired reheating furnace.	Start Pilot projects to produce green hydrogen through Green H_2 Electrolysis replacing natural gas as feedstock.	Replace the gas-based technologies to feasible hydrogen-based alternatives including H_2-DRI.