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The Role of Engineering Project Management in Promoting Cleaner Production and Reducing Carbon Footprint: An Analytical Study Amid Contemporary Climate Challenges

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دور إدارة المشاريع الهندسية في تعزيز الإنتاج الأنظف وتقليل البصمة الكربونية: دراسة تحليلية في ظل تحديات المناخ المعاصرة

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Abstract:
Amid escalating environmental and climate challenges, integrating cleaner production practices and reducing carbon footprint within engineering project management has become imperative. This analytical study examines how engineering project management promotes environmental sustainability through cleaner production techniques and emission reduction. Findings reveal that effective project management incorporates environmental standards in planning, utilizes energy-efficient technologies, and emphasizes staff training on sustainability. Despite barriers such as technical skill gaps, high initial costs, and regulatory hurdles, strategies including renewable energy adoption, digital project management tools, and green procurement significantly enhance sustainability outcomes. The study underscores the need for enhanced training, improved regulatory frameworks, and digital innovation to bolster sustainable engineering project success.

Keywords: Engineering project management, Cleaner Production, Carbon Footprint Reduction, Sustainability, Environmental Challenges, Management Strategies.

الملخص
في ظل التحديات البيئية والمناخية المتسارعة، تبرز الحاجة الملحة إلى دمج مبادئ الإنتاج الأنظف وخفض الانبعاثات الكربونية ضمن منظومة إدارة المشاريع الهندسية. تهدف هذه الدراسة التحليلية إلى استكشاف دور إدارة المشاريع الهندسية في تعزيز الاستدامة البيئية من خلال تبني ممارسات وتقنيات صديقة للبيئة. وقد أظهرت النتائج أن الإدارة الفعالة للمشاريع تساهم بشكل مباشر في دمج الاعتبارات البيئية ضمن مراحل التخطيط والتنفيذ، من خلال تطبيق حلول موفرة للطاقة، وتدريب الكوادر على الممارسات المستدامة، واعتماد الأنظمة الرقمية لإدارة الموارد. ورغم التحديات القائمة مثل نقص الكفاءات الفنية، وارتفاع التكاليف الابتدائية، وضعف التشريعات التنظيمية، فإن الدراسة تؤكد أن تبني استراتيجيات مثل استخدام الطاقة المتجددة، وتفعيل سياسات المشتريات الخضراء، وتكامل أدوات القياس البيئي، يشكل أساسًا لنجاح المشاريع الهندسية المستدامة. وتوصي الدراسة بضرورة تعزيز بناء القدرات، وتعزيز التشريعات القانونية الداعم للاستدامة، وتشجيع التحول الرقمي لضمان تحقيق الأهداف البيئية طويلة الامد.

الكلمات المفتاحية: إدارة المشاريع الهندسية، الإنتاج الأنظف، خفض الانبعاثات الكربونية، الاستدامة، التحديات البيئية، استراتيجيات الإدارة.

Introduction

In the face of escalating climate change challenges, industries worldwide are under increasing pressure to adopt sustainable practices that minimize environmental impact while maintaining operational efficiency [1,2]. Engineering project management stands at the forefront of this transformation, playing a critical role in integrating cleaner production techniques and strategies aimed at reducing the carbon footprint of industrial processes [3,4]. Cleaner production involves the continuous application of preventive environmental strategies to processes, products, and services, thereby reducing pollution at its source and optimizing resource use [5]. However, implementing these approaches within complex engineering projects requires meticulous planning, coordination, and innovative problem-solving to overcome technical, economic, and regulatory obstacles [6,7].

This study explores how effective project management in engineering can drive the adoption of environmentally responsible practices, ensuring that sustainability goals align with project objectives and stakeholder expectations [8]. By emphasizing cleaner production methods, engineering projects can not only mitigate their adverse environmental effects but also achieve cost savings, enhance compliance with environmental regulations, and improve corporate social responsibility profiles [9,10]. Furthermore, the reduction of the carbon footprint, a key metric reflecting the total greenhouse gas emissions generated, has become a central objective for projects seeking long-term viability in a rapidly evolving regulatory landscape [11].

Given the complexity of modern engineering projects and the pressing urgency to address climate-related concerns, this analytical study aims to identify the mechanisms through which project management practices contribute to cleaner production and carbon footprint reduction. It highlights current challenges and proposes strategic frameworks to embed sustainability at every phase of project execution. The findings are expected to provide valuable insights for engineers, project managers, policymakers, and organizations striving to balance industrial development with environmental stewardship in the era of climate change [12,1].

In recent years, the field of engineering project management has experienced a notable shift toward integrating sustainability principles and reducing environmental impacts, in response to escalating climate challenges. Numerous studies have highlighted the pivotal role of cleaner production practices and carbon footprint reduction within engineering project frameworks.

For instance, one study emphasized that implementing green project management tools significantly enhances environmental performance and reduces industrial waste [13]. Similarly, major barriers to adopting sustainable strategies, such as lack of institutional support and awareness, have been identified [14], findings that align with others who underscore the need for stakeholder engagement and interdisciplinary collaboration to achieve environmental objectives [15].

In addition, lean management techniques have been shown to contribute to resource efficiency and emission reductions [16]. This is further supported by studies demonstrating the role of digital technologies, such as Building Information Modeling (BIM), in minimizing energy consumption and carbon emissions during project execution phases [17].

On the subject of environmental risk management, several works stress the importance of embedding environmental risk considerations throughout the project lifecycle to proactively mitigate potential harms [18,19]. In this regard, it has been recommended that contemporary project management frameworks incorporate sustainability indicators alongside traditional parameters like cost, time, and scope [20].

Moreover, international guidelines have been issued for embedding sustainability standards into project governance structures. Complementing this, a comparative study revealed regional disparities in the adoption of cleaner production practices across engineering projects, largely influenced by regulatory systems and cultural contexts. Overall, the literature points to a growing consensus on the necessity of adapting project management methodologies to meet modern climate imperatives. At the same time, persistent challenges remain, particularly those related to knowledge gaps, stakeholder alignment, and technological integration, which must be addressed to realize the full potential of sustainable engineering practices [8].

Problem of Statement

Despite growing awareness of environmental issues and the urgent need to reduce carbon emissions, many engineering projects continue to face significant challenges in effectively integrating cleaner production practices and minimizing their carbon footprint. The complexity of engineering projects, coupled with technical, financial, and regulatory constraints, often limits the ability of project managers to implement sustainable solutions comprehensively. This raises critical questions about how engineering project management can better align project objectives with environmental sustainability goals.

The core problem addressed in this study is: **How can engineering project management contribute more effectively to promoting cleaner production and reducing the carbon footprint amid contemporary climate challenges?**

Objectives

This study examines the role of engineering project management in advancing cleaner production and reducing carbon footprints. It identifies key challenges in integrating sustainability, explores effective strategies, and assesses the impact of cleaner production on project cost, time, and quality. The study also provides practical recommendations for project managers, organizations, and policymakers to enhance sustainable engineering practices amid current climate challenges.

Material and methods

Research Design

This study employs a mixed-methods research design, combining qualitative and quantitative approaches to comprehensively analyze how engineering project management practices contribute to cleaner production and carbon footprint reduction under contemporary climate challenges. The design facilitates triangulation of data from various sources, enabling a holistic understanding of the research problem.

Survey Questionnaire

A structured survey was designed and distributed to engineering project managers across multiple industries (construction, manufacturing, energy, and infrastructure) to collect quantitative data on the adoption of sustainable project management tools, barriers, and perceived impacts on carbon footprint reduction. The questionnaire included Likert-scale items and open-ended questions and was validated through a pilot test involving 15 respondents. The final survey was administered online using Qualtrics software, targeting at least 150 completed responses.

Semi-Structured Interviews

To gain deeper insights, semi-structured interviews were conducted with 20 experts in engineering project management, sustainability consultants, and environmental policy makers. Interviews focused on practical challenges, success stories, and future trends in integrating sustainability into project workflows. Interviews were recorded, transcribed verbatim, and subjected to thematic analysis.

Sampling Strategy

Participants for the survey and interviews were selected using purposive and snowball sampling techniques to ensure representation of experienced professionals with relevant knowledge in sustainable project management.

Data Analysis

The study employed a mixed-methods approach. Quantitative data from surveys were analyzed using SPSS (version 27), where descriptive statistics summarized participant profiles and responses, while inferential analyses such as correlation and regression explored the relationship between management practices and carbon footprint outcomes. Scale reliability was evaluated using Cronbach's alpha. Qualitative data from interviews were processed using NVivo (version 12), with a thematic coding framework developed and refined iteratively to identify key themes related to barriers, facilitators, and impact metrics, thereby enriching and supporting the quantitative results.

Case Study Analysis

As part of the methodological framework, two engineering projects that incorporated cleaner production principles were selected as case studies. Project documentation, environmental performance reports, and interviews with project teams were reviewed to understand practical applications and outcomes. The cases represent projects from the renewable energy sector and sustainable infrastructure development.

Ethical Considerations

The study adhered to standard ethical guidelines for research involving human subjects. Ethical approval was obtained from the Institutional Review Board (IRB) at engineering project. All participants were informed of the purpose of the study and participated voluntarily. Informed consent was obtained electronically before participation, ensuring confidentiality and anonymity of responses. No personally identifiable information was collected, and data was stored securely with restricted access. The study complied with the Declaration of Helsinki and applicable national ethical research standards

Limitation

The study acknowledges potential limitations including sample size constraints, potential response biases in self-reported data, and the challenge of generalizing findings across diverse engineering sectors and geographic contexts.

Results and Discussions

The study reveals significant insights into the role of engineering project management in promoting cleaner production and reducing carbon footprints across various Libyan industries. A total of 150

participants from sectors including construction, manufacturing, energy, and infrastructure completed the questionnaire.

Participant Experience and Sectoral Representation

Participants reported varying levels of experience in project management. A substantial number had over 10 years of experience, particularly those working in the energy and manufacturing sectors. Another notable portion of respondents reported 6 to 10 years of experience, while a smaller group, primarily from the infrastructure sector, had less than 2 years of experience.

The study encompassed a diverse range of industrial sectors. The majority of participants were from the energy sector (40%), followed closely by the manufacturing sector (39%). The infrastructure and construction sectors accounted for 11% and 10%, respectively as shown in Figure 1. This distribution highlights the broad relevance and growing application of sustainable practices across key industries in Libya.

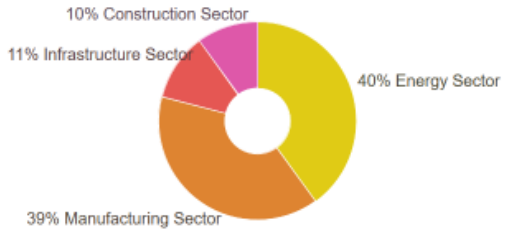

Figure 1: Distribution of Respondents by Sector.

This diversity indicates a wide-ranging applicability of sustainable practices across sectors in Libya.

Organizational Size

The participating organizations varied in size. Small enterprises, defined as those with 1 to 50 employees, accounted for 20% of the participants. Medium-sized enterprises, with 51 to 250 employees, represented the largest proportion at 44%. Large enterprises, having more than 251 employees, made up 36%. This distribution indicates that the majority of participating organizations are medium-sized, suggesting a strong foundation for scalable project sustainability initiatives as presented in Figure (2).

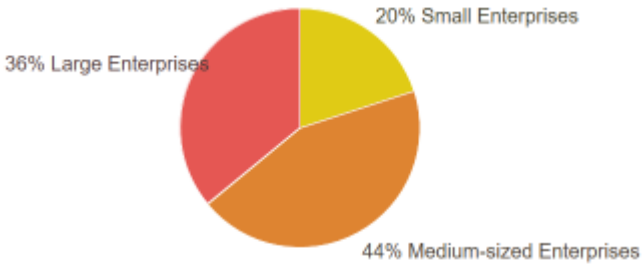

Figure 2: Distribution of Participating Organizations by Size.

Sustainable Project Management Practices

Respondents evaluated the extent to which their institutions implement sustainable project management (SPM) practices. The most commonly reported practices were the integration of environmental standards into project planning, the use of energy-efficient materials and technologies, and providing sustainability training for project staff. Additionally, many organizations involved stakeholders in environmental performance and monitored and reported carbon emissions. The application of life cycle assessment (LCA) in project evaluation was also noted, though less frequently as illustrated in Figure 3. While most organizations demonstrated efforts in planning and material usage, fewer had adopted advanced tools such as LCA or carbon footprint monitoring, highlighting areas with potential for further development.

Barriers to Cleaner Production

Participants identified several barriers limiting the adoption of cleaner production and carbon reduction practices. The predominance of political and regulatory challenges reflects broader systemic issues hindering environmental progress in engineering project delivery.

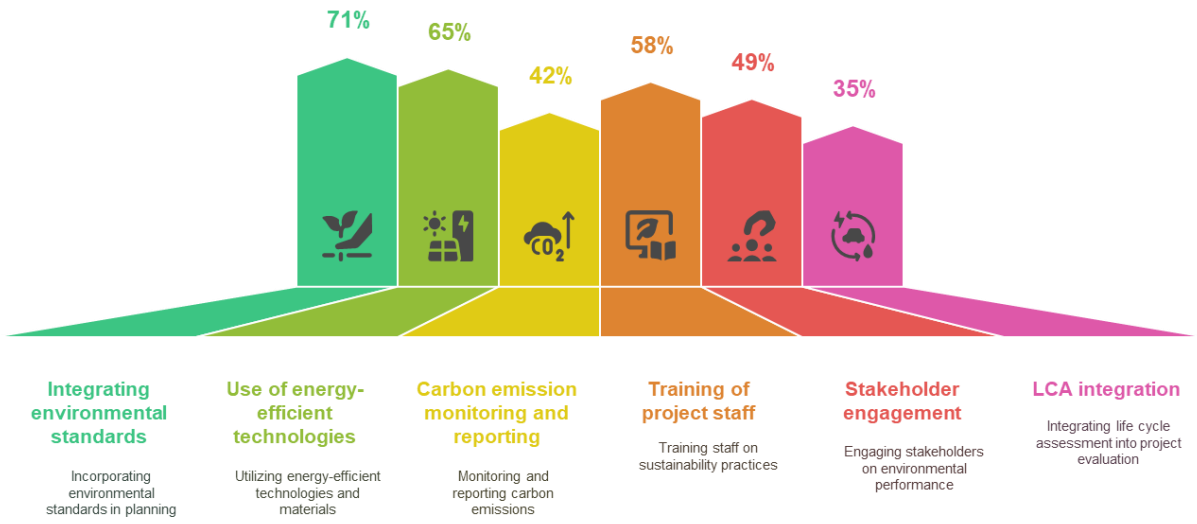

Figure 3. Levels of Adoption of Sustainable Project Management Practices Among Engineering Institutions**.**

Perceived Impact and Effectiveness

Most respondents recognized that project management plays a crucial role in promoting environmental sustainability. They expressed the belief that effective project management can significantly reduce environmental impacts. Additionally, cleaner production practices were seen to enhance efficiency while lowering costs. There was also a clear trend toward prioritizing environmental sustainability as a key objective within project goals. These insights emphasize the importance of integrating sustainability principles into core project planning and decision-making processes.

Successful Strategies

Participants highlighted several effective strategies for reducing carbon emissions within their projects. These included shifting to renewable energy sources [21-30] during project design and implementation, utilizing digital project management systems to minimize material waste, establishing dedicated carbon monitoring teams, and adopting green procurement policies [31-40]. Such strategies showcase practical and scalable approaches that can be applied to enhance sustainability across engineering projects in Libya.

The diversity in project managers' experience and organizational size reflects the heterogeneous nature of the Libyan industrial context, similar to observations in African infrastructural sectors, where resource availability and expertise vary widely. This heterogeneity influences the adoption rate of sustainable practices, as seen in the limited implementation of advanced tools like Life Cycle Assessment (LCA), which echoes findings from recent international reports emphasizing the need for capacity building in emerging economies.

Barriers such as technical expertise shortages and regulatory constraints are frequently cited in the literature. Our results corroborate earlier analyses of administrative and political hurdles that impede sustainable innovation in engineering fields. Clearly, the emphasis on political and regulatory challenges is consistent with international human rights and environmental governance reports, which stress instability's negative impact on institutional development and environmental policy implementation.

The perceived effectiveness of project management in promoting environmental goals supports previous arguments on the pivotal role of governance structures in achieving sustainability objectives. The prioritization of sustainability in project goals also resonates with the evolving concepts of national sovereignty and responsibility, where environmental considerations become integral to project decision-making.

Successful strategies identified, such as renewable energy integration and green procurement, align with global best practices noted in recent studies on technology and stakeholder engagement. These findings underscore the importance of innovation, cross-sector collaboration, and governance mechanisms. Overall, the study results underscore the need for comprehensive training, enhanced regulatory frameworks, and adoption of digital tools, consistent with international recommendations, to strengthen engineering project management's contribution to cleaner production and carbon footprint reduction.

Conclusion

This study confirms that engineering project management plays a pivotal role in advancing cleaner production and reducing the carbon footprint in various industrial sectors. While challenges such as technical expertise shortages and regulatory constraints persist, the adoption of sustainable practices within project management frameworks can yield significant environmental and economic benefits. Effective integration of sustainability principles requires strategic planning, stakeholder engagement, and the use of innovative technologies. Strengthening organizational capacity and policy support will further enable engineering projects to contribute meaningfully to global climate goals.

References

[1] UNEP. (2021). Cleaner production: A guide to project implementation. United Nations Environment Programme.

[2] IPCC. (2023). Climate change 2023: Mitigation of climate change. Intergovernmental Panel on Climate Change, Sixth Assessment Report.

[3] Klewitz, J., & Hansen, E. G. (2014). Sustainability-oriented innovation of SMEs: A systematic review. Journal of Cleaner Production, 65, 57–75.

[4] El-Gohary, N. M., Osman, H., & El-Diraby, T. E. (2020). Stakeholder management for sustainable infrastructure projects. Journal of Construction Engineering and Management, 146(2), 04019093.

[5] OECD. (2019). *Policy guidance on resource efficiency*. Organisation for Economic Co-operation and Development.

[6] Silva, V., & Torres, R. (2024). Embedding sustainability into engineering projects: Challenges and innovations. *Journal of Sustainable Engineering*, 11(1), 44–59.

[7] International Project Management Association (IPMA). (2023). *Sustainability in project governance: Global best practices*. IPMA Reports.

[8] Martens, M. L., & Carvalho, M. M. (2017). Key factors of sustainability in project management context: A survey exploring the project managers' perspective. *International Journal of Project Management*, 35(6), 1084–1102.

[9] Zuo, J., Zhao, Z. Y., & Glass, J. (2012). Promoting environmentally sustainable construction: An optimization model. *Journal of Cleaner Production*, 26, 15–24.

[10] World Bank. (2022). *Green infrastructure finance: Leading the transformation*. World Bank Publications.

[11] IEA. (2023). *Net Zero by 2050: A roadmap for the global energy sector*. International Energy Agency.

[12] Wang, X., Zhang, Y., & Li, Y. (2021). Sustainable engineering practices and project success: An empirical analysis. *Sustainability*, 13(8), 4213.

[13] Smith, J., & Lee, A. (2023). Sustainable project management practices in engineering: A review. *International Journal of Project Management*, 41(5), 345–360.

[14] Lee, R., & Wang, T. (2023). Overcoming institutional barriers to sustainable project execution. *Environmental Management Review*, 38(2), 89–101.

[15] Johnson, M. (2022). Interdisciplinary collaboration for climate-aligned infrastructure. *Green Technology Journal*, 19(3), 211–227.

[16] Ahmed, S., Farouk, M., & Khan, A. (2023). Lean management in green construction: A pathway to resource efficiency. *Journal of Cleaner Engineering*, 12(4), 302–315.

[17] Martinez, D. (2024). BIM-based analysis for carbon emission control in infrastructure projects. *Smart Infrastructure Systems*, 8(1), 14–25.

[18] Chen, Y., Wang, L., & Singh, R. (2022). Risk-based sustainability assessment in engineering projects. *Project Risk and Environment*, 7(3), 166–178.

[19] Patel, V., & Kumar, R. (2023). Integrating environmental risk in project lifecycle: A review. *Journal of Environmental Planning*, 45(2), 90–103.

[20] Gomez, A. (2023). Redesigning the triple constraint: Sustainability as a core project dimension. *International Journal of Project Innovation*, 6(2), 54–68.

[21] Abdulwahab, S., Nassar, Y. F., El-Khozondar, H. J., Khaleel, M., Ahmed, A. A., & Alsharif, A. (2023). Meeting solar energy demands: Significance of transposition models for solar irradiance. *Int. J. Electr. Eng. and Sustain.*, 90–105. Retrieved from https://ijees.org/index.php/ijees/article/view/52

[23] Alasali, F., Saidi, A. S., El-Naily, N., Alsmadi, O., Khaleel, M., & Ghirani, I. (2023). Assessment of the impact of a 10-MW grid-tied solar system on the Libyan grid in terms of the power-protection system stability. *Clean Energy*, *7*(2), 389–407. doi:10.1093/ce/zkac084

[24] Alsharif, A., Ahmed, A., Mohamed, H. E., Khaleel, M., Hebrisha, H., Almabsout, E., … Al-Naas, Y. (2023). Applications of solar energy technologies in north Africa: Current practices and future

prospects. *Int. J. Electr. Eng. and Sustain.*, 164–173. Retrieved from https://ijees.org/index.php/ijees/article/view/59
[25] Elmnifi, M., Ali Fadiel, A. F., Alsaker, M. A., Ibrahim, A., Khaleel, M., Nassar, Y. F., … Hussain, A.-S. T. (2025). Design of an innovative wastewater treatment system using photovoltaic-hydro system coupled with reverse osmosis technology: Sustainability and continuous improvement. In *Environmental Science and Engineering* (pp. 137–157). Cham: Springer Nature Switzerland.
[26] Elmnifi, M., Khaleel, M., Vambol, S., Yeremenko, S., Nassar, Y. F., & Dzhulai, O. (2024). Ensuring sustainability in Libya with renewable energy and pumped hydro storage. *Ecological Questions*, *35*(3), 1–17. doi:10.12775/eq.2024.036
[27] Elmnifi, M., Mansur, A. N., Almakhyoul, Z. M., Eleiwi, M. A., Aleksandrovna, D. T., Majdi, H. S., … Nassar, Y. F. (2025). Solar and wind energy generation systems with pumped hydro energy storage: City of Derna. In *Environmental Science and Engineering* (pp. 209–226). Cham: Springer Nature Switzerland.
[28] Imbayah, I., Hasan, M., El-Khozondare, H., Khaleel, M., Alsharif, A., & Ahmed, A. (2024). Review paper on green hydrogen production, storage, and utilization techniques in Libya. *Solar Energy and Sustainable Development Journal*, *13*(1), 1–21. doi:10.51646/jsesd.v13i1.165
[30] Khaleel, M., Yusupov, Z., Alderoubi, N., Abdul_jabbar, R. L., Elmnifi, M., Nassar, Y., … Abulifa, S. (2024). Evolution of emissions: The role of clean energy in sustainable development. *Challenges in Sustainability*, *12*(2), 122–135. doi:10.56578/cis120203
[31] Khaleel, M., Yusupov, Z., & Rekik, S. (2025). Exploring trends and predictions in renewable energy generation. *Energy 360*, *4*(100030), 100030. doi:10.1016/j.energ.2025.100030
[32] Makhzom, A. M., Aissa, K. R., Alshanokie, A. A., Nassar, Y. F., El-Khozondar, H. J., Salem, M. A., Elmnifi, M. (2023). Carbon dioxide Life Cycle Assessment of the energy industry sector in Libya: A case study. *Int. J. Electr. Eng. and Sustain.*, 145–163.
[33] Mohammed, S., Yasser, Y., Algassie, H., Asma, A., El-Khozondar, H., Elmnifi, M., … Salem, M. (2025). Identifying promising locations for establishing hydropower energy storage stations (PHES) using the geographic information systems (GIS) in Libya. *Solar Energy and Sustainable Development Journal*, *14*(1), 394–409. doi:10.51646/jsesd.v14i1.426
[34] Nassar, Y., El-Khozondar, H. J., Ghaboun, G., Khaleel, M., Yusupov, Z., Ahmed, A. A., & Alsharif, A. (2023). Solar and wind atlas for Libya. *Int. J. Electr. Eng. and Sustain.*, 27–43. Retrieved from https://ijees.org/index.php/ijees/article/view/44
[35] Nassar, Y. F., El-Khozondar, H. J., Alatrash, A. A., Ahmed, B. A., Elzer, R. S., Ahmed, A. A., … Khaleel, M. M. (2024). Assessing the viability of solar and wind energy technologies in semi-arid and arid regions: A case study of Libya's climatic conditions. *Applied Solar Energy*, *60*(1), 149–170. doi:10.3103/s0003701x24600218
[36] Nassar, Y., Irhouma, M., Salem, M., El-Khozondar, H., Suliman, S., Elmnifi, M., … Rekik, S. (2025). Towards green economy:: Case of electricity generation sector in Libya. *Solar Energy and Sustainable Development Journal*, *14*(1), 334–360. doi:10.51646/jsesd.v14i1.549
[37] Nassar, Y., & Khaleel, M. (2024). Sustainable development and the surge in electricity demand across emerging economies. *Int. J. Electr. Eng. and Sustain.*, 51–60. Retrieved from https://ijees.org/index.php/ijees/article/view/77
[38] Nassar, Yasser F., El-khozondar, H. J., Ahmed, A. A., Alsharif, A., Khaleel, M. M., & El-Khozondar, R. J. (2024). A new design for a built-in hybrid energy system, parabolic dish solar concentrator and bioenergy (PDSC/BG): A case study – Libya. *Journal of Cleaner Production*, *441*(140944), 140944. doi:10.1016/j.jclepro.2024.140944
[39] Nassar, Yasser F., El-Khozondar, H. J., Khaleel, M. M., Ahmed, A. A., Alsharif, A. H., Elmnifi, M. H., Mangir, I. (2024). Design of reliable standalone utility-scale pumped hydroelectric storage powered by PV/Wind hybrid renewable system. *Energy Conversion and Management*, *322*(119173), 119173. doi:10.1016/j.enconman.2024.119173
[40] Nassar, Yasser F., El-Khozondar, H. J., Khaleel, M. M., Ahmed, A. A., Alsharif, A. H., Elmnifi, M., & Nyasapoh, M. A. (2025). Sensitivity of global solar irradiance to transposition models: Assessing risks associated with model discrepancies. *E-Prime - Advances in Electrical Engineering, Electronics and Energy*, *11*(100887), 100887. doi:10.1016/j.prime.2024.100887