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Energy Landscape and Emission Analysis of Pakistan's Leather industry

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This study stands as a testament to what can be achieved through shared vision and collaborative effort. We hope its findings and recommendations serve as a catalyst for transformative change and inspire continued progress toward achieving the Sustainable Development Goals (SDGs).

Amjad Nazeer
Chief Executive Officer
Alternate Development Services (ADS)
Islamabad, November 2025

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Executive Summary

This summary presents the analytical findings and recommendations of the conducted study which mapped energy use, renewable uptake, and decarbonization readiness across 40 firms in Pakistan's leather sector and set out a practical, staged pathway for industrial decarbonization. The sector is energy-intensive, geographically grouped, export-oriented and dominated by small and medium enterprises (SMEs), making cluster-level interventions especially effective: modest efficiency gains and targeted renewable deployments deliver measurable cost, reliability and export-competitiveness benefits.

Survey results show that SMEs form the backbone of the sample, representing around 80% of respondents, while large firms account for the remainder; this structure creates both opportunities for scale and constraints because many SMEs face space, capital and tenure limits. Energy reliability is a central concern: 95% of respondents report regular outages and responses are polarized between modest (1–2 hours/day) and severe (6–8 hours/day) interruptions. That instability explains the heavy reliance on diesel generators (used by 85% of respondents) and the rapid, pragmatic shift toward self-supply solutions, most commonly solar photovoltaic (PV), which dominates choices among adopters. Renewable adoption trends are clear but uneven. Solar PV is the preferred technology, with installed capacities clustering around 200 kW for larger firms and 10–40 kW systems for SMEs; importantly, nearly 69% of non-users intend to install within 6–12 months, indicating strong short-term market momentum. Yet four main barriers impede broader uptake: high upfront cost (89.3% cited), space constraints (75%), maintenance concerns (60.7%) and inadequate local technical support (42.9%). Awareness is high, so the challenge is converting intent into bankable, service-backed projects rather than creating demand.

On environmental management, progress is mixed. Only about 31% of firms conduct Life Cycle Assessments (LCAs) and while roughly 42.5% monitor greenhouse-gas emissions, about 40% are uncertain whether they do so. The GHG Protocol is the dominant reference among firms that attempt measurement, but many others use ad-hoc methods or no tools at all. This data gap undermines firms' ability to credibly claim emissions reductions to buyers and to access green finance or export advantages tied to verified sustainability performance.

Taken together, these results imply that coordinated, cluster-level solutions will outperform isolated firm actions. Shared infrastructure; solar clusters, pooled battery storage, common effluent treatment plants with energy recovery; reduces per-firm costs and simplifies compliance. Buyer engagement and finance innovation are equally pivotal: pooled verification, phased compliance timelines and buyer-backed financing or offtake commitments significantly lower adoption barriers for SMEs and strengthen market access for exporters.

Accordingly, the study recommends a sequenced approach. In the short term (2025–2026), convene a Green Leather Policy Framework under the leadership of the Pakistan Tanners Association (PTA) and the Ministry of Industries & Production (MoIP), mandate baseline energy audits for medium and large firms, and launch 6–10 demonstration projects (solar PV ± BESS, solar thermal, biogas) across priority clusters. In the medium term (2027–2029), scale cluster-level shared systems, operationalize a Green Leather Fund with support from the State Bank of Pakistan (SBP) and commercial banks, and subsidize certifications and technical assistance through national programs such as those run by the National Energy Efficiency & Conservation Authority (NEECA). In the long term (2030–2035), integrate the

sector into national decarbonization planning, enable aggregated procurement or corporate PPA participation for large exporters, and institutionalize circular-economy practices and technology renewal cycles.

Efficient and robust measurement, reporting and verification (MRV) is non-negotiable to unlock finance and buyer trust. The study proposes mandatory smart metering and digital reporting for medium and large firms, cluster-based monitoring to reduce transaction costs for SMEs, accredited third-party verification aligned with international standards, and a public sectoral dashboard to track progress. Regulatory clarity and engagement with the National Electric Power Regulatory Authority (NEPRA) will be essential to address net-billing, sanctioned-load and interconnection rules that affect project design and bankability.

Finance strategies should blend concessional donor funds, SBP green windows, buyer co-finance and commercial lending with risk-sharing instruments such as partial guarantees and first-loss facilities. Performance-based incentives; rebates per kWh saved or per tonne CO_2 avoided; will help accelerate adoption and reward verified outcomes. Institutional coordination is best delivered through a representative National Leather Sustainability Council (NLSC) that brings together the Ministry of Climate Change (MoCC), industry, regulators, provincial EPAs and finance partners to oversee implementation, resolve cross-sector barriers and maintain an anonymized sectoral baseline dataset.

Key performance indicators to track progress include the number of certified energy audits completed annually, installed renewable capacity (MW) in the sector, average energy-intensity reductions (kWh or MJ per ton of finished leather), tonnes of CO_2e avoided, the volume of green finance disbursed and the number of SMEs supported, and the number of firms attaining international certifications such as those recognized by the Leather Working Group. Monitoring these KPIs will ensure accountability, demonstrate impact to buyers and funders, and guide adaptive policy.

The window for action is immediate. The leather sector’s geographic concentration, export exposure and existing buyer signals make coordinated initiatives (like pilot projects), cluster infrastructure and MRV systems both practical and of high impact. Forming the NLSC without delay, launching demonstration projects in identified clusters; including Kasur, Lahore and Karachi; rapidly deploying baseline metering for pilot participants, and establishing a blended finance mechanism to mobilize SME uptake is critically recommended. With decisive public-private leadership and clear, verifiable outcomes, Pakistan’s leather sector can turn an emissions and competitiveness challenge into a demonstration of inclusive, export-driven green industrialization.

Chapter 1: Introduction and Contextual Development

1.1 Background of Pakistan's Leather Industry

The leather sector is one of Pakistan's most important sectors in terms of manufacturing and export industries, ranking among the top contributors to national export revenues after textiles. With an increase in the country's large livestock population, the sector has a link with the leather industries. It supports a network of small and medium-sized tanneries, employs hundreds of thousands of workers both directly and indirectly, and sustains ancillary industries including tanning chemicals, machinery, and transport services. This sector has a central role in Pakistan's industrial landscape and is facing deep structural and operational challenges that constrain. From exports, its performance has gradually declined over the past decade, reflecting limited product diversification, outdated processing technologies, and persistent quality and traceability issues in raw materials. However, ADS's main concern is about the energy costs that remain high and volatile, particularly with dependence on fossil fuels and frequent power shortages, which significantly raise production costs for tanneries.

Economic Significance and Export Performance: The leather industry is playing a pivotal role in economic growth, employment, and foreign exchange earnings. As one of the top three export-oriented industries, alongside textiles and rice, it contributes approximately 4–5% to the national GDP and supports over one million direct and indirect jobs, particularly in regions such as Karachi, Lahore, and Kasur (SME Programme, 2023) [1,2]. In FY 2022–23, leather exports reached USD 1.13 billion, with over 95% of production targeting international markets, primarily Europe, North America, and the Gulf countries [3].

Geographical Concentration and Industrial Clusters: Pakistan's leather sector is a significant export-oriented cluster within the national economy. Key export products include finished leather, footwear, and leather goods, with Pakistani tanneries widely recognized for their quality and craftsmanship, as reflected by industry participation in events such as the Pakistan Mega Leather 2023[4]. The sector is geographically concentrated in several industrial hubs notably Karachi (Korangi Industrial Area), Lahore, and Kasur, with an estimated 700–800 tanneries operating nationwide according to industry sources Pakistan Tanners Association (PTA) [5]. These clusters are important not only for export earnings and employment, but also because their industrial footprint concentrates resource use, pollution risks, and energy demand in defined localities.

Energy Consumption Patterns in Leather Processing: Building on national and sectoral statistics, this section now converges to the central technical focus on nature, form, source and magnitude of energy consumed by the leather processing value chain. Drawing on secondary sources (industry association reports, national energy statistics, and published technical studies), this section examines the energy vectors used across tanning and downstream processes (thermal energy for liming, tanning and drying; mechanical/electrical energy for drums, dyeing and finishing; compressed-air systems; and fuels for boilers). It quantifies, where data permits, the relative shares of grid electricity, natural gas, biomass/wood, and captive diesel or furnace-oil generation in typical tannery operations and highlights the overall energy intensity and seasonal/scale-related variation of consumption within cluster types (small, medium and large tanneries).

Leather production is inherently resource-intensive, requiring significant energy and water inputs. A typical tannery consumes approximately 0.97–1.87 MJ per 100 ft^2 of finished leather for processes such as soaking, liming, tanning, dyeing, drying, and finishing [6]. The leather industry in Pakistan is a highly energy-dependent sector, where consistent and affordable energy supply is critical for maintaining production efficiency and competitiveness. This energy is predominantly derived from grid electricity and fossil fuels such as natural gas and diesel sources that expose tanneries to price volatility, supply disruptions, and escalating operational costs [7]. These vulnerabilities are further compounded by Pakistan's ongoing energy crisis, with nearly 40% of the primary energy supply relying on imported fossil fuels. Within this context, the transition toward renewable and solar-based energy emerges as a strategic opportunity to enhance energy security, reduce production costs, and minimize carbon emissions.

Sustainability and energy efficiency are critical for the long-term viability of Pakistan's leather industry. The sector faces a dual challenge: reducing energy costs to remain competitive while aligning with global sustainability benchmarks [8]. Pakistan, despite contributing less than 1% to global GHG emissions, ranks among the top 20 emitters in absolute terms, with the energy sector accounting for 46% of emissions in 2012, a significant portion of which stems from industrial activities like leather processing [9].

Energy and Environmental Concerns: The leather sector's current energy mix and operational practices create two interlinked concerns:

(1) direct environmental and public-health risks from on-site fuel combustion and effluent-related processes, and
(2) a material contribution to greenhouse-gas emissions through fossil-fuel use and inefficient energy practices. The primary purpose of this study is therefore to undertake an Assessment of Renewable Energy (ARE) options for the leather sector with the explicit aim of reducing carbon emissions and mitigating climate-related impacts while safeguarding worker safety and local environmental quality.

While the tanning process also produces wastewater containing chromium and sulfides, these environmental concerns are treated here as secondary issues important but beyond the central scope of this study. The primary analytical focus remains on energy consumption patterns, the feasibility of solarization, and its potential to mitigate climate impacts. Pakistan's market pressures and environmental regulations are increasingly motivating Pakistani tanneries to explore such clean energy transitions as similar solarization initiatives in other industries (e.g., flour milling, textile industries) have already demonstrated tangible economic and environmental benefits, posing significant challenges for sustainable waste management.

Table 1: The key characteristics of Pakistan's leather sector and its relevance to the energy transition

Category	Description	Relevance
Pakistan's Emission Share	< 1% of total GHG emissions	Despite a small share, Pakistan's emissions are significantly high
Leather sector Contribution	Leather processing and tanning industries contribute a notable share to the industrial sector	Energy-intensive and pollution-prone activities (heat, steam, chemicals)
Number of Tanneries	~800–900 (major clusters in Lahore, Kasur, and Karachi)	Concentrated around export-oriented production zones

Leather Tanneries' Energy Sources	Grid electricity, natural gas, diesel generators, biomass (in some units)	High dependency on fossil fuels leads to CO_2 and local air pollution
Tanneries Emission Type	CO_2, VOCs, SO_2, NO_x from energy combustion; indirect emissions from chemical processes	Industrial emissions add to Pakistan's total industrial GHG share
How is this relevant to Energy Transition	The sector offers potential for solar thermal and hybrid systems to replace fossil energy for heating, coloring and drying	Supports national decarbonization and climate goals
Policy/Research Implication	Integration of renewable systems (solar, biomass) under national 2030 targets	Aligns with the clean energy transition agenda

1.2 Pakistan's stand in the leather industry

Pakistan's leather industry remains one of the country's key non-textile export sectors, combining labor-intensive manufacturing with value-added production. The sector directly employs around 500,000 people across tanneries, footwear, and finished-goods units. The industry contributes about 5 – 5.4% of Pakistan's total export earnings, according to reports by Pakistan Tanners Association (PTA) and the Pakistan Business Council [10].

Recent export figures show a mixed but informative picture. For instance, in fiscal year 2021-22 (July-June), exports of leather manufactures reached US$621.081 million, up 10.43% from US$562.428 million in the prior year [11]. In the first ten months of FY21-22 (July–April), exports were US$515.449 million, a growth of 9.98% over the same period the year before [12]. Looking deeper into product categories, in FY23 the industry saw an overall export value of about US$887 million, but this represented a decline of 7% from the previous year; tanned leather exports fell 19.4% to US$167 million, while leather footwear exports rose 14% to US$142 million [13]. According to the PTA & government figures for FY24, exports stood at US$808 million, a drop of 8.9% year-on-year; gloves accounted for US$283 million (~35% of leather exports) and footwear US$125 million (~15.5%).

These stats underline both the strengths and vulnerabilities of Pakistan's leather industry. The strong showing in footwear growth is encouraging and suggests emerging value-addition trends (away from merely raw leather), whereas declines in tanned leather exports raise concern over competitiveness, raw material input costs, and environmental compliance. The fact that gloves make up such a large share (~35%) of total leather exports indicates a relative specialization in that sub-category. Policy interventions, including subsidies for energy, streamlined raw-material import duties and investment in eco-friendly tanning, will play a major role in reversing downward trends and enabling the sector to climb the value chain [14].

1.3 Energy consumption in the leather industry with respect to Pakistan's overall industrial sectors

Pakistan's leather sector is an energy-intensive sector in Pakistan's energy landscape. The leather value chain from soaking and beamhouse operations through chrome tanning, drying, and finishing relies on both thermal energy (steam, fuel for boilers) and electricity (drums, pumps, finishing lines), and many tanneries remain comparatively inefficient in their energy use. Pakistan's tanneries and leather-goods makers directly employ hundreds of thousands of workers, and the sector is responsible for roughly 5% of the country's export earnings, underlining its economic importance despite its relatively small size compared with textiles [15].

Placing leather energy needs in the wider industrial picture shows the scale gap: industry as a whole accounted for about 37% of Pakistan's total energy consumption in recent national assessments, while the textile sector alone has been reported to consume roughly ~17% of total industrial energy (textiles are by far the largest single manufacturing energy user). By contrast, leather given its smaller industrial footprint (export and value-added shares well below textiles) is unlikely to account for more than a low single-digit share of total industrial energy use (roughly 1–3%). That range is an informed estimate based on the sector's share of manufacturing output and export orientation and on published studies highlighting tanneries' high per-unit energy and water intensity. Put another way: leather punches above its weight economically (high value-addition per worker) but consumes a disproportionately large amount of heat and water per tonne processed compared with many light manufacturing sub-sectors [16].

The policy and practical implications are clear and already documented in industry and donor studies: modest investments in energy efficiency and process-level upgrades can produce large savings. Energy-conservation projects run for Punjabi tanneries and sectoral reviews by PTA/TDAP and development partners show that improved boiler efficiency, heat recovery, switching inefficient diesel boilers to more efficient fuels or steam networks, and recovering biogas from organic tannery wastes can cut energy costs substantially at the plant level often by double-digit percentages, and at the same time reduce environmental non-compliance that limits market access. Strengthening these interventions while aligning electricity and fuel pricing and providing targeted finance would therefore both reduce the leather sector's energy intensity and help lower industry-wide energy demand in Pakistan [17].

1.4 Global Context: Leather Industry, Energy Transition and Trade Frameworks

Globally the leather industry is undergoing a significant transition driven by rising energy costs, stricter environmental regulations and sustainability demands from international buyers. Major leather producing countries such as Italy, Turkey, India and Bangladesh have increasingly adopted energy efficient technologies, solar energy, biomass boilers and energy management systems (EMS) that not only reduces emissions but also the operational cost. For example, India has reached around 50% renewable installed power capacity, while Turkey sources over 55% of its electricity capacity from renewables, particularly hydro, wind and solar. In several competing export markets, energy efficiency and low carbon production are now integral to industrial competitiveness rather than an option.

The urgency of energy transition in Pakistan's leather industry is reinforced by evolving global climate and trade frameworks. International compliance and sustainability standards such as Leather Working Group (LWG), ISO 14001 Environmental Management Systems, and ISO 50001 Energy Management System, all of which emphasize energy efficiency and emission reduction. Moreover, global carbon pricing mechanisms such as the EU Emissions Trading System (ETS) now regulate almost half of all greenhouse-gas emissions in the EU. Under this system, companies must pay for the carbon they emit, which makes carbon-intensive production more expensive. Additionally, emerging trade instruments such as the EUs Carbon Border Adjustment Mechanism (CBAM) requirements are expected to impose additional costs or reporting obligations on carbon intensive industries. While Pakistan's overall contribution to GHGs is very low, carbon intensity at product or facility level plays a decisive role.

Failure to reduce fossil fuel dependence and document emissions along the supply chain may expose leather exports to tariff barriers, reputational risks, and declining market share.

1.5 Environmental Concerns in leather industry with respect to overall Pakistan's industrial sectors

Pakistan's leather industry is economically important but environmentally problematic compared with other industrial sectors. The sector directly employs hundreds of thousands and contributes roughly 4–6% of Pakistan's total export earnings, yet its production processes soaking, chrome tanning, dyeing and finishing are water-intensive, heavy chemical-intensive and generate wastewater laden with sulfides, salts, high biochemical oxygen demand (BOD) and heavy metals such as chromium. Pakistan's trade and industry reviews note that many tanneries still lack adequate on-site effluent treatment, and the industry relies on a mix of common effluent treatment plants (CETPs) and individual ETPs that are unevenly implemented across clusters [3].

The environmental footprint is concentrated in tannery clusters such as Kasur, Lahore and Korangi, where studies and news reporting document persistent contamination of surface and groundwater. Kasur alone has been repeatedly flagged in the literature and press: historical surveys and government records identify around 270 tanneries in the Kasur cluster processing on the order of hundreds of tonnes of hides per day, and multiple field studies find elevated chromium and other heavy-metal concentrations in soil and groundwater near tannery drains. Local enforcement actions (including periodic sealing of non-compliant units) and long-running projects for example the Kasur Tannery Pollution Control Project and more recent CETP efforts testify to the scale and longevity of the problem [18].

Beyond local contamination, the problem has national macroeconomic and health dimensions. National environmental assessments estimate that environmental degradation (from industrial pollution, loss of soil and water quality, etc.) costs Pakistan a substantial share of GDP conservative estimates put the loss at around 5–6% of GDP meaning that unchecked tannery pollution contributes to broader economic and public-health burdens. Practical remedies highlighted in TDAP, World Bank and academic studies include stricter enforcement of effluent standards, universal access to functioning CETPs/ETPs, cleaner tanning chemistry and process optimization, and financial/technical support to help smaller tanneries invest in cleaner technology. Those steps would reduce local health risks (contaminated wells, crop uptake of heavy metals), protect downstream communities, and help the industry retain market access in environmentally sensitive export markets [16].

1.6 Contribution/Novelty of This Study

This study offers a distinct and timely contribution by providing sector-specific energy and emission assessments of Pakistan's leather industry with an explicit focus on renewable energy transition. This research places energy consumption, energy security, and decarbonization at the center of analysis. The study's novelty lies in its integrated approach: combining field-level data from major leather clusters with national energy statistics, policy analysis, and international sustainability benchmarks. It systematically identifies energy-intensive processes, evaluates the feasibility of solar and other renewable solutions at both firm and cluster levels, and links technical findings with actionable policy and financing recommendations.

1.7 Scope and aims of the study

This report focuses on leather, leather articles and covers the full value chain from hides and skins supply to finished leather goods such as apparel, handbags, and gloves. Therefore, the aims of the study are as follows:

- Reduce environmental impact and align the industry with sustainability standards;
- Improve energy efficiency and promote renewable and cleaner energy use in tanneries;
- Build governance, policies, institutional coordination and finance mechanisms to support the energy and clean fuel transition.

1.8 Objectives of the Study

There are some specific objectives as follows:

1. Characterize the sector's energy demand profile (by process and cluster) using secondary data and field-validated measurements;
2. Quantify the potential emissions reduction from realistic renewable or cleaner-fuel interventions (technical and economic feasibility); and
3. Identify institutional, regulatory, and technical roadblocks and propose practicable pathways (policy, financing, and operational upgrades) for scalable decarbonization and environmental protection.

Chapter 2: Methodology of Study

2.1 Study Design

This study, conducted by the Alternate Development Services (ADS), aims to analyze the energy landscape and emission profile of Pakistan's leather industry in decarbonization and sustainability perspective. The research seeks to identify the energy sources, consumption patterns, emission hotspots, and the potential for renewable energy (RE) transition within the sector. The primary objectives of this study are to:

1. Examine the types and intensity of energy use (electricity, natural gas, diesel, and biomass) across tanneries and leather-processing units.
2. Assess the carbon and pollutant emissions associated with various stages of leather processing.
3. Evaluate the adoption level and barriers to renewable and energy-efficient technologies in the leather industry.
4. Generate policy-relevant insights to support Pakistan's industrial decarbonization and green export competitiveness.

To achieve these objectives, a mixed-methods research design was employed combining a structured survey with targeted interviews and secondary data analysis. The study focuses on major leather clusters across Lahore, Kasur, and Karachi, which collectively represent the majority of Pakistan's tanning and leather-processing activities.

2.2 Data Collection Approach

2.2.1 Questionnaire Development

A structured questionnaire was designed to capture both quantitative and qualitative data from leather manufacturing and tanning units. The questionnaire consisted of the following sections:

1. Company Profile: Ownership type, scale of operations, annual production capacity, and export orientation.
2. Energy Use Patterns: Sources and quantities of electricity, gas, diesel, and biomass consumed; installed captive generation systems; and energy costs.
3. Production and Process Details: Key tanning and finishing processes, machinery used, and operational hours.
4. Emission Sources: Estimated emissions from boilers, generators, effluent treatment plants, and process heating; adoption of emission control technologies.
5. Renewable Energy and Efficiency Measures: Current or planned RE projects, energy audits, and technology upgrades.
6. Policy, Regulatory, and Market Challenges: Barriers to energy transition, access to finance, and awareness of national emission standards.

The questionnaire combined multiple-choice, Likert-scale, and open-ended questions, enabling collection of measurable data while capturing insights on behavioral and structural challenges. The design was informed by international studies on industrial energy transitions, Pakistan's National Energy and Climate Framework, and prior ADS research on industrial decarbonization.

2.2.2 Sampling Strategy

A purposive sampling strategy was employed to ensure inclusion of representative firms across the major leather clusters. The target was to collect responses from 50 industries, distributed approximately as follows:

Table 2: Sampling Strategy

City / Cluster	Estimated Tanneries (Small and large)	Target Sample
Lahore and Kasur	~270	20
Karachi	~200–250	20

The selection criteria included:

- Active engagement in leather tanning, processing, and finishing.
- Availability of energy and production data.
- Willingness to participate in the study.

The sampling aimed to balance firm size (small, medium, large) and export orientation, ensuring coverage of both traditional tanneries and technologically advanced exporters.

A database of firms was compiled using information from:

- Pakistan Tanners Association (PTA)
- Trade Development Authority of Pakistan (TDAP)
- Provincial Environmental Protection Agencies (EPAs)
- Online directories, Google Maps, and local industry networks

2.2.3 Data Collection Process

Data collection took place between August to October 2025, led by a team of trained enumerators based in each of the selected clusters.

- Each enumerator contacted tannery representatives through in-person visits, phone calls, and virtual interviews.
- Enumerators were trained to administer the survey using Google Forms, enabling real-time data entry and centralized data management.
- Key respondents included energy managers, production heads, and technical officers with knowledge of operational and energy systems.

Where respondents were unavailable, enumerators made follow-up visits or relied on industry association contacts to facilitate introductions. Supplementary qualitative interviews were conducted with 15 industry experts, including environmental auditors and technology vendors, to validate survey findings and provide deeper contextual insights.

2.3 Challenges Encountered

The study faced several logistical and field-related challenges:

1. **Data Sensitivity:** Some tanneries were reluctant and many others were not reluctant to share energy consumption or emission data due to confidentiality concerns, fearing potential regulatory implications.
2. **Informal Operations:** A significant portion of small tanneries operated without formal energy metering, making it difficult to obtain precise consumption figures.
3. **Inaccurate Business Listings:** Some firms listed in directories were found non-operational or relocated, especially in Lahore and Kasur clusters.
4. **Respondent Availability:** Key technical staff were often unavailable during working hours due to production schedules, causing delays.
5. **Seasonal Variation:** Some tanneries operated below capacity during the data collection period, affecting the representativeness of energy use data.

To mitigate these issues, enumerators adopted flexible approaches including repeated visits, cross-verification through local associations, and triangulation of partial data from multiple sources (e.g., energy bills, process logs, and respondent estimates).

2.4 Data Analysis Plan

A mixed-methods analysis was applied to generate comprehensive insights:

i). Quantitative Analysis:
- i). Energy data were analyzed using descriptive statistics (averages, shares, and ratios) to determine energy intensity (kWh or m^3 per ton of leather) and emission factors.
- ii). Emission estimates were calculated using standard IPCC emission coefficients and national fuel emission factors.
- iii). Comparative analysis across cities highlighted regional variations in fuel mix and process efficiency.

ii). **Qualitative Analysis:**
- i). Open-ended responses were coded using thematic analysis, focusing on recurring themes such as financial constraints, technology gaps, and regulatory bottlenecks.
- ii). Findings were cross-referenced with secondary literature and expert interviews to ensure validity and interpretive depth.

The analysis results were triangulated with literature review findings and national industrial energy data to ensure robustness and policy relevance.

2.5 Ethical Considerations

The research followed strict ethical guidelines:

- i). Participation was voluntary, and respondents were informed of the academic purpose of the study.
- ii). Confidentiality of all company-specific data was ensured.
- iii). No sensitive or personally identifiable information was disclosed publicly.
- iv). Enumerators adhered to professional ethics, maintaining transparency and respect for respondents' time and privacy.
- v). Data was securely stored on encrypted digital platforms accessible only to the ADS research team.

2.6 Limitations

While the methodology provides a robust framework, ADS faced several limitations as follows:

i). The purposive sample does not fully capture the diversity of smaller, informal tanneries operating in/outside the clusters.
ii). Incomplete or estimated energy data may affect the precision of emission calculations.
iii). Reliance on self-reported information introduces potential response bias.
iv). The seasonal variation in tannery operations might influence average energy and emission levels.

Despite these limitations, the methodology provides a credible and comprehensive basis for analyzing the energy and emission landscape of Pakistan’s leather sector and offers valuable insights for advancing industrial decarbonization policies.

Chapter 3: Results and Discussion

3.1 Data Collection and Analysis

ADS collected data about the "Year of Establishment", and it presents, from 40 leather sector companies, showing the distribution of their founding years. The responses span several decades, reflecting both long-established and relatively newer enterprises within Pakistan's leather industry. The data shows that the most significant number of companies were established in 1995 and 2001, each accounting for 12.5% (5 companies) of the total. This suggests that these years marked notable phases of industrial activity and investment in the leather sector, possibly linked to favorable trade conditions, industrial expansion, or policy incentives during those periods. A moderate rise in establishments is also visible in 1985, with 7.5% (3 companies) formed during that year, indicating early growth momentum. Several other years, including 1988, 1993, and 2003, each represent 5% (2 companies) of the total, showing consistent but limited establishment of new enterprises over time. The remaining years show smaller contributions, with 2.5% (1 company) per year, reflecting gradual sectoral growth rather than concentrated surges. Overall, the data suggests that Pakistan's leather industry has developed progressively over time, with notable peaks in the mid-1990s and early 2000s. This pattern reflects a mix of mature, long-standing firms and newer entrants, highlighting both the sector's historical roots and its continued evolution. The data underscores a stable but uneven growth trajectory, shaped by changing economic opportunities and market dynamics within the country's industrial landscape.

The **Fig. 1** titled "Scale of Operation" presents data from 40 industries in Pakistan's leather sector, highlighting the distribution between small and medium enterprises (SMEs) and large-scale industries. The results reveal a significant dominance of SMEs, which account for 80% of the total responses, while 20% represent large-scale industries. This distribution clearly indicates that the leather sector in Pakistan is predominantly driven by small and medium-sized enterprises. SMEs form the backbone of the industry, contributing substantially to production, employment, and local value addition. Their dominance reflects the decentralized and labor-intensive nature of leather manufacturing, where smaller units often operate independently or as suppliers to larger firms. These enterprises typically focus on tanning, finishing, and producing leather goods for domestic and export markets, though they often face challenges related to technology adoption, financing, and compliance with international environmental and quality standards.

On the other hand, the 20% share of large-scale industries shows that a smaller number of firms operate at higher production capacities with greater investment, technological sophistication, and export orientation. These industries play a crucial role in maintaining Pakistan's position in leather markets and are likely to have better access to modern infrastructure, skilled labor, and international buyers. Furthermore, Pakistan's leather sector is SME-dominated, with a limited but influential presence of large-scale manufacturers. This structure suggests significant potential for industrial upgrading, where targeted support to SMEs through access to finance, cleaner production technologies, and skill development could strengthen the sector's competitiveness and sustainability.

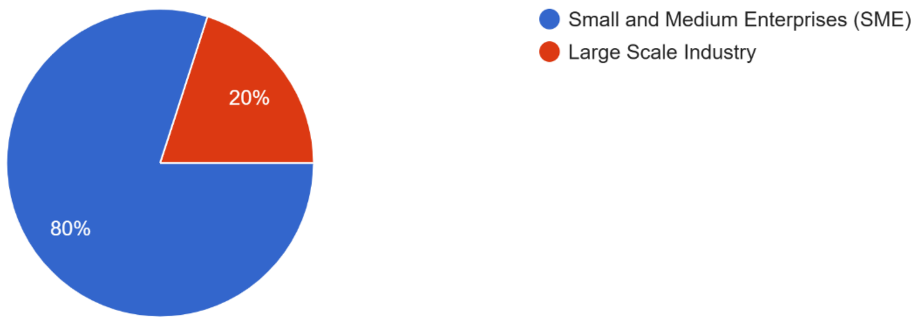


Figure 1: Scale of Operations

The **Fig. 2** presents data on the types of products produced by companies within Pakistan's leather industry. It shows the proportion of companies engaged in four key stages of leather production from raw hides to finished goods. Firstly, Finished Leather – 87.5% (35 companies): this is the most common product among respondents. A very high percentage (almost 9 out of 10) of companies produce finished leather, indicating that the sector is primarily focused on value-added processing rather than only raw material preparation. This suggests substantial capacity and expertise in tanning, finishing, and chemical processing. Secondly, Raw Hides Processing – 50% (20 companies): Half of the companies are involved in raw hide processing, which is an early stage of the value chain. This reflects that many firms still maintain vertical integration handling both the initial and advanced stages of leather production.

Thirdly, leather goods (bags, shoes, gloves, jackets, etc.) – 45% (18 companies): Almost half of the companies produce final consumer goods. This indicates a growing trend toward downstream value addition and diversification into finished leather products, which typically have higher profit margins and export potential. Lastly, Semi-Finished Leather – 37.5% (15 companies): Fewer firms are limited to semi-finished leather production, implying that most are either moving upstream (raw hides) or downstream (finished leather and goods). This could also reflect a declining market for semi-finished exports as buyers prefer fully finished leather or ready-made products.

The data reflects strong vertical integration within Pakistan's leather sector, as many companies are engaged in multiple stages of production from raw hide processing to finished leather and leather goods. The dominance of finished leather production (87.5%) and the notable share of leather goods manufacturing (45%) indicate a clear shift toward value addition, moving away from low-value exports such as wet blue or crust leather toward higher-value, finished products. This trend also points to growing export readiness, as companies increasingly focus on products that cater to international markets, provided they continue adopting sustainable and energy-efficient practices. Moreover, the relatively lower percentage of semi-finished leather producers suggests that the industry is maturing, with fewer firms depending solely on intermediate-level production and more advancing toward complete, market-ready outputs.

This highlights a diverse yet value-driven structure in Pakistan's leather industry. Most companies are involved in finished leather production, showing advanced processing capacity, while a substantial share is also entering leather goods manufacturing, a promising direction for job creation, export diversification, and industrial decarbonization efforts.

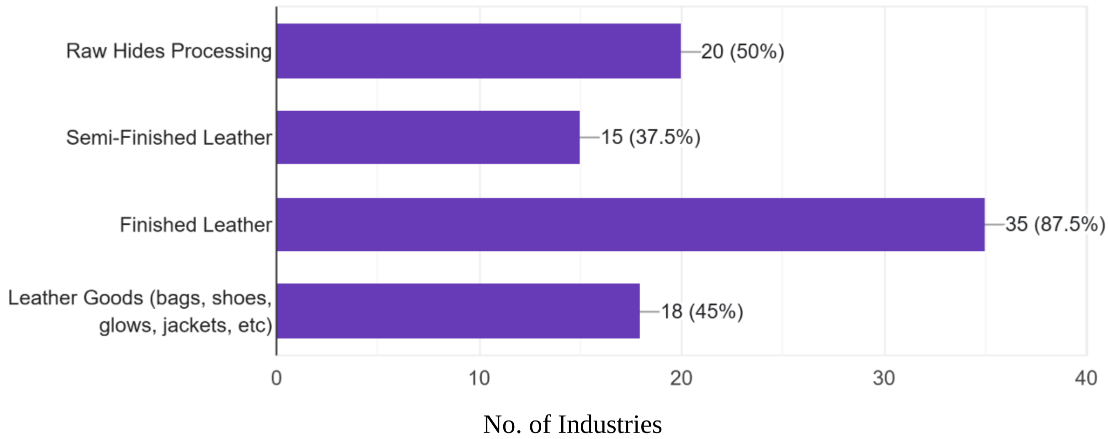


Figure 2: The product variety of the industry

The bar chart in **Fig. 3** illustrates the responses of 40 respondents regarding the number of electricity units consumed monthly for their operations. The data reveals a diverse range of electricity consumption, indicating variations in scale and operational intensity among respondents. The key observations are as follows: Firstly, the most frequently selected consumption level is 350 thousand units, chosen by 4 respondents (10%), suggesting that this may be a typical consumption range for medium-to-large-scale operations. Three consumption ranges each received 3 responses (7.5%): 25,000 units, 35,000 units, and 40,000 units. These responses show that there is a noticeable cluster around the mid-to-high range of consumption. Secondly, the moderately chosen categories are: Two categories received 2 responses (5%) each: 300,000 units, and 400,000 units. This indicates that several operations fall into higher consumption brackets, though not as frequently. Thirdly, the rest of the responses (covering categories such as 18,000 units, 70,000 units, 1.2M bill, 600 thousand bill, etc.) were each selected by 1 respondent (2.5%), showing a broad diversity in electricity usage patterns across companies. Lastly, a small uncertainty with a respondent replied no idea, one response category was labeled "No Idea," indicating that at least one participant was unaware of their electricity consumption, pointing to potential gaps in operational tracking or reporting.

Overall, the chart shows no clear dominant level of electricity consumption among companies, highlighting the variation in scale, production intensity, and energy management practices. While 350,000 units stands out slightly, the spread suggests that each organization has unique operational demands. The data also hints at opportunities for energy audits or efficiency improvements, especially for those unaware of their usage.

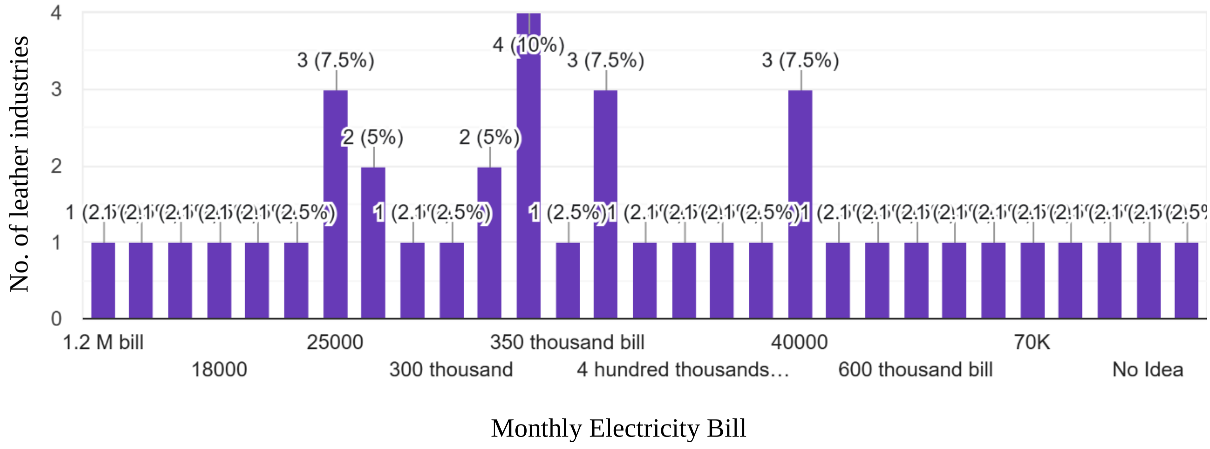


Figure 3: Monthly electricity consumption (in Units) by leather industries for operational use

The bar chart in **Fig. 4** presents data of monthly fuel consumption (in liters) for generator usage. The results reveal a varied pattern of consumption, with some respondents using minimal fuel, others consuming significant amounts, and a few not using fuel or not providing the data.

- The most common responses (Highest Frequency – 21.4% Each): 2,500 liters and "No" (no fuel consumption) were each selected by 6 respondents (21.4%). This suggests a split between companies heavily reliant on generators and those that likely do not use generators at all or use alternate power sources.
- Secondly, moderately common consumption levels: 2,000 liters – 4 responses (14.3%), 1,500 liters – 3 responses (10.7%) These numbers reflect a moderate dependency on fuel-powered generators.
- Thirdly, other reported ranges (Each Below 10%): 3,000 liters – 2 responses (7.1%), 1,000 liters – 2 responses (7.1%), 50, 3,200, 4,000 liters – 1 response each (3.6%).
- Additionally, these categories indicate either low or high consumption, but not common among most respondents.
- Lastly, non-responses: only 1 response suggest either incomplete answers or confusion in entering data.

The chart demonstrates that fuel consumption for generators varies widely across companies. While 2,500 liters/month appears to be a typical usage level for those relying on generators, an equal number of respondents do not use generators at all, possibly due to alternative power sources or reliable electricity supply. A noticeable portion also consumes between 1,000 to 3,000 liters, indicating moderate reliance. The variation in responses reflects differences in company size, operations, and energy infrastructure, with a small portion not using or tracking generator fuel usage at all.

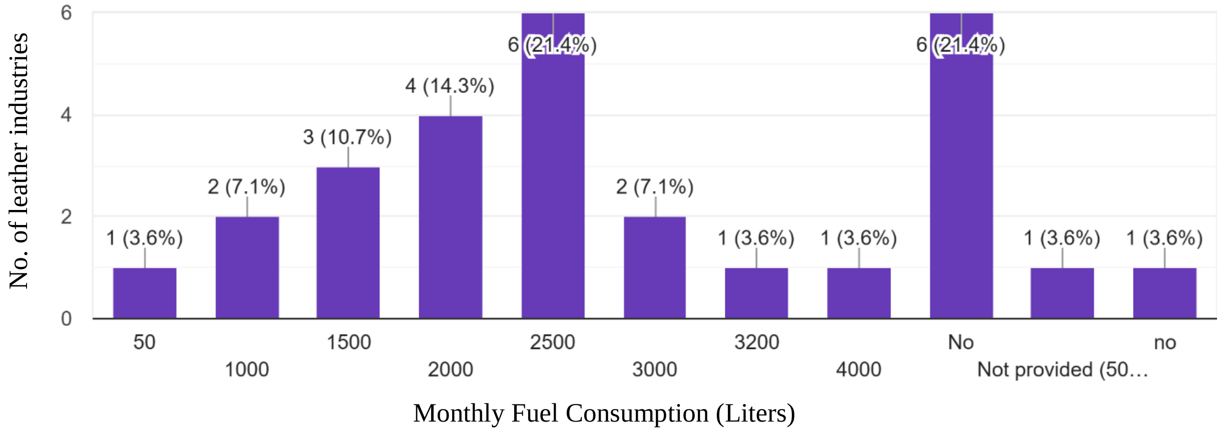


Figure 4: Monthly fuel consumption (in Liters) for generators.

Next, **Fig. 5** presents the distribution of solar photovoltaic (PV) system capacities. The chart illustrates the diversity in installed solar PV capacities, measured in kilowatts (kW), and highlights trends in adoption levels.

The 200 kW category records the highest number of responses (6 respondents, 15.4%), indicating that this capacity is the most popular among the participants. Secondly, the 30 kW and "Yes, but don't know the capacity" categories each have 5 respondents (12.8%), suggesting that a significant portion of users either have medium-scale systems or are uncertain about their system's exact capacity. Thirdly, the 15 kW and 100 kW categories each have 3–4 respondents (7.7%), showing moderate adoption of small to mid-scale systems. Fourthly, a few respondents (around 2–3 in each category) reported capacities like 10 kW, 20 kW, 35 kW, 40 kW, and 50 kW, indicating scattered adoption across various system sizes. Lastly, a small proportion (2.8%) reported no installed PV system (0 kW) or installed but not operational systems, suggesting either early installation phases or inactive systems. However, some respondents indicated uncertainty about their PV capacity, showing a potential gap in user awareness or technical documentation.

Firstly, the dominance of the 200 kW installations suggests that most users in the sample may belong to commercial or institutional sectors, as this capacity typically exceeds residential-scale systems. Secondly, the presence of multiple small-scale capacities (10–50 kW) indicates growing interest in decentralized renewable energy among smaller enterprises or households. Lastly, the notable percentage of respondents unaware of their system capacity highlights a need for improved user education and record-keeping regarding solar installations. Additionally, it demonstrates a diverse distribution of installed solar PV capacities, with a clear peak around 200 kW systems. While large-scale installations are most common, the spread across other capacity ranges reflects increasing participation at different scales. However, the data also reveals that a portion of users lack clarity about their installed capacity, emphasizing the importance of capacity awareness and system monitoring for better energy management and policy implementation.

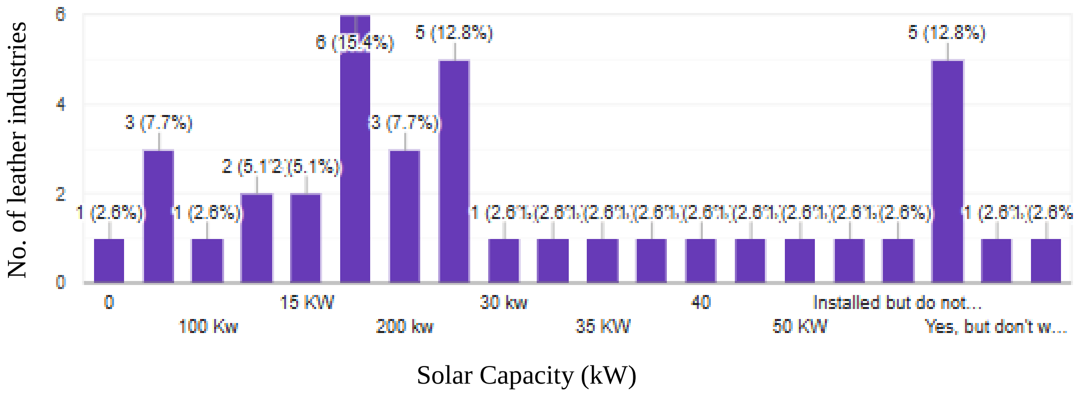


Figure 5: Capacity of installed solar PV in kW.

Next, **Fig. 6** illustrates the response of those who have not yet installed a solar system, showing their intentions regarding future installation. The chart is a pie chart with three categories.

A clear majority, **68.7%**, indicated they plan to install a solar system **within the next 6 months to 1 year**, signaling strong short-term interest. **22.2%** plan to install within **1 to 2 years**, suggesting these respondents are likely in planning or budgeting stages. Only **11.1%** reported they are **not considering** installing a solar system.

Overall, the data indicates a positive outlook for solar adaptation: **88.9%** of respondents are considering installation within the next two years. The high short-term intent (68.7%) likely reflects growing awareness of the economic and environmental benefits of solar power; driven by rising electricity costs, incentives, or sustainability initiatives. The small group not considering installation (11.1%) may be constrained by high upfront costs, limited space, or lack of information about solar technologies.

It indicates a promising trend toward solar energy adoption among non-users. With nearly 70% planning to install solar systems within a year, the data suggests a potential surge in installations in the short term. The results reflect growing confidence and interest in renewable energy solutions, pointing to an expanding market for solar technology. However, addressing financial and informational barriers could help convert the remaining hesitant respondents and further accelerate solar adoption.

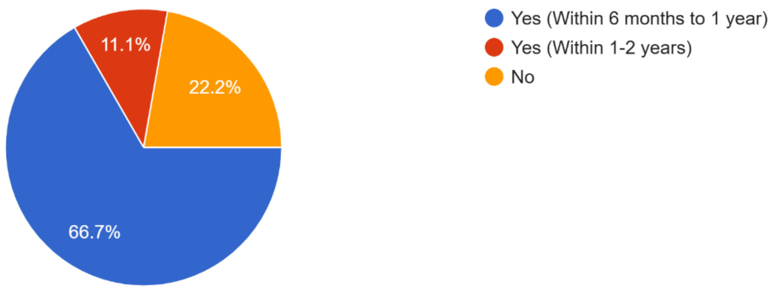


Figure 6: Solar system installation among non-users.

An overwhelming 95% of respondents experience regular power outages, while only 5% report having a stable and uninterrupted electricity supply. This significant disparity highlights a widespread issue with power reliability and energy infrastructure in the surveyed region. Such a high percentage of individuals facing frequent power interruptions suggests that power supply instability is a systemic challenge rather than an isolated problem.

The prevalence of regular outages has several implications. First, it indicates inefficiencies in grid management, inadequate generation capacity, or transmission and distribution bottlenecks. In many cases, such frequent outages can result from aging infrastructure, high demand surpassing supply, fuel shortages, or poor maintenance of power systems. This situation not only affects residential consumers but also has serious economic consequences for businesses, industries, and institutions that rely heavily on a consistent power supply. Repeated outages can disrupt operations, damage electrical equipment, and increase operational costs due to reliance on backup systems like generators.

From a socio-economic and sustainability perspective, the findings also underscore a strong motivation for adopting alternative energy sources, particularly solar photovoltaic (PV) systems. When 95% of respondents face unreliable grid electricity, the drive toward energy independence and reliability through solar power becomes a logical and necessary response. This environment creates a favorable condition for renewable energy adoption, as solar energy can provide a stable, cost-effective, and environmentally friendly alternative. Moreover, the small portion (5%) who do not face outages may represent urban or industrial areas with stronger infrastructure, further emphasizing the rural-urban divide in power reliability.

The data shows a clear picture of widespread energy insecurity among the respondents. The 95% reporting regular power outages reflects a critical energy access issue that undermines productivity, quality of life, and economic development. At the same time, this challenge presents an opportunity to accelerate investment in decentralized renewable energy systems such as solar PV, which can mitigate dependence on unstable grid electricity and enhance resilience. Addressing the root causes of power unreliability, while promoting renewable adoption, will be essential for achieving sustainable and inclusive energy development.

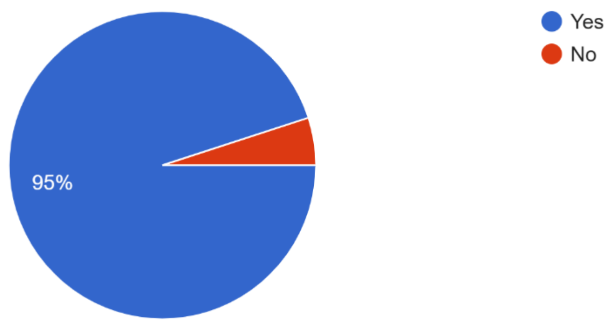


Figure 7: Regular power outages.

Fig. 8 shows how often leather industries face regular power outages, and it presents stark, and revealing figures of a severe infrastructural crisis affecting a surveyed leather industry. The data, while simple at first glance, points to profound implications, the responses are almost perfectly polarized between two extreme scenarios: 44.7% of respondents experience "1–2 hours a day" of power outages, while an equal 44.7% experience "6–8 hours a day." This polarization suggests the community is not uniformly affected by a single, predictable load-shedding schedule but is instead divided into two distinct groups. Those with 1-2 hours of outages likely reside in areas with lower grid stress, better infrastructure, or on a prioritized feeder line, allowing for a semblance of routine life. In contrast, the other 44.7% facing 6-8 hours without power endure a state of near-constant disruption that cripples the ability to work from home, study effectively, or run a business. The fact that this group is as large as the "moderately affected" one indicates a systemic failure impacting on a massive portion of the population.

The complete absence of the middle option ("3–5 hours a day") is particularly telling, as it implies the underlying cause is likely that official load-shedding schedules are structured in a way that creates these two distinct tiers of service with no middle ground. Further emphasizing the severity of the situation is the silent minority of 10.5% who face "9–10 hours a day" of outages. While a smaller segment, their situation is the direst, representing a level of power deprivation that goes beyond inconvenience and enters the realm of a severe humanitarian and economic blockade. This likely indicates areas that are either deliberately deprioritized or are suffering from compounded infrastructural failures.

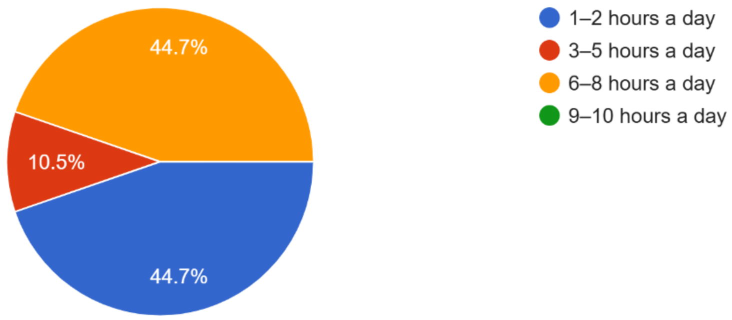


Figure 8: Power Outage Frequency

Based on the information shown in **Figure 9**, titled *"Which energy source(s) do you use during power outages?"*, it's clear that the community depends on a wide range of alternative energy sources to handle frequent blackouts. The fact that many people reported using multiple backup options shows that power outages are a serious and regular issue, pushing individuals and businesses to invest in backup power systems. The most common solution is diesel generators, used by 85.2% of respondents. This shows that generators are considered dependable and powerful, able to support heavy electricity needs during long outages. However, this heavy reliance on fossil fuels also means high fuel expenses and negative environmental effects, such as air pollution and carbon emissions.

Solar power systems and UPS (Uninterruptible Power Supply) units come next, each used by 66.7% of respondents. The popularity of solar energy reflects a growing shift toward renewable options, likely because of lower costs, a desire for energy independence, and the rising expense of generator fuel. Meanwhile, UPS systems are commonly used to keep essential devices like computers, lights, and routers running during short outages or until larger backup systems kick in. Their high usage rate shows how important it is for people to maintain power for their daily activities, especially in today's technology-driven world.

A small portion of respondents, 7.4%, reported having no backup power source at all, making them completely exposed during outages. Even more concerning, 3.7% said they must stop work entirely when the power goes out, which directly affects productivity and income. Another 3.7% gave unspecified answers, possibly representing other minor or informal solutions. Overall, Figure 9 shows a community that has adapted to unreliable electricity by creating its own network of backup systems. Most people rely heavily on diesel generators, while many are also adopting solar and battery-based technologies. Yet, the data also reminds us that some members of the community remain vulnerable, continuing to face the full challenges of an unstable power supply.

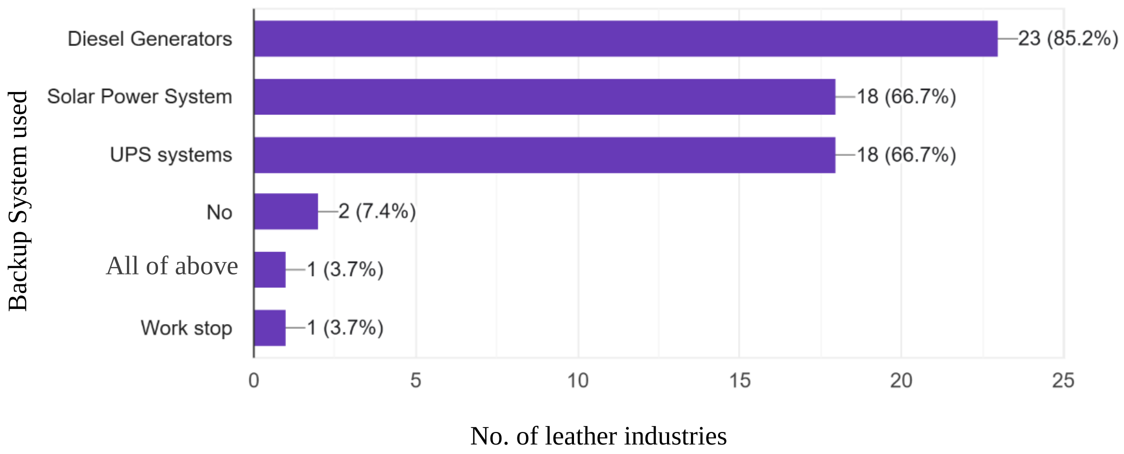


Figure 9: Energy sources used during power outages

Based on the surveyed data presented in **Fig. 10**, titled "type of solar energy systems," a clear and decisive trend emerges regarding solar technology adoption within the surveyed leather industries. The overwhelming majority, a striking **81.8%** of respondents, report using **Solar PV** systems. This indicates that the primary driver for investing in solar energy is the generation of electricity, which aligns directly with the context of frequent and prolonged power outages established in previous analyses. The dominance of Solar PV underscores a pragmatic focus on achieving energy independence for a wide range of electrical needs; from lighting and appliances to powering businesses and charging electronic devices. This is not a minor convenience but a critical adaptation to a deficient public grid, allowing users to maintain daily routines and economic activities that would otherwise be impossible during blackouts.

In contrast, a much smaller segment, **18.2%**, utilizes **Solar Water Heating** systems. This technology serves a single, specific purpose rather than providing general electricity. Its relatively low adoption rate suggests that while it is a valuable technology for reducing electricity or gas costs for water heating, it is not perceived as a solution to the core problem of power outages. The minimal usage of standalone solar thermal systems highlights that the community's energy crisis is comprehensive, affecting all aspects of modern life that require electrical power, not just hot water.

The category of **"Both"** systems received **no responses (0%)**, a fact that is highly revealing. The complete absence of users who have invested in both photovoltaic and thermal systems suggests that households and businesses are making targeted, cost-conscious decisions. Investing in a Solar PV system is likely seen as the higher priority, addressing a broader set of urgent needs. The choice to forgo a complementary solar thermal system implies that capital is limited and is being allocated to the technology that provides the most fundamental and versatile benefit of electricity itself.

In conclusion, Fig. 10 demonstrates that the adoption of solar energy in this community is not about luxury or environmental preference alone but is a necessary and strategic response to a severe infrastructural failure. The near-universal preference for Solar PV systems reveals a population prioritizing survival and continuity, channeling their resources into the technology that most directly mitigates the crippling effects of regular power cuts.

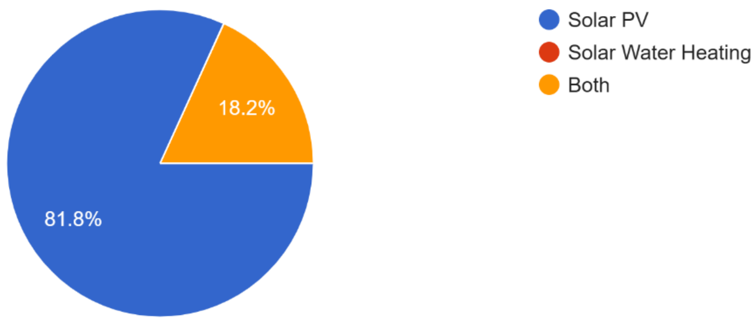


Figure 10: Type of used solar energy systems

Fig. 11 presents responses to "What are the main reasons for not installing solar panels?" and reveals a clear, actionable profile of the primary barriers preventing broader market uptake. While earlier figures show strong demand, this chart identifies the obstacles that must be addressed to convert interest into actual purchases.

Overwhelming dominance of high initial cost: The most significant barrier by a large margin is **"High Initial Costs" (89.3%)**. This confirms that, despite awareness of solar benefits, upfront investment; including panels, batteries, inverters, and professional installation, remains prohibitive for most potential customers. For commercial actors and program designers, financing models (installment plans, leasing, on-bill financing), transparent ROI analyses, and clear messaging on lifecycle savings versus generator fuel costs are essential to close sales.

Significant secondary barriers; space and maintenance: The next most-cited barriers are **"Space Constraints" (75%)** and **"Higher Maintenance Cost" (60.7%)**. High concern over space suggests many respondents are in dense or constrained settings where roof area or orientation is limited, indicating the need for more space-efficient solutions or alternative deployment models (carports, community/shared arrays). Perceived high maintenance costs point to a view of solar systems as complex or fragile; offering robust, low-maintenance products plus affordable long-term service and warranty packages will materially reduce this reluctance.

Critical weakness in market infrastructure; lack of technical support: "Lack of Technical Support" (42.9%) is a revealing barrier that goes beyond perception: it signals a real gap in installer networks, after-sales service, and trusted technicians. This is both a market failure and an opportunity: establishing a visible, certified installer and service network; with rapid response, clear SLAs, and credentialed technicians; will directly address this trust gap and become a competitive differentiator.

Implications: Together, these findings show that converting demand into uptake requires an integrated approach: accessible finance, product and deployment diversification to overcome space limits, strong service/warranty offerings to lower perceived maintenance risk, and a scaled technical support network to build trust. Addressing these four barriers in parallel will be necessary to unlock substantial additional market penetration.

Negligible Barriers: Awareness and Perceived Benefits: It is equally important to note the barriers that are virtually non-existent. "Lack of Awareness" scored 0%, and "No Perceived Benefits" was only 3.6%. This is excellent news. It confirms that our market education on the *why* of solar is largely complete. Customers know what solar is, and they understand its benefits, particularly in the context of persistent power outages. Our marketing efforts, therefore, do not need to focus on creating demand but on overcoming specific objections related to cost, space, and support. Additionally, Fig. 11 provides a blueprint for our market strategy. The barrier is not a lack of desire, but a combination of financial, practical, and infrastructural concerns. To capitalize on this, Leader Industries must execute a multi-pronged approach:

1. Develop Innovative Financial Models: Create and aggressively market financing solutions that break down the high initial cost into manageable payments, directly targeting the 89.3% barrier.
2. Product and Service Diversification: Engineer and source a range of products, including high-efficiency panels for limited spaces and low-maintenance system designs. Bundle these with premier service contracts to address the concerns of 75% and 60.7% of respondents, respectively.
3. Invest in Support Infrastructure: Make "Leader Industries Certified Support" a primary selling point. Building a reliable technical support network is the key to capturing the 42.9% of the market stalled by this concern.

By systematically addressing these identified barriers, Leader Industries can effectively unlock the vast potential of the non-adopter market and solidify its position as the leading solution provider.

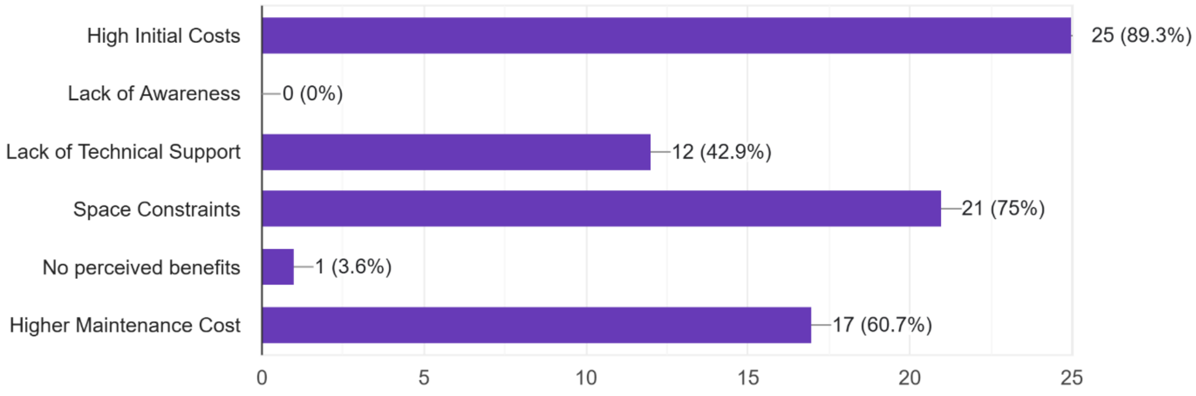


Figure 11: The main reasons for not installing solar.

Based on the data presented in **Fig. 12**, it is evident that corporate awareness and accountability for greenhouse gas (GHG) emissions are in a critical state of ambiguity within the surveyed leather industries. The responses are almost evenly split across the three options, revealing a significant lack of standardized environmental practice. While a respectable 42.5% of companies affirm that they do monitor or estimate their emissions, this positive step is undermined by the nearly equal proportion of 40% who are "Not sure." This high level of uncertainty suggests a profound lack of internal process, communication, or understanding regarding environmental impact at the organizational level, indicating that environmental management is not yet an integrated or prioritized business function for many.

Furthermore, the fact that 17.5% openly admit to not tracking their emissions at all confirms that a substantial segment of the market has not yet begun to engage with their environmental responsibilities. This tripartite division highlights a clear market need for education and accessible solutions. For Leader Industries, this presents a direct strategic opportunity. The widespread uncertainty and lack of monitoring are not just a societal issue but a business one. We can position our solar energy solutions not merely as a cost-saving measure for power outages, but as a foundational tool for carbon accounting and emissions reduction. By providing clear data on the GHG savings our systems offer, we can help these "Not sure" and "No" companies take their first critical step toward environmental compliance and sustainability reporting, thereby adding a powerful new dimension to the value proposition of our products.

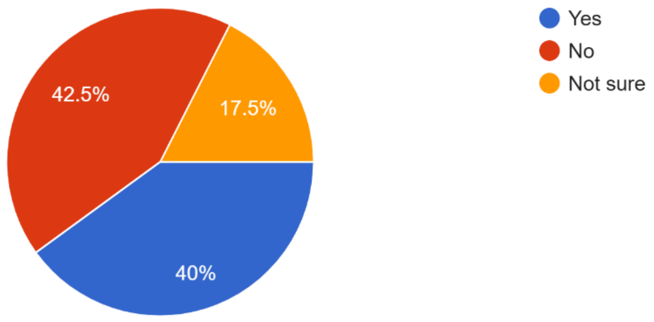


Figure 12: Does solar companies monitor GHG emissions?

Based on the data presented in **Fig. 13**, which details the tools used for emissions calculation, a clear picture emerges of a market in the early, fragmented stages of adopting environmental management practices in leather industries. The most striking finding is that the GHG Protocol Tools are the dominant application, used by 63% of the respondents who attempt to calculate their emissions. This establishes the GHG Protocol as the de facto standard and common language for carbon accounting in this market. For Leader Industries, this is a critical insight; any claims or tools we develop regarding the carbon footprint reduction of our solar systems must be aligned with or directly reference this framework to be seen as credible and verifiable by the majority of our engaged customers.

However, this apparent standardization is overshadowed by a more significant finding: a full 33.3% of respondents use "None." This indicates that a substantial portion of companies who claim to monitor their emissions (from Fig. 12) are likely doing so through informal, non-standardized methods, such as simple spreadsheet calculations or rough estimations. This severely questions the accuracy and robustness of their environmental data and highlights a gap between the intent to measure and the implementation of proper tools.

The remaining tool usage is highly fragmented, with minimal adoption of specialized software like SimaPro (3.7%) and ISO-compliant calculators (7.4%). The response "He doesn't have an idea," along with the use of unrelated tools like "EcoSoft or Leather Impact Tool," further underscores the confusion and lack of expertise in this domain. Many companies are clearly navigating this landscape without specialized knowledge.

In short, Fig. 13 reveals a market that recognizes the importance of the GHG Protocol but lacks widespread, sophisticated tool implementation. For Leader Industries, this presents a significant opportunity to add value beyond hardware. We can develop and market a simple, accessible calculator or a verified methodology that helps customers easily translate their solar energy usage into GHG savings directly compatible with the GHG Protocol. By providing this service, we can bridge the gap for the "None" users, build credibility with the GHG Protocol users, and position Leader Industries not just as an energy provider, but as an essential partner in our customers' sustainability journeys.

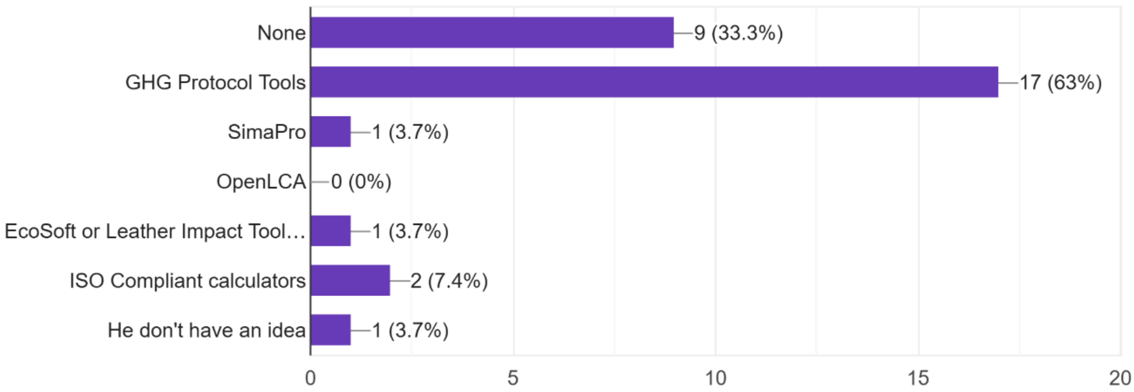


Figure 13: Application or tool used to calculate emissions.

Fig. 14 shows a clear shortfall in advanced product-level environmental management among surveyed businesses: **69%** of respondents do **not** conduct a Life Cycle Assessment (LCA). This suggests that, while some firms are beginning to measure operational emissions (see Fig. 12), most have not advanced to a comprehensive evaluation of environmental impacts across a product's entire life cycle — from raw-material extraction to end-of-life disposal. The current emphasis remains on direct, operational metrics rather than holistic product sustainability.

By contrast, the **31%** that do perform LCAs represent a more sophisticated market segment—likely firms engaged in international supply chains, pursuing green certifications, or targeting environmentally conscious buyers. For these companies, verified product-level data is increasingly a commercial and regulatory requirement; LCAs help them demonstrate compliance, reduce reputational risk, and access green premiums or preferential procurement.

For Leader Industries, the 69% gap represents a substantial commercial opportunity. Many firms need education, simplified tools, and accessible pathways to product-level sustainability. Leader Industries can position its solar solutions not only as clean energy systems but as measurable interventions that reduce cradle-to-gate emissions in manufacturing processes—an LCA-relevant benefit that supports customers' sustainability claims.

By offering clear, data-driven evidence of emissions reductions (for example, metered on-site generation data, estimated displaced grid/generator emissions, and guidance for incorporating these figures into an LCA), Leader Industries can help clients close the LCA gap. This value proposition—combining technology, verification-ready data, and practical LCA support—can accelerate clients' progress toward product sustainability, strengthen market access, and meet evolving buyer and regulatory expectations.

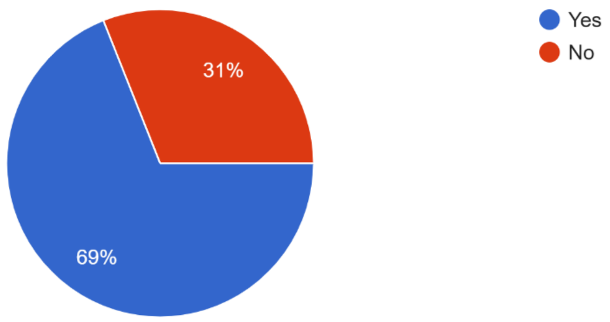


Figure 14: Prevalence of Life Cycle Assessment (LCA) in Product Development

The data in **Fig. 15** provides a critical roadmap for energy demand within the tannery sector, identifying clear priorities for intervention. The processes of Mechanical Drying (94.4%) and Chemical Mixing (88.9%) are the near-universal drivers of energy consumption, representing the primary targets for any energy efficiency or solar power integration strategy. Steam Generation (61.1%) is also a significant, majority concern.

This data reveals a direct and powerful application for solar energy. The high energy demand for Mechanical Drying and Chemical Mixing is typically met with grid electricity, which is expensive and unreliable. Solar PV systems can directly power this equipment, offering immediate cost savings and operational stability. Furthermore, the significant need for Steam Generation and Water Heating (19.4%) presents a complementary opportunity for solar thermal systems, which can directly provide process heat, thereby displacing the fossil fuels traditionally used for these operations.

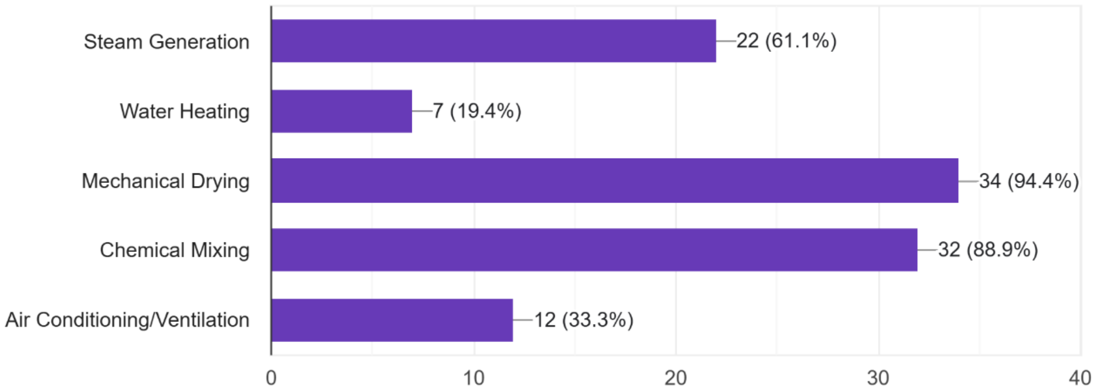


Figure 15: Main energy-intensive processes in your tannery

The data in **Fig. 16** reveals a heavy reliance on expensive and polluting fuels for thermal energy in the tannery sector. The most common boiler types are Diesel-fired (55.6%) and Electric (55.6%), both of which are subject to high and volatile operating costs, directly impacting profitability. The significant use of Gas-fired (41.7%) and even Coal-fired (22.2%) boilers further highlights an energy mix with substantial cost and environmental liabilities.

This presents a direct and compelling opportunity for Leader Industries. The prevalence of electric boilers is a key strategic entry point; these can be powered by our Solar PV systems, allowing tanneries to generate their own heat from sunlight and drastically reduce grid electricity costs. Furthermore, the dominance of diesel, gas, and coal boilers identifies a major market for displacement with solar thermal systems. By offering high-temperature solar thermal solutions, we can provide a clean, reliable, and cost-effective alternative to fossil fuels for essential processes like steam generation and water heating, directly addressing the primary energy-intensive processes.

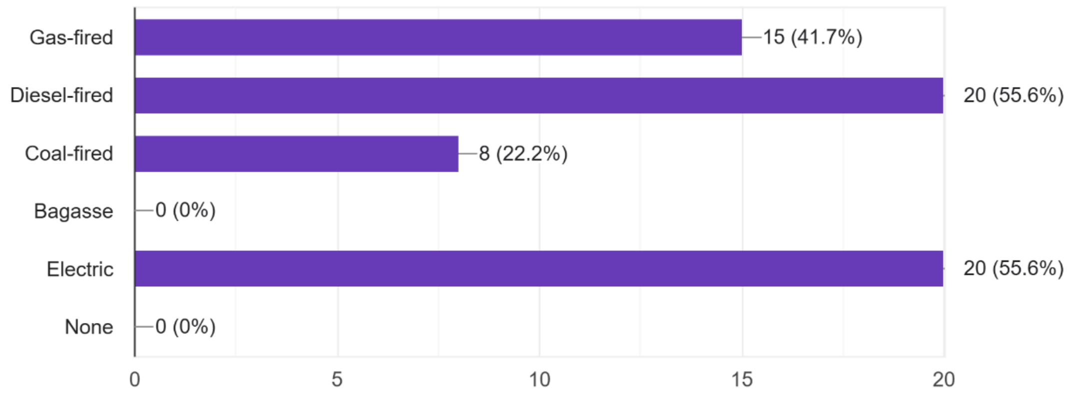


Figure 16: Types of boilers used.

The data in **Fig. 17** indicates universal awareness within the surveyed tanneries that environmental regulations apply to their operations, with a 100% "Yes" response rate. This demonstrates a foundational level of regulatory consciousness across the industry. However, this universal awareness of *existing* regulations does not necessarily indicate preparedness for future compliance or proactive environmental stewardship. For Leader Industries, this creates a critical strategic opening. We can position our solar energy and energy efficiency solutions not merely as cost-saving measures, but as essential tools for achieving and exceeding these known environmental standards. By helping clients reduce their emissions and energy consumption, we provide a direct pathway to compliance with current and anticipated regulations, turning a regulatory challenge into an operational advantage.

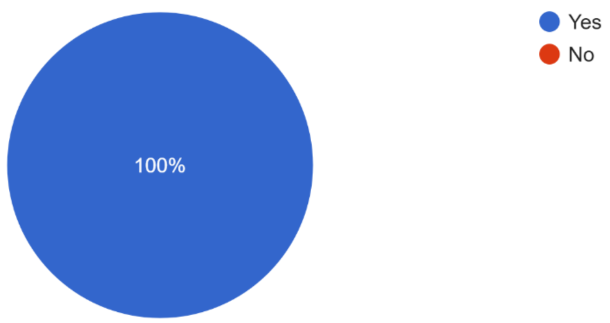


Figure 17: Awareness of national and international environmental regulations

The data in **Fig. 18** reveals a critical finding: 100% of the surveyed industries/tanneries are aware of specific emission reduction regulations governing their operations. This universal awareness signifies that regulatory pressure is a tangible and recognized business reality for the entire sector, moving beyond general environmental awareness to a specific focus on emissions.

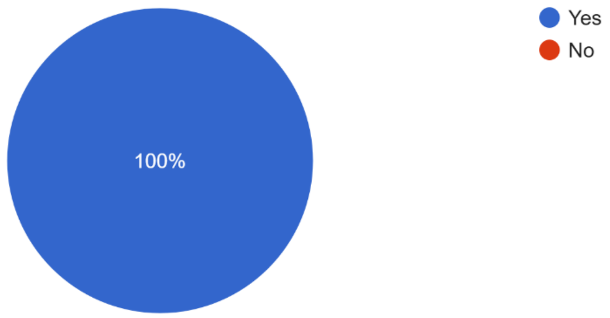


Figure 18: Awareness national and international emission reduction regulations that apply

The bar chart in **Fig. 19** illustrates the extent to which companies comply with different national regulatory frameworks related to environmental management and sustainability in Pakistan. The key findings are as follows:

1. National Energy Efficiency and Conservation Authority (NEECA) Guidelines: 21 companies (53.8%) reported compliance with NEECA guidelines. This represents the highest level of compliance among all listed frameworks. It suggests that energy efficiency and conservation measures are the most widely adopted regulatory area, possibly due to increased national focus on energy management and cost-saving benefits for industries.

2. Provincial Environmental Protection Agency (EPA) Requirements: 17 companies (43.6%) comply with EPA requirements. This shows strong adherence to environmental protection standards at the provincial level, although slightly lower than NEECA compliance. It indicates that while environmental regulation is recognized, enforcement or awareness may vary across provinces.

3. Pakistan Climate Change Policy: 8 companies (20.5%) reported compliance. This relatively lower percentage may reflect limited implementation mechanisms or lower perceived urgency among companies regarding climate policy obligations.

4. None: only 1 company (2.6%) stated that it does not comply with any of the listed frameworks. This indicates that almost all respondents are engaged with at least one national framework, demonstrating a generally positive regulatory engagement trend.

The overall results show a moderate to high level of compliance with national frameworks. The dominance of NEECA compliance suggests that energy efficiency is a key focus area for companies, possibly due to direct operational and financial benefits. Lower compliance with the Pakistan Climate Change Policy indicates that climate-focused initiatives may not yet be a mainstream corporate priority, potentially due to limited enforcement, incentives, or awareness. The minimal "None" responses indicate that the majority of companies are at least partially integrated into national regulatory structures, reflecting growing environmental consciousness in the corporate sector.

This Fig. 19 highlights that while energy efficiency and environmental protection frameworks have achieved considerable adoption among companies, climate change policy compliance still lags behind. This trend suggests a need for stronger policy implementation, awareness programs, and incentives to encourage broader and deeper engagement with climate-related regulations.

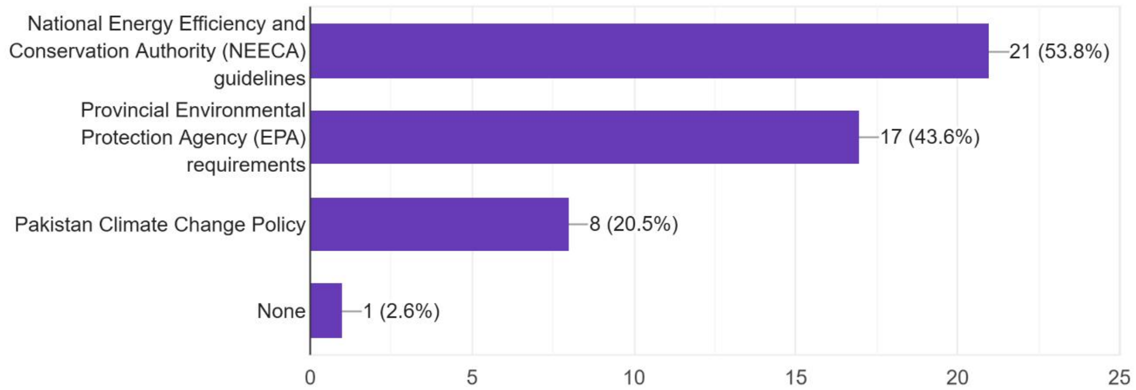


Figure 19: Compliance with National Regulatory Frameworks

The data in **Fig. 20** reveals a critical gap between regulatory requirements and practical compliance within the tannery sector. While a combined 33.3% of companies are subject to reporting requirements, their compliance is split: 19.4% fulfill their obligation to submit reports, while a significant 13.9% acknowledge they are required but do not submit. This indicates a substantial level of non-compliance, suggesting that many firms find the process too complex, lack the necessary data, or do not perceive a strong enforcement risk.

The majority, 66.7%, report they are not required to submit such reports. For Leader Industries, this landscape defines a clear two-pronged opportunity. For the non-compliant 13.9%, we can offer a solution that simplifies reporting; our solar systems provide verifiable data on clean energy usage that directly contributes to emission reduction metrics, making compliance easier to achieve. For the larger 66.7% segment not currently regulated, we can position solar adoption as a form of future-proofing, preparing them for inevitable regulatory expansion while delivering immediate cost savings. This allows us to address both the present need for compliance and the strategic need for preparedness.

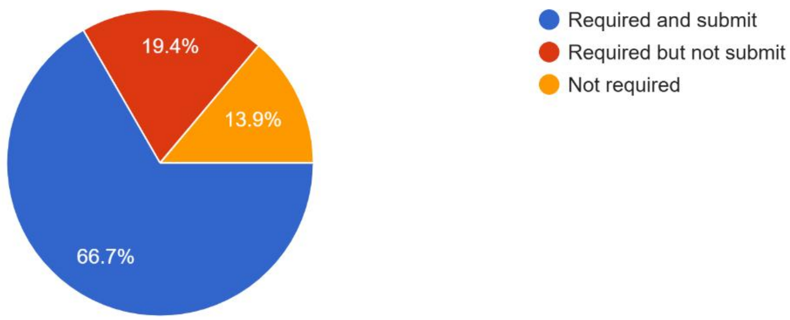


Figure 20: Environmental Reporting Compliance and Requirements

The bar chart in **Fig. 21** illustrates the extent to which companies follow international environmental or sustainability standards. The respondents could select multiple options, reflecting the diverse range of standards applied in their operations. The main findings are as follows:

1. ISO 14001 (Environmental Management System): 21 companies (65.6%) reported compliance with ISO 14001. This represents the highest level of adherence among all listed international standards. ISO 14001's dominance indicates that companies are prioritizing structured environmental

management systems to control impacts, comply with regulations, and enhance sustainability credentials.

2. ISO 50001 (Energy Management System): 6 companies (18.8%) have adopted ISO 50001. This standard focuses on improving energy efficiency and reducing energy costs, which suggests that a minority of companies have formalized energy management practices despite rising energy costs.

3. Other Standards (Higg Index, ISO 9001): Each of these standards was followed by only 1 company (3.1%). Their low uptake suggests either limited awareness or relevance within the respondent industries.

4. Leather Working Group (LWG) Certification: 13 companies (40.6%) follow LWG standards. This high percentage reflects the significant representation of the leather and textile industry in the respondent group. However, LWG certification is often driven by export requirements and international buyer expectations, highlighting the sector's focus on sustainable leather sourcing and production.

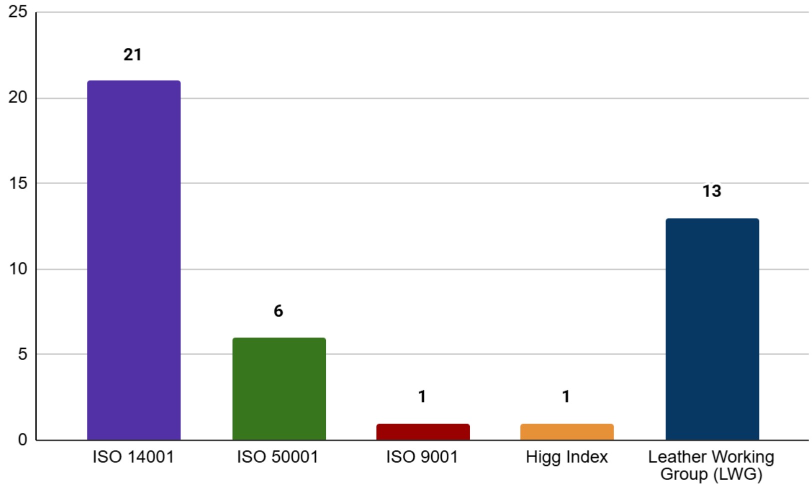


Figure 21: Adoption of International Environmental or Sustainability Standards

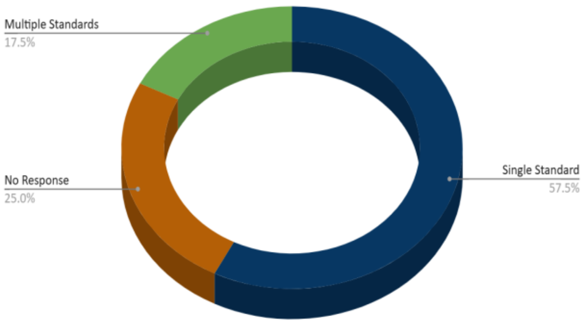
Figure 22 shows a generally positive trend in adoption of international sustainability standards across the industries surveyed. Of the 40 industries sampled, **31** reported following at least one recognized standard, indicating growing awareness of sustainability and compliance requirements across the sector.

However, the depth of adoption varies. **20** industries follow only a single standard, while **11** have adopted multiple standards (for example, **ISO 14001** and **Leather Working Group (LWG)** certifications). Multiple-standard adopters appear to follow a more structured approach to sustainability, often driven by higher regulatory pressure, export orientation, or stronger stakeholder expectations.

When disaggregated by scale, small and medium enterprises (SMEs) dominate the sample and largely shape the overall results. Most SMEs reported compliance with at least one standard but tend to rely on a single certification: likely due to financial and technical constraints. In contrast, larger firms, though fewer, show a stronger tendency to adopt multiple standards, reflecting greater capacity to invest in comprehensive sustainability systems.

In summary, Figure 22 highlights widespread baseline engagement with standards but reveals a clear gap between single-standard SME adoption and multi-standard, advanced practices among larger firms;

pointing to opportunities for targeted support, capacity building, and financing to help SMEs deepen their sustainability credentials.



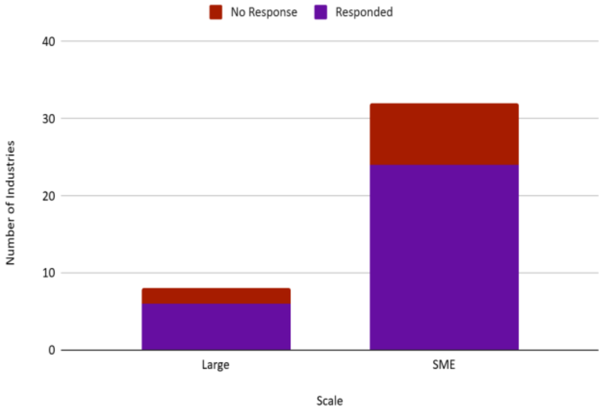


Figure 22: Adoption and depth of sustainability standards among surveyed industries

The data in **Fig. 23** reveals a clear and significant demand for external expertise, with a strong majority (60%) of companies expressing interest in receiving support or training on energy efficiency and emissions tracking. This indicates a market that recognizes its own knowledge gaps and is actively seeking solutions to improve its environmental and energy management practices. For Leader Industries, this presents a powerful strategic opportunity that extends beyond equipment sales. This 60% represents a captive audience for value-added services. By developing and offering training programs, workshops, or consulting services on these topics, we can position ourselves as a trusted partner and industry leader. This approach builds deeper client relationships, establishes credibility, and directly funnels participants toward our core solar and energy efficiency products as the logical solution to achieve their newly defined goals. The 40% who declined represent a segment for continued awareness building, focusing on the direct cost-saving benefits of our solutions.

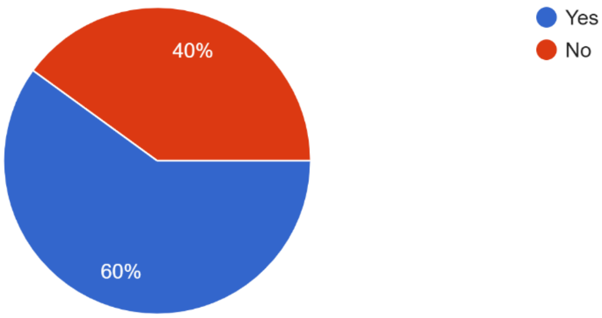


Figure 23: Interest in Support for Energy Efficiency and Emissions Tracking

The bar chart in **Fig. 24** presents the types of support that companies consider most helpful in strengthening their environmental and sustainability initiatives. Furthermore, the main key findings are as follows:

Technical Training: All 24 respondents (100%) indicated that technical training would be the most helpful form of support. This unanimous response reflects a strong demand for capacity building, indicating that many companies may lack the technical expertise or knowledge required to effectively implement sustainability measures. It highlights the importance of skill development programs, workshops, and hands-on training to bridge existing knowledge gaps in environmental management and compliance.

Certification Support: 23 respondents (95.8%) identified certification support as a key need. This high level of demand suggests that while companies recognize the value of sustainability certifications (e.g., ISO 14001, LWG, GOTS), many face barriers such as complex procedures, high costs, or lack of guidance in the certification process. Additionally, providing institutional or financial assistance for certification could significantly enhance compliance with international standards and improve market access.

Financial Incentives: 20 respondents (83.3%) highlighted financial incentives as an important enabler. This indicates that cost remains a major constraint in adopting sustainable technologies or practices. However, Government subsidies, low-interest green loans, or tax rebates could motivate companies to invest in energy efficiency, cleaner production, and waste management.

Policy Advocacy: 2 respondents (8.3%) expressed interest in policy advocacy support. The relatively low response suggests that companies may currently prioritize direct operational support over broader policy engagement. However, it also indicates a potential opportunity for industry associations to play a more active role in voicing sector needs and shaping sustainability-related regulations.

Free Audits or Assessments: Only 1 respondent (4.2%) chose free audits or assessments as a preferred form of support. This low percentage may imply that companies either already undergo external audits (as part of certifications) or do not view free assessments as immediately beneficial compared to tangible financial or technical aid.

The results clearly show that technical training, certification support, and financial incentives are the most critical areas where companies seek help. Secondly, the overwhelming preference for training underscores that knowledge and skills gaps are a key bottleneck in implementing sustainability measures effectively. Thirdly, the strong demand for certification assistance aligns with earlier findings (e.g., Figure 21), where many companies follow international standards but may struggle with maintaining or expanding compliance. Fourthly, financial support is also vital, as sustainability investments often require upfront costs that smaller firms cannot easily absorb without incentives or funding mechanisms. Lastly, the low interest in policy advocacy and audits suggests that companies are currently more focused on practical, implementation-level support rather than regulatory or assessment-based interventions.

In short, this Fig. 24 highlights that companies prioritize capacity building (100%), certification facilitation (95.8%), and financial incentives (83.3%) as the most needed forms of support for advancing sustainability efforts. These findings point to a clear need for integrated programs that combine technical training with financial and procedural assistance, enabling companies to meet both national and international sustainability requirements more effectively.

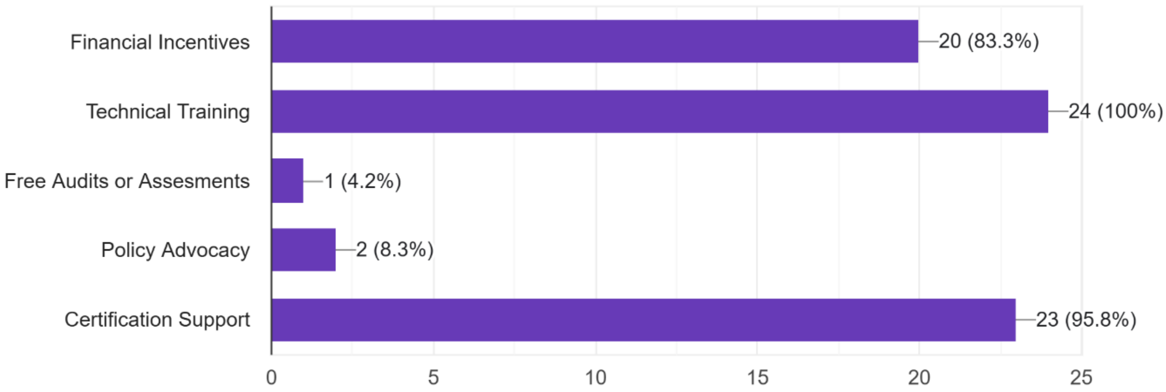


Figure 24: Preferred Types of Support for Enhancing Sustainability Practices.

Fig. 25 compares small and medium enterprises (SMEs) with large-scale leather industries and highlights clear structural differences in energy consumption and renewable adoption. Large firms incur substantially higher monthly electricity expenditures; averaging about **PKR 1,800,000** versus roughly **PKR 127,000** for SMEs; creating a strong financial incentive for on-site solar investment to cut operating costs and hedge against tariff volatility.

Accordingly, large-scale industries show higher solar uptake, with an average installed capacity of approximately **143 kW**, compared with about **32.5 kW** for SMEs. This gap reflects differences in capital availability, physical space, and institutional readiness: large firms typically occupy purpose-built facilities with ample rooftop or open land suitable for solar arrays, whereas many SMEs operate in crowded industrial zones or rented premises with limited space and insecure tenure, constraining larger installations.

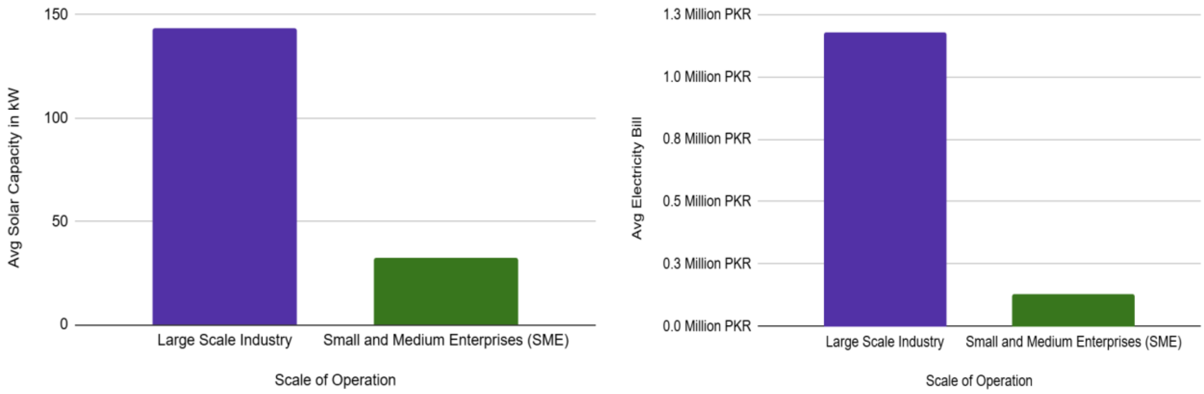


Figure 25: SMEs Vs Large Scale Industry In Terms of Electricity and Solar Pricing.

Table 2 shows an encouraging result: SME-scale solar systems (10–40 kW) are both affordable and meaningful for the leather sector. These capacities align well with typical SME electricity demand profiles, available rooftop area, and prevailing financial constraints, making small-scale systems technically and economically viable for many firms.

A 10-kW system, reachable for many SMEs, can cut annual CO_2 emissions by roughly **6.7 tonnes**; equivalent to avoiding combustion of about **6 tonnes of coal** per year; and can yield estimated annual electricity cost savings on the order of **PKR 0.8 million**. These monetary estimates are illustrative, based on standard assumptions about generation, tariffs, and production; firm-level savings will vary with operating hours, load profile, fuel mix, tariff structure, and system performance. Nonetheless, the numbers provide a realistic order of magnitude and underline the solid economic rationale for solar adoption under current market conditions.

For SMEs operating on thin margins, such savings are material: solar reduces dependence on an unreliable grid and expensive diesel generation, stabilizes operating costs, and shortens payback periods. Small systems also require only modest rooftop space, making them feasible even in dense industrial clusters.

Beyond cost and reliability benefits, solar adoption strengthens market positioning. International buyers increasingly require demonstrable energy-efficiency measures and verified emissions reductions as part of procurement criteria; adopting on-site renewables therefore supports market access and helps firms meet evolving buyer and regulatory expectations.

Table 3: Estimated electricity generation, carbon emission and coal reduction from SME scale solar PV installations under typical operating assumptions.

Sr #	Solar Capacity in kW	Annual Electricity Generation (kWh)	CO_2 Emissions Reduced (kg/year)	Coal Saved (kg/year)
1	10	15,000	6,750	6,000
2	20	30,000	13,500	12,000
3	30	45,000	20,250	18,000
4	40	60,000	27,000	24,000

Chapter 4: Policy Recommendations

4.1 Introduction

The leather industry holds a pivotal position in Pakistan’s manufacturing and export landscape, providing significant employment and contributing to foreign exchange earnings. However, the sector’s energy-intensive and emission-heavy nature poses challenges to national commitments on climate change mitigation, energy efficiency, and green export competitiveness.

Building on the findings of this study, this chapter outlines policy directions and strategic recommendations aimed at facilitating a sustainable transition toward cleaner energy systems, reduced carbon emissions, and improved environmental performance within the leather sector. The recommendations target three key levels of intervention like policy and regulatory reform, industrial transformation, and institutional and financial support mechanisms.

4.2 Policy and Regulatory Recommendations

4.2.1 Develop a Sector-Specific “Green Leather Policy Framework”

Pakistan currently lacks a dedicated national policy addressing energy efficiency, renewable integration, and emission control in the leather sector. The government, in collaboration with the Pakistan Tanners Association (PTA), Ministry of Industries and Production (MoIP), and Ministry of Climate Change (MoCC), should establish a “Green Leather Policy Framework” that:

- Sets energy and emission benchmarks for tanneries and processing units.
- Encourages renewable energy (RE) integration, especially solar and biogas systems for process heating.
- Links environmental compliance to export incentives and access to financial support.
- Provides clear roadmaps for decarbonization and energy audits by 2030.

4.2.2 Strengthening Environmental Standards and Monitoring

Existing National Environmental Quality Standards (NEQS) focus mainly on effluents and solid waste, with limited enforcement of air and energy-related parameters. It is recommended that:

- Energy-based emission standards (CO_2 , NO_x, SO_2) be incorporated into NEQS for tanneries.
- Periodic monitoring and reporting of energy use and emissions become mandatory for medium and large firms.
- Digital monitoring systems (smart meters and emission trackers) be introduced in partnership with provincial EPAs.

Such reforms would help move beyond reactive compliance toward proactive environmental performance management.

4.2.3 Promote Integration with National Energy Transition Plans

The leather sector should be recognized within Pakistan's Industrial Decarbonization and Renewable Energy Transition Plans (including the NEECA programs). This can be achieved through:

- Inclusion of leather tanneries in NEECA's sectoral energy audits and efficiency certification programs.
- Incorporating the sector in renewable integration initiatives under the Competitive Trading Bilateral Contract Market (CTBCM) model.
- Facilitating grid-connected solar and hybrid systems for industrial clusters (e.g., Kasur and Karachi).

4.3 Technological and Industrial Recommendations

4.3.1 Encourage Cleaner Production Technologies

To reduce energy consumption and emissions, the adoption of modern and cleaner tanning technologies should be prioritized:

- Replace conventional chrome tanning with low-salt, water-efficient, and low-emission technologies.
- Introduce energy-efficient boilers, heat recovery systems, and variable frequency drives (VFDs) in process machinery.
- Support biogas generation from organic tannery waste to supplement process heating needs.

Government and donor-supported programs should provide technology demonstration grants to early adopters.

4.3.2 Promote Renewable Energy Adoption

Given Pakistan's high solar potential, on-site solar PV systems represent a practical solution for tanneries facing high energy costs and unreliable grid supply. Recommended measures include:

- Establish solar clusters in Kasur, Lahore, and Karachi, enabling shared infrastructure and cost savings.
- Encourage solar-diesel hybrid systems for continuous operations.
- Offer tax rebates, net-metering benefits, and soft loans for RE installations in industrial estates.

4.3.3 Implement Energy Audits and Management Systems

To institutionalize energy efficiency, firms should adopt ISO 50001 Energy Management Systems. Supporting policies should:

- Require annual energy audits for large and export-oriented tanneries.
- Provide subsidized technical assistance through NEECA-accredited audit firms.
- Develop an Energy Efficiency Code of Practice for the leather sector with clear performance indicators.

4.4 Financial and Institutional Recommendations

4.4.1 Green Financing Mechanisms

Limited access to finance remains a major barrier to technology and energy upgrades. To overcome this:

- Establish a "Green Leather Fund" in collaboration with the State Bank of Pakistan (SBP) and commercial banks to support renewable and efficiency investments.
- Expand SBP's Green Banking Guidelines to explicitly include leather tanning and processing units.
- Encourage public–private partnerships (PPPs) and donor co-financing (e.g., GCF, UNIDO, or IFC programs) for pilot energy transition projects.

4.4.2 Cluster-Level Common Facilities

Given the dominance of small and medium tanneries, cluster-based approaches are vital. Policy should support:

- Establishment of shared renewable energy systems (solar mini-grids or biogas units).
- Common Effluent Treatment Plants (CETPs) integrated with energy recovery modules.
- Centralized energy and emission monitoring centers in Kasur and Lahore clusters.

These collective solutions can enhance efficiency, lower costs, and simplify environmental compliance.

4.4.3 Institutional Coordination and Capacity Building

The fragmentation between industrial, energy, and environmental authorities hinders policy coherence. A National Leather Sustainability Council (NLSC) should be established under MoIP to:

- Coordinate efforts among PTA, EPAs, NEECA, AEDB, and energy utilities.
- Facilitate capacity-building programs for factory managers and technicians on energy management and cleaner production.
- Promote data transparency through a national energy and emission reporting portal for the leather sector.

4.5 International and Market-Oriented Recommendations

4.5.1 Align with Sustainability Standards

To maintain export competitiveness, Pakistan's leather industry must align with international environmental standards such as:

- Leather Working Group (LWG) certification
- ISO 14001 Environmental Management Systems
- EU Green Deal and Carbon Border Adjustment Mechanism (CBAM) requirements

The government should facilitate capacity-building, certification subsidies, and technical guidance to help firms meet these benchmarks.

4.5.2 Promote Circular Economy Practices

Circular practices can reduce waste and emissions while improving resource efficiency. Recommended initiatives include:

- Reuse of process water through closed-loop systems.
- Valorization of solid waste (e.g., leather shavings, sludge) into by-products like gelatin, fertilizers, or energy.
- Establishment of waste exchange platforms for industrial symbiosis among nearby sectors.

Table 4: Roadmap for Implementation

Phase	Timeframe	Key Actions
Short-term (2025–2026)	Policy formulation, baseline energy audits, pilot solar/biogas projects	MoIP, NEECA, PTA
Medium-term (2027–2029)	Technology upgradation, cluster-level RE systems, energy certification rollout	Provincial EPAs, TDAP, SBP
Long-term (2030–2035)	Full integration with national decarbonization goals, export-linked compliance standards	MoCC, MoIP, Industry Associations

The transition of Pakistan's leather industry toward a low-carbon, energy-efficient, and sustainable future is both a necessity and an opportunity. Implementing the above recommendations will help: reduce the sector's energy intensity and carbon footprint, secondly, strengthen its competitiveness under evolving environmental trade regimes, and lastly, contribute meaningfully to Pakistan's nationally determined contributions (NDCs) and industrial green growth agenda. Therefore, by aligning policy instruments, financial incentives, and technological support, Pakistan's leather sector can evolve into a model of sustainable industrial transformation.

Chapter 5: Conclusions

5.1 Overview and synthesis

This study set out to map the energy landscape and emissions profile of Pakistan's leather industry, assess practical renewable-energy and energy-efficiency interventions, and identify the policy, institutional, financial and technical actions required to enable a credible industrial decarbonization pathway. Drawing together the evidence and analysis presented in Chapters 1–4, this concluding chapter synthesizes the key findings, highlights the strategic implications for industry and policymakers, lays out a sequenced and realistic implementation roadmap, addresses residual uncertainties and limitations, and specifies an agenda for monitoring, future research and capacity building. The conclusion emphases three core messages:

Pakistan's leather sector is economically important, regionally concentrated and energy-intensive; therefore, even modest efficiency and renewable deployments can yield meaningful economic, environmental and competitiveness benefits.

A successful transition will require an integrated approach that combines sector-specific policy instruments, cluster-level shared infrastructure, tailored finance mechanisms and hands-on technical support to small and medium enterprises (SMEs).

Implementation must be evidence-based, staged, and accompanied by robust monitoring and capacity-building to ensure sustainability, equitable benefits and export market alignment.

The remainder of this chapter unpacks these messages in detail and translates them into concrete actions.

5.2 Key findings (summary of evidence)

5.2.1 Economic and structural profile

The leather industry remains a notable export-oriented sector, employing many thousands directly and indirectly in Karachi, Lahore and Kasur clusters and contributing meaningfully to foreign exchange. Sectoral concentration around these clusters provides an operational advantage for interventions that exploit economies of scale (e.g., shared energy systems and CETP integration).

5.2.2 Energy consumption and dependency

Leather processing is energy- and heat-intensive. The industry's energy mix is dominated by grid electricity and fossil fuels (natural gas and diesel for captive generation and thermal processes). Energy intensity varies by tannery size, technology vintage, and process mix, with smaller informal units typically less efficient and less instrumented for measurement.

5.2.3 Emissions and environmental risks

Emissions arise primarily from fuel combustion (CO_2 , NO_x, SO_2) and indirectly from process chemicals and wastewater handling. Local air-quality and public-health risks from on-site combustion and inadequate emission controls remain important, even if national GHG shares are small in international standard terms.

5.2.4 Technical potential for decarbonization

Practical interventions: energy audits, fuel switching, solar PV for electrical loads, solar thermal for process heat, biogas from organic waste, heat recovery, and equipment upgrades (VFDs, efficient boilers) can materially reduce energy intensity and emissions. Cluster-level solutions (solar mini-grids, shared biogas, CETPs with energy recovery) are particularly attractive for SMEs that lack capital or roof area for individual solutions.

5.2.5 Institutional, financial and policy barriers

Major barriers include: weak policy focus specifically targeting leather-sector energy transition, limited access to tailored green finance, low regulatory enforcement on energy and air emissions, fragmentation across ministries and agencies, lack of technical capacity in SMEs, and data paucity due to poor metering and confidentiality concerns.

5.2.6 Market and trade drivers

Export markets (Europe, North America, Gulf) and incoming regulatory regimes (e.g., environmental due diligence, carbon-adjustment mechanisms) create both risk and opportunity. Firms that demonstrate environmental compliance and lower carbon footprints can access premium markets and avoid trade friction.

5.3 Strategic implications

5.3.1 For industry competitiveness

Energy cost volatility materially affects competitiveness. Investing in predictable, low-cost renewable generation and efficiency reduces production cost vulnerability, improves margins, and strengthens export credentials (certification readiness, LWG/ISO compliance). For exporters, proactive decarbonization is becoming a de-risking and market-access strategy.

5.3.2 For environmental and public health outcomes

Reducing fossil fuel combustion through fuel-switching and cleaner production reduces local air pollutants and occupational health risks, an immediate co-benefit that strengthens social license to operate for tanneries in densely populated clusters.

5.3.3 For national decarbonization goals

Although the leather sector's absolute contribution to national emissions is modest, its concentrated nature and export orientation make it a high-leverage target: scalable cluster-level interventions provide replicable models for other industrial sub-sectors and feed into Pakistan's NDC implementation and industrial decarbonization objectives.

5.4 Prioritized recommendations (actionable and sequenced)

The recommendations below synthesize measures in Chapters 3–4 but add sequencing and responsible actors to enable immediate follow-through. They are grouped into short-term (Year 1–2), medium-term (Years 3–5) and long-term (Years 6–10) horizons.

5.4.1 Short-term (2025–2026): establish foundations and pilots

1. **Formally adopt a Green Leather Policy Framework (MoIP lead; PTA & MoCC partners).** Define sectoral energy and emissions benchmarks; mandate baseline energy audits for medium and large firms; set pilot targets for renewable adoption in representative tanneries.
2. **Launch targeted pilot projects.** Deploy 6–10 pilot solar-PV (plus battery/ hybrid where needed) and solar-thermal/biogas projects across Kasur, Lahore and Karachi to demonstrate technical feasibility, business models, and cost savings.
3. **Data & monitoring baseline.** Roll out smart-metering and energy use reporting for pilot firms and a select group of SMEs to create an anonymized baseline dataset for sector-level modeling.
4. **Establish a Green Leather Fund design taskforce (SBP, MoIP, commercial banks).** Define product features soft loan windows, partial grant de-risking, results-based rebates and pilot a first tranche.

5.4.2 Medium-term (2027–2029): scale-up and institutionalize

1. **Scale shared infrastructure.** Build cluster-level solar mini-grids and shared biogas/CETP energy recovery projects, prioritizing clusters with high energy costs and dense SME presence.
2. **Regulatory strengthening.** Amend NEQS to include energy-based emission parameters for tanneries, mandate annual energy audits and public, anonymized sectoral reporting for medium & large firms.
3. **Certification and market-readiness programs.** Subsidize LWG/ISO 14001 certifications for export-oriented firms and provide technical assistance for compliance with evolving EU and global international standards.
4. **Expand green finance products.** Operationalize Green Leather Fund; mainstream risk-sharing with commercial banks and mobilize concessional donor co-finance for SMEs.
5. **Capacity building.** Implement large-scale training programs (factory managers, maintenance technicians, local service providers) on ISO 50001, energy management and renewable operations.

5.4.3 Long-term (2030–2035): integration and resilience

1. **Full integration with national decarbonization programs.** Lock leather sector targets into Pakistan's national industrial decarbonization strategy, including explicit reporting toward NDC contributions.
2. **Technology renewal cycles.** Encourage end-of-life replacement programs for obsolete equipment and continued R&D adoption (e.g., low-emission tanning chemistries).
3. **Market mechanisms.** Facilitate participation in renewable trading markets or aggregated corporate power purchase agreements (CPPAs) for large exporters and consortia.
4. **Resilience and circularity.** Institutionalize circular-economy practices valorization of waste, water reuse systems and embed them in procurement and export preference mechanisms.

5.5 Institutional roles and coordination

Effective delivery requires clarity of responsibilities:

- **Ministry of Industries & Production (MoIP)**; convenor of the Green Leather Policy Framework, industry incentives, and establishment of the National Leather Sustainability Council (NLSC).
- **Pakistan Tanners Association (PTA) & industry bodies** — industry mobilization, co-financing pilots, dissemination of best practices, and facilitating certification uptake.
- **Ministry of Climate Change (MoCC) & Provincial EPAs** — regulatory direction, monitoring of air and energy emissions, and enforcement.
- **NEECA & energy utilities** energy audits, technical standards, integration of leather sector into national energy efficiency programs, and grid integration support.
- **State Bank of Pakistan (SBP), commercial banks & donors** — design and provision of green financing products, risk-sharing instruments and concessional finance.
- **Academic and technical institutions** — training, research on low-emission tanning technologies and techno-economic feasibility studies.

Coordinated governance should be operationalized through a time-bound, representative NLSC with public-private membership and a clear mandate to oversee implementation, monitor progress and resolve cross-sector barriers.

5.6 Financing strategy and cost considerations

A pragmatic financing approach must blend public subsidy, concessional donor funds, commercial debt, and industry equity. Key elements:

- Blended finance to lower upfront cost barriers for SMEs grant or catalytic capital covering feasibility and a share of capital expenditures.
- De-risking instruments such as partial credit guarantees or first-loss facilities to encourage banks to lend for renewable and energy-efficiency projects.
- Performance-based incentives (e.g., rebates per kWh savings or per ton CO_2 avoided) to reward verified outcomes and accelerate adoption.
- Tax and tariff reforms targeted tax rebates, import duty waivers on RE equipment, and streamlined net-metering regulations to improve payback profiles.

Cost modeling from pilots should inform national scale-up, but preliminary analysis suggests payback periods for solar PV and energy-efficiency retrofits in many tanneries will be attractive under subsidized financing and with recognition of avoided diesel/gas costs and reduced maintenance.

5.7 Monitoring, verification and reporting

Robust measurement, reporting and verification (MRV) is non-negotiable:

1. **Sectoral baseline dataset** creates an anonymized national leather energy and emissions database to track progress.
2. **Mandatory meters and digital reporting** for medium and large firms; graduated requirements for SMEs with cluster-based monitoring to reduce transaction costs.
3. **Third-party verification** employs accredited auditors for energy savings and emission reductions, aligned with international standards to aid export-market credibility.

4. **Public dashboards and periodic sectoral reports** maintain transparency, incentivize continuous improvement, and support evidence-based policy adjustments.

MRV functions should be coordinated by the NLSC in partnership with NEECA and provincial EPAs, ensuring interoperability with national GHG inventories.

5.8 Social, labor and equity considerations

The transition must protect livelihoods. Key measures include:

- **Reskilling and upskilling programs** for tannery workers to maintain employment in upgraded operations and new maintenance roles.
- **Inclusive finance windows** for women-led and micro tanneries that historically lack bank access.
- **Community engagement protocols** for cluster interventions (e.g., siting of shared plants) to ensure local buy-in and minimize displacement risks.
- **Health and safety improvements** as co-benefits (reduced indoor air pollution, lower exposure to combustion by-products).

Equity considerations should be embedded into funding criteria and technical assistance targeting.

5.9 Limitations, uncertainties and research gaps

While the study offers a robust foundation, key limitations persist:

- **Data quality and coverage**: widespread informal operations and poor metering reduce precision in energy and emissions estimates; further field-level measurement campaigns are needed.
- **Seasonality and operational variability**: data from the August–October 2025 field period may not capture full seasonal peaks and troughs in energy demand.
- **Behavioral and adoption dynamics**: willingness to invest, risk aversion, and proprietary concerns about operational data could slow scaling. Social-science research to understand behavioral levers is necessary.
- **Technology performance in local conditions**: long-term operational performance of some interventions (e.g., biogas from tannery waste, solar-thermal in humid conditions) requires demonstration at scale and context-specific design.

Research priorities include longitudinal monitoring of pilots, techno-economic optimization for hybrid systems, lifecycle emission analyses for tanning chemistries, and market-based studies on export price premiums for lower-carbon leather.

5.10 Key performance indicators (KPIs) for tracking progress

To ensure momentum and accountability, the following KPIs are recommended:

- Number of tanneries completing certified energy audits (annual target).
- Installed renewable capacity in the leather sector (MW) and number of pilot-to-scale projects.
- Average energy intensity reduction (kWh or MJ per m^2 or per ton finished leather) across monitored firms.
- Tons of CO_2 -equivalent avoided per year attributable to interventions.
- Number of firms with LWG/ISO 14001 certification and export volumes from certified firms.

- Volume of green finance disbursed and number of SMEs financed.
- Number of technicians and managers trained in ISO 50001 and renewable operations.

KPIs should be periodically reviewed and updated by the NLSC.

5.11 Final remarks and call to action

The leather sector sits at a crossroads: its economic relevance and geographical clustering make it uniquely tractable for targeted policy action, while rising energy costs and tightening sustainability standards make action imperative. The analysis in this report demonstrates that a pragmatic, phased transition built on pilots, cluster-scale infrastructure, strengthened regulation, and innovative finance can deliver both environmental and economic dividends. Importantly, the transition is not solely about technology; it is about governance, institutions, market linkages and people. Success will depend on credible leadership (public and private), carefully designed incentives, sustained technical assistance, and transparent monitoring.

This study offers a blueprint. The next steps are straightforward and urgent: form the council coordinating; launch the pilots and the green financing window; establish baseline monitoring; and immediately begin capacity-building at scale. If Pakistan leverages this moment aligning industry needs with climate commitments and market opportunities the leather sector can transform from an emissions challenge into a demonstration of competitive, sustainable industrial development in Pakistan.

In final synthesis, this study of ADS, demonstrates that Pakistan's leather industry is a pillar of national exports and employment is now at a defining crossroads where economic survival, environmental responsibility, and competitiveness converge. The findings reveal that the sector's current dependence on fossil fuels and inefficient technologies is not only raising costs but also exposing firms to emerging trade and climate risks. Yet, this challenge presents an opportunity: by adopting renewable and energy-efficient technologies, strengthening policy and regulatory frameworks, enabling access to green finance, and fostering institutional coordination through mechanisms like a National Leather Sustainability Council, Pakistan can steer its leather sector toward a low-carbon and high-value future. A phased, evidence-based transition anchored in pilot demonstrations, cluster-level renewable systems, and rigorous monitoring will not only reduce emissions and energy intensity but also enhance export resilience under Pakistan's sustainability regimes. Ultimately, the shift toward cleaner energy and circular production is both a climate necessity and a strategic pathway for transforming Pakistan's leather industry into a regional model of sustainable industrialization and green economic growth in Pakistan.

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