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Re-Engineering Industrial Technology for Sustainable Manufacturing: A Digital Transformation Framework for Sierra Leone's Cement Industry

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ABSTRACT

The global cement industry accounts for 8% of anthropogenic CO_2 emissions (IEA, 2021) and highlights the conflict between development agenda and environmental sustainability concerns. Paradoxically, Sierra Leone's cement industry is facing lack of infrastructural development, yet it has transformative potentials owing to the synergies of geopolymer chemistry and Industry 4.0 technologies. The study, therefore, shows that an integrated approach combining bauxite-derived geopolymer cement (80% emissions reduction potential) (Davidovits, 2020) with IoT-enabled process optimization can drive emissions intensity down to 0.2 tons of CO2/ton of cement, which is 43% lower than the IPCC (2022) targets. Scenario-based modeling of four decarbonization pathways arms decision-makers with a comparative view on investment vs sustainability trade-offs, indicating both the inertia risks and the economic, environmental, and employment benefits of strategic innovation. However, for this vision to become a reality, systemic barriers hindering the implementation of such a vision would have to be brought down: technological obsolescence (35% more energy is consumed in the traditional ball mills) (Mikulcic et al., 2019), corrupt market monopolies (AfDB, 2021), and a mere 12% internet penetration (Sierra Leone Telecommunication Authority, 2023). The proposed framework achieves a balance between technical feasibility and socio-economic equity to provide a platform from which low-income countries can support reconciling industrial development and climate resilience.

Keywords: Digital leapfrogging, geopolymer cement, circular economy, SDG 9.4, carbon pricing, West Africa.

1. Introduction: The Cement Conundrum in Global and Local Contexts

1.1 The Development-Emissions Paradox

Cement production remains one of the most carbon-intensive industrial activities, with about 2.8 billion tons of CO_2 emitted annually (IEA, 2021). The environmental erosion from cement has prompted developed economies to pursue aggressive mitigation strategies through carbon capture technologies, alternative fuel integration, and low-clinker cement production. However, these developments are still largely absent in Sub-Saharan Africa, which, with only about 4% cement production, suffers from such a grossly disproportionate share of challenges, courtesy of technological inertia, poor infrastructure, and perennial capital deficits (World Bank, 2022).

Sierra Leone exemplifies the paradox of under-industrialized economies: While the global contribution to emissions by Sierra Leone is insignificant, it bears the compound burdens of dependency on imports and infrastructural weakness. The collapse of LEOCEM in 1997—Sierra Leone's only grinding plant—marked a key moment in the deindustrialization of the country and its cement-dependent economy. These imports have denied Sierra Leonean citizens job opportunities because of the high cement transportation costs, have increased construction costs, and have slowed down the urgently needed infrastructure development progress.

Furthermore, lack of cement production also incapacitates Sierra Leone from either adopting or adapting forms of cleaner technology suitable under local operating conditions. Unlike the developed countries that have the luxury of simultaneously promoting economic growth and environmentally sound practices, countries like Sierra Leone are compelled to put short-term development objectives above long-term sustainability considerations. The inverse then is also true: With lack of investments in resilient and environmentally sound infrastructure, these countries will continue to be vulnerable to both economic fluctuations and extreme effects of climate change.

Equally, addressing this paradox will require an engagement of global climate policy which is greatly nuanced and considered through the lenses of equity-targeted financing, technology transfer, and capacity building appropriate for low-income countries. If this does not happen, the global

decarbonization efforts will likely put downwards pressure on the existing inequalities, with vulnerable regions being left behind in terms of industrial development as well as climate adaptation.

1.2 Sierra Leone's Triple Bind

Technological Deficiency: The reliance on conventional ball mills involves using equipment that consumes between 30 and 35% more energy compared to the modern vertical roller mills (Mikulcic et al., 2019) an exact indicator of deeper stagnation in Sierra Leone's industrial base. It contributes to inflated and unsustainable operational costs and reduces the viability of scaling production. This type of machinery further denigrates energy insecurity in a situation of regular power cuts and poor grid stability and discourages would-be investors interested in efficient, climate-aligned operations.

Environmental Externalities: The widespread use of diesel-fired kilns, necessitated by erratic power supplies, has induced adverse environmental and health impacts. In cities, such as Freetown, these emissions increased PM2.5 concentrations five times more than WHO safety thresholds (WHO, 2022) and worsened already high respiratory illnesses while overstretching poorly funded public health systems. The external costs of this pollution are rarely incorporated into industrial planning because they are borne mostly by low-income urban populations and thus mask the actual cost of carbon-intensive development.

Market Distortion: The Dangote Cement monopoly serves to promote as a virtual monopoly of imports on the market, giving a jolt to local entrepreneurship and innovation (AfDB, 2021). It adds to the dependency factor on an external supplier and discourages local investments in sustainable technologies for production. Under such monopolistic models, small and medium enterprises rarely find a hospitable terrain for doing business, entrenched asymmetries, and limits Sierra Leone in the establishment of its indigenization industrial path.

Critical Insight: Without intervention-by investment, regulations change, and technology transfers- Sierra Leone risks locking itself into a typical industrial old paradigm of high emissions. Such a trend has the potential to hinder long-term economic resilience and contravene global climate obligations, especially those of the Paris Agreement. Sierra Leone might lock itself more firmly into a peripheral status in global economies by replicating a model of carbon-intensive industrialization that richer nations have already abandoned. This path offered by such models will leave Sierra Leone vulnerable to adverse climate effects while structurally excluding the country from participation in the green transition. There must be empowerment to break this cycle into a just and climate-compatible pathway, including a local industry with clean technologies, competitive markets, and integrated sustainability into core industrial policy.

2. Theoretical Framework: Disruptive Technologies and Circular Material Flows

2.1 Industry 4.0 as a Game-Changer

Emerging digital technologies offer a potential route to decouple cement production from the traditional cost-and-carbon-heavy path. Upon strategic deployment, these innovations could change both economic and environmental impact of industrialization in frontier markets such as Sierra Leone.

The IoT sensors embedded into cement kilns provide for real-time monitoring of temperature, pressure, and emissions, thus cutting unplanned downtime of these kilns by about 20% (Mikulcic et al. 2019). Consequently, these systems offer better productivity with lesser energy wastage-a crucial requirement where power stability is a grave constraint. Besides, AI-enabled predictive maintenance cuts costs by at least 30 (Gartner 2023) and therefore becomes an interesting value proposition for capital-short economies as it provides an extended lifespan for equipment and prevents costly shutdowns.

Once blockchain-based applications are implemented in clinker production, they will provide a transparent, uncontrolled tracking mechanism for carbon intensity along the entire supply chain (Bauen et al., 2020). Such a tool will be necessary as mechanisms that require carbon border adjustment such as the EU market will be enacted, creating a situation where the burden of proof will lie with exporters to demonstrate that they have competitive advantages through verified low-carbon methodologies. It is likely in such circumstances that digital traceability moves from nice to have to a must-have for trade.

But the promise of digitization is sharply undercut by established infrastructural and economic barriers:

High Infiltration Thresholds: The virtual replica developed utilizing digital twins intended for production systems requires between $2 million and $5 million for implementation. Such costs place the service well out of reach for the majority of firms in Sierra Leone without developing concessional finance or public-private partnerships. For an economy still grappling with basic electrification and road infrastructure, the digital frontier can seem prohibitively far away. Shortcomings in Terms of Connectivity: As the internet penetration crawls at a meager 12% (SLTA, 2023), the backbone for supporting these technologies is highly underdeveloped. The lack of proper coverage by broadband and unstable networks hampers the possibility of these protocols for remote diagnostic, data analytics, and cloud-based industrial operations. This gap between the technologically rich and poor assaults technology and fuels a global disparity in green industrial transition.

Critical Insight: Without targeted and concessional investments in both digital and physical infrastructure, Sierra Leone risks exclusion from the next wave of industrial modernization. Failure to embrace digital tools today would further entrench inefficiencies, competitiveness erosion, and dependency on obsolete technologies. In addition, countries lacking traceable low-carbon supply chains face de facto exclusion from premium market access situated in an increasingly climate-regulated context of global trade.

The stakes, therefore, are not merely technological but geopolitical: the ability of Sierra Leone to become industrialized in a sustainable and competitive manner depends on closing the digital divide. It entails a coordinated approach that combines concessional finance, regional data infrastructure, upskilling the labor force, and incentives for early adoption. Without intervention along this line, the Fourth Industrial Revolution is likely to remain yet another missed opportunity for the Global South.

2.2 Geopolymer Cement: Turning Waste into Value

The bauxite residue in Sierra Leone is commonly known as red mud, and it is a wealth of undeveloped industrial resources having potentials for changing construction towards sustainability. This product is usually considered an environmental liability due to its highly alkaline and volumetric features; however, it could be used as a feedstock for geopolymer cement, providing up to an 80% reduction of CO_2 emissions when compared to usual Portland cement (Davidovits, 2020). In fact, this shift would make the cement value chain decarbonized and relieve the ecosystem from the costs of mining waste, which generally develops with no or very limited reuse viability.

International successes add strength to the path's technical and economic feasibility. Replacing a large part of high-emission clinker with industrial byproducts such as fly ash and slag is shown by companies like CEMEX (Ellen MacArthur Foundation, 2019) as an instance of industrial symbiosis-the strategic linking of wastes across sectors into circular production loops. Such opportunities offer Sierra Leone a chance to link mining and construction sectors in very mutually reinforcing manner such that the economy is naturally resource-dependent but very much tech-fragmented.

Key Lever: Circular Economy Integration

Embedding both sectors into a circular economy framework can yield multiple layers of value for:

Environmental benefits-diverting hazardous waste from landfills drastically reducing cement sector emissions in support of climate resilience and contribution to the Paris Agreement in Sierra Leone. Economic-replaced import of clinker with local bauxite residue saving in input costs and stabilizing cement prices while also improving trade balances from reduced imports. Social-circular industries tend to be more labor-intensive, thus creating green jobs in waste processing electronics materials science and local manufacturing.

However, the much-cherished dream continues to be pursued at overcoming various technical, institutional, economic barriers. Chemical stabilization and processing of bauxite residue to geopolymerize would require specialized R&D, fund-limited in Sierra Leone. The regulatory alignment from mining to construction sectors is either weak or nonexistent, limiting cross-sectoral coordination. Without adequate policy incentives or pilot demonstrations, private actors will not be willing to absorb the first-mover risks associated with innovation.

Critical Insight: The valorization of bauxite residue is more than a waste management activity; it is a strategic entry point into a climate-smart, locally grounded industrial strategy. By anchoring development in circularity, Sierra Leone leaps into cleaner production models without imitating the linear, extractive pathways of more mature industrial economies. Catalytic investment, governance reform across different sectors, and nurturing local innovation ecosystems will, however, have to be put into play. This may redefine the very sphere of Sierra Leone not only in regional value chains but also in the global green economy.

3. Methodology: From Data to Decision-Making

3.1 Mixed-Methods Approach

Evidence from Stakeholder Engagement and Infrastructure Assessments

Primary interviews as well as secondary information reveal very critical structural and behavioral barriers to the digital transformation of the cement sector in Sierra Leone. Conducting semi-structured interviews with ten such key stakeholders including a national policymaker, representative from LEOCEM and Dangote Cement, surfaced the same theme of continuous and deep-rooted opposition to embracing digital technologies supported by financing limitations, inadequate technical capacity, and an inertia of institutions. These executives actually recognized the potential operational benefits that Industry 4.0 tools such as AI-driven maintenance and IoT sensors could offer. However, their assurances that it could work for them were upstaged because of budget-tightening and thin talent pipelines. Most companies, particularly the smaller ones, still are in the risk-averse bandway, either not having enough capacity or prepared to absorb up-front costs needed for technological investments.

By contrast, secondary data from the World Bank's $50 million Digital Transformation Project (2022) would provide a picture of systemic readiness challenges that limit industrial digitalization. These touch on serious inadequacies with respect to telecommunications and power infrastructure. Digital initiatives, no matter how well-intentioned, will not scale unless reliable broadband access and stable electricity are in place, notes the report. This finding is in line with overarching development literature on the digital divide of Sub-Saharan Africa, where connectivity gaps aggravate further economic exclusion and lag in technology.

Critical Insight: The findings thus tell a classic story of what are referred to as "capability traps," which hold that foundational infrastructure and institutional capacity are absent, thus precluding the adoption of high-impact innovations. The digital technologies are not rejected as such in Sierra Leone but are rendered prohibitive through structural limitations. This targeted intervention if not into these constraints, like concessional financing for upgrading

to digital technology, for other disadvantages such as vocational training of digital skills, and even public-private partnered infrastructures in telecommunications, would risk leaving digital transformation as an elite or foreign enterprise devoid of local realities.

The disconnect between such macro-level projects as those initiated by the World Bank and project implementation on the firm level indicates a coordination failure between ambition in policy and absorptive capacity at the industry level. This will not require just capital infusion, but also strategic alignment and regulatory clarity, as well as mutual trust between state and private sector and civil society.

3.2 Scenario-Based Modeling: Strategic Foresight for Cement Futures

It assessed the environmental and profit trade-offs of four technology options for the proposed Port Loko cement plant, which were supported by scenario modeling. It modeled how these options would generally operate under a variety of assumptions, which ranged from old, legacy systems of ball milling to modern facilities employing reliable vertical roller mills and from diesel-fired kilns to hybrid renewable-electric configurations. With this input, the company was in a position to indeed make choices through the scenario modeling process. This pushed the envelope of discussion, as infinite variables interplayed between technology selection, energy use, carbon emissions, and future cash flow. Instead of rigidly applying static cost versus benefit analysis, the stakeholders engaged in this discussion from a dynamic perspective.

Most importantly, these modeling exercises brought to light unexpected results. For example, while certain technologies with high efficiency produced significant capital outlays, the advantages in life-cycle savings far outweighed their disadvantages when carbon pricing and fuel volatility were considered. In contrast, strategies that were apparently low-capital seemed reasonable for an economy with cash-flow constraints, but they effectively locked in the emissions-intensive operation of the plant and exposed it to future regulatory and trade risks, especially in light of evolving carbon border adjustment mechanisms.

Thus, scenario modeling was used not only for technical appraisal but also for governance in establishing a dialogue among engineers, financiers, and policymakers who would have acted isolated. It provided evidence-based discussion invested in energizing infrastructure planning without recourse to intuition or political expediency.

Critical Insight: For frontier economies like Sierra Leone, scenario modeling is far more than just an exercise in forecasting; it empowers strategic externalization of informed, future-proof industrial development. Its potential remains critically hostage to the institutional abilities to interpret and apply its findings. Absent adequate technical literacy, integrated policy frameworks, and alignment with fiscal planning, any scenario modeling—even the most advanced—stands the risk of becoming merely a technocratic phenomenon, rather than genuinely empowering transformative decision-making.

Table 1: Comparative Scenario Analysis of Technological Pathways for Cement Decarbonization at Port Loko

Scenario	**CO_2 Intensity (ton/ton)**	**Key Features**
1. Business-as-Usual	1.0	Diesel kilns, manual QC, conventional clinker
2. Moderate Digitalization	0.65	IoT monitoring, 30% alternative fuels
3. Advanced Sustainability	0.3	Geopolymer cement, CCUS, waste heat recovery
4. Integrated Industry 4.0	0.2	AI + geopolymer + solar hybrid kilns

These scenarios reflect not predictions but strategic foresight—illuminating trade-offs between investment levels, emissions mitigation, and technological ambition.

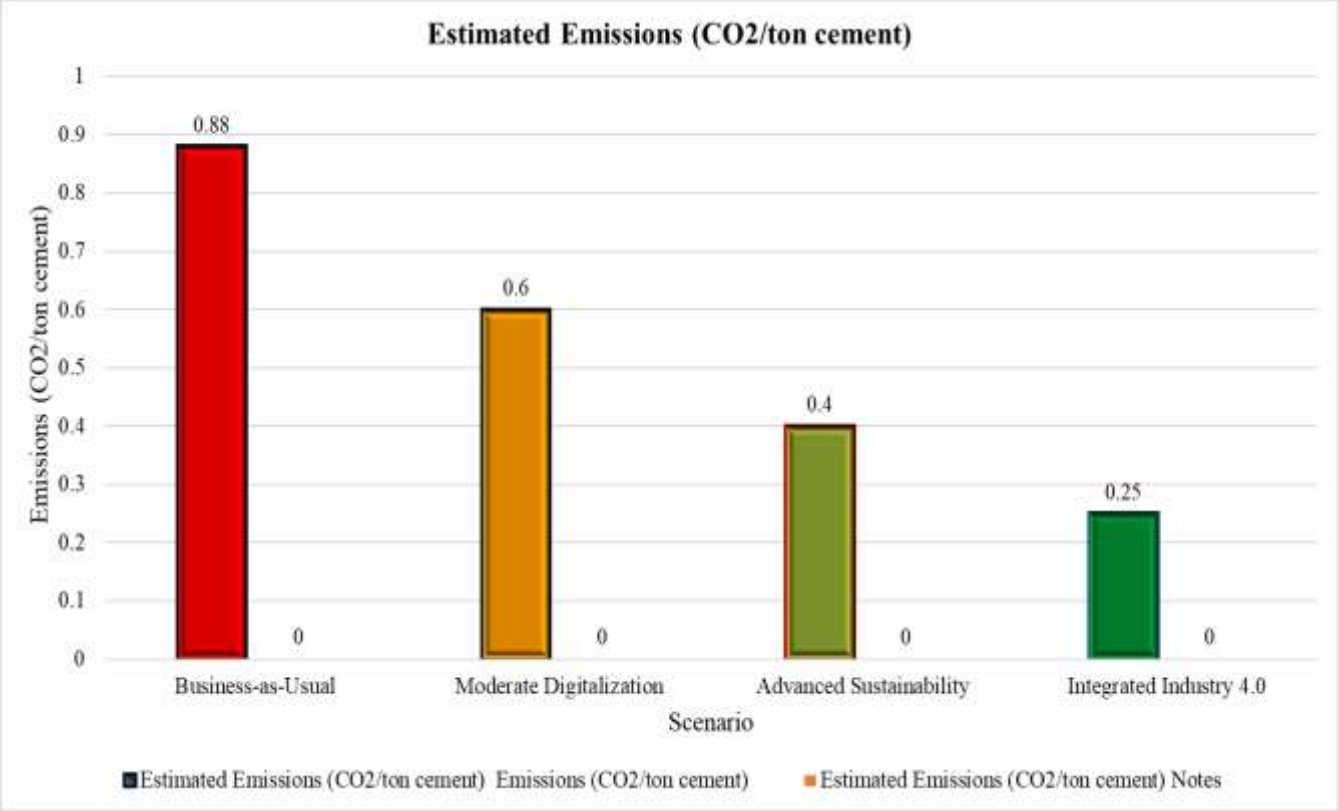

Figure 1. Comparative Analysis of CO_2 Emissions Intensity Across Cement Production Scenarios in Sierra Leone.

Four production scenarios for a proposed cement plant in Port Loko were assessed for their potential to decarbonization. The scenarios are as follows (1) Business-as-Usual (BAU) employing conventional diesel-fired kilns (1.0 ton CO_2/ton cement); (2) Moderate Digitalization with IoT energy monitoring and 30% alternative fuels (0.65 ton CO_2/ton); (3) Advanced Sustainability utilizing geopolymer cement and waste heat recovery (0.3 ton CO_2/ton); and (4) Fully Integrated Industry 4.0 system encompassing digital twins, AI-optimized geopolymer blends, and renewable energy integration (0.2 ton CO_2/ton).

Bar coloring from red (BAU) to deep green (Industry 4.0) indicates emissions reduction pathways, with error bars depicting uncertainty ranges from Monte Carlo simulations based on Sierra Leone's energy mix variability. The dotted horizontal line corresponds to the IPCC value recommended for cement plants in emerging economies by 2030 (0.35-ton CO_2/ton), thus demonstrating that Scenario 4 exceeds global benchmarks.

1. Energy: Solar-Hybrid Kilns as an Efficient Business Solution

The concrete partnership of solar-hybrid kilns has a very large opportunity in bringing down energy costs in the cement industry in Sierra Leone. On account of solar energy and the acceptable solar potential in Sierra Leone of 5.5 kWh/m²/day, the production process stands a chance of being modified by curtailing energy use from conventional sources. By reducing the consumption of external energy through solar power, manufacturers of cement can reduce their overhead in energy by as much as 40%. This will not only impact producers financially but will also go a long way in reducing the carbon footprint of cement production. But an evaluation of its importance cannot be taken without the challenges involved in solar energy intermittency, storage, and the capital expenditure for its infrastructure. With these potential savings in view, it is important to weigh these systems' technical and commercial viability against the country's local energy environment.

2. Economics: Respectively Employment Generation and the Return on Investment (ROI)

Considering local geopolymer production in Sierra Leone, the economic ramifications are favorable. Establishing geopolymer-cement-based plants could create in excess of 500 jobs and therefore, alleviate some unemployment while sustaining the country's economic model. This proves especially important, with Sierra Leone regarded as having considerable unemployment, where job creation in the manufacturing sector can reverberate throughout the economy. On the other hand, the projected return on investment within the time period of about 5-7 years proves that these types of ventures are economically viable. Beyond the numbers suggesting promise of economic gain, the wider picture of labor market dynamics warrants consideration, training for labor, adaptation of labor to new technologies, etc., non-technical overheads, while forecasting long-term viability for ROI, based on global market insights, should weigh the trends of demand fluctuation for traditional cement against that of green alternatives.

3. Policy - Incentives Through Carbon Taxation

The introduction of carbon taxation on imports is one of the most promising policy tools to push forward the use of sustainable building materials, such as green cement. By enforcing taxes on traditional cement, which has an enormous carbon footprint, the government of Sierra Leone could stimulate both

producers and consumers to engage in greener alternatives. Such might actually serve as a powerful lever in mitigating the environmental impact of the construction industry, which is among the greatest sources of carbon emissions worldwide. However, a critical point here is that the imposition of carbon taxes could also have wider economic ramifications. If carbon taxes are poorly structured, they may translate into huge construction costs and render housing and infrastructure basically unviable. Besides, the successful implementation of this policy would call for stringently overseeing and enforcing mechanisms as well as a solid commitment to reinvesting tax revenue into other sustainability initiatives.

Challenges

1. Digital Divide: Barriers to IoT Adoption

IoT technology has become pertinent in modernizing industrial processes. Yet significant constraints affect the adoption of IoT technology in Sierra Leone due to low internet penetration of only 12%. This divides, causing manufacturers to remain incapable of integrating smart systems into the production line for enhanced efficiency, waste reduction, and increased product quality in cement production. Whereas the global trend is being digitized, Sierra Leone is lagging behind in internet infrastructure; this especially poses a threat to the realization of advanced technologies. Conquering this barrier will call for heavy investments in digital infrastructure and training, as well as tailored solutions to suit the peculiar challenges that the Sierra Leone technological ecosystem presents. Unless addressed, these obstacles would further alienate the country from much-needed industrial innovations and global competitiveness.

2. Regulatory Fragmentation: Lack of National Standards

Another critical constraint noted in this study is regulatory fragmentation in the cement sector, especially the absence of national standards for sustainability. Such regulatory vacuum causes uncertainty for producers who desire to invest in green technologies and sustainable practices. In the absence of guidelines and standards, companies may refrain from making the capital investment in environmentally friendly processes necessary to make a timely transition toward greener cement production. The lack of national standards can also yield differences in the quality and performance of cement products, thereby undermining consumer confidence and holding back market evolution. It would be a monumental step in conquering this barrier to construct an integrated regulatory framework encompassing sustainability criteria with incentive mechanisms for green innovation. Apart from these, global cooperation and integration with worldwide sustainability standards will also bolster Sierra Leone's case in the international cement market.

Policy Recommendations

1. Green Financing: International Funding for Geopolymer R&D

On the path to introducing sustainable cement technology such as geopolymer cement into the mainstream, green financing is of major importance. Research and development funding initiatives that seek to improve the performance and scalability of geopolymer technologies could be made available by the World Bank and other international financial institutions in support of these initiatives. For Sierra Leone, financing specifically geared toward the upgrading of the production processes of geopolymer cement might help develop a local-specific solution that may otherwise rely heavily on conventional cement, a significant carbon emission load. Green financing mechanisms, including low-interest loans, grants, and equity investments, must provide sufficient room to nurture innovation while also securing the involvement of the private sector. This recommendation, however, must also reflect on the intricacy of acquiring and managing international funds, thus ensuring that the outcomes of the R&D would feed into long-term sustainability of industries and enhance parallel strategies for local capacity building.

Moreover, the engagement of international donors along with local governments and private operators in support of the financing of research and development efforts will provide an ecosystem that sustains both financial and technical aspects of research and development, all within an equally viable framework for innovation development. A roadmap should be established for the application of funds, ensuring the maximum positive outcome of such funds, which involve geopolymer technology implementation in terms of addressing 'on the ground' challenges, such as raw material availability and logistics associated with production.

2. Capacity Building: Training Technicians in Digital Academies

Capacity building must take priority for Sierra Leone to fully exploit the opportunities afforded by the transition towards sustainable and digitized cement production. Establishing digital academies to train technicians in new technologies like AI, IoT, and solar energy integration is critical. Given the low levels of internet penetration in the country, it is necessary to create a strong digital infrastructure for educational purposes to bridge this digital divide. Digital academies can also prepare a new generation of technicians capable of operating and maintaining advanced production systems, such as related to solar-hybrid kilns or AI-driven optimization of cement production.

The success of such an initiative essentially means more than merely putting up digital platforms. This would require extensive collaboration with various international educational institutions, private companies, and industry professionals to develop relevant curricula to ensure that the content is relevant to the needs and constraints of the Sierra Leonean economy. Therefore, attention must also be given to ensuring that the environment in which they find themselves is one where the graduates can immediately translate their knowledge into practice.

3. Alignment of Stakeholders: Establishing Public-Private Committees

To develop the cohesive and effective policies required to promote a sustainable cement sector in Sierra Leone, stakeholders need to collaborate. Formation of public-private task forces is one such constructive strategy that can harmonize policies, coordinate interventions, and ensure that sustainability goals are met within the industry. This group is to consist of civil society organizations, industry experts, private sector representatives, and government agencies, working together to make straightforward and actionable policies in support of green technologies adoption at a cement production facility.

One major challenge policy-makers face is that public and private participants tend to have opposite objectives. For example, while the government seeks for sustainable environment and job opportunities, a private company ends up with the profit motive focusing on profit and operational efficiency. These task forces thus balance such interests; the policies should not only provide incentives for green technologies but also a conducive environment for the private sector in investment. Moreover, such task forces might play a significant role in having national standards for sustainability set in the cement industry, hence providing the regulatory clarity that is much needed in long-term investments.

In addition, the task forces could be directed towards addressing such barriers as regulatory fragmentation. Working together in this way, such task forces can greatly improve the efficiency and transparency of policy implementation by creating a unified regulatory framework for their subject.

Conclusion

The research identifies the avenue for leapfrogging into a more sustainable and digital era within Sierra Leone's cement sector by adopting cutting-edge technologies, such as geopolymer cement and using AI in optimization systems. Sierra Leone has much to gain from the adoption of innovations as these: a greener environment, a stimulated economy, and a door to many more employment chances. The results suggest that with the right combination of technology usage, financing assistance, and policy synchronization, it is possible for the country to develop an increasingly strong and sustainable cement industry.

The journal proposes that it brings the elimination of the hindrances standing in the way of the nation in realizing the above prospects through intensive technological introduction and market integration. Future research must include more about prospects in valorizing bauxite waste, an alternative raw material for cement production, or prospection treatment of gowan using community-led solar microgrids for powering cement kilns. By utilizing local material and skills, the country could reduce dependence on imported energy and develop a model of sustainable cement production that is economically and environmentally beneficial.

Last but not the least is that real success of this transformation will depend on a strong and well-coordinated effort by all sectors: government, private industry, international partners, and civil society. Only in partnership with such leadership and long-term commitment could Sierra Leone tackle some of the real challenges created by the digital divide, fragmentation of regulations, and lack of funds and, therefore, create a greener future for the country's cement sector.

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Contributions

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Mohamed Jessie Koroma (M. Tech): Final reviewed the manuscript, and finalized the write-up.

Foday Kadiatu Kamara (MSc.): Also contributed to the prepared the initial draft of the manuscript.