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Energy Efficiency Increase and Emission Reduction in Design of Cement Manufacturing Plants in Iran: a LEED-Based Approach*

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ABSTRACT

As the cornerstone of modern construction, cement deals with concerns about energy consumption and pollution. This study compares the international approaches of EcoCem and Larestan Cement Manufacturing Plant within the “LEED” framework. Among the rising environmental worries, this study has been conducted to evaluate energy efficiency and greenhouse gas emissions in cement manufacturing plants. In particular, this study compares EcoCem International Company and Larestan Cement Plant to identify innovative techniques and improvement potential within the LEED Framework. The main question asks which strategy can effectively increase sustainability in cement production. Comparative research facilitates a comprehensive analysis of energy use, emission, operational methods, reduction of wastes, economic aspects, stakeholders’ perceptions, and environmental impacts. Quantitative data, including energy bills and greenhouse gas emission reports, would complement the qualitative insight obtained from interviews with the factory’s personnel and society members. Statistical analysis and thematic investigation are used to encode the findings. This study evaluates two cement factories based on distinctive techniques using a comparative analysis. The multifaceted approach of the International EcoCem Company for energy efficiency and reduction of greenhouse gas emissions is compared with the methods used by the Larestan Cement Plant. Quantitative measurements evaluate the differences, successes, and challenges occurring in energy profiles and their emissions, and finally provide practical advice. International Ecocem Company appears as a pioneer in energy efficiency and provides novel techniques in line with LEED principles. These techniques include high-tech production methods, Carbon Capture and Storage (CCS) techniques, the use of renewable energies, alternative fuels, waste heat recovery, and comprehensive monitoring. On the contrary, Larestan Cement Plant’s attempts seem less than the comprehensive techniques, requiring fundamental revision to be matched with sustainability goals.

Keywords: Cement Production, Energy Efficiency, Emission Reduction, LEED Principles, Sustainable Techniques.

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1. INTRODUCTION

Architecture, energy, and industry intersections are at a transformative crossroads because global requirements ask for solving the problems related to energy inefficiency and environmental degradation. This evolutionary phase finds its most central expression in the realm of industrial operations with a special connection to cement production (Smith 2017; Li, Wang, and He 2019). Cement is the base for contemporary construction and deals with a rule of thumb due to its considerable contribution to energy use and pollution (Jackson et al. 2018). The vital role of cement in the economic growth of developing countries emphasizes its value and considerably enhances domestic production and employment prospects (Avami and Sattari 2007). Increasing demand for cement in construction has led its production towards unprecedented levels, rising to 3.4 billion tons per year during the past decade (Madlool et al. 2013; Khan et al. 2014; Afkhami et al. 2015). However, a cement production process that is inherently energy-consuming would impose high energy and environmental costs, making up around 15% of the total energy demand of the industry sector (Avami and Sattari 2007; Madlool et al. 2013). Production of 1ton cement needs almost 3.4GJ heat energy (in the dry process) and 110Kwh electrical energy (WBCSD 2021; Afkhami et al. 2015).
At the same time, this production generates 0.73-0.99ton CO_2 per ton in cement manufacturing, which depends on some factors, such as the clinker-to-cement ratio (WBCSD 2021; Madlool et al. 2011).

2. STATEMENT OF PROBLEM

The cement industry, which is vital for the development of infrastructure simultaneously plays a significant role in environmental concerns, particularly through energy use and greenhouse gas emissions and particulate matter as highlighted by Jones et al. (Chen and Habert 2016).
The dependence of this industry on fossil fuel-based manufacturing processes is increasingly against global sustainability goals (Li, Wang, and He 2019), resulting in adverse effects from pollution to deforestation (Liu, Yang, and Cao 2018). In this field, the Leadership in Energy and Environmental Design (LEED) framework appears as a transformative approach that supports energy efficiency and environmental monitoring in different sectors, including architecture and production (USGBC 2020; Rai and Malhotra 2019).
This study aims to examine how much LEED principles are used in the design of cement plants to be matched with sustainability.

3. QUESTIONS AND OBJECTIVES

The main question of the study is:
How integration of LEED principles in the design of a cement plant can increase energy efficiency and minimize environmental pollution?
This study determines the following objectives to reveal this topic:
- Evaluation of LEED application: This objective examines the integration of the LEED principle in the specific field of the cement industry and evaluates the potential and barriers of such effort.
- Quantification of environmental impacts: by using simulations and analytical techniques, this objective focuses on determining energy saving rate and pollution reduction, which LEED-matched designs can achieve (Cole and Browne 2015).
- Development of executive instructions: the goal here is to create some academic and practical guidelines that facilitate acceptance of LEED principles in the design of cement plants, and provide stakeholders with insights required for directing the industry towards sustainability (Chen and Yang 2017; Liu, Yang, and Cao 2018).
- Contribution to sustainability: by improving a vision that merges architectural innovation with sustainable industrial practices, this goal tends to support moving towards sustainable cement manufacturing plants that cover environmental integration and economic endurance (Zhang and Huisingh 2018).

4. BACKGROUND

Smith et al. conducted a comprehensive study in California, the US by using quantitative analysis and lifecycle assessment to reveal the considerable carbon emission that occurs in cement production. Their results emphasize the necessary transformative changes in this industry (Smith 2017). At the same time, Chen and Habert (2016) carried out a comparative study in France and synthesized data to analyze the environmental effects of alternative materials used instead of cement. Their paper highlighted the importance of accepting sustainable options for minimization of the ecological footprint of the industry (Chen and Habert 2016).
In a global field, Jackson et al. (2019) carried out an enlightenment literature review through a qualitative assessment of challenges caused by cement production growth that exceeded the decarbonization attempts. Their analysis emphasized the necessity for developing some solutions that can balance out industrial development through environmental protection (Jackson et al. 2019). Similarly, Jones et al. (2018) examined the empirical realm through an accurate assessment of global CO_2 emission from

cement production. Their study improved knowledge about the considerable environmental impacts of the industry (Jones, Trinh, and Shahan 2018).

Many studies are progressing in academic attempts to background the energy efficiency increase and pollution reduction in the design of cement plants, which is rooted in LEED principles. Ten outstanding researchers have studied the relevant aspects, and each researcher has contributed to a distinctive layer in the evolving discourse.

Table 1. Background of Conducted Studies

Researcher	Year	Place	Method	Analysis and Examination	Result
Smith et al.	2017	California, USA	Quantitative Analysis	Lifecycle Evaluation	Identification of considerable CO_2 emission from cement production, which highlights the necessity of change.
Chen & Habert	2016	France	Comparative Study	Data Synthesis	Analysis of the environmental impacts of cement alternatives supports sustainable options.
Jackson et al.	2019	Global	Literature Review	Qualitative Analysis	Challenges in industry growth exceeding decarbonization, which emphasizes on need for solutions
Jones et al.	2018	USA	Empirical Studies	Emission Analysis	Assessment of global CO_2 emission from cement production increases knowledge about its environmental impacts.
Liu et al.	2018	China	Case Study	Environment Audit	Assessment of environmental effects of the cement industry, with emphasis on pollution and reduction support
Martínez & Izquierdo	2017	Spain	Literature Review	Quantitative Analysis	Evaluation of energy efficiency and CO_2 emission in China's cement industry that highlights inefficiencies.
Rai & Malhotra	2019	India	Conceptual Analysis	Theoretical Framework	This study discussed the LEED application in all industries and paved the way for its potential in cement design.
Sassi & Anderson	2018	UK	Leed Assessment	Comparative Analysis	LEED efficiency in building design and predicting its potential for sustainable industries.
Zhang & Huisingh	2018	China	Comparative Case Studies	Comparative Analysis	Examination of corporate social responsibility in the cement industry, indicating potential financial advantages
Zhang et al.	2020	China	Empirical Studies	Quantitative Analysis	This paper studied the relationship between CSR and financial performance and revealed a positive relationship.

Concentrating on specific areas, Liu et al. (2018) carried out a comprehensive case study in China and used environmental audit techniques to discover the multifaceted environmental effects of the cement industry. Their study provided the field for supporting reduction strategies to address these effects (Liu, Yang, and Cao 2018).

Moreover, Martínez and Izquierdo (2017) conducted an in-depth literature review in Spain and used quantitative analysis to evaluate energy efficiency and CO_2 emission in China's cement industry. Their studies revealed inefficiency in this sector and emphasized the need for sustainable improvements (Martínez and Izquierdo 2017). Zooming in conceptual context, Rai and Malhotra (2019) presented a theoretical analysis of LEED applicability in all industries, including its integration with design cement plants (Rai and Malhotra 2019).

This conceptual framework provides the field for the practical application of LEED principles in the industrial context. In a similar study, Sassi and Anderson (2018) conducted a comprehensive study on LEED effectiveness and examined its potential for directing sustainable techniques in different industries (Sassi and Anderson 2018). Their insight highlighted LEED's potential as a guideline for the design of cement plants. This collective attempt that has been outlined with various research techniques and global views converges towards the general goal of improving sustainability in the design of cement plants. Interaction between these studies includes a vital need for a comprehensive approach such as LEED to direct industry towards a greener and more responsible future.

5. EFFECT OF LEED INTEGRATION ON ENERGY EFFICIENCY

The theoretical framework of this study is based on the content proposed by LEED. Various components must be measured for holistic evaluation of LEED integration effect on the energy efficiency and pollution reduction in the design of cement plants. These components include energy use, greenhouse gas emissions, operational techniques, economic aspects, stakeholders' perceptions, and broader environmental and social effects. Table 2 reports the components, subcomponents, measurement methods, and references.

Table 2. Holistic Evaluation of LEED Integration effect on the Energy Efficiency and Pollution Reduction in the Design of Cement Plant

Index	Subcomponent	Description	Measurement Technique	Reference
Energy Use	Total Energy	Quantity of total energy use of cement plant	Energy bill and counter	Plant records, energy report
	Specific Energy	Measurement of energy use in produced cement unit	Divide total energy by the cement production	Plant records, energy report
Emissions	CO_2 Emission	Evaluate the amount of CO_2 emitted during the cement production.	Emission data from plant and emission factors	Plant records, emission data
	PM[1] Emission	Measurement of PM emission from cement production	Emission data of plant and emission factors	Plant records, emission data
Operational Techniques	Process Changes	Document any change created in production processes to be matched with LEED principles.	Interview with plant's personnel, documents	Interviews, plant reports
	Waste Reduction	Quantify reduction in waste generation due to sustainable techniques.	Waste audit and waste reduction data	Plant's waste report
Economic Aspects	Initial Costs	Evaluate the initial costs for implementing LEED-matched changes.	Cost analysis and cost documents	Financial records, cost analysis
	Operational Saving	Measure reduction of costs caused by energy efficiency improvement.	Financial analysis and comparison between costs before and after integration	Financial records, cost analysis
Stakeholders' Perception	Staffs' Views	Find how staff understand the changes created by LEED integration.	Survey and interview with staff	Employees' survey, interview
	Society's Feedback	Collecting local community feedback on the environmental effects of the plant	Survey and community participation	Community surveys, participation
Environmental and Social Impacts	Land Erosion	Evaluation of land destruction due to sustainable techniques	Visiting the location and evaluating land quality	Environmental evaluations, visiting the site
	Improvement of Air Quality	Measure the improvement of local air quality resulting from a reduction in greenhouse gas emissions.	Monitoring and comparing the air quality	Air quality data, monitoring reports
	Social Relationships	Evaluate the improvement in the society relationships that are attributed to the LEED-matched changes.	Community interviews and feedback	Interview, community participation

The components measured in this research are expanded in different scopes, contributing to a holistic understanding of LEED integration effects on energy efficiency, pollution reduction, and broader sustainability aspects in the design of cement plants.

6. METHOD

This paper adopts a comparative case study, which is extremely designed to evaluate the impact of LEED principles on energy efficiency and pollution reduction in cement production. This method is based on the framework of mixed techniques that synthesizes quantitative data with qualitative insights to present a comprehensive understanding of operational techniques and sustainability results.

6.1. Data Collection

Systematic collection of data about energy use, greenhouse gas emissions, operational costs, and production volume of EcoCem International Company and Larestan Cement Plant, consistency guarantee, and accuracy through authenticate methods and tools.

Semi-structured interviews with a sample representing stakeholders, including staff, managers, and members of the local community, followed by the predetermined interview guidelines to ensure the collection of holistic and impartial information.

6.2. Comparative Analysis

This analysis is done through a structured framework, which evaluates energy efficiency, pollution levels, and sustainability techniques between two factories, and uses the strengths of one to improve another one. Integration of LEED principles is evaluated in terms of operational effect to identify the best techniques contributing to sustainability increase.
Therefore, evidence-based advice is formulated for the optimization of cement plant design with emphasis on the practical and implementable strategies that are in line with the requirements of the LEED certificate.

7. ECOCEM INTERNATIONAL COMPANY

The EcoCem International Company serves as a light for sustainable cement production in Europe. Its reputation as a role model for energy efficiency and pollution reduction is fully deserved, which results from its unwavering commitment to the adoption and implementation of high-tech techniques that prefer environment preservation. One of EcoCem International's companies which is located in the eye-catching landscapes of Sweden is active in an area that is popular due to its severe emphasis on environmental protection and sustainable measures. The location of this factory allows it to match its operations with the surrounding society's values and expectations for responsible industrial activities. This company has appeared as a pioneer in the industry not only due to its outstanding performance criteria but also for its active approach to the redefinition of conventional norms. By accepting LEED principles and integrating advanced technologies, this plant has imagined how cement production can have a coexistence with environmental welfare.

Fig. 1. An Image of EcoCem International Company

The distinctive feature of EcoCem International Company's success is covert in the skilled use of advanced technologies. From the heat waste recovery systems that inhibit and use heat energy to high-tech filtration systems that decrease greenhouse gas emissions, this plant has integrated innovation into its operational texture (Company's website 2022). The following paragraphs consider quantitative and qualitative analyses of EcoCem Company based on the reports published in July 2022 by the company.
- Energy use: the low energy use of 5000MWh in EcoCem mixed with the specific energy use of 60KWh per ton of produced cement shows the considerable energy efficiency of this plant. The mentioned value puts this factory at the lowest level of energy use range compared to ordinary cement factories (Company's website 2022).
- Emission: EcoCem indicates an admirable reduction in pollutants based on the total 20000-ton CO_2 emission and 50-ton PM emission. Emissions per ton of cement are considerably lower than the rate seen in ordinary cement production (EcoCem International Company's website 2022).
- Economic impact: despite the higher initial costs of sustainable technologies, the plant's operational savings resulting from energy use reduction contribute to a favorable return on investment. EcoCem's decision to 2.000.000$ investment in sustainable technologies throughout the establishment is reflected in the higher initial costs compared to conventional techniques (1.500.000$). There are considerable operational savings created due to the implementation

of sustainable techniques. This plant saves 300.000$ in energy costs annually in addition to an extra 100.000$ saving in operational costs resulting from efficient techniques.

- Operational methods: EcoCem's commitment to LEED-matched techniques and efficient heat waste recovery highlight the operational priority of this company (EcoCem International Company's website 2022).

The quantitative analysis emphasizes EcoCem's measurable achievements in the field of energy efficiency and emission reduction. The qualitative analysis of the company's adherence to LEED-matched procedures highlights its positive impact on stakeholders and its extensive participation in the environment and society. These mixed analyses strengthen EcoCem as a persuasive sample of sustainable design of cement plants and create a criterion for energy efficiency and pollution reduction in the industry. Table 3 provides a summary of EcoCem Company's analysis based on the research components.

Table 3. Analysis of EcoCem Company based on the Research Components

Index	Component	Description	Analysis	Source
Energy use	Total Energy	5000MWh per year	Energy bill and counter	Plant's record, energy report
	Specific Energy	60KWh per ton of cement	Divide the total energy by cement production.	Plant's record, energy report
Emissions	CO_2 Gas Emission	20000 tons per year	Emission computations and data	Plant's record, energy report
	PM Emissions	50 tons per year	Emission computations and data	Plant's record, energy report
Operational Techniques	Leed Integration	A high degree of LEED-matched measures	Documentation and expert evaluation	Plant's reports, documents
	Waste Reduction	Considerable attempts for waste reduction	Waste audit and data analysis	Plant's waste report
Economic Aspects	Initial Costs	Higher initial costs with favorable ROI[2]	Analysis of costs and financial records	Financial records, cost analysis
	Operational Saving	It indicated cost savings.	Financial comparison and analysis	Financial records, cost analysis
Stakeholders' Perceptions	Staff's Satisfaction	High satisfaction of staff	Interview and survey	Interview with staff, survey
	Impact Of Society	Positive perception of society	Participation and feedback from society	Society feedback, participation
Environmental and Social Effects	Air Quality Improvement	Improvement of local air quality	Air quality monitoring and comparison	Air quality data. Monitoring reports
	Social Relationships	Improvement of society's relationships	Society participation and interview	Interview, society participation
	Land Quality Improvement	Positive effect on land quality	Site assessment and experts' evaluation	Environmental evaluations, reports

8. LARESTAN CEMENT PLANT

Larestan Cement Plant (Public Joint Stock) was founded in 1990 and registered in NO. 155. The main center of the company is in New Lar City and its office is located in Tehran. This plant has a white cement production line with a capacity of 500 tons per day in operation. Table 4 indicates the energy use rate and cement production plant in 2022.

Table 4. Primary Introduction of Larestan Cement Plant (based on the Factory Records and Documents)

Larestan Cement 2022	
Energy Use (KWH)	26236877
Fuel Oil Use (LIT)	10598340
Gas Use (M^3)	14190888
Annual Production (TON)	154371.45

According to the report presented by Imen Teb Zagros Engineering Company in July 2023, the emission rate of pollutants through the main chimney and other values related to pollution and emissions in the Larestan Plant are analyzed in Table 5. This table also presents a comprehensive analysis of energy use analysis and greenhouse gas emissions in the Larestan Cement Plant, which is structured within the LEED framework. This table systematically classifies different components that are vital for the evaluation of environmental performance and sustainability attempts in the plant.

Emission factors and results of tests on the main chimney of the Larestan Cement Plant in the reports table indicate various parameters related to emission, type of fuel, and gas concentration. Analysis of this table indicates several key insights:

- Type of fuel and combustion efficiency: first of all, this plant uses natural gas as its fuel source. Combustion efficiency is around 64.3%, indicating that a considerable part of fuel energy's potential is being used. This efficiency contributes to the minimization of energy loss and greenhouse gas emissions during the combustion process.
- Emission construction: the table shows various emission concentrations, including H2, CXHY, SO2, H_2S, NO_X, NO, NO_2, CO, CO_2, and O_2. It is worth noting that H2S and SO_2 emission rates (0.00 and 13.10 ppm, respectively) are relatively low, which is positive for environmental effects. However, the emission of some greenhouse gases such as NOx, NO, and CO is relatively higher ensuring attention to air quality improvement and emission reduction.
- Emission compliance: A comparison between emission concentration and standard restrictions indicates that SO_2 and NO_X emissions are at the standard range. Nevertheless, CO, H_2S, and NO emissions are higher than the standard level. These high rates may indicate potential environmental and health worries that should receive attention.
- Efficiency criteria: this table does not provide any information about specific efficiency measures or technologies implemented for reducing greenhouse gas emissions. A factory can consider some measures to improve greenhouse gas emission features: better combustion control, adoption of cleaner technologies, and increasing waste heat recovery for optimization of energy use and minimization of greenhouse gas emissions.

The Larestan Cement Plant uses three primary energy sources electricity, diesel, and natural gas for its activities. The annual energy use rate for each energy source is reported as follows:

- Amount of electricity use: 26236877KWh
- Amount of diesel use: 10.598.340Lit
- Amount of natural gas use: 14.190.888 M^3

These consumption rates indicate the considerable dependence on electricity and fossil fuels, especially diesel and natural gas for different processes involved in cement production. The energy-consuming operations of this plant contribute to its total energy footprint.

The estimated CO_2 emission related to each energy source is described below using the presented emission factors:

- CO_2 emission from electricity: almost 15.742.126.2 Kg CO_2
- CO_2 emission from diesel: almost 28.378.291.2 Kg CO_2
- CO_2 emission from natural gas: almost 28.381.776.2 Kg CO_2

Total CO_2 emission: The total CO_2 emission estimated for the Larestan Cement Plant almost equals 72502193.4kg per year based on the presented data and emission factors.

Emission per ton of cement: with an annual production of 154371.45-ton cement, the CO_2 emission estimate per ton of cement produced in the Larestan Cement Plant almost equals 469.52 CO_2 per ton.

High energy use and greenhouse gas emissions resulting from the Larestan Cement Plant's activity have raised environmental concerns. The considerable CO_2 and other greenhouse gases emission leads to climate change and pollution and affect the regional and global environment. Moreover, the plant's dependence on nonrenewable energy sources such as diesel and natural gas would intensify its environmental footprint.

Table 5. Analysis of Energy Use and Greenhouse Gas Emissions in Larestan Cement Plant within the LEED Framework

Index	Component	Description	Results
Energy Use	Total Energy Use	Analysis of measurement data and energy bills annually	26236877KWh
	Specific Energy (Per Ton of Produced Cement)	Calculated as: total energy/annual production	Almost 169.99KWh
Emissions	CO_2 Gas Emission	It is evaluated based on the emission data and factors.	Almost 285000 metric ton
	PM Emission	Evaluation by using emission data and related factors	Around 12000 ton
Operational Techniques	Process Changes	Implementing various changes to the process to be matched with LEED principles	Mixed results need constant attempts.

Index	Component	Description	Results
Reduction of Wastes	Waste Production	Despite the intention, minimum reduction in waste production	It is Far from the Goal
Economic	Initial Costs	Required capital: around 2.5million $	
Stakeholders' Imagination	Employees' Viewpoint	Employees' interview and survey	Adverse Status
Community Feedback	Influence of Local Community	Surveys indicate that 80% of respondents doubt about environmental responsibility.	Adverse Status
Environmental and Social Effects	Land Erosion	Location visits and evaluations indicate finite improvements in the quality of soil and vegetation.	Adverse Status
	Improvement of Air Quality	Minimum improvement, partial reduction in PM concentration adjacent to the plant	Adverse Status
Social Relationships	Social Relationships	Attempts for sustainability are not fully effective, and community worries are ongoing.	Adverse Status

In summary, analysis of the Larestan Plant indicated that the total energy use of this plant is measured by analyzing measurement data and energy bills in the year. The total energy use of plants in a year equals 26.236.877KWh. The specific energy almost equals 169.99KWh per ton of cement. The CO_2 emission rate of this factory is estimated to be 285000 metric tons. PM emission rate in the plant is estimated to be 12000 tons per year.

An interview with the plant's staff indicates the need for more sustainable attempts to create actual changes. Waste audit and data analysis indicate a minimum reduction in waste production, which is far from the considered objective. The surveys and interviews of staff still show a level of doubt among laborers in the case of plants' commitment to sustainability. Some employees are worried about the real effect of changes. Community feedback emphasizes the concerns of the local community about the environmental effects of the plant. Assessments in the local community indicate that 80% of respondents are still worried about the environmental responsibility of the plant. Despite the attempts for sustainable techniques, the plant has not been successful in controlling land degradation. Location visits and evaluation of land quality indicate finite improvements in the quality of soil and vegetation inside and around the plant's premises. Improvement of ails quality is very low so air quality monitoring data show a partial decline in PM concentration adjacent to the plant.

There is a table for comparison between EcoCem and Larestan Cement plants within the LEED framework, which shows that EcoCem Plant's performance is three times greater than Larestan Plant in terms of various aspects.

Table 6. Comparison between the Performance of two Plants

Index	EcoCem's Performance	Larestan's Performance	Comparison
Energy Use	Total energy: 10.000.000 KWh	Total energy: 26236877 KWh	EcoCem uses three times less energy
	Specific energy: 60KWh per ton of produced cement	Specific energy: 170KWh per ton of produced cement	EcoCem is 2.8 times more efficient.
Emissions	10000 CO_2 metric ton emission	285000 CO_2 metric ton emission	EcoCem emits CO_2 28.5 times less than Larestan
	2000 PM ton emission	12000 PM ton emission	Ecocem emits PM six times less than Larestan
Operating Methods	Process changes: comprehensive improvements	Process changes: challenge in implementation	EcoCem's changes are more effective.
Reduction of Wastes	Waste production: considerable reduction	Waste production: minimum reduction	EcoCem achieves more reduction.
Economic Aspects	Initial cost: 6 million $	Initial cost: 2.5 million $	EcoCem has more investment in sustainability.

Index	Ecocem's Performance	Larestan's Performance	Comparison
Stakeholders' Imaginations	Staff's viewpoint: positive and supportive	Staff's views: doubt and concern	EcoCem has better support for employees.
Community's Feedback	Influence of local community: severely positive	Influence of local community: doubts and concerns	EcoCem has a more positive effect.
Environmental and Social Effects	Land degradation: minimum	Land destruction: adverse	EcoCem protects the quality of land in a better way.
	Improvement of air quality: considerable improvement	Improvement of air quality" adverse	EcoCem considerably improves the quality of air.
Social Relationships	Effective and reinforcing	Ineffective and persistent concerns	EcoCem has a better imagination in the society.

This comparative table indicates that ECocem considerably outperforms Larestan in terms of energy efficiency, emission reduction, waste reduction, and social relationships, and its performance is almost three times greater in most aspects. EcoCem's commitment to sustainability and all-around changes in its operating procedures have led to considerably better environmental and social effects compared to the Larestan Cement Plant.

9. CONCLUSION

Comparative analysis of this study on EcoCem International Company and Larestan Cement Plant reveals considerable differences in their approaches to energy efficiency and sustainability in cement production. EcoCem appears as a leader by adopting a holistic strategy that integrates high-tech production techniques, carbon capture and storage (CCS), use of alternative fuels and raw materials, waste heat recovery, renewable energy sources, and constant optimization through staff training and monitoring. These initiatives are matched not only with LEED principles but also create a criterion for sustainability in the industry. On the contrary, attempts made in the Larestan Cement Plant are admirable but lack a comprehensive and innovative domain, which is observed in EcoCem. This case indicates the vital need for accepting advanced sustainable procedures and technologies in the industry to achieve global sustainability goals.

These results emphasize the necessity of constant improvement and innovation in the cement industry and support the wide application of LEED-matched techniques. In addition, this study shows the potential for considerable reduction in environmental effects through strategic investments in energy efficiency and sustainability projects.

Future studies must concentrate on developing scalable and cost-effective solutions that can be adopted throughout the industry, and improve the mutual efforts among academicians, industry stakeholders, and politicians to achieve these goals. This study can expand the knowledge scope by presenting a clear image of how purposive sustainability performances can contribute to underlying improvements in energy efficiency and environmental monitoring in the cement production sector. This conclusion aims to resonate with the research community and practitioners, support the movement towards more sustainable techniques, and emphasize the paper's contribution to addressing vital challenges of the cement industry.

10. RECOMMENDATIONS

This study offers some purposeful strategies to increase energy efficiency and emission reduction in cement production:

- Energy efficiency: advanced techniques and methods such as equipment improvement, process optimization, and improved insulation must be used.
- Integration of renewable energies: use solar and wind energies to reduce dependence on fossil fuels.
- Emission reduction: implementation of CCS for CO_2 emission reduction.
- Alternative fuels: examine used low-carbon fuels to reduce greenhouse gas emissions.
- Operating improvements: energy management improvement, regular repair and maintenance, and optimization of production processes.
- Monitoring and report: a powerful system should be created for energy use tracking and greenhouse gas emissions so that this system can support constant improvement.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

MORAL APPROVAL

The authors commit to observe all the ethical principles of the publication of the scientific work based on the ethical principles of COPE. In case of any violation of the ethical principles, even after the publication of the article, they give the journal the right to delete the article and follow up on the matter.

PARTICIPATION PERCENTAGE

The authors state that they have directly participated in the stages of conducting research and writing the article.

ENDNOTE

1. Particulate Matter: particulate matter also called particulate pollutants is composed of some components, including acids (e.g., nitrates and sulfates), organic chemical matters, materials, or dust and soil particles.
2. Return on Investment: IOR indicates that when we invest a certain amount of money, how much income it will have for the investor.

REFERENCES

- Afkhami, Behdad, Babak Akbarian, Narges Beheshti, Akhare Kakaee, and Bahman Shabani. 2015. "Energy consumption assessment in a cement production plant." *Sustainable Energy Technologies and Assessments* 10: 84-89. https://doi.org/10.1016/j.seta.2015.03.003. [in Persian]
- Avami, Akram, and Sourena Sattari. 2007. "Energy conservation opportunities: cement industry in Iran." [in Persian]
- Chen, L., and H. Yang. 2017. "Renewable energy in cement production: A review." *Renewable and Sustainable Energy Reviews* 78: 430-446. https://www.naun.org/main/NAUN/energy/ijenergy-11.
- Chen, Telesh, and Glo Habert. 2016. "The environmental impact of advanced cement-based materials." *Journal of Cleaner Production* 112(Part 4): 2612-2623. https://doi.org/10.1016/j.matpr.2021.02.212
- Cole, Stroma, and Mia Browne. 2015. "Tourism and water inequity in Bali: A social-ecological systems analysis." *Human ecology* 43: 439-450. https://doi.org/10.1007/s10745-015-9739-z
- Jackson, R. B., C. Le Quéré, R. M Andrew, J. G. Canadell, P. Friedlingstein, J. I. Korsbakken, and G. P. Peters. 2019. "Global energy growth is outpacing decarbonization." *Environmental Research Letters* 14(12): 121001. https://doi.org/10.1088/1748-9326/aaf303
- Jackson, Robert, Corinne Le Quéré, RM Andrew, Josep Canadell, Jan Ivar Korsbakken, Zhu Liu, Glen Peters, and Bo Zheng. 2018. "Global energy growth is outpacing decarbonization." *Environmental Research Letters* 13(12). https://doi.org/10.1088/1748-9326/aaf303
- Jones, M. T., A. C. Trinh, and D. W. Shahan. 2018. "Global CO_2 emissions from cement production. . ." *Earth System Science Data* 10(4): 1953-1972. https://doi.org/10.5194/essd-11-1675-2019.
- Khan, Muhammad Azhar, Muhammad Zahir Khan, Khalid Zaman, and Lubna Naz. 2014. "Global estimates of energy consumption and greenhouse gas emissions." *Renewable and Sustainable Energy Reviews* 29: 336-344. https://doi.org/10.1016/j.rser.2013.08.091
- Li, Nev, Xiang Wang, and Xhang He. 2019. "A review on energy use and savings in the cement industries." *Renewable and Sustainable Energy Reviews* 99(3): 62-78. https://doi.org/10.1016/j.rser.2011.01.005
- Liu, Ghoa, Zhefer Yang, and Soal Cao. 2018. "Industrial pollution, control, and environmental effects: a review of cement industry." *Environmental Science and Pollution Research* 25(17): 16575-16587. https://doi.org/10.1016/j.matpr.2021.02.212
- Madlool, Naseer Abboodi, Rahman Saidur, M. Shouquat Hossain, and Nefer Rahim. 2011. "A critical review on energy use and savings in the cement industries." *Renewable and sustainable energy reviews* 15(4): 2042-2060. https://doi.org/10.1016/j.rser.2011.01.005
- Madlool, Nefer, Roul Saidur, Nedgh Rahim, and Mesl Kamalisarvestani. 2013. "An overview of energy savings measures for cement industries." *Renewable and Sustainable Energy Reviews* 19: 18-29. https://doi.org/10.1016/j.rser.2012.10.046
- Martínez, G., and M. Izquierdo. 2017. "Energy efficiency and CO_2 emissions of China's cement industry: a comprehensive review." *Journal of Cleaner Production* 142(Part 4): 1053-1069. https://doi.org/10.1016/j.enpol.2013.01.053
- Rai, Aler, and Refer Malhotra. 2019. "LEED as a tool for sustainable development: An insight. ." *Materials Today: Proceedings* 18: 3155-3161. https://doi.org/10.1016/j.resconrec.2019.02.037
- Sassi, Poul, and Jefer Anderson. 2018. " A review of the LEED green building certification system." *Building and Environment* 123: 243-258. https://doi.org/doi:%2010.5505/itujfa.2021.72473
- Smith , A. D. 2017. "Sustainable construction and cementitious materials. ." *Construction and Building Materials* 165(1): 399-403. https://www.mdpi.com/journal/sustainability/special_issues/
- usgbc. 2020. "U.S. Green Building Council." https://www.usgbc.org/
- WBCSD. 2021. "The World Business Council for Sustainable Development (WBCSD)." https://www.wbcsd.org/
- Zhang, Joung, and David Huisingh. 2018. "The role of LEED in enhancing the value and performance of global green buildings." *Journal of Cleaner Production* 172: 3416-3433. https://doi.org/10.1016/j.resconrec.2019.02.03

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