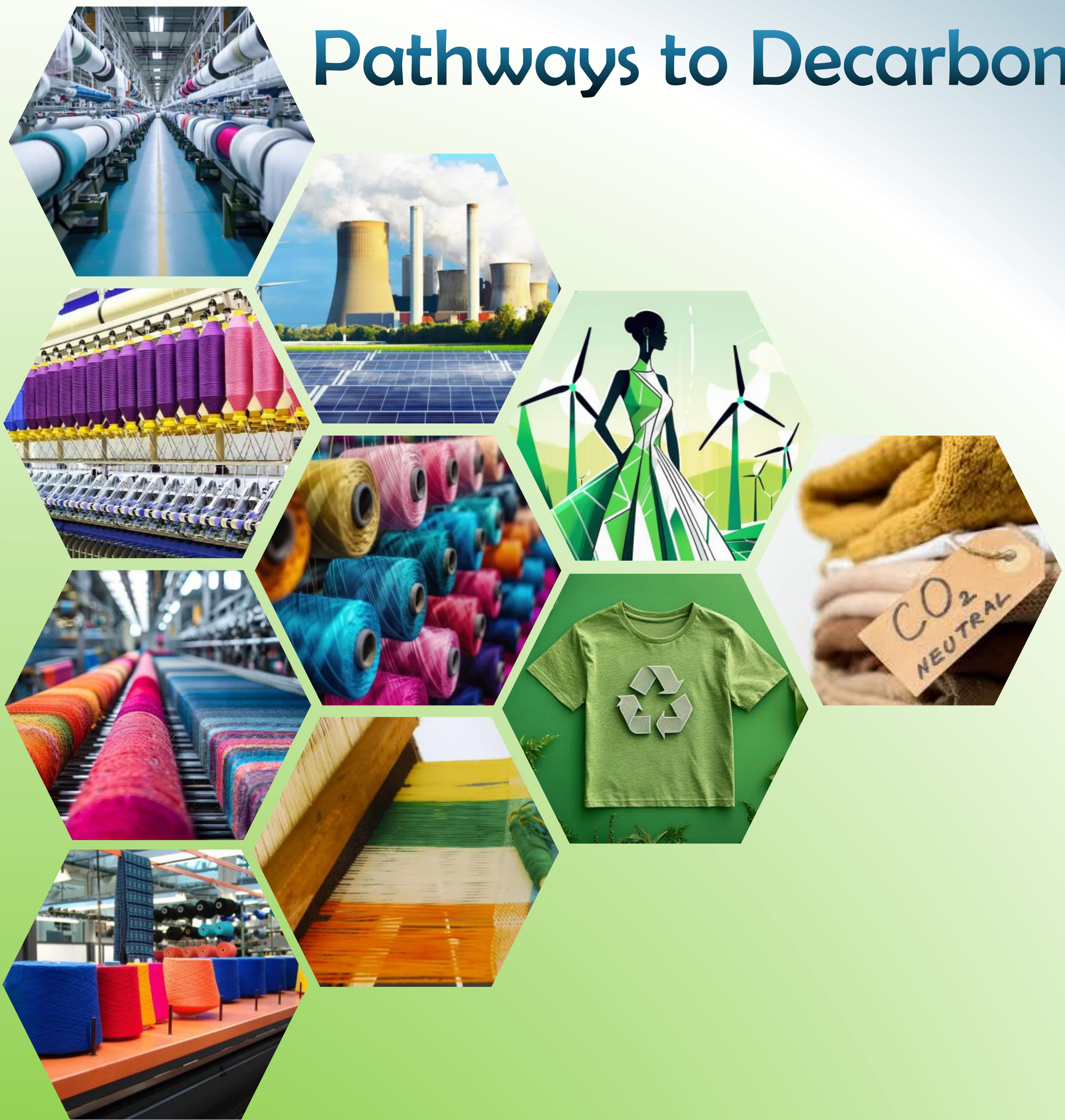
Energy Landscape of Pakistan's Textile Sector

Pathways to Decarbonization



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Pathways to Decarbonization

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Amjad Nazeer
CEO – Alternate Development Services.
Islamabad
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Executive Summary

The textile industry is a cornerstone of Pakistan's economy, contributing 8.5% to the national GDP and employing 40% of the industrial workforce. Despite its economic significance, the sector is beset by critical challenges, including energy inefficiency, reliance on fossil fuels, and a substantial environmental footprint. Pakistan’s reliance on non-renewable energy sources such as natural gas and coal exacerbates its carbon footprint, while international mandates like the European Union's Carbon Border Adjustment Mechanism (CBAM) increase pressure for compliance with sustainability standards. Failure to adapt could severely impact Pakistan’s textile exports, which account for 57% of national export revenues.

This report presents findings from a comprehensive survey of 29 textile units, conducted by Alternate Development Services (ADS in collaboration with National Textile University (NTU). The study aimed to assess energy consumption patterns, the potential for renewable energy integration, and current decarbonization efforts in the industry. The survey revealed that the energy mix of the textile sector is heavily dominated by non-renewable sources, accounting for 43% of the total energy used. Grid electricity, which constitutes 42%, also relies significantly on fossil fuels, while renewable energy sources make up only 15%.

Despite the promising potential for renewable energy integration, barriers to progress remain significant. High upfront costs of renewable technologies, limited access to green financing, and inadequate policy support are key obstacles. Only 48% of the surveyed industries conduct energy audits, and a mere 28% assess their carbon footprint, highlighting gaps in energy efficiency practices and emissions tracking.

The adoption of renewable energy and efficiency improvements could dramatically reduce the sector’s environmental impact. During the survey, several industries expressed their commitment to adopting or expanding renewable energy projects. The aggregated responses reveal ambitious plans for renewable energy integration, with the potential to significantly reduce projected GHG emissions by approximately 450 tons of CO_2 per day, underscoring the vital role these initiatives play in advancing decarbonization efforts. Export-oriented industries are particularly motivated to adopt sustainable practices, driven by global market demands and the imperative to align with international sustainability standards, including CBAM compliance.

To address the challenges of decarbonizing textile industry, the report emphasizes the importance of policy interventions, such as tax incentives, subsidies, and accessible green financing schemes, to support renewable energy adoption. Regulatory frameworks mandating energy audits and carbon footprint assessments could help improve energy efficiency across the sector. Capacity-building initiatives, technical training, and public-private partnerships are also critical to equipping industries with the skills and resources needed to navigate the transition to renewable energy. Strengthened waste management practices and the promotion of a circular economy could further bolster the industry's sustainability efforts.

The textile sector's shift toward sustainable energy practices is not only vital for environmental conservation but also crucial for maintaining competitiveness in global markets. By addressing financial and technical barriers, fostering innovation, and aligning with international sustainability standards, Pakistan's textile industry can significantly reduce its carbon footprint while ensuring long-term economic resilience.

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Chapter 1: Introduction

1.1. Background

The textile industry is a cornerstone of Pakistan's economy, contributing approximately 8.5% to the national GDP and employing about 40% of the industrial labor force [1]. Pakistan is the fifth largest producer of raw cotton globally and holds the third largest spinning capacity in Asia, following China and India [2]. It accounts for around 57% of Pakistan's export revenues, making it a key player in Pakistan's economic stability and growth [3]. However, this sector faces multiple challenges, including high energy costs, reliance on fossil fuels, and the environmental impact of its energy-intensive processes. Globally, the textile industry is one of the largest contributors to greenhouse gas (GHG) emissions, responsible for nearly 10% of total emissions, surpassing the aviation and maritime industries combined. Regulations such as the European Union’s Carbon Border Adjustment Mechanism (CBAM) and rising consumer demand for sustainable products are compelling businesses to adopt environmentally friendly processes, as the international markets increasingly prioritize sustainability. Failing to meet these requirements could threaten the competitiveness of Pakistan's textile exports in global markets.

1.2. GHG Emissions in Various Sectors

GHG emissions are distributed across various sectors, with energy production being the most significant contributor. According to the data typically presented in Figure 1 by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), the major sectors responsible for global GHG emissions include energy, industry, agriculture, land-use change, municipal waste, and transportation [4, 5].

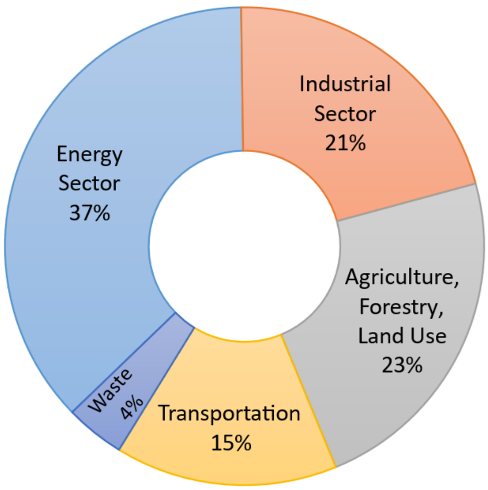

Figure 1: Global GHG emissions breakdown by sector

Energy Sector (including electricity and heat production): The energy sector is the largest contributor to global GHG emissions (share of global emissions: approx. 35-40%), primarily through the combustion of fossil fuels for electricity, heat, and energy production. This includes emissions from power plants, refineries, and other energy infrastructure. CO_2 from burning coal, oil, and gas, as well as CH_4 from natural gas production are main gasses produced in this sector [6].

Industrial Sector: The industrial sector includes emissions from manufacturing (share of global emissions: approx. 20-22%), cement production, steel making, and chemical industries. These processes release large amounts of CO_2 and other gases through energy consumption and industrial processes. CO_2 and some fluorinated gases (F-gases) from chemical processes are main gasses produced in this sector.

Agriculture, Forestry, and Other Land Use: Agricultural practices such as livestock rearing, and rice cultivation contribute to high levels of methane (CH_4) and nitrous oxide (N_2O) emissions. Deforestation and land-use changes also release significant amounts of CO_2. Share of global emissions is approximately 20-25%. CH_4 (from livestock), N_2O (from fertilizers), and CO_2 (from deforestation and land-use change) are main gases produced by this.

Transportation: Transportation emissions come from road vehicles, aviation, shipping, and railways (share of global emissions: approx. 14-16%). This sector is primarily reliant on oil-based fuels, leading to CO_2 emissions. CO_2 from fuel combustion is major source.

Emission from Waste Management and Incineration: Waste emissions are primarily from landfill methane (CH_4) and other waste management processes like wastewater treatment (share of global emissions: approx. 3-5%). CH_4 from waste decomposition and CO_2 from waste incineration are major sources of emissions.

Key points extracted from this discussion are:

- The energy sector is the largest contributor, followed by industry and agriculture.
- Transportation and buildings together contribute a significant portion of emissions due to fuel combustion and energy consumption.
- Addressing emissions from each sector requires targeted solutions, such as energy efficiency, renewable energy, sustainable agriculture, and reducing deforestation.

1.3. Impact of the Textile Sector on GHG Emissions

The textile industry is one of the most significant contributors to environmental pollution, including GHG emissions. The sector is responsible for a substantial portion of carbon emissions, with estimates suggesting that the industry accounts for nearly 10% of total global emissions, surpassing the emissions of international flights and maritime shipping combined [7]. The entire lifecycle of textiles, from fiber production to garment manufacturing, transportation, and disposal, is energy-intensive and environmentally impactful. During fiber production, particularly in cotton farming, large amounts of pesticides, fertilizers, and water are consumed, further exacerbating environmental degradation and resource depletion. The transition to synthetic fibers like polyester has not significantly alleviated this impact, as their production remains heavily reliant on fossil fuels and emits microplastics into the oceans, creating long-term ecological damage. The production of synthetic fibers like polyester, which is derived from petroleum, and the processing of natural fibers like cotton, involves significant energy use and chemical processing. Dyeing and Finishing processes involve toxic chemicals and substantial water and energy use, leading to GHG emissions and other environmental pollution. These stages contribute to water pollution as untreated or improperly treated effluents are often discharged into water bodies, affecting aquatic life and contaminating drinking water sources in surrounding communities. The rise of fast fashion has increased textile production and waste, contributing to higher GHG emissions.

1.4. Pakistan’s Textile Industry

Pakistan’s textile industry is a cornerstone of the country's economy, accounting for a significant portion of its exports and industrial employment. However, the industry also has a substantial environmental footprint, particularly concerning energy use and emissions. The textile sector contributes around 8.5% to Pakistan's GDP and employs about 40% of the industrial labor force. The sector is highly energy-intensive, relying primarily on fossil fuels, which significantly contribute to GHG emissions [8, 9].

The textile sector in Pakistan, much like in other parts of the world, involves energy-intensive processes that contribute to the country's overall carbon footprint. Understanding the carbon footprint and GHG emissions from Pakistan's textile industry is crucial to devising strategies for sustainable development. Figure 2 presents the key sources of emissions in the textile sector which are explained in detail below.

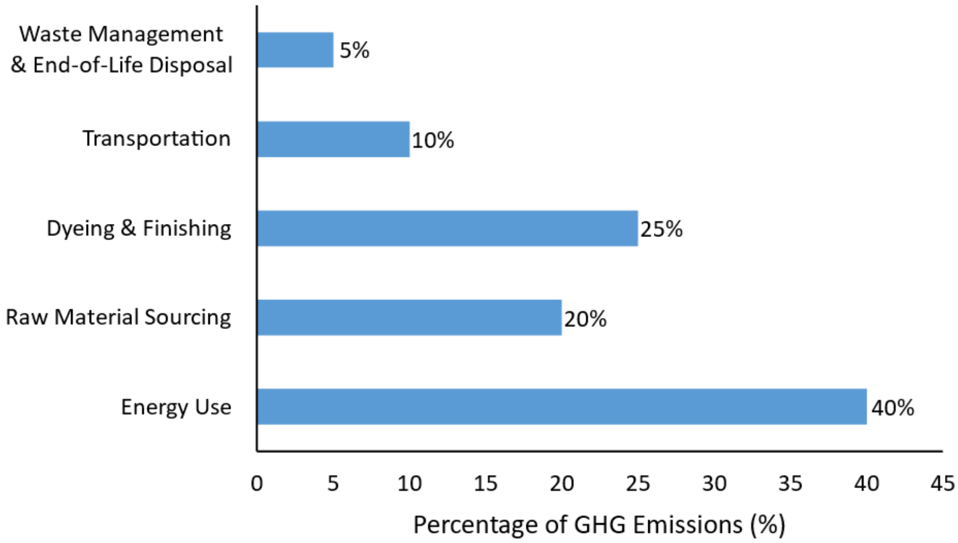

Figure 2: Greenhouse gas emissions in Pakistan's textile industry

Energy Use: The textile industry in Pakistan heavily relies on non-renewable energy sources, particularly natural gas and electricity derived from fossil fuels, for its operations. From fiber processing to dyeing and finishing, each step of the textile production process requires a considerable amount of energy. According to estimates, one of the major portions of energy used in textile manufacturing is related to drying and heating processes [10]. These operations release significant amounts of carbon dioxide (CO_2), the most prevalent greenhouse gas.

Raw Material Sourcing: Pakistan is a major producer of cotton, which is the primary raw material for its textile industry. The cultivation of cotton involves the use of fertilizers and pesticides, which contribute to emissions of nitrous oxide (N_2O), a potent greenhouse gas [11, 12]. In addition, cotton farming is water-intensive and has associated energy use, contributing indirectly to the carbon footprint. Transitioning to more sustainable fiber sources and improving farming practices are critical strategies to reduce emissions at this stage.

Dyeing and Finishing: One of the most carbon-intensive stages of textile production in Pakistan is the dyeing and finishing process. This process involves significant chemical use and high-temperature water baths, both of which require large energy inputs. The use of synthetic dyes and high-temperature processes requires significant energy input, leading to CO_2 emissions. Additionally, water contamination from untreated dye effluents is a significant environmental concern.

Waste Management and End-of-Life Disposal: Textile waste, whether from manufacturing offcuts or discarded garments, also adds to the carbon footprint of the industry. A large portion of textile waste in Pakistan ends up in landfills, where it contributes to methane (CH_4) emissions as organic materials decompose.

1.5. Challenges and Opportunities for Reducing Emissions in Pakistan's Textile Industry

Pakistan's textile sector faces several challenges in addressing its carbon footprint. The lack of access to cleaner energy sources, inefficient production techniques, and outdated infrastructure contribute to high energy consumption. However, there are also opportunities for reducing emissions:

- Investing in energy-efficient technologies, such as heat recovery systems and more efficient drying techniques, can significantly reduce energy use.
- Transitioning to solar and wind energy can help decrease reliance on fossil fuels and reduce GHG emissions.
- Innovations in waterless dyeing processes can mitigate both water usage and energy consumption.
- Promoting the recycling and reuse of textiles can help reduce waste and lower emissions associated with raw material extraction and end-of-life disposal.

The textile industry in Pakistan has a sizable carbon footprint, but there are numerous opportunities to reduce GHG emissions through improved energy use, waste management, and cleaner technologies. Encouraging the adoption of sustainable practices can lead to a more environmentally friendly and economically resilient textile sector.

The textile industry is a cornerstone of Pakistan's economy, but it also poses significant environmental challenges due to its substantial carbon footprint and GHG emissions. Addressing these environmental concerns requires both an understanding of the obstacles that hinder progress and an exploration of viable opportunities for reducing emissions. Here is a detailed breakdown of the major challenges and corresponding opportunities to promote sustainability in Pakistan's textile sector.

1.5.1. Challenges in Reducing Emissions

Dependence on Fossil Fuels: One of the primary challenges facing the textile industry in Pakistan is its heavy reliance on fossil fuels for energy. Most textile factories in the country use natural gas, coal, or oil to power their operations, particularly in energy-intensive stages like drying, heating, and dyeing. The country's grid electricity is also largely dependent on non-renewable sources, contributing to high CO_2 emissions. Shifting away from fossil fuels is hindered by the lack of access to affordable renewable energy solutions. The cost of transitioning to cleaner energy technologies is high, and many manufacturers, especially small and medium-sized enterprises (SMEs), face financial constraints that prevent investment in renewable energy infrastructure.

Outdated Machinery and Inefficient Technologies: Many textile factories in Pakistan continue to use outdated machinery that is not energy efficient. This leads to higher energy consumption and increased GHG emissions during production processes such as weaving, dyeing, and finishing. The lack of modernization in the industry is a significant challenge for reducing emissions. Upgrading machinery requires substantial capital investment, which is often out of reach for smaller businesses. Additionally, there is limited awareness and technical expertise to implement newer, energy-efficient technologies across the sector.

Modern technologies such as air-jet looms, which consume significantly less energy compared to traditional shuttle looms, offer faster production rates and reduced mechanical wear. In dyeing and finishing processes, low-liquor ratio dyeing machines and continuous dyeing systems can drastically cut water and energy usage, making them more sustainable alternatives to conventional batch dyeing methods.

Water-Intensive Processes: The textile industry in Pakistan, particularly in dyeing and finishing, consumes large quantities of water. These processes not only contribute to water scarcity but also require energy to heat water, leading to increased CO_2 emissions. Additionally, water pollution from chemical dyes and untreated wastewater poses an environmental threat.

The adoption of water-saving technologies and pollution control systems is limited due to high upfront costs and a lack of regulatory enforcement. Many factories lack the infrastructure for proper wastewater treatment, leading to environmental degradation.

Lack of Regulatory Enforcement: Pakistan’s environmental regulations, while present, are often not enforced rigorously. There is limited oversight of GHG emissions from industrial operations, and many textile factories operate without adhering to global environmental standards. Weak enforcement mechanisms, corruption, and the absence of comprehensive environmental policies hinder efforts to reduce emissions. Without stringent regulatory frameworks, factories have little incentive to adopt cleaner production methods.

Waste Management and End-of-Life Emissions: Textile waste management is another challenge. Many manufacturing processes generate significant waste, and a large portion of discarded textiles end up in landfills, where they decompose and emit methane, a potent greenhouse gas.

The absence of circular economy initiatives and poor waste segregation practices contribute to high levels of textile waste. There is also a limited infrastructure for recycling textiles or repurposing them into new products.

1.5.2. Opportunities for Reducing Emissions

Transition to Renewable Energy: One of the most effective ways to reduce emissions in the textile sector is through the adoption of renewable energy sources such as solar and wind power. Pakistan has significant potential for solar energy, especially in areas with high levels of sunlight. By investing in solar power, textile factories can reduce their dependence on fossil fuels and lower their carbon footprint.

Solar panels and wind turbines can be installed on-site to generate clean energy for textile operations. Government incentives and subsidies for renewable energy investments could help reduce the financial burden on manufacturers, especially SMEs. International partnerships and funding for clean energy projects could further accelerate the shift toward renewables.

Energy Efficiency Improvements: Improving energy efficiency through the adoption of modern, energy-efficient machinery can significantly reduce emissions. Newer technologies in weaving, dyeing, and finishing processes use less energy and water, leading to lower GHG emission. Textile factories can benefit from energy audits that identify areas where efficiency improvements can be made. Government programs that provide financial support for upgrading to energy-efficient machinery could further motivate factories to modernize. Additionally, training and capacity-building initiatives to educate manufacturers on energy-saving techniques can lead to widespread adoption of best practices.

Waterless and Low-Water Dyeing Technologies: Innovation in dyeing processes can drastically reduce the water and energy used in textile production. Waterless dyeing technologies, such as air-dyeing or using supercritical carbon dioxide, eliminate the need for water and reduce the energy required for the water heating process, thus lowering emissions. Collaboration with international organizations and technology providers can bring waterless dyeing technologies to Pakistan. Pilot projects that demonstrate the effectiveness of these technologies can encourage wider adoption in industry.

Sustainable Cotton and Raw Material Sourcing: Sustainable cotton farming practices, such as organic farming and integrated pest management, can reduce the environmental impact of raw material production. Organic cotton farming eliminates the use of synthetic pesticides and fertilizers, which are major sources of N_2O emissions. Encouraging farmers to adopt sustainable practices through training, certification programs, and financial incentives can lead to significant reductions in emissions from cotton farming [13]. International markets are increasingly demanding sustainable cotton, offering a potential competitive advantage for Pakistan's textile sector.

Circular Economy and Textile Recycling: Moving toward a circular economy model, where textiles are designed for reuse, repair, and recycling, can reduce waste and emissions at the end of the product life cycle. Circular fashion initiatives promote resource efficiency and lower the need for virgin raw materials, leading to fewer emissions throughout the supply chain [14]. Implementing recycling programs and creating a market for recycled textiles can reduce the industry's overall carbon footprint. Collaborations with fashion brands that are committed to circular fashion can open up new business opportunities for textile manufacturers in Pakistan [15]. Public awareness campaigns promoting sustainable consumption, and the importance of recycling can help reduce textile waste.

Strengthening Environmental Regulations: The enforcement of environmental regulations and setting stricter emissions standards can incentivize manufacturers to adopt greener practices. Introducing penalties for non-compliance and rewards for environmentally responsible behavior can foster a culture of sustainability. The government, in collaboration with environmental agencies, can develop more robust policies that require factories to monitor and report their emissions. Partnerships with international organizations and adherence to global standards like the Paris Agreement can also push the industry toward greater accountability and transparency.

1.6. Current Energy Consumption in the Pakistan Textile Industry

The energy consumption in Pakistan's textile industry is high, with most mills operating on outdated technologies that are energy inefficient. This includes traditional looms, inefficient dying machines, conventional ring frames that consume more electricity, etc. There is a growing need to transition to renewable energy sources and adopt energy-efficient practices. The industry primarily uses electricity generated from non-renewable sources, including coal and natural gas. Many textile mills opt for captive power systems powered by diesel generators, coal-fired plants, or natural gas, which can lead to high levels of greenhouse gas (GHG) emissions. While CPG (Captive Power Generation) offers some advantages, such as reducing dependency on the grid and ensuring a more reliable power supply, it also poses several challenges related to energy efficiency and emissions. These systems often lack the emission control technologies found in larger, centralized power plants, resulting in higher emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and particulate matter. There is minimal use of renewable energy sources like solar or wind. Efforts to reduce energy consumption include the introduction of more energy-efficient machinery, waste heat recovery systems, and better energy management practices.

The textile production process consists of several stages, including fiber production, spinning, weaving, dyeing, finishing, and garment manufacturing. Each stage requires significant energy inputs, and most factories in Pakistan rely on non-renewable energy sources to power these processes. According to estimates from industry reports, around 45-50% of the energy used in the textile sector is consumed by activities such as spinning, weaving, and knitting as shown in Figure 3.

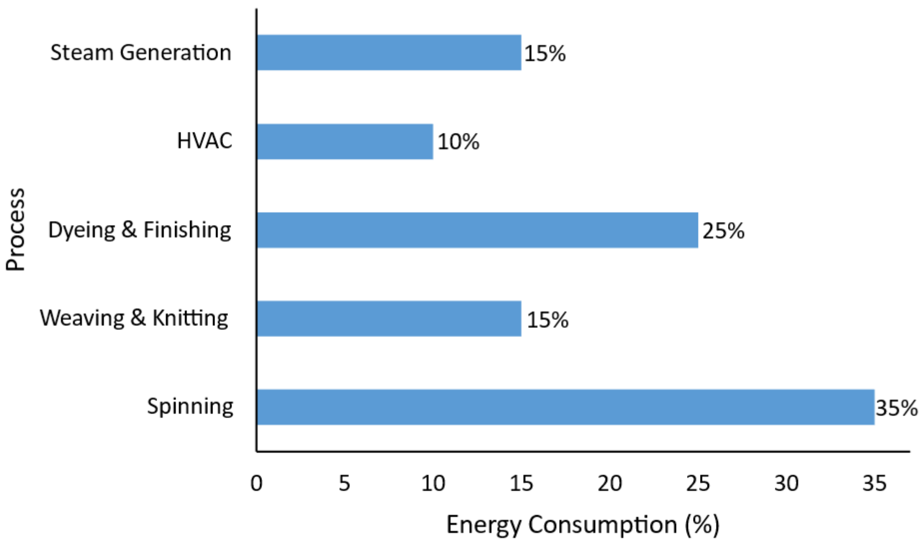

Figure 3: Percentage of energy consumption in Pakistan textile industry

These processes are highly mechanized, and the machinery involved requires constant power supply to operate efficiently. Dyeing and finishing processes account for another significant portion of energy consumption, as they involve heating water, using steam, and applying chemicals to fabrics, all of which demand substantial amounts of energy. In the dyeing process, heating water is a critical step, as most dyes are applied in aqueous solutions. Heating water to the required temperatures can be energy-intensive, especially in batch dyeing systems where large volumes of water need to be heated quickly. The use of steam in dyeing is also prevalent, as it helps fix dyes to the fabric and enhance color fastness. Steam generation typically requires a boiler system, which often operates on fossil fuels, adding to the carbon footprint of the dyeing process. Moreover, the application of chemicals during dyeing, such as mordants, fixing agents, and softeners, often necessitates additional energy use for mixing and processing. These chemicals can also increase the environmental impact of the dyeing process, particularly if effluents are not treated properly, leading to pollution of water bodies [16].

Pakistan's textile industry is particularly dependent on natural gas and grid electricity. While natural gas is primarily used for steam generation and heating, electricity is used for operating machinery, lighting, and air conditioning in factories [16, 17]. Given that Pakistan's energy grid is largely powered by fossil fuels (including coal, oil, and natural gas), the carbon footprint of the textile industry is considerable. In recent years, fluctuations in energy supply and increasing energy costs have added to the challenges faced by industry. Key areas of energy consumption in Pakistan's textile industry are described below:

Spinning: Spinning is one of the most energy-intensive stages of textile production. The process involves converting raw fibers into yarn, and it requires the use of high-speed machines such as ring spinners, air-jet spinners, and carding machines. Spinning mills consume a large portion of the industry's total electricity, with some estimates suggesting that the energy consumption in spinning accounts for up to 35% of the total energy used in textile production. Most of the energy used in this stage comes from electricity, which powers the machinery.

Weaving and Knitting: Weaving and knitting processes, which turn yarn into fabric, are also major consumers of electricity. The looms and knitting machines used in these stages operate continuously, often for 24 hours a day, making energy efficiency critical to reducing production costs. Weaving, in particular, is more energy-intensive than knitting due to the complexity and speed of the machines used. This stage consumes around 10-15% of the total energy in textile manufacturing [10, 17].

Dyeing and Finishing: The dyeing and finishing stage is another significant energy consumer, particularly due to the need for heating water and generating steam. These processes involve washing fabrics, applying dyes and chemicals, and heat-setting the final product. It is estimated that dyeing and finishing account for around 20-25% of the total energy consumption in the textile sector. Natural gas is predominantly used in this stage to generate steam for washing and finishing, while electricity is used to power other equipment.

Heating, Ventilation, and Air Conditioning (HVAC): Maintaining the right temperature and humidity in textile factories is crucial for ensuring the quality of the products, especially in the spinning and weaving stages. HVAC systems are often necessary to create controlled environments, and these systems consume a significant amount of electricity. It is estimated that HVAC systems contribute to approximately 10-12% of total energy consumption in the textile industry. Factories that use outdated or inefficient HVAC systems tend to have higher energy consumption, adding to production costs and environmental impact.

Steam Generation: Steam is an essential component in many textile processes, particularly in dyeing and finishing. Steam is used to heat water, cure fabrics, and dry materials. Most factories in Pakistan rely on boilers fueled by natural gas to generate steam. Energy consumption from steam generation can account for 15-20% of total energy use in a textile factory. Energy-efficient steam systems and technologies, such as heat recovery systems, have the potential to significantly reduce energy consumption in this area.

1.7. Challenges in Energy Usage

Energy Shortages and Unreliable Supply: One of the most significant challenges faced by Pakistan's textile industry is the unreliable energy supply. The country has experienced energy shortages, with frequent power outages and natural gas supply interruptions. These energy shortages disrupt production, increase downtime, and force factories to rely on backup systems, such as diesel generators, which further increase operational costs and emissions. In response to these challenges, many textile manufacturers have turned to Captive Power (CP) systems, which allow them to generate their own electricity. While CP systems can offer certain advantages, they also come with significant drawbacks. CP systems allow textile mills to reduce their dependency on the national grid and protect themselves from fluctuations in electricity prices or supply interruptions. By generating their own power, mills can maintain consistent operations despite broader energy crises. CP systems can utilize various energy sources, including diesel, natural gas, biomass, or renewable energy options, allowing mills to choose the most feasible or cost-effective option available.

However, many CP systems, particularly those that rely on fossil fuels like coal or diesel, contribute significantly to greenhouse gas emissions and air pollution. The environmental impact can undermine the sustainability goals of the textile sector. On the other side, the installation of captive power systems often requires substantial upfront investment, which can be a barrier for many textile firms.

High Energy Costs: The cost of energy in Pakistan has risen steadily over the years, making it one of the most expensive inputs for the textile industry. Energy costs account for a significant portion of total production expenses, affecting the competitiveness of Pakistani textiles in the global market. According to the Pakistan Bureau of Statistics, energy costs constitute approximately 30-40% of the total production expenses for textile manufacturers, which is substantially higher than in many competing countries, such as Bangladesh and India, where energy costs typically represent around 15-20% of production costs. High electricity tariffs, combined with fluctuating natural gas prices, create financial pressures on manufacturers, particularly SMEs (small and medium-sized enterprises), which often lack the capital to invest in energy-efficient technologies. For context, Pakistan's energy tariffs are notably higher than those of regional counterparts, potentially undermining its industrial competitiveness. With electricity tariffs at 17.5 US cents/kWh, Pakistan exceeds Vietnam's 7.2, Bangladesh's 8.6, and India's 10.3 cents/kWh. The disparity is even starker in gas tariffs, where Pakistan's blended rate is 12.4 US dollars/MMBtu, compared to lower rates in Vietnam, India, and Bangladesh [18].

Outdated Machinery: A large portion of the textile industry in Pakistan operates with outdated and inefficient machinery, which consumes more energy than modern alternatives. For instance, many spinning mills continue to use traditional ring spinning frames, which are known for their higher energy consumption compared to newer technologies like rotor spinning. Similarly, in the weaving sector, outdated shuttle looms are still prevalent. These looms not only consume more energy due to their mechanical inefficiencies but also operate at slower speeds, resulting in increased production time and higher overall energy use. Many textile firms still utilize old dyeing machines that lack proper insulation and energy recovery systems, leading to significant heat loss during operation. These machines require excessive energy to maintain the high temperatures needed for dye application, thereby increasing operational costs and GHG emissions. The lack of investment in energy-efficient equipment not only increases energy consumption but also reduces productivity. The high cost of upgrading machinery and limited access to financing further exacerbate this issue.

1.8. Opportunities for Optimizing in Energy Usage

Adoption of Energy-Efficient Technologies: Modernizing equipment and adopting energy-efficient technologies offer substantial opportunities for reducing energy consumption. For example, installing energy-efficient motors, automated systems, and heat recovery systems can significantly lower energy use in spinning, weaving, and dyeing processes. These technologies not only reduce energy consumption but also improve production efficiency, leading to lower operating costs [19]. Figure 4 explains the potential energy saving percentages that can be achieved by implementing the efficiency improvements and modern technologies.

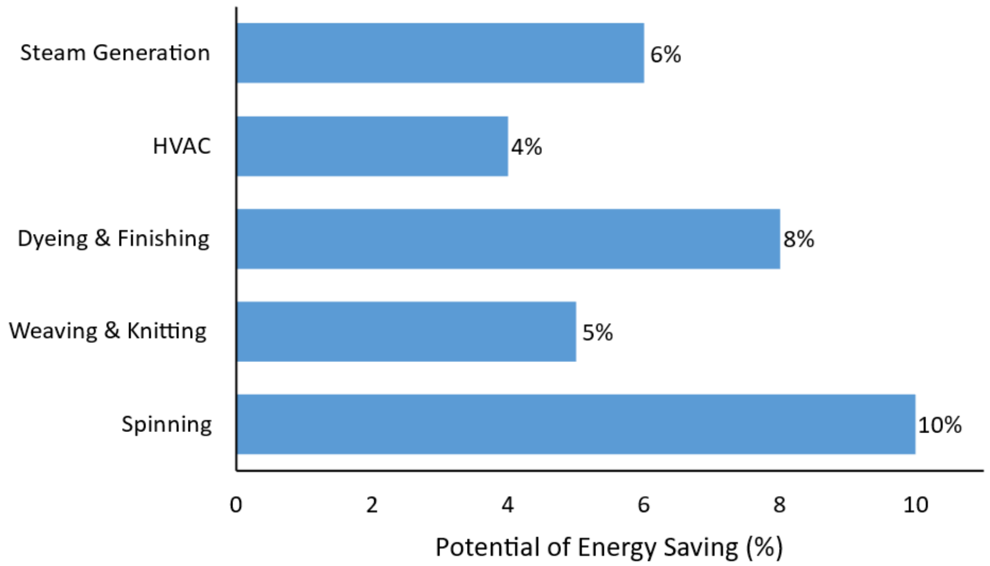

Figure 4: Potential of energy saving from efficiency improvements

Renewable Energy Integration: Pakistan has significant potential for renewable energy generation, particularly solar and wind power. Textile factories can reduce their dependence on grid electricity by installing solar panels or utilizing wind energy. Several textile mills in Pakistan have already begun investing in solar energy systems to reduce their energy costs and carbon footprint. Government incentives and international financing programs could further accelerate the adoption of renewable energy in the sector.

Energy Audits and Management Systems: Conducting regular energy audits and implementing energy management systems can help textile manufacturers identify areas where energy is being wasted. These audits provide detailed insights into energy consumption patterns, allowing factories to take corrective measures to reduce energy use. Implementing ISO 50001, an international energy management standard, can also help textile industries in Pakistan systematically improve energy efficiency [20].

Government Support and Policy Interventions: To promote energy efficiency in the textile industry, the government of Pakistan can play a vital role by offering financial incentives for upgrading machinery, reducing tariffs on energy-efficient equipment, and providing benefits for renewable energy projects. Establishing industry-specific energy benchmarks and offering training programs to build capacity in energy management can also contribute to more sustainable energy practices in the textile sector.

Chapter 2: Methodology

The importance of Textiles in Pakistan is explained in the previous chapter, but the sector is also energy-intensive, contributing to a large portion of the country's industrial greenhouse gas (GHG) emissions and it was important to work on Energy Consumption and Decarbonization in Textile Industry of Pakistan. As the world moves toward sustainable production methods and decarbonization, the need for energy efficiency and emission reduction in Pakistan's textile industry has become increasingly urgent.

To better understand the energy consumption patterns and decarbonization efforts within the industry, a comprehensive survey was conducted. This survey aimed to gather insights on current energy use, the adoption of energy-efficient practices, and the challenges faced by textile industries in transitioning to low-carbon production. The participants were key stakeholders from various areas within the textile industry, including spinning, weaving, textile processing, and garment manufacturing, with both local production units and export-oriented industries taking part. The survey was conducted by the experts from National Textile University (NTU), Faisalabad, in collaboration with Alternate Development Services (ADS), Islamabad. And results were compiled with mutual understanding of the data.

The survey was conducted using a mixed-methods approach, combining both quantitative and qualitative data collection techniques. The primary tool for collecting data was a Microsoft Teams-based survey form, which allowed respondents from various textile industries to participate both online and through direct contact with industry professionals. This section outlines the procedure followed for data collection and the overall methodology used to gather information.

2.1. Survey Design

The survey was designed to cover several key areas related to energy consumption and decarbonization in the textile industry and consisted of both multiple-choice questions and open-ended questions to allow respondents to provide detailed feedback. The questions were categorized into the following sections.

a) Energy Consumption Patterns

Questions focused on how much energy the industry uses in various production processes, including spinning, weaving, textile processing, and garment manufacturing.

b) Energy Efficiency Measures

Questions aimed to explore what kinds of energy-saving technologies and practices have been adopted within the industry.

c) Challenges in Decarbonization

Respondents were asked to outline the key challenges their industries face in reducing their carbon footprint and transitioning to renewable energy sources.

d) Waste Management

Gathered data on waste management practices, including waste reduction efforts, recycling processes, and disposal methods.

e) Future Plans and Opportunities

The survey also gathered information on whether industries have future plans to invest in energy-efficient technologies and how they perceive government policies related to decarbonization.

2.2. Data Collection Procedure

The data collection process involved contacting textile industries across different sectors and regions within Pakistan. Both local production units and export-oriented industries were included in the survey to ensure a comprehensive understanding of the industry's energy usage and decarbonization efforts.

2.2.1. Online Survey Distribution

The primary method of data collection was through an online form distributed via Microsoft Teams. Invitations to participate in the survey were sent to various textile industries across the country. The survey form was designed to be user-friendly, allowing respondents to fill in their answers directly online.

Participants included key decision-makers and energy managers within the textile industries, who were encouraged to provide detailed information on energy use, efficiency initiatives, and decarbonization challenges.

2.2.2. In-Person and Virtual Interviews

In addition to the online survey form, volunteers were mobilized to collect data directly from industries through in-person visits or virtual interviews. In cases where respondents preferred face-to-face interactions or had difficulty completing the online form, interviews were arranged. During these interviews, the volunteers asked survey questions and filled out the form based on the respondent's answers. These in-person and virtual interviews helped clarify points, obtain more in-depth responses, and ensure higher participation rates.

2.2.3. Follow-Up Discussions

In some cases, follow-up discussions were conducted with respondents to clarify certain answers or to gain additional insights into the data provided. These discussions were either done via phone calls, Microsoft Teams meetings, or email exchanges. This follow-up approach ensured that all the necessary data was accurately captured and that participants could elaborate on specific challenges and opportunities related to energy consumption and decarbonization.

2.3. Sampling Strategy

A purposive sampling strategy was used to select industries for the survey. The goal was to obtain a representative sample of the textile industry in Pakistan, encompassing a range of operations from spinning mills and weaving factories to textile processing units and apparel or garments manufacturers. This approach ensured that the survey results would reflect a broad cross-section of the industry, capturing insights from industries with varying production capacities and market focuses.

2.4. Types of Industries in the Survey

A total of 50 textile industry units were contacted for participation in the survey, including both local production units and export-oriented firms. The survey successfully received approximately 29 responses from different key sectors of textile industry from Lahore, Faisalabad, Multan, Khanewal and Karachi.

- Spinning units: 9
- Weaving units: 4
- Apparel or Garments units: 6
- Textile processing units: 2
- Composite units: 8

a) Spinning Unit

A significant portion of the surveyed industries, accounting for 9 respondents, are engaged in spinning activities. Spinning is the process of converting fibers into yarn, which is a foundational activity in textile production. The high percentage suggests that spinning plays a critical role in the overall textile sector of Pakistan. Given the energy-intensive nature of spinning, this finding underlines the importance of addressing energy consumption and efficiency in this part of the industry.

b) Weaving Unit

About 4 of the respondents are from weaving units, where yarn is turned into fabric. Weaving is a crucial stage in the textile value chain, and its energy consumption is also significant, particularly in power looms. Although a smaller portion of the survey compared to spinning, weaving still represents a substantial part of the textile ecosystem.

c) Apparel or Garments Unit

Apparel or garments manufacturing units comprise 6 of the respondents. These units are involved in converting processed fabrics into finished garments, a highly labor-intensive part of the textile value chain. Although energy consumption in garment production is relatively lower than in spinning and weaving, the sector plays a vital role in the overall output and export of textile products from Pakistan.

d) Textile Processing Unit

The processing units, which include dyeing, printing, and finishing of fabrics, account for 2 of the surveyed industries. This category is crucial for adding value to the raw fabrics by making them ready for garment production. Processing tends to be energy-intensive, particularly in the areas of water heating and chemical treatments, making energy efficiency efforts in this sector vital.

e) Composite Unit

Composite units, which handle multiple stages of the textile production process (such as spinning, weaving, processing, and garment production), account for 8 of the surveyed industries. These vertically integrated units have the potential to optimize energy use across different stages and reduce overall costs, but they also face challenges in managing energy efficiency across multiple processes. The complexity of operating various production stages under one roof means that inefficiencies in one area can significantly impact the overall energy consumption of the entire unit. For example, if outdated machinery is used in the spinning or dyeing processes, it can lead to higher energy use that offset gains made in other, more efficient stages of production. Additionally, the need to synchronize energy demands across different processes adds to the challenge, as fluctuating energy loads can cause inconsistencies in power supply and increase reliance on less efficient backup systems like diesel generators. Without a comprehensive energy management strategy, these units may struggle to fully realize the benefits of their integrated setup, limiting their ability to reduce emissions and lower operational costs.

2.5. Types of Industries based on the Products in the Survey

Figure 5 represents the breakdown of product destinations, indicating whether the production is for local use, export, or both.

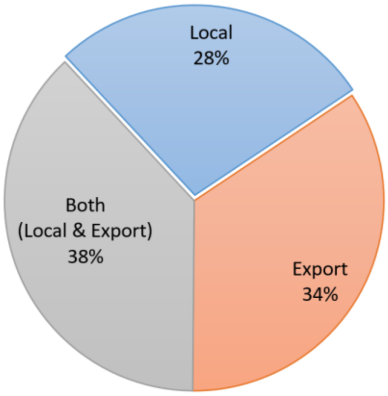

Figure 5: Type of industries participated in the survey

a) Export-Oriented Units

A significant 34% of the textile industry respondents focus on exporting their products. The export-driven nature of this part of the industry is expected, given that Pakistan's textile industry is one of the largest contributors to the country's export revenues. Export-oriented firms are often subject to stricter sustainability and energy efficiency standards imposed by international buyers, which may drive them to adopt greener practices and technologies.

b) Local Production

Only 28% of the respondents cater solely to the local market. These industries may not face the same level of pressure to adopt sustainable practices, but they represent an important segment of the industry that may benefit from improved energy management and green energy solutions. In Pakistan, the regulatory framework concerning greenhouse gas (GHG) emissions is relatively weak, with few binding standards or compulsion for industries to reduce their carbon footprints. While the government has initiated various programs aimed at promoting sustainability, there are still significant gaps in enforcement and compliance mechanisms. As a result, many local textile manufacturers operate without stringent oversight regarding their environmental impact. As global trends shift toward greater environmental accountability, even local industries may find it advantageous to pre-emptively adopt sustainable practices to remain competitive in a rapidly evolving market landscape.

c) Both Local and Export

Nearly half of the respondents (38%) produce goods for both local consumption and export. This dual-market focus highlights the need for these firms to balance international standards with local market dynamics. These firms are more likely to be exposed to both local and international market pressures, potentially making them more inclined to improve energy efficiency, adopt renewable energy sources, and reduce their environmental footprint.

2.6. Data Processing and Analysis

After the data collection phase was completed, the responses from both the online survey and in-person interviews were compiled into a single dataset. The quantitative data from multiple-choice questions was analysed to identify patterns in energy consumption, the adoption of energy-efficient technologies, and the common challenges faced by industries. Descriptive statistics, including means and percentages, were used to summarize this data.

The qualitative responses from open-ended questions and interviews were analysed using thematic analysis. Key themes related to decarbonization challenges, such as high energy costs, the lack of available technology, and policy-related issues, were identified and grouped together. The insights gathered from qualitative responses provided a deeper understanding of the barriers and opportunities for decarbonization within the textile sector.

2.7. Challenges Faced During Data Collection

While the survey was generally well-received by participants, a few challenges were encountered during the data collection phase.

2.7.1. Limited availability of respondents

In some cases, key decision-makers were unavailable to participate due to their busy schedules. This issue was mitigated by scheduling follow-up interviews and extending the survey response period.

2.7.2. Data Privacy Issues and Concerns in the Survey

Some industries were hesitant to share detailed information about their energy use and decarbonization efforts, citing concerns about data privacy, primarily due to fears of compromising relationships with international clients and the desire to maintain a competitive edge. To address this concern, participants were reassured that the survey results would be anonymized, and individual industrial data would not be disclosed. The following points summarize the key concerns identified during the survey.

a) Reluctance to Share Information

The survey revealed that a substantial portion of the respondents, especially those from export-oriented units, were hesitant to disclose sensitive data. Many feared that sharing information about their energy consumption, sustainability practices, or decarbonization efforts could lead to their international customers being compromised. This concern was particularly strong in units that rely heavily on maintaining exclusive relationships with foreign buyers.

b) Data Privacy Concerns Across All Industries

Figure 6 highlights the overall data privacy concerns across the surveyed industries that 59% of the respondents expressed significant concerns about data privacy, while the remaining 41% were willing to share details. These industries were especially concerned about protecting their client relationships and to stay ahead of their competitors.

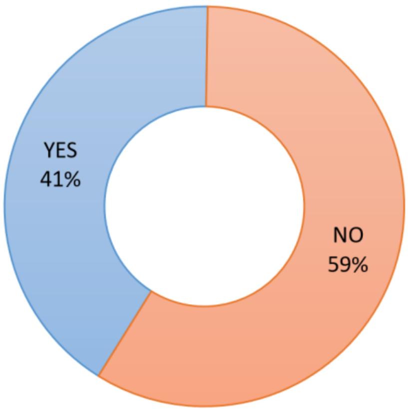

Figure 6: Data privacy concerns of participating industries

c) Concerns about Competitive Advantage

A third major concern related to data privacy was the potential for competitors to claim pioneering status in areas like green energy, decarbonization, and waste management. Industries were cautious about sharing details regarding their sustainability initiatives, as these developments could be leveraged to gain a competitive advantage in the global market. Many respondents indicated that they preferred to protect their position by keeping such information private until the initiatives were fully realized.

Chapter 3: Results and Discussions

3.1. Energy Demand of Surveyed Textile Industries

Energy demand varies significantly across different types of industries. Composite units have notably higher energy consumption, whereas garment and stitching units typically consume much less energy in comparison. Energy consumption of the surveyed industries is categorized as shown in Figure 7. Among the surveyed industries, 3 reported energy demand of up to 1 MW, 11 reported energy demand between 1–5 MW, 5 reported energy demand between 5–10 MW, and 7 reported the energy demand between 10–15 MW. Additionally, 3 participants indicated energy consumption exceeding 15 MW. The adoption of renewable energy within each textile sector will largely depend on these energy demand patterns.

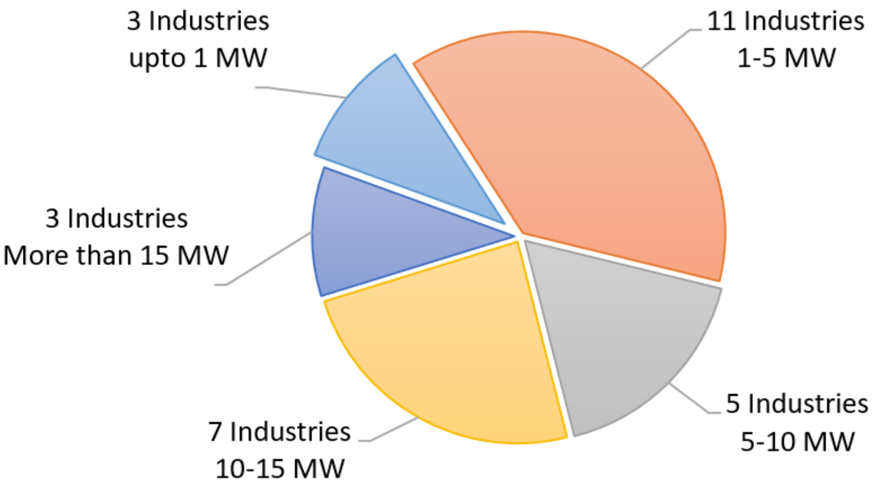

Figure 7: Energy demands of industries participated in the survey

3.2. Type of Energy Sources being Used

The survey revealed the various types of energy sources being used across different textile industries in Pakistan. The Figure 8 shows the distribution of respondents using each type of energy source, with grid electricity, natural gas, and solar energy being the most commonly used. Here is a breakdown of the energy usage, as reflected in the graph. It should be noted that multiple sources were selected by industries if they were using more than one source of energy.

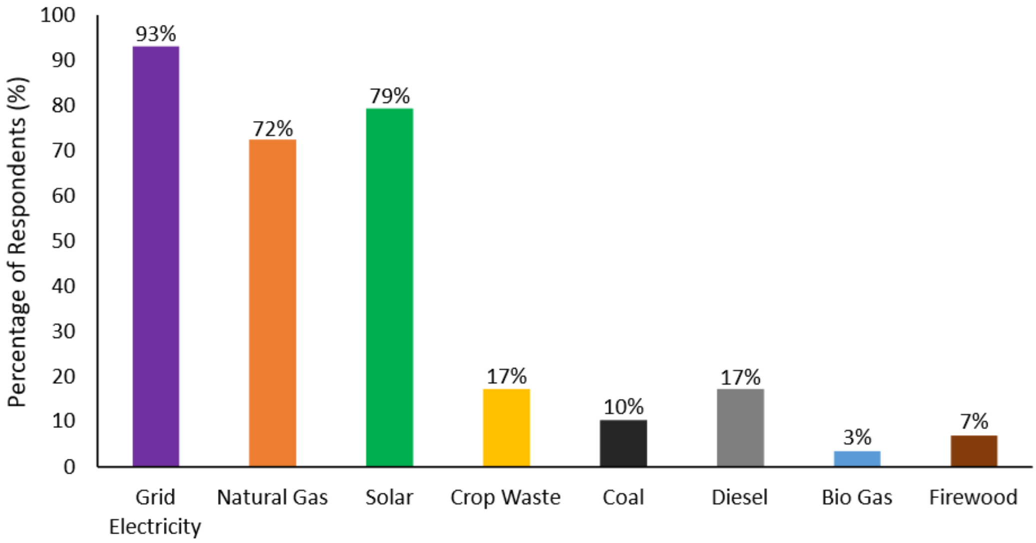

Figure 8: Type of energy sources being used in textile industry

a) Grid Electricity

Grid electricity was the most common energy source, with 93% of the respondents reporting its use. This is not surprising, as grid electricity is the primary energy source for running machines, lighting, and other electrical equipment in textile factories. However, the reliance on grid electricity can pose challenges, given Pakistan's energy shortages and frequent power outages.

b) Natural Gas

A close second, natural gas is used by 72% of the respondents. Natural gas is typically used for electricity generation, heating, steam generation, and other energy-intensive processes like dyeing and finishing. The widespread use of natural gas reflects its relative affordability and availability in the country, though the sector is increasingly facing supply challenges due to limited reserves and higher demand.

c) Solar Energy

Solar energy adoption appears to be relatively high, with 79% of respondents indicating its use. This suggests that the textile industry is beginning to embrace renewable energy solutions, likely due to rising energy costs and the unreliability of traditional energy sources. Solar energy provides a promising opportunity for reducing the industry's carbon footprint while addressing energy shortages.

Solar energy can be effectively harnessed to power machinery, lighting systems, and other equipment that previously relied on grid electricity or fossil fuels. One of the key areas where solar and other renewable energy sources can be transformative is in thermal processes, such as heating water or producing steam for boilers. Advanced technologies like solar thermal systems or biomass-based boilers can be integrated into the production line, significantly reducing the industry's dependence on natural gas and other non-renewable fuels. Transitioning these energy-intensive operations to renewables not only reduces greenhouse gas emissions but also helps industries cut down on fuel costs and enhance energy security.

d) Crop Waste

The use of crop waste as an energy source, indicated by 17% of respondents, is an interesting development. Crop waste can be a sustainable alternative to fossil fuels, especially in regions with abundant agricultural resources. Its use in textile production highlights the potential for integrating biomass energy into the industry's energy mix. One of the primary advantages of using crop waste as an energy source is its ability to utilize agricultural by-products that would otherwise be discarded, reducing waste and contributing to a circular economy. Biomass energy from crop waste typically emits lower levels of sulphur dioxide and other harmful pollutants compared to fossil fuels, making it a cleaner energy option. However, there are also some drawbacks to consider. While crop waste energy produces fewer emissions than traditional fossil fuels, it can still release significant amounts of particulate matter and nitrogen oxides, which can contribute to air pollution if not properly managed.

e) Coal

Coal, despite its environmental impacts, is used by 10% of respondents. Coal is generally employed for heating or steam generation in industries where natural gas or other energy sources are insufficient or too costly. However, the global push toward decarbonization will likely see coal use decline in favour of cleaner alternatives. As countries around the world commit to reducing their carbon emissions and transitioning to renewable energy sources, the demand for coal is projected to decrease significantly. Initiatives such as the Paris Agreement emphasize the need for nations to limit global warming by reducing reliance on fossil fuels, including coal, which is one of the most carbon-intensive energy sources.

f) Diesel

Diesel is used by 17% of respondents, likely as a backup energy source for power generation during grid outages. Although diesel is reliable, it is expensive and contributes significantly to greenhouse gas emissions. Its use is expected to decrease over time as more sustainable energy options become available.

g) Biogas

Only a small portion (3%) of respondents reported utilizing biogas, which is a renewable energy source derived from organic waste. Biogas represents a sustainable option for energy production and could play a larger role in the future if more textile units invest in biogas generation systems. While biogas is considered a cleaner alternative to fossil fuels, it is essential to recognize that its combustion does produce emissions, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). However, the overall carbon footprint of biogas is significantly lower than that of traditional fossil fuels due to the renewable nature of its source material and its potential for carbon neutrality. Properly managed biogas systems can minimize methane emissions, making them a more sustainable option.

h) Firewood

Firewood, used by 7% of respondents, is one of the more traditional energy sources. Its use is more common in rural areas or small production units where modern energy sources may be less accessible. However, it poses sustainability concerns due to deforestation and its carbon emissions. When firewood is burned, it releases several gases, including carbon dioxide (CO_2), carbon monoxide (CO), particulate matter, and volatile organic compounds (VOCs). While CO_2 is a greenhouse gas that contributes to climate change, the burning of firewood also emits CO, which is harmful to human health, leading to respiratory issues and other health problems. Moreover, the combustion of firewood can release significant amounts of particulate matter, which contributes to air pollution and poses health risks to communities that rely on it as a primary energy source.

3.3. Energy Mix of Industries

Figure 9 provides a stacked breakdown of energy sources used by the industries. Each column represents a participant, and the total energy usage is broken down into various energy sources, including grid electricity, natural gas, solar energy, and others.

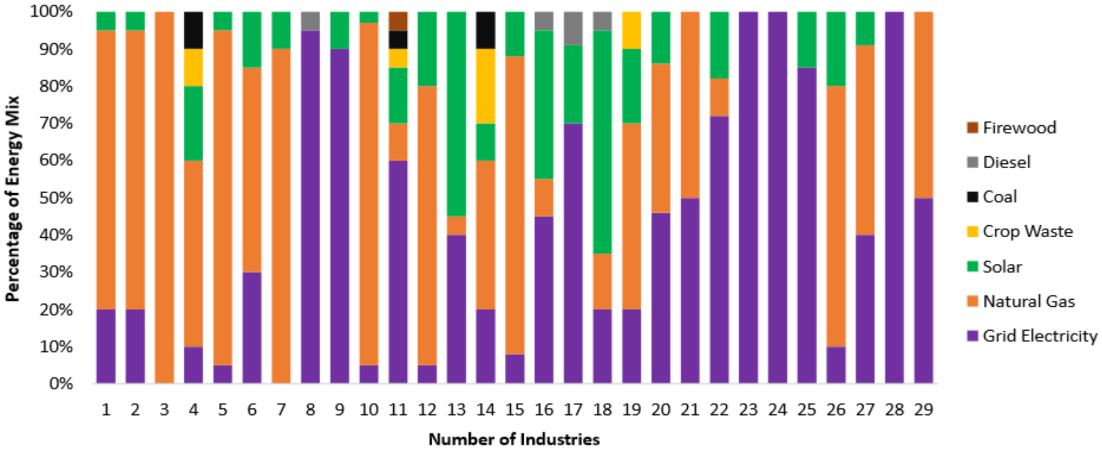

Figure 9: Energy source breakdown of participated industries

Participant 1 and Participant 2 relies on grid electricity (20%), natural gas (75%), and solar energy (05%). Non-renewable sources dominate their energy mix, with renewables accounting for only a small portion. Participant 4, Participant 11 and Participant 14 shows a more diversified energy mix, with solar energy, grid electricity, natural gas, coal and crop waste being utilized to meet their energy demand. Participants 13, Participant 16 and Participant 18 incorporate a higher proportion of renewable sources (55%, 40% and 60% respectively), showing a commitment to sustainable energy practices. In contrast, Participants 3, Participant 5, Participant 7 and Participant 10 depend heavily on non-renewables like natural gas. Among these, Participant 8 relies 95%, Participant 9 relies 90% while Participant 23, Participant 24 and Participant 28 relies 100% on grid energy that is situation to note due to current Grid energy combination of renewable and non-renewable sources. Participants 4, Participant 12, Participant 17, Participant 19 and Participant 26 exhibit moderate usage of solar energy (around 20% each), highlighting a growing but still limited adoption of renewables.

3.3.1. Dominance of Non-Renewable Energy

Across all participants, grid electricity and non-renewable energy sources dominate the energy mix, as shown by the significant presence of blue and red bars in Figure 10. For instance, Participant 3 has 100% of energy coming from non-renewable sources.

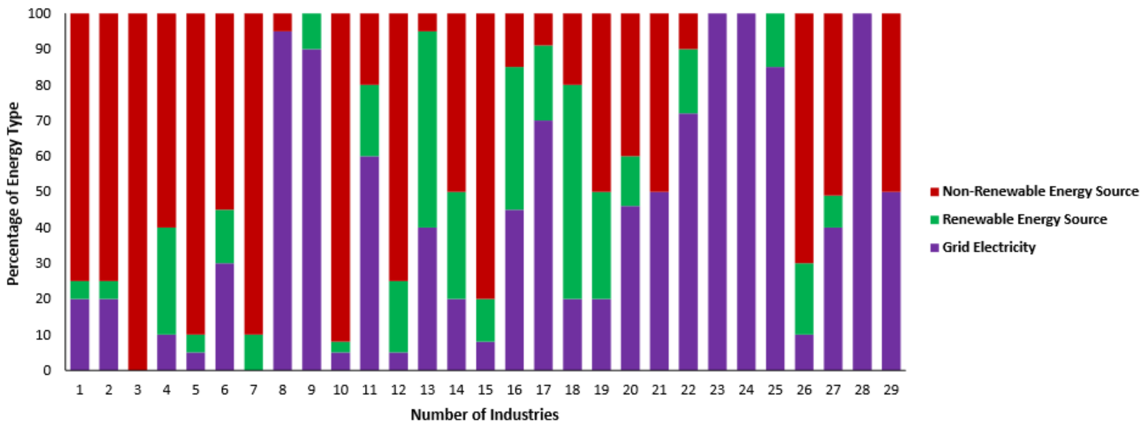

Figure 10: Energy source breakdown (renewable vs nonrenewable energy sources)

Some participants showed mixed diversion by utilizing grid energy, renewable and non-renewable energy sources. Participant 16, showing better diversification with about 45% reliance on grid electricity, also incorporates a mix of green energy and other energy sources.

3.3.2. Grid Electricity's Role

Grid electricity plays a dominant role in the energy mix for many participants. For instance, Participant 8 and Participant 9 relies on grid electricity for more than 90% of their energy consumption, while Participant 23, Participant 24 and Participant 28 relies 100 % on grid electricity which highlights that despite the adoption of renewables, many industries are still heavily reliant on the national grid.

3.3.3. Adoption of Renewable Energy

Solar energy is the most used green energy source across the participants. For example, Participant 14 indicated that 20% of their energy comes from crop waste, complemented by 10% from solar energy. Participant 13, Participant 16, and Participant 18 have a notable mix of renewable and non-renewable energy, with solar energy accounting for 55%, 40%, and 60% respectively. The reliance on renewable energy highlights the participant's commitment to sustainability.

Some Participants have diverse mix of energy source with green energy dominant followed by grid energy that is mixture of renewable and non-renewable energy sources in the country. Participant 16 shows a diverse mix, with 15% from non-renewables, 40% green energy and 45% grid energy, reflecting an industry shift towards renewable sources. Some Participants still rely heavily on grid energy e.g. Participant 8 and Participant 9, using 95% and 90% grid energy respectively. If we consider percentages on hydroelectricity, solar and wind energies in grid electricity, these industries are still consuming handsome amount of renewable energy, but it completely relies on the country level adoption of renewable energy instead of individual efforts.

3.3.4. Impact of Energy Sources

Figure 11 provides an overview of the energy breakdown across three categories: Grid Electricity (42%), Renewable Energy (15%), and Non-Renewable Energy Sources (43%). The data highlights the significant dependence on non-renewable energy sources and grid electricity, with only a small percentage of overall energy usage being supplied by renewable sources.

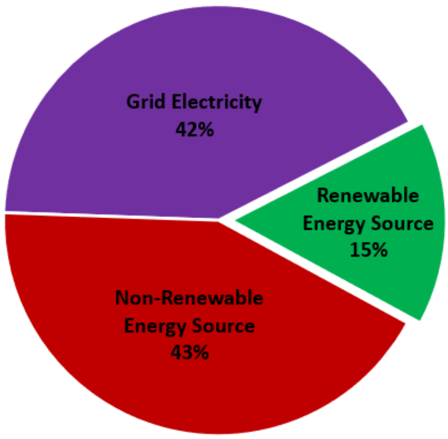

Figure 11: Overview of energy source breakdown

a) Non-Renewable Energy

Non-renewable energy sources such as natural gas, diesel, coal and firewood make up the largest portion of energy consumption in the surveyed industries. The heavy reliance on these energy types contributes significantly to the industry's carbon footprint. The continued use of non-renewables also exposes the industry to energy price fluctuations and supply risks due to the finite nature of these resources. With the upcoming implementation of the Carbon Border Adjustment Mechanism (CBAM) by the European Union, the stakes are even higher for textile exporters. CBAM will impose tariffs on imported goods based on their carbon content, meaning that products from industries with high GHG emissions will face significant cost disadvantages in the EU market.

b) Grid Electricity

Grid electricity is another major energy source, accounting for over 42% of the total energy used. In Pakistan, the electricity grid is largely powered by fossil fuels, particularly natural gas and coal. As a result, the use of grid electricity also contributes indirectly to carbon emissions and environmental degradation. Furthermore, grid electricity is often subject to supply shortages and outages along with price fluctuation, which can disrupt operations in energy-intensive sectors like textiles and its subsectors.

c) Green Energy

Green energy sources, including solar energy and biogas, account for only 15% of the total energy usage, a relatively small share compared to the other energy sources. However, the adoption of green energy is a positive step toward reducing the carbon footprint of the textile industry. Increasing the use of renewable energy can help alleviate reliance on non-renewable sources and reduce the industry's contribution to greenhouse gas emissions.

3.4. Assistance for Green Energy Adoption

The survey results depicted in Figure 12 show the level of technical and financial assistance that participants received during the installation of green energy systems.

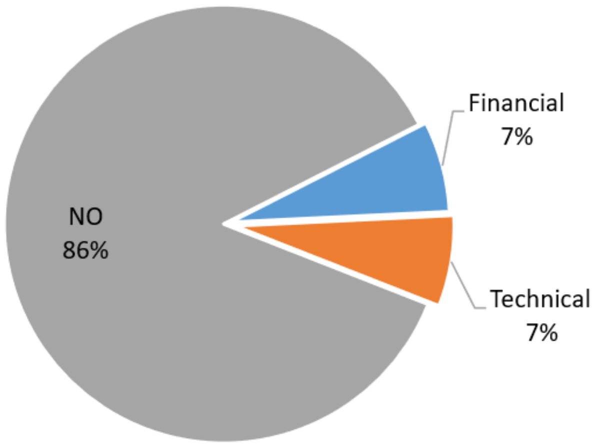

Figure 12: Technical/Financial assistance for green energy adoption

3.4.1. Lack of Support in Green Energy Installation

A vast majority of respondents, 86%, reported that they did not receive any assistance neither technical nor financial, when installing green energy systems. This is a clear indication that many industries are independently investing in renewable energy without external support, which could be a barrier for smaller or less financially stable industries. A small percentage, 7%, of the respondents reported receiving technical assistance. This suggests that there is limited access to expertise or consulting services in the area of renewable energy system installation, which may hinder the adoption of green energy technologies. Only 7% of respondents reported receiving financial assistance for their green energy projects. This low percentage is indicative of the lack of financial incentives, subsidies, or funding support available to businesses looking to invest in green energy solutions. One of the primary obstacles to adopting green energy is the high upfront cost. Without financial support, many industries especially smaller ones struggle to justify the investment in renewable energy infrastructure. Subsidies, grants, and financing options are crucial to making these projects viable.

Implementing green energy systems requires specialized knowledge. Technical assistance programs can provide industries with access to experts who can help them choose the right technology, install systems efficiently, and optimize their energy usage. This support is critical in ensuring that renewable energy projects are both successful and sustainable in the long run.

3.4.2. The Need for Government and Institutional Support

Given that 86% of respondents reported no assistance, there is a clear need for government intervention. Financial incentives, such as low-interest loans, or tax breaks, could help reduce the upfront costs of renewable energy installations. Additionally, providing technical training and support could help industries navigate the complexities of renewable energy projects. Financial institutions can play a key role in supporting the textile industry’s transition to green energy by offering sustainable finance products. Banks and investment funds could offer preferential financing options for industries looking to invest in green technologies, which would encourage wider adoption of renewable energy.

The lack of technical assistance (only 7% received it) highlights the need for establishing consulting networks or partnerships with technical experts. Governments or industry associations could facilitate partnerships between energy experts and industries to provide them with the necessary technical knowledge for the efficient installation and use of renewable energy systems. Public-private partnerships can be a powerful tool in encouraging the installation of renewable energy. Governments could work with private sector players and NGOs to create support programs that offer both financial backing and technical expertise, helping industries reduce their carbon footprint and energy costs.

3.5. Energy Audits

An energy audit is a systematic process to evaluate the energy use of an organization, facility, or process. The goal is to identify areas where energy is being wasted and to recommend improvements that can reduce consumption, lower costs, and increase energy efficiency.

Energy audits typically involve assessing heating, cooling, lighting, equipment, and operational practices to determine where energy-saving measures can be implemented. In addition to pinpointing inefficiencies, energy audits can also play a crucial role in guiding the energy transition of industries.

By identifying areas where energy is being wasted, industries can implement changes that lead to significant cost reductions, especially in energy-intensive industries like textiles. Audits help optimize energy usage, making the production process more efficient. Reducing energy consumption helps lower the carbon footprint, contributing to sustainability efforts. Many international buyers and standards require textile industries to meet certain sustainability goals, which include energy efficiency. Conducting regular energy audits ensures that the industry remains compliant with these global requirements.

Figure 13 indicates that 52% of the respondents do not perform energy audits, while 48% do conduct them.

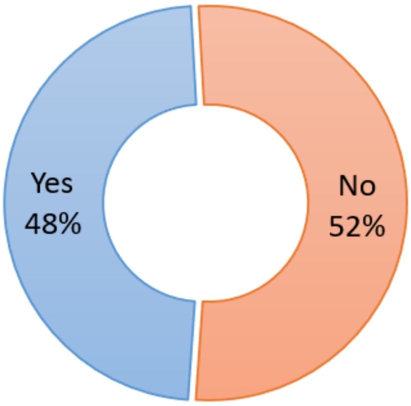

Figure 13: Energy Audit for production process

A significant portion of the participants, 52%, indicated that they do not perform energy audits in their production processes. This suggests that many industries may be missing opportunities to improve efficiency, reduce costs, and enhance sustainability. These industries are likely operating without a clear understanding of their energy consumption patterns, leading to higher operational costs and a larger environmental footprint. On the positive side, 48% of respondents reported conducting energy audits. These industries are taking proactive steps to improve their energy management and operational efficiency. Conducting energy audits positions these industries to reduce costs, enhance productivity, and meet sustainability targets, which are increasingly demanded by international markets.

Given that more than half of the respondents do not perform energy audits, there is a need for increased awareness about the benefits of energy audits and assessments of energy usages in textile industry. Governments, industry associations, and environmental bodies should offer incentives and support programs that encourage energy audits. Offering tax breaks, grants, or financial support to industries that conduct energy audits could motivate more industries to participate. This would ultimately result in better energy efficiency across the entire sector. Implementing an Energy Management System (EMS) can help organizations monitor energy use in real-time and identify areas where energy savings can be made without needing frequent audits. EMSs provide continuous insights that allow industries to adjust their energy consumption strategies regularly.

3.6. Future Plans to Adopt Renewable Energy Sources and Potential of GHG Emissions Reduction

During the survey, several industries expressed their commitment to installing renewable energy sources in the future, while a smaller subset also provided specific details about the capacities of the renewable energy systems they plan to deploy as shown in Figure 14.

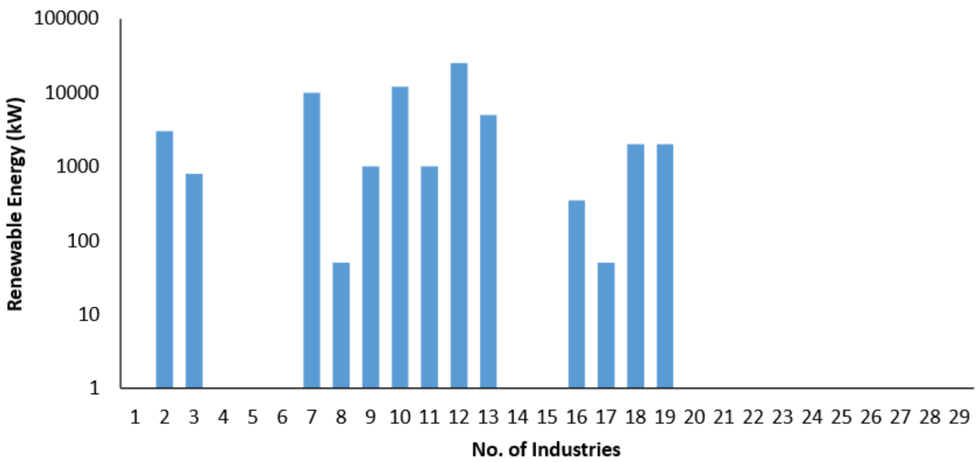

Figure 14: Planned capacities of renewable energy installations of surveyed industries

Using the available data, an analysis was conducted to estimate the potential reduction in GHG emissions if these planned renewable energy installations are implemented. Figure 15 represents the current emissions under existing energy practices to provide a baseline view without these planned renewable sources installations.

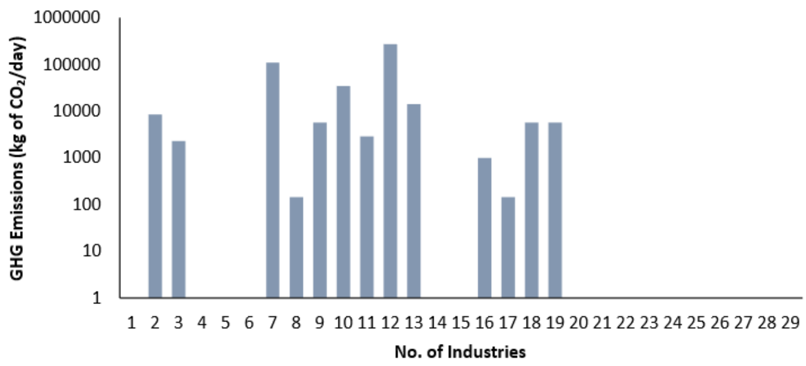

Figure 15: Current GHG emissions under existing energy practices (Baseline view)

The results of this analysis are presented in Figure 16**,** which illustrates the projected GHG emissions reduction across surveyed industries for assessing the future impact of adopting cleaner energy sources. It is estimated that projected GHG emissions will be significantly reduced by approximately 450 tCO2/day, showcasing the significant impact that renewable energy adoption can have on decarbonizing Pakistan's textile sector.

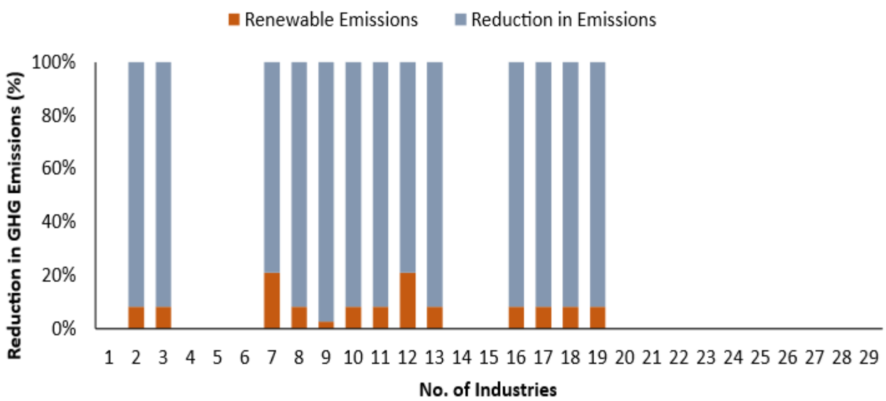

Figure 16: Projected emissions reduction after planned renewable energy sources are operational

The graph highlights the comparative emissions levels before and after the adoption of renewable energy systems, showcasing the significant environmental impact of transitioning from fossil fuels to cleaner energy sources. Figure 17 illustrates the aggregated projection of overall responses of participants regarding their future plans to adopt renewable energy sources to their production processes.

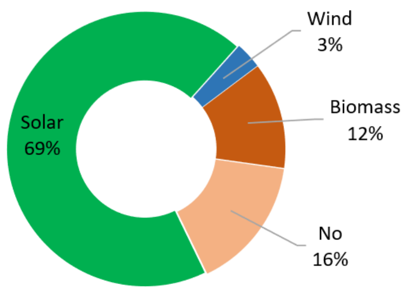

Figure 17: Plan to adopt renewable energy

a) Solar Energy

The vast majority of participants, 69%, indicated that they plan to adopt solar energy as part of their future green energy initiatives. This reflects the growing recognition of solar power as a reliable, cost-effective, and scalable renewable energy source for the textile industry. Solar energy is one of the most accessible and scalable renewable energy sources. It offers numerous benefits, including reduced energy costs, minimal maintenance, and the ability to generate electricity in both small and large-scale applications. With solar technology becoming more affordable, it is a practical choice for industries looking to reduce their carbon footprint and energy costs.

b) Biomass

About 12% of respondents plan to incorporate biomass energy. Biomass can be a sustainable energy source derived from organic materials like agricultural waste, making it an environmentally friendly option for industries with access to such resources. Biomass energy is derived from organic materials such as agricultural residues or wood waste. For industries that have access to these resources, biomass can be a sustainable and low-carbon alternative to fossil fuels. Biomass can also help reduce waste by repurposing organic materials that would otherwise be discarded.

c) Wind Energy

Another 3% of respondents indicated their intent to invest in wind energy. Wind power is a highly sustainable energy source, although its adoption might be limited by geographic conditions and the availability of sufficient wind resources. Wind energy is a clean, renewable resource that generates electricity without emitting greenhouse gases. It is highly sustainable and has low operating costs once the initial investment is made. However, the feasibility of wind energy is largely dependent on geographic location and consistent wind speeds.

d) No Plans

16% of the respondents reported no plans to adopt green energy, which suggests that there may still be challenges such as financial constraints, lack of expertise, or other barriers preventing some industries from pursuing renewable energy.

3.7. Challenges Faced in Implementing Renewable Energy Practices

Figure 18 illustrates the various challenges that participants face when trying to implement renewable energy practices in their industries.

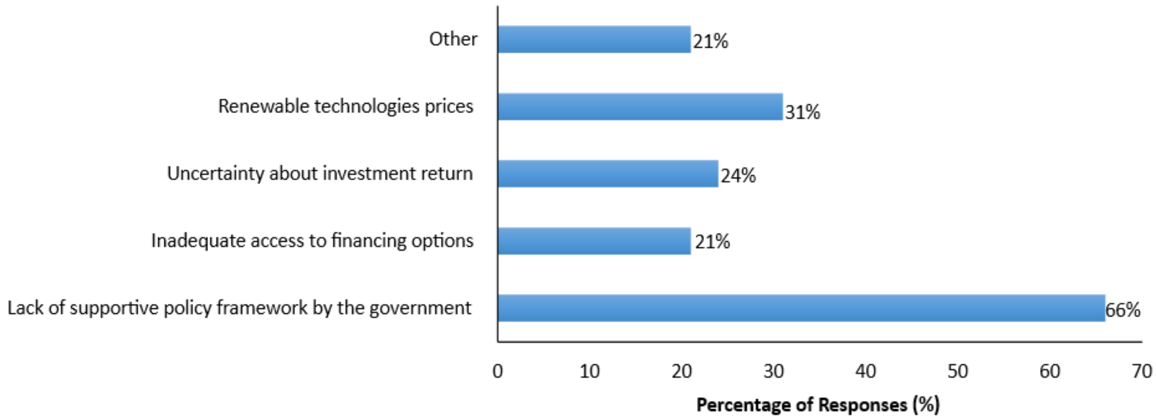

Figure 18: Challenges faced in implementing green energy

a) Lack of Supportive Policy Framework

The majority of respondents (66%) cited the absence of a supportive government policy framework as the most significant challenge. This indicates that businesses require strong governmental backing in the form of policies, incentives, and regulatory frameworks to promote renewable energy investments. The Pakistani government needs to establish clear, supportive policies that encourage businesses to invest in renewable energy. This could involve offering tax incentives, subsidies, or streamlined regulations to facilitate easier adoption.

b) Inadequate Access to Financing

Financing is a critical barrier for 21% of respondents aiming to adopt renewable energy. Without access to affordable financing options, businesses find it difficult to make the significant initial investments required for renewable energy projects. Financial institutions can play a vital role by offering green financing options, such as low-interest loans, grants, or other incentives, making it easier for businesses to fund their renewable energy projects. In Pakistan, many companies, particularly small and medium-sized enterprises (SMEs), may find it challenging to secure the necessary financing, leading to slower adoption of green energy practices. Introducing green financing options, such as low-interest loans or grants for renewable energy projects, could significantly reduce the financial burden on industries and encourage more companies to transition.

c) Uncertainty about Investment Return

Uncertainty surrounding the return on investment (ROI) for renewable energy projects deters 24% of respondents from adopting these technologies. Businesses need more information about the long-term cost savings and benefits of renewable energy to make informed decisions. Providing industries with success stories, case studies, and government-backed guarantees could help reduce concerns about the ROI for renewable energy projects, encouraging wider adoption. In an unstable economic environment like Pakistan's, industries may be concerned about the financial risks of investing in renewable energy, especially if there is a lack of government guarantees or incentives. To alleviate these concerns, the government could consider offering more robust financial guarantees, such as risk insurance for renewable energy investments or guaranteed buy-back rates for excess energy produced by industrial units. The establishment of public-private partnerships where the government shares some portion of the investment risks might also encourage industries to adopt cleaner technologies.

d) Renewable Technology Prices

The high cost of renewable technologies is another obstacle, with 31% of respondents citing it. Solar panels, wind turbines, and biomass systems still represent a considerable investment, especially for small and medium-sized enterprises (SMEs). While prices for renewable energy technologies have fallen globally, the costs in Pakistan may still be prohibitive due to import tariffs, lack of local manufacturing, or limited availability of technology. Promoting local production of renewable energy technologies or offering subsidies for importing these technologies could help reduce their costs and make them more accessible to industries in Pakistan.

e) Other Challenges

A range of additional challenges, cited by 21% of respondents, include technical expertise, lack of infrastructure, geographic constraints, or logistical barriers, further complicates the adoption of renewable energy systems. For example, not all regions in Pakistan are suitable for solar or wind energy production due to climate and environmental factors.

3.8. Greenhouse Gas (GHG) Emissions and their Importance in Pakistan's Textile Industry

Greenhouse gas (GHG) emissions are a critical environmental concern, particularly for industries like textiles that consume large amounts of energy in their production processes.

GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), contribute to global warming and climate change. In the textile industry, energy use for activities like spinning, weaving, dyeing, finishing, and logistics are primary sources of GHG emissions. The growing global focus on reducing carbon footprints has made it essential for industries to assess their emissions and implement sustainability measures.

In Pakistan, the textile sector is the backbone of the economy, contributing significantly to exports and employment. However, the industry's environmental impact, particularly GHG emissions, is coming under increasing scrutiny from both local regulators and international buyers. Many international markets require suppliers to meet sustainability standards, including reducing carbon emissions, making GHG reduction critical for the competitiveness of Pakistan's textile industry.

3.8.1. Carbon Footprint Assessment Practices in Pakistan's Textile Industry

When asked whether they had conducted any carbon footprint assessment in their production facility, 72% of respondents said they had not conducted such an assessment, while only 28% confirmed that they had, as shown in Figure 19.

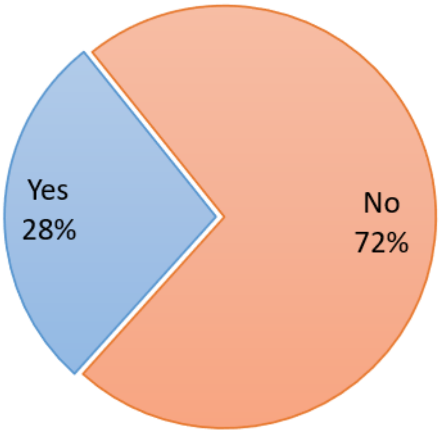

Figure 19: Carbon footprint assessment in production facility

This large percentage (72%) highlights a significant gap in awareness or implementation of carbon management practices. It suggests that many textile industries in Pakistan are not yet monitoring their GHG emissions, which could hinder their ability to meet international sustainability standards and remain competitive in global markets. A smaller portion of respondents, 28%, reported conducting carbon footprint assessments. These industries are taking steps towards understanding and managing their GHG emissions, which can help them improve their sustainability practices and meet the expectations of international buyers.

3.8.2. GHG Reduction Efforts and Plans in Textile Production

In continuation of the previous question regarding carbon footprint assessments, participants were asked if they had a plan to reduce GHG emissions in their production processes. If they had plans, they were further queried about the specific targets or frameworks they were following, such as compliance with the Carbon Border Adjustment Mechanism (CBAM), Net-zero by 2050, or whether they were still in the planning stage. The responses are presented in the Figure 20.

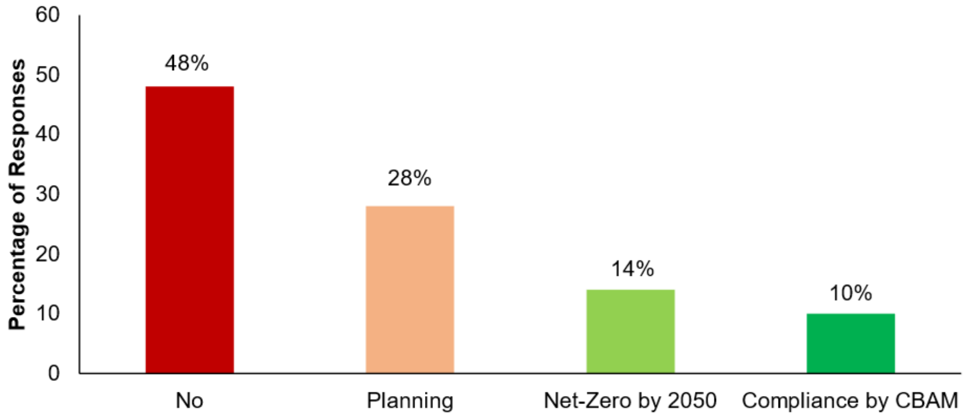

Figure 20: Plans to reduce carbon emissions

The largest portion of respondents (48%) reported that they do not have a plan to reduce GHG emissions. This suggests that more than one-third of the participants are not yet addressing the environmental impact of their production processes, which could pose challenges in future sustainability efforts. About 28% of respondents are in the planning stage of developing a strategy to reduce their GHG emissions. These industries have recognized the importance of GHG reduction but are still formulating concrete steps and objectives to implement these practices. A smaller group, 14%, indicated that they are working towards achieving Net-zero emissions by 2050. This target aligns with global climate goals set by the Paris Agreement, and these industries are likely committed to long-term sustainability, striving to reduce emissions to near zero and offset the remaining emissions through carbon capture or other mitigation methods. 10% of respondents indicated that they are planning to comply with the Carbon Border Adjustment Mechanism (CBAM). CBAM is a regulatory mechanism proposed by the European Union to tax carbon emissions embedded in imported goods. Compliance with CBAM will likely be a key requirement for industries exporting to the EU, making this target important for industries looking to maintain access to global markets. Starting in 2026, CBAM will also include indirect emissions, such as those from electricity and other forms of energy used in manufacturing processes. This means that textile manufacturers exporting to the EU will need to carefully monitor and report their energy consumption and the associated emissions. Accurate carbon accounting will be crucial, as they will be required to provide detailed data on the energy sources used and the carbon emissions generated throughout their production cycles. Failing to comply with these reporting standards could lead to significant financial penalties, making it essential for the industry to adopt cleaner energy solutions and enhance transparency in their carbon footprint calculations to maintain their competitive edge in the EU market

3.8.3. Challenges and Gaps in GHG Reduction Planning in Pakistan's Textile Industry

It is concerning that 48% of the participants do not have any plan to reduce their GHG emissions. As global markets and regulations increasingly prioritize sustainability, industries without a clear GHG reduction strategy may face challenges related to market access, regulatory compliance, and competitive positioning. The fact that 28% of industries are in the planning stage indicates growing awareness but also highlights the need for more concrete action. These industries are aware of the importance of GHG emission reduction but require more time, resources, or technical expertise to implement meaningful strategies.

Achieving Net-zero by 2050 is a significant commitment, aligning with global climate objectives. Industries pursuing this goal are likely to be seen as industry leaders in sustainability, improving their brand reputation and competitiveness in markets that value environmentally responsible practices. With 10% of industries aiming for compliance with the CBAM, it is clear that international regulatory pressures, particularly from the European Union, are already influencing GHG reduction strategies in Pakistan's textile industry. As this mechanism becomes a reality, more industries need to adopt similar targets to ensure their products remain viable in export markets.

These details indicate the significant gap in carbon management practices within the surveyed industries. As global attention shifts toward sustainability and reducing carbon emissions, it is vital that more industries in Pakistan's textile industry begin conducting carbon footprint assessments. These assessments are the first step toward identifying and mitigating greenhouse gas emissions, which can improve the industry's environmental impact, efficiency, and competitiveness in international markets. To remain competitive and align with global sustainability goals, the textile industry in Pakistan must prioritize GHG management by conducting regular carbon footprint assessments. This will allow industries to identify sources of emissions, reduce their carbon footprint, and improve energy efficiency. Moreover, international buyers increasingly prefer or mandate that suppliers demonstrate sustainable practices, including GHG emission control.

Government policies and industry bodies should encourage early adoption of GHG reduction practices by offering financial incentives, technical support, and recognition for industries leading the transition towards sustainability. For industries in the planning stage, more assistance is needed in terms of access to financing, expertise, and guidance on how to transition to low-carbon operations efficiently. As global markets introduce stricter environmental regulations, like the CBAM, industries need to be made aware of the potential consequences of not complying with such frameworks. Export-dependent industries must adopt GHG reduction strategies to maintain competitiveness.

3.8.4. The Way Forward: Improving GHG Management and Sustainability Practices

To effectively reduce GHG emissions in Pakistan's textile sector, the government must take proactive steps to address the needs of industrialists and provide them with the necessary tools, incentives, and support. Key areas of focus should include:

- Creating long-term policies that offer certainty and guide sustainable investments.
- Reducing the cost of green energy through subsidies, incentives, and support for local manufacturing.
- Facilitating access to innovative technologies and R&D investments that can help overcome technical barriers.
- Rebuilding trust with stakeholders who feel that there is no hope for government support by actively engaging them in policy formulation and offering tangible, actionable assistance.

3.9. Importance of Waste Management in the Textile Industry

Waste management plays a critical role in reducing the environmental impact of the textile industry. The textile sector produces significant amounts of waste, from raw material scraps to chemical waste used in dyeing and finishing processes. Efficient waste management practices, including reduce, reuse, and recycle (3Rs), can help industries minimize their overall waste output and reduce their carbon footprint. Waste management is also linked directly to GHG emissions because improper disposal of waste, particularly organic and chemical waste, can result in methane emissions (a potent greenhouse gas) and other harmful environmental pollutants. By reducing waste, industries can not only lower their environmental impact but also improve energy efficiency and resource management.

3.9.1. Relationship between Waste Management and GHG Emissions

Efficient waste management helps reduce GHG emissions in several ways:

- By preventing organic waste from ending up in landfills, industries can reduce methane emissions, a highly potent greenhouse gas.
- Recycling materials and reducing waste helps industries conserve energy. The production of new materials often requires more energy compared to recycling, thus lowering the overall energy consumption and related emissions.
- When waste is incinerated, it releases CO_2 and other harmful pollutants. Reducing the amount of waste that needs to be disposed of reduces the emissions from such processes.

3.9.2. Purpose of Waste Management

When participants were asked about their waste management practices, the responses highlighted a mix of proactive and passive attitudes towards waste management in the textile industry, as shown in Figure 21.

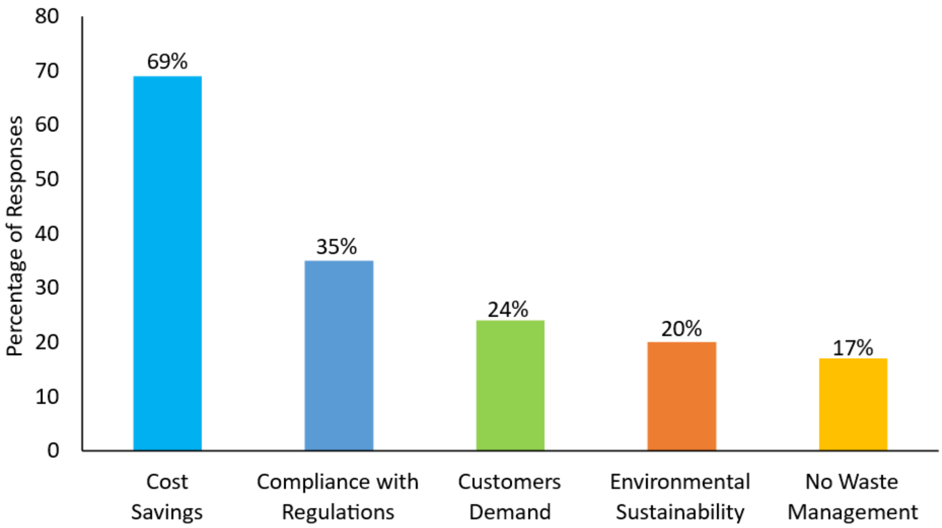

Figure 21: Purpose of waste management in textile industry

The primary driver for waste management is cost savings (69%), showing that industries recognize the financial benefits of reducing, reusing, and recycling waste materials. A significant portion of participants (35%) implement waste management practices to comply with local and international regulations. The rise in customers demand for sustainable products is also pushing industries (24%) to implement waste management. Some industries (20%) are motivated by a commitment to sustainability, aiming to reduce their environmental impact through waste management while 17% of industries still do not have any waste management systems in place, indicating a gap in adoption of these practices.

Among the industries that practice waste management, the reduction in waste varied between 10% and 40%. This demonstrates the tangible benefits of implementing waste management strategies. Industries that successfully reduce waste are likely to see improvements in operational efficiency, cost savings on raw materials, and reductions in their GHG emissions.

a) Cost Savings

One of the primary reasons cited for implementing waste management is cost savings (69%). Recycling waste materials reduces the need for purchasing new raw materials, which can significantly lower production costs. For example, reusing fabric scraps or recycling water in the dyeing process can help reduce both the cost of materials and the resources required, making waste management a financially sound decision.

b) Compliance with Regulations

Many industries (35%) also cited regulatory compliance as a motivation for waste management. Local and international regulations increasingly require industries to manage their waste and reduce their environmental footprint. Compliance with these regulations is essential not only for avoiding fines but also for maintaining access to international markets that demand sustainability.

c) Customer Demand

Customer demand for eco-friendly products is rising globally, particularly in markets like Europe and North America. Textile industries that can demonstrate sustainable practices, including effective waste management, are better positioned to meet the expectations of environmentally conscious consumers. Implementing waste management is therefore not only an operational necessity but also a competitive advantage in global markets.

d) Environmental Sustainability

The drive for environmental sustainability was another key factor in adopting waste management practices (20%). Industries recognize the importance of reducing their environmental impact, both for corporate social responsibility and for long-term sustainability. Efficient waste management can help reduce GHG emissions, conserve natural resources, and promote a circular economy within the textile industry.

e) No Waste Management

The 17% of Participants with no waste management represent a missed opportunity. These industries are not only increasing their environmental footprint but also missing out on cost-saving measures and the chance to align with global sustainability standards. For these industries, the lack of waste management could become a significant barrier to future growth and market access as sustainability becomes a key driver in international trade.

3.9.3. How Waste Management is Adopted

In the next step, Participants were asked how they were managing their waste management practices. As the waste management approach is directly related to the benefits and targets to be achieved by these practices. Various industries have different targets and hence waste management policies are varied from industry to industry. Findings of this are presented in the Figure 22.

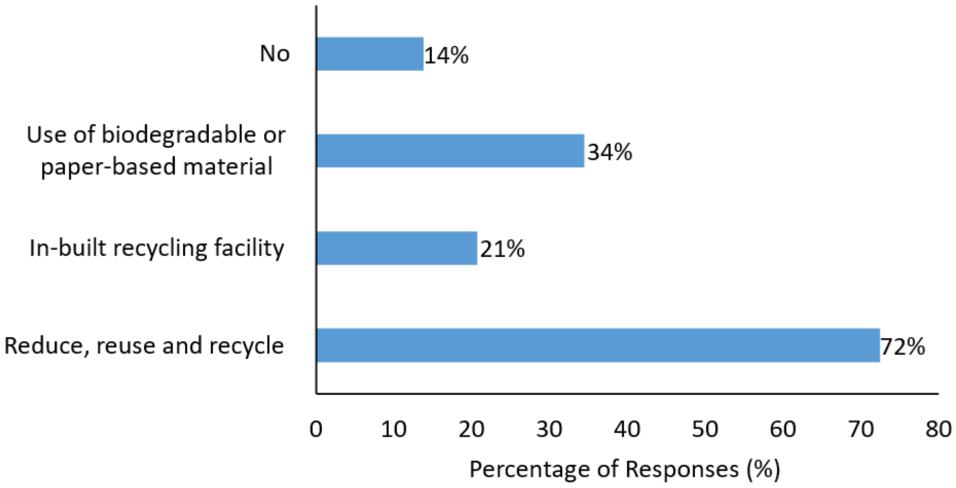

Figure 22: How Waste Management is Adopted

a) Reduce, Reuse, Recycle (3R)

72% of participants attested to their industry's adherence to the 3R policy. The industry's transition to a circular model is an intriguing and constructive development. The initial phase is to encourage resource reduction, which is followed by industry-wide reuse policies where feasible. Lastly, discarded and used materials are recycled so they can be used again for the same purpose or for different purposes.

b) In-built Recycling Facility

The majority of participants indicated that they have adopted waste management practices, such as in-house recycling facilities (21%) and the implementation of Reduce, Reuse, and

Recycle (3Rs) techniques. This approach is encouraging, as it helps divert waste from landfills and promotes resource efficiency by reusing materials within the production cycle. By reducing the amount of waste generated, these industries are also reducing their overall GHG emissions, contributing to sustainability goals.

c) Use of Biodegradable Materials

The majority of biodegradable materials are used in finished goods packaging. It might be ready-to-wear clothing that has been packaged before being shipped to its destination, or it could be yarn or fabric. Approximately 34% of participants reported using paper-based packaging materials to control waste and lower greenhouse gas emissions, which is advocated in order to save the environment and promote environmentally friendly production.

Chapter 4: Conclusion, Findings and Policy Recommendations

This survey sheds light on the sustainability practices and challenges within Pakistan's textile industry, a sector crucial to the country's economy. While the survey sample was relatively small, the findings offer a valuable inside look into how the textile industry approaches carbon footprint reduction and green energy adoption. The results underscore the urgent need for industry to pivot towards more sustainable practices, not only to meet global standards but also to secure its competitive position in international markets. As the global marketplace increases emphasis on environmentally sustainable practices, the survey provides important insights that can guide future policymaking, industry practices, and government interventions. The highlighted gaps in knowledge and resource accessibility call for strategic collaborations between stakeholders, including industry leaders, policymakers, and research institutions, to drive innovation and adopt best practices for a greener future.

4.1. Key Findings of the Survey

The key finding of this survey are listed below:

Lack of Carbon Footprint Assessment: A significant proportion of participants (72%) haven't conducted a carbon footprint assessment, indicating a lack of awareness or capability to monitor GHG emissions. This suggests that a large part of the industry is unprepared for international sustainability requirements, which could affect its long-term competitiveness in export markets.

GHG Reduction Plans: Encouragingly, 14% of the respondents are working towards achieving Net-zero emissions by 2050, aligning their goals with international climate targets and another 10% are targeting compliance with the Carbon Border Adjustment Mechanism (CBAM), signaling awareness of the EU's upcoming regulations while 28% are in the planning stage but 48% of respondents have no plan to reduce their GHG emissions.

Waste Management Practices: A majority of participants are implementing Reduce, Reuse, and Recycle (3Rs) techniques, with waste reduction reported between 10-40%. However, 17% of respondents have no formal waste management system, which suggests that a significant portion of the industry still lacks the infrastructure and know-how for effective waste management.

Green Energy Adoption: One of the key insights from the survey is the growing recognition of the importance of green energy for reducing GHG emissions. Many respondents identified renewable energy sources, such as solar, wind, and biomass, as crucial for achieving long-term sustainability. However, barriers such as the high cost of green energy technologies and the lack of supportive government policies were cited as obstacles to broader adoption.

The survey also revealed that the textile industry recognizes that green energy is an effective way to reduce both emissions and energy costs in the long run. Despite these benefits, many industries lack financial resources or government incentives to make significant investments in renewable energy infrastructure.

4.2. Policy Recommendations

Awareness and Capacity Building: The survey highlights the need for awareness programs that educate industries about the benefits of green energy, carbon footprint assessments, and waste management. Training programs targeting both management and employees should be introduced to foster a culture of sustainability within the textile industry.

Policy Making and Implementation: The government must establish a long-term policy framework that provides incentives for industries to invest in renewable energy and sustainable practices. This could include tax breaks, subsidies for green technologies, and penalties for excessive GHG emissions. A clear regulatory framework will give industries the confidence to make long-term investments in green energy.

Research and Development (R&D): Investment in R&D is critical for discovering and implementing innovative green technologies. Public and private sector partnerships should focus on developing cost-effective, suitable renewable energy solutions, such as solar and biomass energy, to lower adoption costs and improve accessibility for industries. This includes technologies like carbon capture and storage (CCS), advanced energy-efficient machinery, and digital solutions that monitor and optimize energy use.

Government Financial Support: Financial constraints are a major barrier for industries looking to invest in green energy. The government should consider offering subsidized loans, tax incentives, or direct subsidies for businesses that adopt renewable energy sources or implement energy efficiency measures. Green energy must be made more affordable for widespread adoption. Financial support can help bridge the gap between intention and action for many industries. By reducing the financial burden of adopting sustainable technologies, the government can encourage faster transitions and create a more sustainable industrial sector. By the end, we also suggest that industries collaborate with private financial organizations to develop green financing models, such as energy efficiency loans or investment funds dedicated to sustainable technology, to not only dependent on government aid while still progressing towards their sustainability goals.

Waste Management and Circular Economy Practices: A more comprehensive approach to waste management should be encouraged, with government support for circular economy practices such as recycling, upcycling, and zero-waste initiatives. These practices not only help reduce GHG emissions but also promote resource conservation and reduce operational costs.

Facilitate Adoption of Green Energy: Given the high costs associated with green energy technologies, the government should work to reduce the cost of renewable energy through tariff reductions, increased local production of renewable energy equipment, and infrastructure development. This would encourage more industries to switch to cleaner energy sources, significantly reducing their carbon emissions.

4.3. The Imperative of Green Energy Transition in Textile Industry

Reducing Carbon Emissions: As the textile industry contributes significantly to global greenhouse gas emissions, shifting toward green energy can help mitigate the environmental impact. By increasing the adoption of solar, biogas, and other renewable sources, the industry can reduce its reliance on fossil fuels and contribute to global climate targets. To achieve this, industries need to collaborate closely with technology providers and energy experts to identify the most suitable green energy solutions for their production processes.

Energy Security and Stability: Renewable energy sources such as solar and wind provide greater energy security by reducing dependence on fossil fuels, which are subject to price volatility and supply constraints. By investing in on-site renewable energy generation, industries can achieve more reliable and cost-effective energy solutions. Distribution Companies, Power Generation Companies, and Independent Power Producers (IPPs) must prioritize the integration of renewable energy into their grids and offer flexible solutions that allow industries to feed excess energy back into the system. Policymakers should also focus on regulatory frameworks that encourage these companies to support industrial green energy initiatives.

Long-Term Cost Savings: While the initial investment in green energy infrastructure (such as solar panels) may be high, renewable energy sources offer long-term cost savings by reducing dependence on expensive fossil fuels. As renewable technologies become more affordable, industries that transition early will benefit from lower operating costs and reduced exposure to future carbon pricing mechanisms. Industry associations and chambers of commerce should play a proactive role in negotiating bulk purchase agreements for green technologies, making them more affordable for smaller industries. Research institutes and universities can support this transition by conducting studies that demonstrate the financial viability of renewable energy investments and by developing localized solutions that are tailored to the specific needs of the textile sector.

Meeting Global Sustainability Standards: Many international buyers are increasingly prioritizing suppliers that adopt sustainable practices. Textile firms that invest in renewable energy and reduce their carbon footprint will be better positioned to meet global standards, remain competitive, and attract more environmentally conscious customers. With the upcoming implementation of the Carbon Border Adjustment Mechanism (CBAM) by the European Union, the stakes are even higher for textile exporters. CBAM will impose tariffs on imported goods based on their carbon content, meaning that products from industries with high GHG emissions will face significant cost disadvantages in the EU market. Textile firms that proactively adopt renewable energy sources and sustainable practices will not only reduce their carbon footprint but also minimize potential financial impacts under CBAM regulations. This transition will enable them to maintain their market share in Europe and other regions that are increasingly adopting stringent climate policies.

Industry leaders must take immediate action to adopt renewable energy and sustainable practices to minimize the impact of these regulations. The government should also provide a clear policy roadmap that aligns with global sustainability benchmarks to guide industries in their transition to green energy.

Final Words

The results of this survey make it clear that while some strides have been made in reducing carbon footprints, there is still much work to be done in terms of awareness, policy implementation, and green energy adoption. The textile industry in Pakistan must take immediate steps to reduce its environmental impact, particularly in the areas of GHG emission reduction, energy efficiency, and waste management.

With government support, financial incentives, and capacity building, industry can make the necessary transition towards sustainable production, ensuring long-term competitiveness in global markets that increasingly demand environmentally responsible practices. A concerted effort from both the public and private sectors will be crucial in meeting international sustainability standards and securing the future of Pakistan’s textile industry in an evolving global market.

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