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INVESTIGATING CIRCULAR ECONOMY BARRIERS IN NOWSHERA'S MARBLE FACTORIES

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Article Info

Abstract

The marble industry in District Nowshera, Khyber Pakhtunkhwa, plays a vital role in Pakistan's economy but remains heavily dependent on a linear production model, resulting in excessive waste generation, high energy consumption, and environmental degradation. This study investigates the barriers to adopting circular economy (CE) practices in the marble sector, focusing on Shaidu, Jehangira, and Khaira bad. A quantitative research design was employed, incorporating two structured surveys: one targeting CE experts and professionals (n = 64) and another engaging marble factory managers (n = 10). Data were analyzed through descriptive statistics, weighted averages, cross-tabulations, and correlation analysis to capture both systemic and operational perspectives. Findings reveal that weak regulatory enforcement, high electricity costs, lack of financial incentives, minimal awareness, and inadequate technological infrastructure are the principal barriers to CE adoption. Notably, 90% of factory managers had no prior awareness of CE, yet all expressed willingness to adopt sustainable practices when informed. The study concludes that integrated policy reforms, financial support, awareness campaigns, and technological investments are essential for transitioning Pakistan's marble industry toward circular models aligned with sustainable development goals.

Keywords:
Circular economy, Marble industry, Nowshera, Waste management, Sustainability.

INTRODUCTION

Background of Study

The circular economy (CE) is another radical sustainability strategy that emphasizes resource efficiency, waste avoidance, and environmental restoration. By reducing waste, maximising resource usage, and lengthening the life of materials, CE cuts not only environmental impact but also economic costs by decreasing material prices and promoting innovation. Moreover, it contributes to the growth of employment and business survivability, which is why it is an absolutely necessary framework of sustainable development and long-term economic stability (Sariatli, 2017).

One of the most economically and culturally important metamorphic rocks is Marble, a rock formed by recrystallization of limestone or dolomite. The marble industry, especially in Khyber Pakhtunkhwa (KP) province, is on the rise again. It has an estimated 297 billion tons of marble reserves and more than 100 colours and varieties of marble, and approximately 30 types of marble in KP alone (Ahmad et al., 2022). Although this industry is of great economic value, it also has a large environmental impact, since it consists of resource-intensive extraction conditions, intensive energy use, and waste. Marble factories specifically consume significant amounts of water and electricity, leading to energy-related emissions and resource depletion. What is more is that these factories create large amounts of waste, such as marble sludge, dust and offcuts, which are frequently disposed of incorrectly causing soil and water pollution (Khan et al., 2023).

The marble industry has undergone a shift in recent years with the rising demand of sustainability and newer technologies (Xiamen SRS Trading Co., 2024). Nevertheless, there are substantial challenges to the implementation of the circular economy in marble factories regardless of the perceived advantages. Among these barriers are economic, technological, regulatory, and social barriers (Circular Economy of Construction and Demolition Waste, 2021). Lack of adoption of circular practices leads to increased cases of environmental degradation, resource scarcity, increasing cost of materials and possible loss of business competitiveness (Momentum Contributing Writer, 2025).

Problem Statement

Environmental and economic benefits associated with circular economic practices, marble factories in District Nowshera continue to operate under traditional, linear production systems that result in high levels of waste, energy use, and environmental degradation. While the CE model offers solutions to these issues, adoption within the marble sector remains low due to multiple barriers, including weak regulatory frameworks, financial constraints, lack of awareness, and limited access to recycling technology. Without identifying and addressing these specific challenges, the sector risks further resource loss, environmental harm, and declining competitiveness. Therefore, there is an urgent need to investigate and understand the key factors hindering circular economic implementation in this industry.

Objectives of the Research

The following are the objectives of this research study:

1. To identify key barriers (Policy, Financial, Awareness, Technological) to circular economy adoption in the marble industry of District Nowshera, focusing on the areas of Shaidu, Jehangira, and Khaira bad.
2. To compare expert perceptions with industry-level realities regarding circular economy practices.
3. To evaluate the level of awareness and readiness among marble factories for transitioning toward circular economy models.

Significance of Study and Relevance

This study is significant and relevant for several reasons:

1. It addresses a research gap by focusing on the barriers to circular economy adoption within a specific and impactful industrial sector in Pakistan: the marble industry.
2. The study contributes to the field of sustainable industrial development by identifying the real-world obstacles that hinder the implementation of CE principles in developing economies.
3. As environmental pressures rise and global markets shift toward green production, this research helps ensure that Pakistan's marble industry remains competitive, resilient, and aligned with sustainable development goals (SDGs).

Literature Review

Circular Economy

The circular economy is a systemic approach to economic development designed to benefit businesses, society, and the environment (Ellen MacArthur Foundation, 2024). It represents a paradigm shift from the traditional linear economic model, which is characterised by resource extraction, production, consumption, and disposal (Tel Aviv University, 2024). Conversely, the circular economy emphasises minimising waste and pollution, extending product and material life through reuse and recycling, and regeneration of natural systems (Ellen MacArthur Foundation, 2024).

The fundamentals of circularity trace back to the 1960s when scholars and practitioners sought alternatives to linear systems (Blomsma and Brennan, 2017). This transformation can include reconsidering resource management, product design, and consumption, and material disposal (Twice Commerce, 2023).

Key Operational Principles Linking Circular Economy and SDGs

Seven major tenets of operation that relate the CE concept to SDGs involve aligning waste production and resource consumption with ecological limitations, material loop closure of goods, lengthening product useful life, reducing overall material throughput, and adopting sustainable design and education. The practices save production costs due to recuperation of the resources as well as creating employment (Suarez-Eiroa et al., 2019). Moreover, the shift toward CE frameworks has long-term environmental advantages, increasing energy security and economic resilience (Knäble et al., 2022).

Nonetheless, Velenturf & Purnell (2021) suggested that a sustainable circular economy should transcend recycling and resource efficiency, as these approaches are sometimes too economically centered. Their suggested principles focus on social equity, ecological regeneration, long-term systems thinking, and intergenerational responsibility, providing a comprehensive course map of aligning circular economy practices with the primary objectives of sustainable development, in contrast to these narrower economic views.

Adoption of Circular Economy Models in Europe and Asia

Several countries across Europe and Asia have taken significant steps to implement circular economy principles (Ogunmakinde, 2019).

Germany

The circular economy in Germany is defined by the Circular Economy Act (KrWG, 2012, Section 1) that prioritizes the prevention and systematic recovery of waste as an attempt to conserve natural resources and protect the environment. The legal framework is bolstered by the circularity vision pursued by Germany, which is aligned with the EU Circular Economy Action Plan and the UN Sustainable Development Goals to strategically direct policies (Federal Ministry for the Environment, 2023, p. 3).

Moreover, Germany seeks to create market environment that fosters durable, resource-efficient products, and international cooperation that would lead to achieving circularity along the global supply chains (Federal Ministry for the Environment, 2023, p. 4). The example of the so-called Green Dot system exemplifies this trend of policy action - an Extended Producer Responsibility (EPR) policy scheme that hugely increased the recycling of packaging discards and has had an impact on other circular economy programs in Europe (OECD, 2016).

Netherlands

The Netherlands has published a comprehensive and ambitious plan on how it will move to a full-scale circular economy by 2050. The objective was initially outlined in the 2016 State report called A Circular Economy in the Netherlands by 2050 that expresses the aim of the state to reduce dependence on primary raw materials and increase sustainable resource use. The programme will be organised into five major transition agendas, including Biomass and Food, Plastics, Manufacturing Industry, Construction, and Consumer Goods, and supported by ten cross-cutting themes. The effectiveness of the initiative depends on the active involvement of governmental institutions, industry players, and civil society members (Government of the Netherlands, 2023a; 2023b).

One of the prime examples of a circular economy in action in the Netherlands is the Energy & Raw Materials Factory (ERMF), spearheaded by Dutch water authorities. The target materials and compounds intended to be recovered in this project include cellulose, phosphate, bioplastics, biogas, and bio-ALE, an industrial polymer that can be used as a biodegradable replacement. RMF illustrates the prospect of turning waste into economically and environmentally sustainable resources. In 2030, projections indicate that this initiative will yield up to 233 million euro per year, with a forecast of 85,000 tonnes of bio-ALE and 200 million cubic meters of biogas (Van Leeuwen et al., 2018).

Finland

The Finnish Innovation Fund outlined practical strategies to shift from a linear to a circular economy by targeting five key sectors: food systems, forest-based loops, technical cycles, transport, and collaborative actions (Sitra, 2016). To support this transition, the Finnish government implemented a range of regulatory and fiscal measures, including increased waste taxation, the introduction of a mining tax, and the reclassification of recycling activities under industrial electricity tax categories (Ministry of the Environment, 2021a).

Finland also promotes circularity through sustainable public procurement. National targets are being developed to reduce carbon and ecological footprints in public purchases, supported by tools such as the Criteria Bank and the KEINO Competence Centre. Public sector Green Deals and projects like low-carbon infrastructure procurement aim to embed circular principles into service delivery. Moreover, Finland has committed substantial funding to research and innovation to support the circular transition. Initiatives such as Business Finland's "Circular Transition for Zero Waste" mission and the Sustainable Growth Programme allocate millions of euros toward recycling, reuse, and green innovation projects. A total of €110 million has been earmarked to support industrial investments in recycling by 2026, while the EU's Innovation and Skills in Finland 2021–2027 programme supports climate-focused circular projects (Ministry of the Environment, 2021b).

China

China has been at the forefront of integrating circular economy principles, beginning with the enactment of the Circular Economy Promotion Law in 2008. The law mandates the development of industrial policies aligned with circular economy objectives, encourages the adoption of resource-efficient technologies, and establishes systems for monitoring and evaluating progress (Circular Economy Promotion Law, 2008). Building upon this foundation, China has incorporated circular economy goals into its Five-Year Plans. The 13th Five-Year Plan (2016–2020) set targets such as increasing resource productivity by 15% and achieving a 73% utilization rate for solid waste. It also projected over 75 percent of national industrial parks to achieve complete circular strategies by 2020 (China's 13th Five-Year Plan, 2016).

The following 14th Five-Year Plan (2021-2025) has this trend, furthering resource intensity, involving recycling industries and creating less waste. The main targets are to increase major resource output efficiency by 20%, decrease the use of energy and water per unit of GDP by 13.5 and 16 percent, respectively, and reach a construction waste utilization level of 60 percent (14th Five-Year Plan, 2021). This industrial symbiosis concept has a direct relevance to the national CE goals and illustrates the potential application of the concept of a circular economy in large-scale industrial planning (Geng et al., 2013).

Pakistan

Pakistan is moving slowly towards adopting a circular economy (CE) model, focusing on sustainable use of resources, which includes reduction and reuse of waste, as well as recycling. Such a transformation is starting to be reflected in major industries, such as cement, textile, construction, automobile, leather, and waste management (Iqbal et al., 2023). There is a growing interest in converting to circular business models to tackle environmental issues and sustain economic activities (Shah et al., 2024). The opportunities presented by addressing the systemic issues are a great potential at sustainable development and resource efficiency across different sectors (Khan and Ali, 2022).

CE practices are of specific importance to waste management, where they are relevant to challenges of the developing environment. For instance, the municipal solid waste (MSW) sector emits approximately 14.30 million tonnes of CO_2 equivalent ($MtCO_2e$), accounting for nearly 53% of the country's total waste-related emissions (Ayub et al., 2024). This emphasizes the urgent need for CE-based strategies such as waste minimization and recycling.

Urban centers like Lahore exemplify this need and potential. Data Ganj Bakhsh Town alone generates roughly 1,369.8 tonnes of waste per day, with organic waste comprising about 67.02% indicating a strong potential for organic waste valorization through CE approaches (Batool and Ch, 2009). Furthermore, the Lahore Waste Management Company (LWMC) has improved waste collection efficiency, currently managing to collect approximately 73% of the city's waste an important milestone in advancing circular practices in urban waste management (Iqbal et al., 2022).

Marble Industry

Marble is a highly esteemed metamorphic rock that forms through the recrystallization of limestone or dolomite under intense heat and pressure within the Earth's crust. It is scientifically characterized as a non-foliated rock composed predominantly of interlocking calcite ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) crystals, which grant it a distinctive granular and crystalline texture.

Khyber Pakhtunkhwa (KPK) is the leading marble-producing province, contributing 98–99% of Pakistan's marble reserves. An estimated 300 billion tonnes of marble are spread across the province, including former FATA regions such as Buner, Chitral, Hazara, Kohistan, Swat, Bajaur, Mohmand, and others (Khan, 2018). The province produces around 2.47 million tonnes annually, with a robust network of industrial estates and processing units located in Mardan, Peshawar, Abbottabad, and Nowshera (SCCIP).

Despite its natural wealth, the sector in KPK faces numerous obstacles. One of the most critical issues is the energy crisis; more than 6,000 marble factories are at risk of closure due to rising electricity costs and power shortages (Pakistan Today, 2023). Additionally, poor infrastructure and security concerns in rural areas limit operational efficiency and access to export markets (DAWN, 2015).

Marble Slurry Waste

Marble slurry is a waste product of marble processing whose disposal poses serious environmental challenges as well as massive quantities. This slurry, which mostly consists of water and fine particles of calcium carbonate, is usually released into open lands or into water bodies resulting in soil degradation, water contamination, and pollution of the air. The fine particles will also lead to respiratory problems and also affect plant life.

The known efforts to curtail the environmental impact of these activities have precipitated some investigation on methods of utilization. The new product that shows potential is the addition of marble slurry to construction products. It has been estimated that when mixed with clay and heated to an elevated temperature, marble slurry can create a type of cement made of marble, called marble cement (Shah et al., 2015). There is a higher compressive strength of this marble cement that enables its usage as an alternative in construction methods. Regarding the second one, a study was conducted to determine the possibility of reusing marble slurry in making bricks, which has shown that bricks with marble slurry can have a high compressive strength, thus a viable method of waste management using reutilised materials (Waheed-ur-Rehman et al., 2018).

Types of Marble Waste

The often-used marble waste generated through the different processes involved in the quarry and processing business include marble powder, marble slurry, and marble chips. Slurry, or a semi-fluid by-product, and marble powder are formed in the course of cutting and polishing of the material, and marble chips are formed during quarrying of the mass. The waste types are of significant concern to the environment as they are bulky and are quite difficult to dispose. Nevertheless, many studies have proved that they can be reused as construction materials. As an example, the special feature of marble powder is the increase in certain mechanical characteristics of the concrete when it is used as part of the cement mass (Aliabdo et al., 2014). Fine aggregates in mortar and concrete can also be substituted by marble waste hence enhancing durability and workability (Singh et al., 2017). Moreover, due to mixing of marble sludge in the manufacture of bricks the bricks have been made lighter and with better insulating capacity. These results promote environmental sustainability and the innovation of construction materials utilizing the reuse of marble waste (Cobo-Ceacero et al., 2019)

Circular Economy Approaches in the Marble Industry

Marble waste has great versatility, with uses in asphalt, glass, textile, and building industries. Marble dust is widely employed as a mineral filler or partial substitute of natural aggregates in hot mix asphalt, improving the mechanical properties (stiffness and resistance to deformation) and replacing the use of non-renewable resources (de Medeiros, Neto and Luz, 2023). Likewise, in glass industries, the presence of calcium carbonate in marble wastes can act as a fluxing agent when introduced alongside recycled glass (cullet), reducing the required melting temperature, resulting in energy savings and improving mechanical strength and durability (Alemu et al., 2025). This also aids in redirecting large amounts of waste out of landfills (Megna et al., 2021).

Pakistan has weak regulatory guidelines and enforcement with regards to environmental protections and waste management in the marble industry (Iqbal et al., 2023). The introduction of the circular economy is hampered currently, as the regulation of marble waste are weak and, in some cases, nonexistent. Due to this gap in regulation, monitoring and control of pollution or resources consumed is weak (Anwar, 2024).

Economic limitations are set to be considerable, such as a lack of investment in greener technologies as well as recycling facilities (Khan et al., 2025). In Pakistan, the marble processing industries prefer to focus on short-term economic advantages rather than a long-term approach because there is no motivation or financial support to consider CE (Sufian et al., 2021).

Poor knowledge and the implications of implementing circular economic practices are among the key social obstacles (Pechuho, 2024). Cultural resistance to change and untrained personnel on sustainable practices also discourage CE adoption. Furthermore, the existence of a fragmented industry structure including many SMEs who cannot afford to implement CE models also has a negative impact on collaborations (Durrani et al., 2024).

The shortage of the developed and adequate technological solutions is a crucial obstacle. A large number of stone processing factories in Pakistan are prone to waste recycling and environmental degradation due to backward means of production. Technological discrepancies restrain the effective practice of recycling and cleaner production processes, as well as the potential industrial symbiosis or circular material flows in the sector (Akhtar et al., 2022).

Research Gap

The concept of the circular economy (CE) has gained international attention as a strategy for reducing waste and promoting sustainable development, its implementation in developing countries like Pakistan remains limited. Existing literature focuses primarily on the theoretical benefits of CE or case studies from advanced economies, with little emphasis on the practical challenges faced in specific sectors such as the marble industry. Moreover, there is a lack of empirical studies that explore CE adoption barriers in Pakistan's marble sector, particularly at the factory level. Most available studies do not include direct feedback from industry stakeholders or analyze local operational constraints. This study addresses that gap by collecting and comparing primary data from both circular economy experts and marble factory managers in District Nowshera to identify the real, on-ground barriers to CE implementation.

Methodology

This research adopted a quantitative design to investigate barriers to circular economy (CE) adoption in the marble industry of District Nowshera, Khyber Pakhtunkhwa. The methodological framework was designed to capture both systemic perspectives from experts and operational realities from marble factories. By integrating these two levels of data, the study ensured a balanced assessment of structural and ground-level challenges.

Area of Study

The empirical component was conducted in Shaidu, Jehangira, and Khaira bad, sub-regions of District Nowshera that collectively form one of the province's largest marble industry clusters. These areas were selected purposively because they host a concentration of marble processing units and provide representative insights into industry practices.

District Nowshera

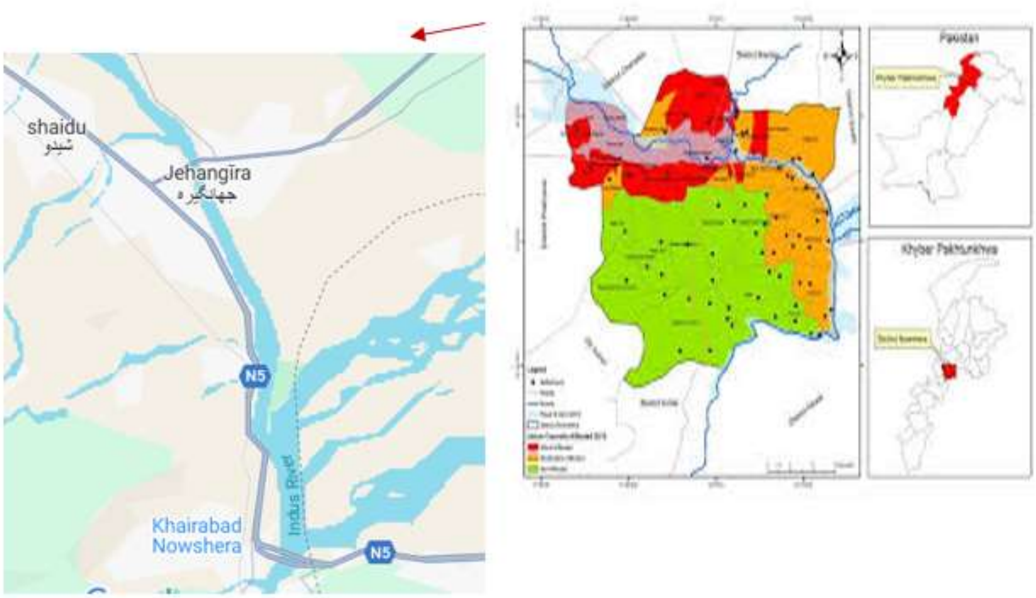

Figure 1: Location of Study Area

Research Design

A dual-survey strategy was employed. The first survey targeted CE experts and professionals working in fields such as sustainability, waste management, climate change, and industrial policy. The second survey engaged factory managers and owners directly involved in operational decision-making. This two-pronged approach enabled a comparative analysis between macro-level policy/strategy views and micro-level operational practices.

Sampling Strategy

1. Expert survey: A purposive non-probability sampling technique was adopted to reach individuals with relevant expertise. The questionnaire was distributed online via LinkedIn, generating 64 valid responses.
2. Factory survey: Due to logistical and accessibility constraints, a convenience sampling approach was used. The researcher personally visited 10 factories in Nowshera, conducting on-site surveys with owners or managers. This ensured direct engagement with stakeholders responsible for production and waste management.

Data Collection

Two structured questionnaires were developed:

1. Expert Questionnaire – Designed to capture national- and sector-level perspectives on CE barriers. Items included Likert-scale ratings of policy effectiveness, financial incentives, awareness, and technological availability.
2. Factory Questionnaire – Adapted to local conditions, focusing on operational realities such as waste disposal practices, awareness of CE, financial constraints, and willingness to adopt CE principles.

Both instruments contained close-ended questions for quantification and comparability, supported by categorical items for cross-tabulation. Prior to administration, respondents were informed about the study's purpose, and consent was obtained.

Data Analysis

The data analysis combined descriptive statistics, weighted averages, and cross-tabulations:

1. Experts (n = 64): Percentages and weighted averages were calculated to rank perceived barriers. Additionally, a Spearman's rank correlation test was applied to examine relationships between variables such as awareness, willingness to invest, policy enforcement, and technological availability.
2. Factories (n = 10): Given the small sample size, data were analysed through descriptive summaries and cross-tabulations. For example, awareness levels were cross-tabulated with willingness to adopt CE, and waste reuse was cross-tabulated with collaboration readiness. This highlighted not only prevalence but also relational insights.

This multi-layered analysis approach strengthened validity by revealing both frequency-based patterns and interconnections among barriers.

Ethical Considerations

Participation was voluntary. For the expert survey, anonymity was ensured through online distribution. For the factory survey, verbal consent was obtained prior to data collection. No personal identifiers were recorded, and confidentiality of responses was maintained throughout.

Limitations

The study's small factory sample (n=10) limits generalizability beyond District Nowshera. Non-probability sampling introduces potential bias, as respondents may not represent the entire diversity of industry stakeholders. Moreover, reliance on self-reported data could reflect subjectivity. Nevertheless, triangulating expert-level and factory-level datasets enhances reliability and provides a credible empirical foundation.

Results

This study draws on two complementary datasets to capture both macro-level expert perspectives and micro-level industry realities. The first dataset comprises 64 responses from circular economy experts and professionals, analyzed using descriptive statistics and weighted averages to identify key patterns and rank barriers. This dataset provides a broader, policy- and strategy-oriented view. The second dataset includes responses from 10 marble factories in Nowshera, representing operational-level insights. Given its small sample size and categorical nature, the factory data was analyzed through descriptive summaries and cross-tabulations to highlight practical constraints and readiness for circular economy adoption. Together, these datasets enable a balanced assessment of systemic barriers and on-ground realities, strengthening the study's empirical contribution.

Factory-Level Results (n=10)

Waste Management Practices

The findings reveal a complete absence of formal waste management systems across all ten surveyed factories. Every respondent (100%) reported dumping waste either in open land or nearby rivers, with none engaging in controlled disposal or recycling mechanisms. Furthermore, no factory reported tracking the type or quantity of waste produced.

In terms of reuse, the majority (70%) indicated that they reused only between 0–10% of their marble waste, while 20% reported slightly higher reuse rates in the 11–30% range. These results point to a critical deficiency in resource recovery practices at the operational level.

Table 1. Waste Management Practices in Factories (n=10)

Indicator	Count	Percentage
Waste disposal in land/rivers	10	100%
Tracking waste	0	0%
Reuse 0–10%	7	70%
Reuse 11–30%	2	20%
Reuse >30%	0	0%

Awareness and Knowledge of Circular Economy

Awareness of circular economy concepts was negligible among factory respondents. Nine out of ten factories (90%) had never heard of the circular economy before this survey. Despite this lack of prior knowledge, all factories (100%) agreed that circular economy principles, once explained, were useful for industry sustainability.

When cross-tabulating "Heard of CE" with "Willingness for CE adoption," it was evident that lack of awareness did not deter willingness. Even those who had never heard of CE expressed readiness to adopt such practices once informed.

Table 2. Cross-Tabulation: Awareness vs Willingness to Adopt CE

Heard of CE	Willing for CE
No (9)	Yes (9)
Yes (1)	Yes (1)

This result underscores the latent potential for adoption if awareness campaigns and training initiatives are implemented.

Barriers to Adoption

Factories identified a range of barriers preventing circular economy adoption. Policy gaps dominated the responses: "weak policy" was mentioned in six responses, "weak policy only" in two, and variations of policy-related deficiencies appeared in nearly all accounts. Other recurring themes included high electricity costs and financial constraints.

Table 3. Barriers Reported by Factories

Barrier Type	Frequency
Weak policy (general/variations)	8
High electricity bills/costs	3
Lack of awareness	1
Operational/financial constraints	1

Cross-tabulation between "Main Challenge reported" and "Willingness to Collaborate" showed unanimous openness to collaboration despite diverse challenges. This suggests that policy and financial barriers, while severe, do not diminish willingness to engage in partnerships for CE adoption.

Support and Incentives

A striking 100% of factories reported receiving no government support. Yet, when asked about needed assistance, all respondents (100%) emphasized the need for financial or technical support to transition toward CE models.

Cross-tabulation of "Got Support" and "Willingness to Collaborate" confirmed that even in the absence of external assistance, every factory expressed openness to collaboration with stakeholders.

Table 4. Support and Incentives

Indicator	Count	Percentage
Received government support	0	0%
No government support	10	100%
Need financial/technical support	10	100%

Readiness for CE Adoption

The readiness of factories to adopt circular practices emerged strongly from the data. All respondents (100%) declared willingness to adopt CE measures and expressed openness to collaboration with external factors such as government agencies, NGOs, and industry peers.

Cross-tabulation between "% Waste Reused" and "Willingness to Adopt CE" further highlighted that even factories with minimal waste reuse (0–10%) expressed readiness for CE adoption.

Table 5. Cross-Tabulation: Waste Reuse vs Willingness to Adopt CE

% Waste Reused	Willing for CE
0–10% (7)	Yes (7)
11–30% (2)	Yes (2)

This finding indicates that operational practices are currently misaligned with attitudes: although factories are not actively implementing CE practices, their willingness provides a crucial entry point for interventions.

Overall, factory-level analysis highlights severe gaps in waste management, absence of awareness, and lack of governmental support. However, the results also reveal unanimous willingness to adopt CE and collaborate with stakeholders. This suggests that with targeted awareness programs, supportive policies, and financial incentives, the marble industry in Nowshera could significantly improve its circular economy performance.

Expert-Level Results (n=64)

Policy and Regulation

Experts identified policy and regulatory gaps as the most significant barrier to circular economy (CE) adoption. A plurality (42.2%) rated current CE policies as very ineffective, while only 9.4% considered them very effective. The majority emphasized weak enforcement, unclear regulations, and the absence of financial incentives as core obstacles.

Table 6. Expert Perceptions of Policy Effectiveness

Policy Effectiveness Rating	Percentage (%)
Very Ineffective	42.2
Neutral	25.0
Somewhat Effective	23.4
Very Effective	9.4

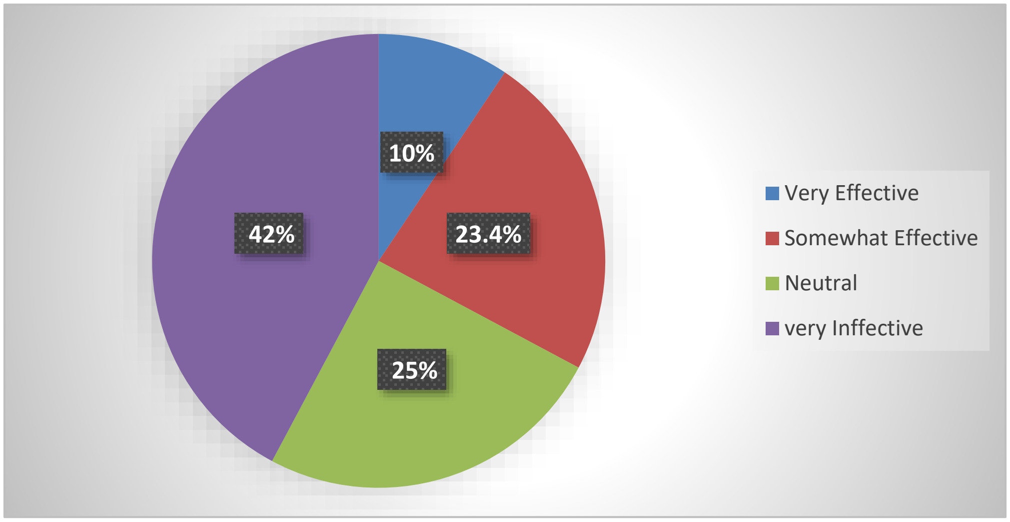

Figure 1: Policy and Regulatory Constraint Reported by Experts

Respondents also highlighted the most pressing policy barriers: poor enforcement (39.2%), absence of CE-specific regulations (29.1%), lack of incentives (20.3%), and low stakeholder engagement (1.3%).

Financial Constraints

Financial barriers emerged as equally influential. More than half (51.6%) of experts prioritized government subsidies or tax breaks as the most critical incentive for CE adoption, followed by low-interest CE loans (25.0%) and CE-focused investment funds (20.3%).

Table 7. Preferred Financial Incentives for CE Adoption

Incentive Type	Percentage (%)
Government Subsidies / Tax Breaks	51.6
Low-Interest CE Loans	25.0
CE-Focused Investment Funds	20.3
Other (corporate leadership, internal commitment)	3.1

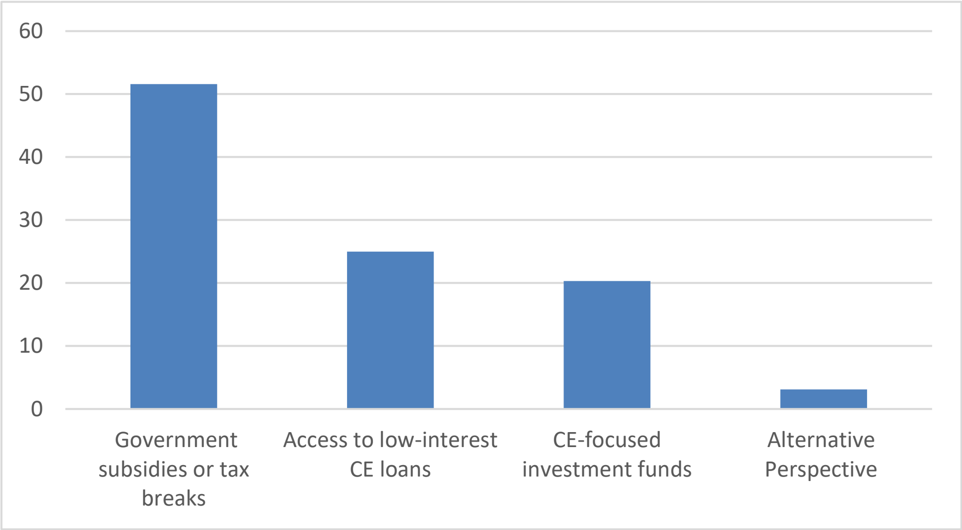

Figure 2: Financial Incentives for Encouraging Business Adoption of Circular Economy Practices

Additionally, willingness to invest in CE solutions varied: 35.9% reported being somewhat willing and 18.8% highly willing, while 28.1% remained undecided. Only 17.2% were unwilling. This suggests a significant base level of interest but also hesitancy requiring targeted policy and financial interventions.

Awareness and Training

The expert survey indicated that business understanding of CE benefits is mixed. While 32.8% of respondents considered awareness levels to be poor, 25.0% rated them as somewhat well understood, and 20.3% as very well understood. Meanwhile, 21.9% remained neutral.

When asked about the primary reasons for low awareness, 46.9% pointed to lack of education and training, 29.7% to the absence of immediate financial benefits, and 21.9% to insufficient government campaigns.

Table 8. Primary Reasons for Low CE Awareness

Reason	Percentage (%)
Lack of education/training	46.9
No immediate financial benefit	29.7
Lack of government support	21.9
Cultural resistance	1.6

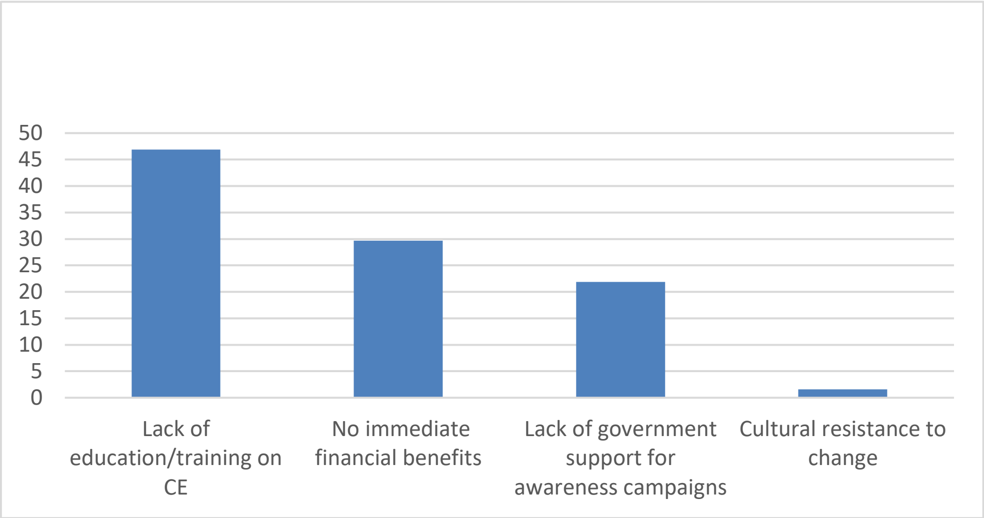

Figure 3: Reasons for Low Circular Economy Awareness among Industries

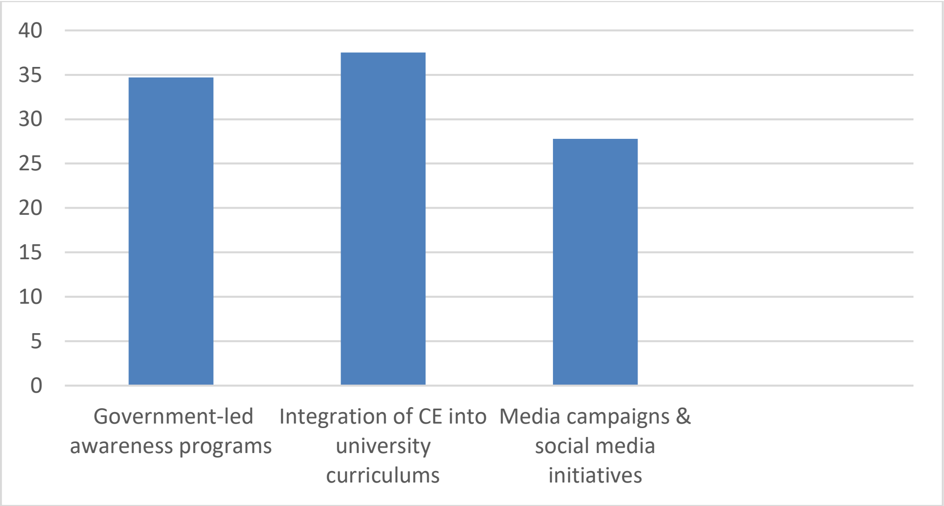

Figure 4: Effectiveness of Methods for Raising Awareness about the Circular Economy

Technological Limitations

Technological barriers were also widely acknowledged. A large proportion of experts rated the availability of CE-related technologies as poor (35.9%) or neutral (31.9%), while only 31.3% considered it good. The strongest limitations cited were lack of recycling infrastructure (57.8%), outdated waste management systems (48.4%), limited expertise (35.9%), and high costs (29.7%).

Table 9. Perceived Technological Constraints

Technological Constraint	Percentage (%)
Lack of recycling infrastructure	57.8
Outdated/inefficient waste systems	48.4
Limited expertise in CE technologies	35.9
High costs	29.7

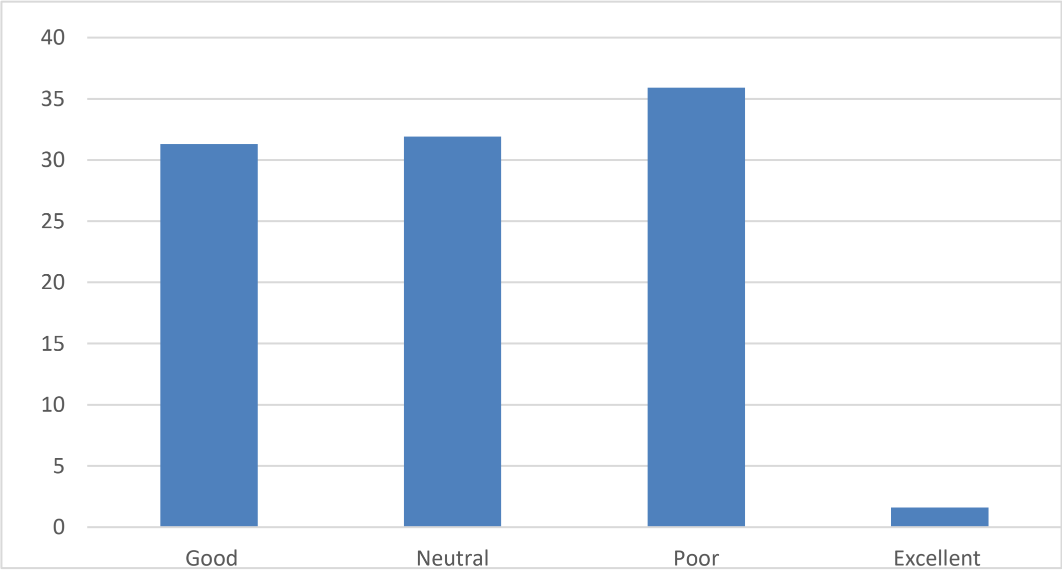

Figure 5: Availability of Circular Economy-Related Technology in Pakistan

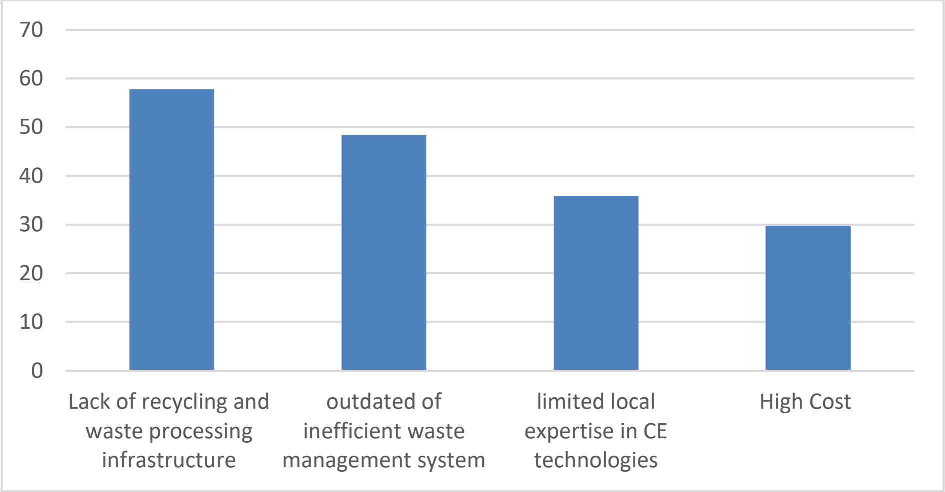

Figure 6: Technological Constraints in Circular Economy Implementation

Correlation Analysis of Barriers

To examine potential relationships between barriers, a Spearman's rank correlation was applied to expert responses (n=64). The results revealed statistically significant associations:

1. Awareness ↔ Willingness to Invest ($\rho = 0.48$, $p < 0.01$): Higher levels of awareness corresponded with stronger willingness to adopt CE practices.
2. Policy Enforcement ↔ Preference for Subsidies ($\rho = 0.52$, $p < 0.01$): Experts perceiving poor enforcement also strongly supported financial subsidies.
3. Technological Availability ↔ Investment Readiness ($\rho = 0.35$, $p < 0.05$): Limited technological availability was moderately linked to lower willingness to invest.

Table 10. Spearman's Correlation Results among Key Barriers

Variables Compared	Correlation (ρ)	Significance (p)	Interpretation
Awareness ↔ Willingness to Invest	0.48	<0.01	Moderate positive
Policy Enforcement ↔ Preference for Subsidies	0.52	<0.01	Strong positive
Technological Availability ↔ Investment Readiness	0.35	<0.05	Moderate positive

These findings reinforce the interconnected nature of CE adoption barriers: financial, policy, and awareness dimensions operate synergistically rather than in isolation.

Comparative Insights: Experts vs Factories

The dual-dataset approach highlights both alignment and divergence between expert-level and factory-level perceptions.

1. Policy and Regulation: Experts emphasized weak enforcement and absence of CE-specific policies. Factory managers echoed this, reporting "weak or no policy" as their main barrier. Thus, both datasets converge on policy as the most critical obstacle.
2. Financial Constraints: Experts stressed subsidies and tax breaks as key incentives. Factories, on the other hand, described immediate financial burdens such as electricity costs and machinery expenses. This reflects divergence: experts propose structural incentives, while factories emphasize operational survival.
3. Awareness: Among experts, awareness gaps were seen as significant but variable; among factories, awareness was nearly non-existent (90% had never heard of CE). This highlights a severe ground-level knowledge gap.
4. Technology: Experts reported poor availability of advanced recycling infrastructure; factories confirmed this reality, with all 10-dumping waste into open land or rivers. Both perspectives align, showing structural and operational deficiencies.
5. Readiness: Despite challenges, both experts and factories demonstrated willingness—experts through investment interest (54.7% willing) and factories through unanimous willingness to adopt CE and collaborate.

Table 11. Comparative Insights: Experts vs Factories

Dimension	Expert Insights (n=64)	Factory Insights (n=10)
Policy & Regulation	42.2% rated policies *very ineffective*; poor enforcement and absence of CE-specific rules cited as dominant barriers.	"Weak or no policy" repeatedly identified as main challenge; unanimous consensus on regulatory failure.
Financial Constraints	51.6% preferred subsidies/tax breaks; other incentives included CE loans and investment funds.	Reported immediate operational costs (e.g., high electricity bills, taxes) as primary financial barrier.
Awareness	Mixed levels: 32.8% rated awareness *poor*, 25% *somewhat good*, 20.3% *very good*.	90% had never heard of CE; after explanation, 100% acknowledged CE as useful.
Technology	57.8% cited lack of recycling infrastructure; 48.4% outdated waste systems; 35.9% limited expertise.	All factories dump waste in rivers/land; 70% reuse only 0–10% waste; no tracking systems in place.

Readiness	54.7% expressed willingness to invest in CE; correlation showed awareness strongly linked to readiness.	100% willing to adopt CE and collaborate; willingness observed even with minimal waste reuse.

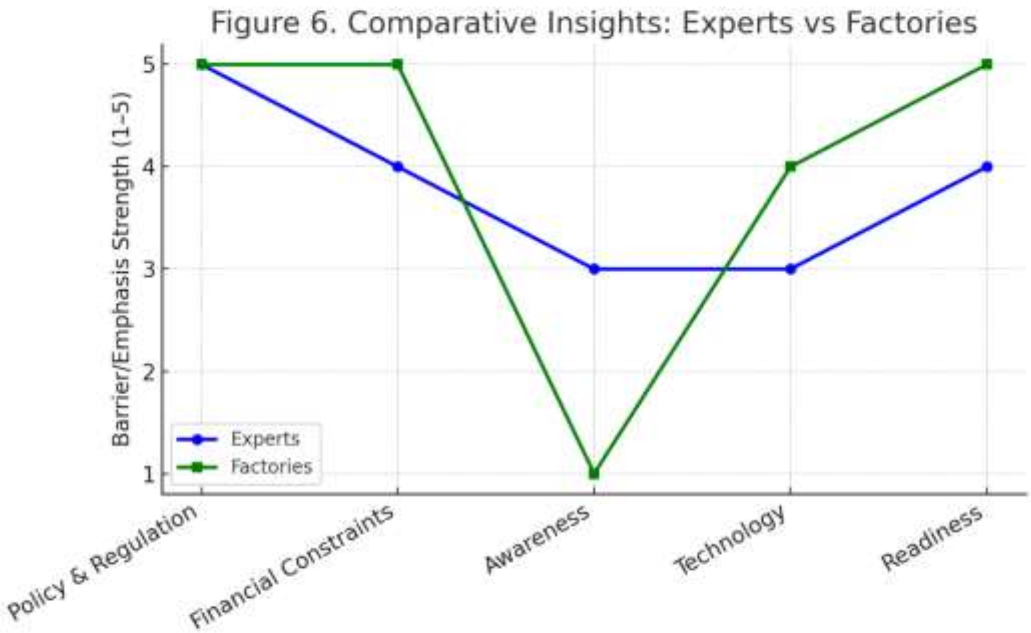

Figure 7. Comparative Insights: Experts vs Factories

The expert dataset (n=64) highlights structural issues such as policy frameworks, financial incentives, and technological infrastructure, while the factory dataset (n=10) emphasizes immediate operational constraints and lack of awareness. Together, they reveal that while systemic barriers hinder CE adoption, the readiness of both stakeholders presents a promising entry point for integrated interventions.

Summary of Results

The findings from both datasets highlight critical structural and operational barriers to circular economy adoption in Nowshera's marble industry. Expert-level analysis (n=64) emphasized weak policy enforcement, insufficient CE-specific regulations, and the absence of financial incentives as the dominant constraints, while also identifying limited awareness and inadequate technological infrastructure as significant obstacles. Correlation analysis further revealed that awareness, policy, and technology are strongly interlinked with willingness to invest.

Factory-level evidence (n=10) provided a stark ground reality: all factories disposed of waste in open land or rivers, none tracked waste, and 90% had never heard of CE. Despite this, all respondents expressed willingness to adopt CE and collaborate, underscoring latent readiness if policy, financial, and technical support are provided. These descriptive and cross-tabulated insights complement the broader expert findings, confirming that systemic barriers persist, but both knowledge interventions and targeted incentives could unlock substantial progress toward CE adoption.

Discussion

The results reveal a consistent, multi-level constraint structure—regulatory, financial, informational, and technological—that collectively explains low circular economy (CE) uptake in Nowshera's marble factories. Factory reports of "weak or no policy" and experts' ratings of CE policy as "very ineffective" align with prior accounts of Pakistan's under-specified and weakly enforced environmental/CE governance (Iqbal et al., 2023; Anwar, 2024). By contrast, jurisdictions such as Germany and the Netherlands have anchored CE transitions in coherent statutory and programmatic frameworks (KrWG, 2012; Federal Ministry for the Environment, 2023; Government of the Netherlands, 2023a, 2023b), underscoring the policy design and enforcement gap that this study surfaces. At a conceptual level, such governance deficits hinder the translation of CE principles—waste prevention, loop closure, and regeneration—into industrial practice (Ellen MacArthur Foundation, 2024; Blomsma & Brennan, 2017; Velenturf & Purnell, 2021).

Financial barriers are pervasive at plant level (e.g., electricity costs) and, at the system level, map onto experts' emphasis on subsidies and tax relief as first-order enablers. This is consistent with evidence that limited investment and short-term cost pressures deter technological upgrading in Pakistan's materials industries (Sufian et al., 2021; Khan et al., 2025). Comparative policy experience suggests that targeted fiscal instruments and green-investment programmes can catalyse adoption when embedded in national CE strategies (Sitra, 2016; Ministry of the Environment, 2021b). The study's correlation between perceptions of weak enforcement and preference for subsidies indicates that credible rules and well-designed incentives are complements, not substitutes, in early-stage CE diffusion.

Information and capability deficits are acute: 90% of factories had not heard of CE, and experts attributed low awareness chiefly to lack of education/training and absent short-term business cases. This mirrors broader accounts of organisational and cultural frictions in SMEs (Durrani et al., 2024; Pechuho, 2024). The positive association between awareness and willingness to invest, together with respondents' support for university curricula and government-led programmes, reinforces CE's knowledge-intensive character and the need for demand-creation alongside supply-side finance (Ellen MacArthur Foundation, 2024; Suarez-Eiroa et al., 2019; Knäble et al., 2022).

Technological and infrastructural deficits—universal uncontrolled disposal; absence of tracking; minimal reuse—confirm earlier diagnoses of limited industrial symbiosis capacity and outdated waste systems (Akhtar et al., 2022). Yet the literature documents practical valorisation routes for marble by-products in cement, concrete, bricks, asphalt, and even glass fluxes (Aliabdo et al., 2014; Singh et al., 2017; Cobo-Ceacero et al., 2019; de Medeiros et al., 2023; Alemu et al., 2025), suggesting immediately actionable pilots if financial and policy supports are aligned.

Conclusion

This study has demonstrated that the marble industry in District Nowshera operates under a linear production model characterised by uncontrolled waste disposal, high energy use, and negligible awareness of circular economy (CE) principles. Findings from both experts and factory managers confirm that the foremost barriers to CE adoption are weak regulatory frameworks, financial burdens, lack of awareness, and technological deficits. Experts consistently rated CE policies as ineffective, citing poor enforcement, absence of specific regulations, and inadequate incentives, while factories echoed these concerns by reporting the complete absence of government support. Financial constraints, especially electricity costs and lack of subsidies—emerged as the most pressing operational challenge. Equally significant is the knowledge gap: 90% of factories had no prior awareness of CE, yet all expressed willingness to adopt such practices once informed.

Technological shortcomings further compound the issue, with all factories dumping waste into open land or rivers and reusing only marginal amounts. Despite these barriers, the unanimous willingness of factories and positive investment signals from experts point to a promising entry point for interventions. An integrated policy package—combining enforceable regulations, financial incentives, training programmes, and technological investment—offers the most viable pathway to embed CE principles and ensure long-term sustainability in Pakistan's marble sector.

References

Ahmad, T., Hussain, M., Iqbal, M., Ali, A., Manzoor, W., Bibi, H., Ali, S., Rehman, F., Rashedi, A., & Amin, M. (2022). Environmental, energy, and water footprints of marble tile production chain in a life cycle perspective. Sustainability, 14(14), 8325. https://doi.org/10.3390/su14148325

Akhtar, N., Bokhari, S. A., Martin, M. A., Saqib, Z., & Khan, M. I. (2022). Uncovering barriers for industrial symbiosis: Assessing prospects for eco-industrialization through small and medium-sized enterprises in developing regions. Sustainability, 14(11), 6898. https://doi.org/10.3390/su14116898

Alemu, M. Y., Yehualaw, M. D., Nebiyu, W. M., & Nebebe, M. D. (2025). Marble and glass waste powder in cement mortar. Applied Sciences, 15(7), 3930. https://doi.org/10.3390/app15073930

Aliabdo, A. A., Elmoaty, A. E. M. A., & Auda, E. M. (2014). Re-use of waste marble dust in the production of cement and concrete. Construction and Building Materials, 50, 28–41. https://doi.org/10.1016/j.conbuildmat.2013.09.035

Anwar, S. (2024). Analyzing impacts of marble industry on public health.

DOI:10.20944/preprints202410.1382.v1

Ayub, F., Naqvi, S. L. H., Naqvi, S. H. Z., & Yasar, A. (2024).: Closing the Loop: Advancing Circular Economy Practices in the Global Textile Industry https://doi.org/10.1007/978-981-97-5341-3_15

Batool, S. A., & Ch, M. N. (2009). Municipal solid waste management in Lahore city district, Pakistan. Waste Management, 29(6), 1971–1981. https://doi.org/10.1016/j.wasman.2009.01.015

Blomsma, F., & Brennan, G. (2017). The emergence of circular economy: A new framing around prolonging resource productivity. Journal of Industrial Ecology, 21(3), 603–614. https://doi.org/10.1111/jiec.12603

Cobo-Ceacero, C. J., Cotes-Palomino, M. T., Martínez-García, C., Moreno-Maroto, J. M., & Uceda-Rodríguez, M. (2019). Use of marble sludge waste in the manufacture of eco-friendly materials: Applying the principles of the circular economy. Environmental Science and Pollution Research, 26(35), 35399–35410. https://doi.org/10.1007/s11356-019-06540-2

DAWN. (2015, March 9). Drags in marble industry's growth. DAWN News. https://www.dawn.com/news/

de Medeiros, W. R. P., Neto, O. M. M., & Luz, P. M. S. G. (2023). Utilizing marble and granite industry waste in asphalt mixtures for enhanced road performance and sustainability. Case Studies in Construction Materials, 19, e03049. https://doi.org/10.1016/j.cscm.2023.e03049

Durrani, N., Raziq, A., Mahmood, T., & Khan, M. R. (2024). Barriers to adaptation of environmental sustainability in SMEs: A qualitative study. PLOS ONE, 19(3), e0298580. https://doi.org/10.1371/journal.pone.0298580

Ellen MacArthur Foundation. (2024a). Circular economy principles. Retrieved from https://ellenmacarthurfoundation.org/

Ellen MacArthur Foundation. (2024b). What is a circular economy? Retrieved from https://ellenmacarthurfoundation.org/

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. (2023). The national circular economy strategy: Fundamentals for the process of transforming to a circular economy. Berlin: Federal Government of Germany. https://www.bundesumweltministerium.de/en/download/fundamentals-of-the-national-circular-economy-strategy-nkws

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2012). Towards a national circular economy indicator system in China: An evaluation and critical analysis. Journal of Cleaner Production, 23(1), 216–224. https://doi.org/10.1016/j.jclepro.2011.07.005

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2013). Towards a national circular economy indicator system in China: An evaluation and critical analysis. Journal of Cleaner Production, 23(1), 216–224. https://doi.org/10.1016/j.jclepro.2011.07.005

Government of China. (2008). Circular Economy Promotion Law of the People's Republic of China. Beijing: National People’s Congress. https://www.lawinfochina.com/display.aspx?id=7025&lib=law

Government of China. (2016). The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016–2020). Beijing: Central Compilation & Translation Press. https://en.ndrc.gov.cn/policies/202105/P020210527785800103339.pdf

Government of the Netherlands. (2023a). National Circular Economy Programme 2023–2030. The Hague: Government of the Netherlands. https://www.government.nl/documents/reports/2023/09/27/national-circular-economy-programme-2023-2030

Government of the Netherlands. (2023b). Accelerating the transition to a circular economy. The Hague: Government of the Netherlands. https://www.government.nl/topics/circular-economy/accelerating-the-transition-to-a-circular-economy

Iqbal, A., Abdullah, Y., Nizami, A. S., Sultan, I. A., & Sharif, F. (2022). Assessment of solid waste management system in Pakistan and sustainable model from environmental and economic perspective. Sustainability, 14(22), 15310. https://doi.org/10.3390/su142215310

Iqbal, A., Yasar, A., Tabinda, A. B., Haider, R., Sultan, I. A., Kedwii, A. A., Chaudhary, M. M., Sheikh, M. M., & Nizami, A. S. (2023). Waste as resource for Pakistan: An innovative business model of regenerative circular economy to integrate municipal solid waste management sector. Sustainability, 15(7), 6281 https://doi.org/10.3390/su15076281

Iqbal, J., Raza, M. H., Imran, M., & Ullah, I. (2023). A critical analysis of implementation of economic & industrial development strategies in Pakistan. NIPA Peshawar. https://nipapeshawar.gov.pk/KJPPM/PDF/CIP/36th/js5.pdf

Kuoribo, E. & Mahmoud, H. 2022. Utilisation of waste marble dust in concrete production: a scientometric review and future research directions. Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2022.133872

Khan, F., & Ali, Y. (2022). A facilitating framework for a developing country to adopt smart waste management in the context of circular economy. Environmental Science and Pollution Research, 29(52), 79211–79223. https://doi.org/10.1007/s11356-022-22162-9

Khan, M. A. (2018). Mitigation Plan for Identified Problems Faced by the Marble Industry in Khyber Pakhtunkhwa. DOI:10.17582/journal.jeas/39.1.77.86

Khan, N. H., Nafees, M., Khan, S., Alzahrani, E., & Khan, M. A. (2025). Marble production and environmental pressure. Research Square. https://doi.org/10.21203/rs.3.rs-6031990/v1

Khan, N. H., Nafees, M., Saeed, T., Zuljajal, F., Akbar, H., & Rehman, A. (2023). Marble production and environmental pressure: A case study of Hayatabad Industrial Estate Peshawar, Pakistan. University of Swabi. https://doi.org/10.21203/rs.3.rs-3244303/v1

King, H. M. (2025). Marble – A comprehensive guide to this elegant stone. Geology.com. https://geology.com/rocks/marble.shtml

Kishore, I. S., & Chowdary, C. M. (2015). A study on waste utilization of marble dust in high strength concrete mix. International Journal of Civil Engineering and Technology, 6(12), 1–7. https://www.researchgate.net/publication/287994273

Knäble, D., de Quevedo Puente, E., Pérez-Cornejo, C., & Baumgärtler, T. (2022). The impact of the circular economy on sustainable development: A European panel data approach. Sustainable Production and Consumption, 34, 233–243. https://doi.org/10.1016/j.spc.2022.08.013

KrWG. (2012). Act to promote circular economy and safeguard the environmentally-compatible management of waste (Circular Economy Act). Federal Law Gazette I, 212. https://bit.ly/49Kij72

Ministry of the Environment. (2021a). Strategic programme to promote a circular economy. Helsinki: Government of Finland. https://ym.fi/en/strategic-programme-to-promote-a-circular-economy

Ministry of the Environment. (2021b). Government resolution on the strategic programme for circular economy. Helsinki: Government of Finland. https://bit.ly/3K2fOCC

Momentum Contributing Writer. (2025). The economic barriers to a circular economy. The Momentum. https://www.themomentum.com/roundups/the-economic-barriers-to-a-circular-economy

OECD. (2016). Extended producer responsibility: Updated guidance for efficient waste management. OECD Publishing. https://doi.org/10.1787/9789264256385-en

Ogunmakinde, O. E. (2019). A review of circular economy development models in China, Germany and Japan. Recycling, 4(3), 27. https://doi.org/10.3390/recycling4030027

Pakistan Today. (2023, March 5). Over 6,000 marble factories in KP face closure amid surging electricity prices. Pakistan Today. https://bit.ly/49D5JX4

Pechuho, A. A. (2024). Integrating circular practices in the planning, design and construction of urban built environment: A shift in the traditional approach for the climate change. https://www.theseus.fi/bitstream/handle/10024/880889/Pechuho_Altaf.pdf?sequence=2

PMC. (2021). Circular economy of construction and demolition waste. Retrieved from https://pmc.ncbi.nlm.nih.gov/

Sariatli, F. (2017). Linear economy versus circular economy: A comparative and analyzer study for optimization of economy for sustainability. Visegrad Journal on Bioeconomy and Sustainable Development, 6(1), 31–34. https://doi.org/10.1515/vjbsd-2017-0005

SCCIP. (n.d.). Khyber Pakhtunkhwa: A province rich of natural resources. Small & Cottage Industries Department. https://sccip.com.pk/downloads/Mines_&_Minerals_Resources_in_KPK.pdf

Shah, H. H., Amin, M., Pepe, F., & Tregambi, C. (2024). Sustainable waste management and waste-to-energy in the context of a circular economy through various waste management technologies. Environmental Science and Pollution Research, 31(15), 20555–20572. https://doi.org/10.1007/s11356-024-34567-x

Shah, W., Nafees, M., & Iqbal, M. (2015). Evaluation of marble slurry waste for preparation of commercial grade cement. Journal of Engineering and Applied Sciences, 34(1), 28–37. DOI:10.25211/JEAS.V34I1.12

Singh, M., Srivastava, A., & Bhunia, D. (2017). An investigation on effect of partial replacement of cement by waste marble slurry. Construction and Building Materials, 134, 471–488. https://doi.org/10.1016/j.conbuildmat.2016.12.155

Sitra. (2016). Leading the cycle: Finnish road map to a circular economy 2016–2025. Helsinki: The Finnish Innovation Fund. https://arkisto.sitra.fi/en/projects/leading-the-cycle-finnish-road-map-to-a-circular-economy-2016-2025/

StoneNews.eu. (2024). Pakistan: Marble City to be big opportunity for investors. Stone News. https://stonenews.eu/pakistan-marble-city-to-be-big-opportunity-for-investors/

Sufian, M., Ullah, S., Ostrowski, K. A., Ahmad, A., & Zia, A. (2021). An experimental and empirical study on the use of waste marble powder in construction material. Materials, 14(14), 3829. https://doi.org/10.3390/ma14143829

Tel Aviv University. (2024). Circular economy: Principles, benefits, and applications. Tel Aviv University Press. https://il.boell.org/en/2024/03/09/understanding-circular-economy-principles-benefits-and-applications

The Express Tribune. (2024, July 11). K-P in deal to harness marble waste. The Express Tribune. https://tribune.com.pk/story/2463209/k-p-in-deal-to-harness-marble-waste

Twice Commerce. (2023). Product life cycle management as a catalyst for circular business models. Twice Commerce Reports. https://www.twicecommerce.com/blog/product-life-cycle-management-as-a-catalyst-for-circular-business-models

U.S. General Services Administration. (2016). Marble: Characteristics, uses and problems. Washington, DC: GSA. http://bit.ly/3KnFytb

Uddin, A., Ali, Y., Sabir, M., Petrillo, A., & De Felice, F. (2023). Circular economy and its implementation in cement industry: A case point in Pakistan. Science of the Total Environment, 854, 158706. https://doi.org/10.1016/j.scitotenv.2022.158706

Van Leeuwen, C. J., de Vries, E., Koop, S. H. A., & Roest, K. (2018). The Energy & Raw Materials Factory: Role and potential contribution to the circular economy of the Netherlands. Environmental Management, 61(5), 786–795. https://doi.org/10.1007/s00267-018-1008-9

Velenturf, A. P. M., & Purnell, P. (2021). Principles for a sustainable circular economy. Sustainable Production and Consumption, 27, 1437–1457. https://doi.org/10.1016/j.spc.2021.03.021

Waheed-ur-Rehman, Riaz, M., Ishaq, M., & Faisal, M. (2018). Utilization of marble waste slurry in the preparation of bricks. Journal of the Pakistan Institute of Chemical Engineers, 42(1), 47–54. https://www.researchgate.net/publication/325711319

Xiamen SRS Trading Co., Ltd. (2024). The marble industry: Embracing sustainability and innovation. News Report. https://www.srsstone.com/news/the-marble-industry-embracing-sustainability-81121109.html