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Analysis of The Technical, Environmental, and Economic Indicators of A Diesel Power Plant: Case of A Cement Manufacturing Plant in Bobo-Dioulasso, Burkina Faso

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ABSTRACT

This work focused on analyzing the technical, environmental, and economic performance of a diesel power plant supplying a cement manufacturing plant located in Bobo-Dioulasso, Burkina Faso, from 2023 to the first half of 2025. The objective was to evaluate the energy efficiency, environmental impact, and profitability of electricity production in a context of high dependence on fossil fuels. The methodology is based on the collection of operational data (power output, energy generated, diesel and lubricant consumption, operating time), the analysis of historical technical data, and the calculation of key indicators such as specific consumption (L/kWh), the CO_2 emission factor ($kgCO_2$/kWh), and the specific production cost (FCFA/kWh). The results show a specific consumption generally between 0.20 and 0.35 L/kWh, with a notable deterioration in 2024 marked by peaks exceeding 0.5 L/kWh, reflecting partial load operation and maintenance constraints. CO_2 emissions vary according to the production level, but the emission factors reveal occasional malfunctions, particularly in September and November 2024, when they exceeded 1.4 $kgCO_2$/kWh, indicating a significant decrease in energy efficiency. Economically, the average specific production cost amounts to 343.70 FCFA/kWh in 2023, 377.48 FCFA/kWh in 2024, and 358.64 FCFA/kWh in the first half of 2025, values significantly higher than the cost of electricity from the national grid (approximately 160 FCFA/kWh). The study highlights an inverse relationship between the load factor and the unit cost of production, emphasizing that the overall performance of the power plant depends heavily on the quality of its operation, maintenance, and the alignment between installed capacity and actual demand. It concludes that optimizing control, strengthening energy monitoring, and the gradual integration of a hybrid solar-diesel solution are essential levers for improving energy efficiency, reducing emissions, and enhancing the economic viability of the system.

Keywords: Diesel power plant, technical indicators, environmental indicators, economic indicators.

1. Introduction

Electricity generation is a fundamental element for the operation of modern industries, particularly in developing countries where access to reliable energy remains a major challenge. In many industrial settings, diesel power plants are emerging as a backup or supplementary solution to public electricity grids due to their flexibility, mobility, and ability to provide power tailored to the specific needs of the plant [1]. In Burkina Faso, dependence on fossil fuels to power industrial sites is particularly evident in the cement production sector, where energy demands are high and continuous [2]. In an initial study, our research team worked to determine the efficiency of the power plant that is the subject of this study and showed that the efficiency depends heavily on the load imposed on the different generator sets. While technically efficient when used correctly [3], industrial diesel power plants present significant environmental challenges. They are associated with greenhouse gas emissions such as carbon dioxide (CO_2), nitrogen oxides (NOx), and particulate matter (PM), thus contributing to air pollution and climate change [4]. These emissions represent a major concern in urban and peri-urban areas, where industrial facilities can impact the health of local populations [5]. Therefore, assessing the environmental performance of diesel power plants is now an essential requirement for companies committed to sustainability and social responsibility. From a technical standpoint, analyzing indicators such as energy efficiency, plant availability, specific fuel consumption, and failure rate is crucial for optimizing the plant's performance and reliability [6]. These indicators not only allow for the evaluation of the operational efficiency of generator sets but also for the comparison of different technological configurations with a view to future improvements [7]. Furthermore, operating a diesel power plant in an industrial context raises significant economic questions. Fuel costs, maintenance costs, equipment depreciation, and external costs related to environmental impacts directly influence the company's competitiveness [8]. For a cement plant in Bobo-Dioulasso, where competition is often based on controlling production costs, a rigorous economic analysis is essential to ensure the financial viability of energy operations. In this context, an integrated approach combining technical, environmental, and economic analysis provides a holistic view of the diesel power plant's performance. Such an approach is fundamental for proposing energy optimization strategies, reducing polluting emissions, and improving the plant's overall profitability [9]. Furthermore, it helps inform decision-makers about potential investment opportunities in cleaner technologies or hybrid solutions [10]. This study therefore focuses on a cement manufacturing plant located in Bobo-Dioulasso, a major industrial city in Burkina Faso. This plant represents a significant example of the energy challenges faced by the national industrial sector, particularly in terms of access to reliable energy, cost control, and environmental impact management. The main objective is to analyze the technical, environmental, and economic indicators of its diesel power plant in order to identify opportunities for improvement and propose recommendations based on empirical data. Thus, this research aims to contribute to a better understanding of the challenges related to the use of diesel power plants in energy-intensive industries and to propose concrete approaches for more sustainable industrial energy management in Burkina Faso and similar contexts. It relies on the collection and analysis of operational data from electrical and thermal measurement instruments, historical operating records, and consumption logs, supplemented by field observations and discussions with technical staff.

2. Materials and methods

2. 1. Materials

To conduct the analysis of the diesel power plant's technical, environmental, and economic indicators, we used the following tools and equipment to ensure the accuracy of the measurements and the reliability of the results:

• All of this data (electrical power produced by each unit (kW); total power output of the alternators (kW); available electrical power output of the transformer (kW); fuel consumption (L/h); operating time and load conditions) was collected real-time via a network of sensors, all computer-assisted.

• The power plant's database, stored on the monitoring computer, was consulted.

• Technical documents: installation plans, equipment datasheets, consumption readings, and operating history.

2. 2. Methods

2. 2. 1. Data collection

This phase consisted of a series of interviews with plant managers to clarify the objectives, needs, expectations, and scope of the analysis. Following these discussions, a site visit schedule was developed in consultation with the plant teams. Simultaneously, information gathering involved reviewing plans, technical specifications, consumption history, and electrical diagrams to gain a better understanding of the site's energy architecture and to rigorously define the scope of the analysis.

During the technical visits, on-site observations were supplemented by discussions with the supervisor and their team to thoroughly assess operating conditions.

2. 2. 2. Technical indicators

These indicators aim to assess the overall energy performance of the production system. They provide a basis for estimating the quantities of fuel and lubricant required to generate one unit of energy, thus allowing for the evaluation of the efficiency of the conversion processes. **Calculation of Specific Diesel Fuel Consumption Specific**

Diesel fuel consumption represents the amount of fuel consumed to produce one kilowatt-hour of electricity. This consumption is determined by equation [11,12].

$$\mathrm{Csg\ (L/Kwh)} = \frac{\mathrm{Vg\ (L)}}{\mathrm{Ep\ (kWh)}} \quad \textbf{(1)}$$

Calculation of Specific Lubricant Consumption Specific

Lubricant consumption corresponds to the amount of fuel used to produce one kilowatt-hour of electrical energy. It is an indicator of the thermal group's energy performance and allows for the evaluation of the efficiency of the conversion process. Its value is obtained from the following mathematical relationship [11,12]:

$$C_{sL}\ \mathrm{(L/kWh)} = \frac{V_L\ \mathrm{(L)}}{E_P\ \mathrm{(kWh)}} \quad \textbf{(2)}$$

Environmental indicators

Environmental indicators are assessment parameters used to evaluate the effects of energy production on ecosystems and the environment, particularly through the quantification of greenhouse gas (GHG) emissions.

Determination of CO_2 emissions (kg)

CO_2 emissions (kg) are the total amount of carbon dioxide emitted by the power plant over a given period, as a function of the amount of fuel consumed. It expresses the amount of CO_2 emitted per kWh of energy produced, given by equation 3:

The CO_2 emission factor (kg/L) for diesel is 2.68 kg CO_2/L [13]

$$E_{CO_2}\ \mathrm{(Kg)} = V_g \times F_{CO_2}\mathrm{(kg/L)} \quad \textbf{(3)}$$

Determination of the CO_2 Emission Factor (Kg/kWh)

The carbon dioxide (CO_2) emission factor, expressed in kilograms per kilowatt-hour (kg/kWh), corresponds to the ratio between the mass of CO_2 released and the amount of energy produced during the conversion process. This factor is determined using equation 4 [14-16].

$$F_{CO_2}\mathrm{((Kg/\ Kwh)} = \frac{E_{CO_2}\ \mathrm{(kg)}}{E_P\ \mathrm{(kWh)}} \quad \textbf{(4)}$$

Determining the Cost of Diesel Fuel

The total cost of diesel fuel is determined by multiplying the volume actually consumed by the unit price per liter, according to the following formula:

$$C_G(\text{ FCFA}) = V_C\text{ (L)} \times P_u\text{ (FCFA)} \quad \textbf{(5)}$$

Determining the Lubricant Cost

The total cost of the lubricant is obtained by dividing the volume consumed by the unit price applied, according to the following formula:

$$C_L(\text{ FCFA}) = V_C\text{(L)} \times P_u\text{ (FCFA)} \quad \textbf{(6)}$$

Determining the Total Cost

To estimate the expenses related to operating the generator set, it is necessary to consider all the consumables involved in its operation. Among these consumables, diesel fuel and lubricant are the main sources of operating costs. Thus, the total cost can be expressed as the sum of the individual costs of these elements, given by equation 7.

$$C_T\text{(FCFA)} = C_g + C_L \quad \textbf{(7)}$$

Determining the Specific Cost

The specific cost of electricity production quantifies the average cost of each kilowatt-hour produced. It is calculated by dividing the total cost incurred for production by the energy actually generated, according to the following relationship [17]:

$$C_S\text{(FCFA/kWh)} = \frac{C_T\text{(FCFA)}}{E_P\text{ (Kwh)}} \quad \textbf{(8)}$$

Determining the Average Annual Specific Cost

To assess the average cost of electricity production, it is necessary to calculate the specific cost over an annual period. This approach smooths out monthly variations and provides a representative value for the average cost per kilowatt-hour. Thus, the average annual specific cost is determined from the monthly specific costs over the year in question, as given by equation 9:

$$C_{S,M}\text{(FCFA/Kwh)} = \frac{\sum C_S\text{ (2023)}}{12} \quad \textbf{(9)}$$

3. Results and discussion

3. 1. Specific Consumption

Figure 1 highlights the monthly evolution of specific diesel consumption (L/kWh) over three consecutive years (2023, 2024 and 2025).

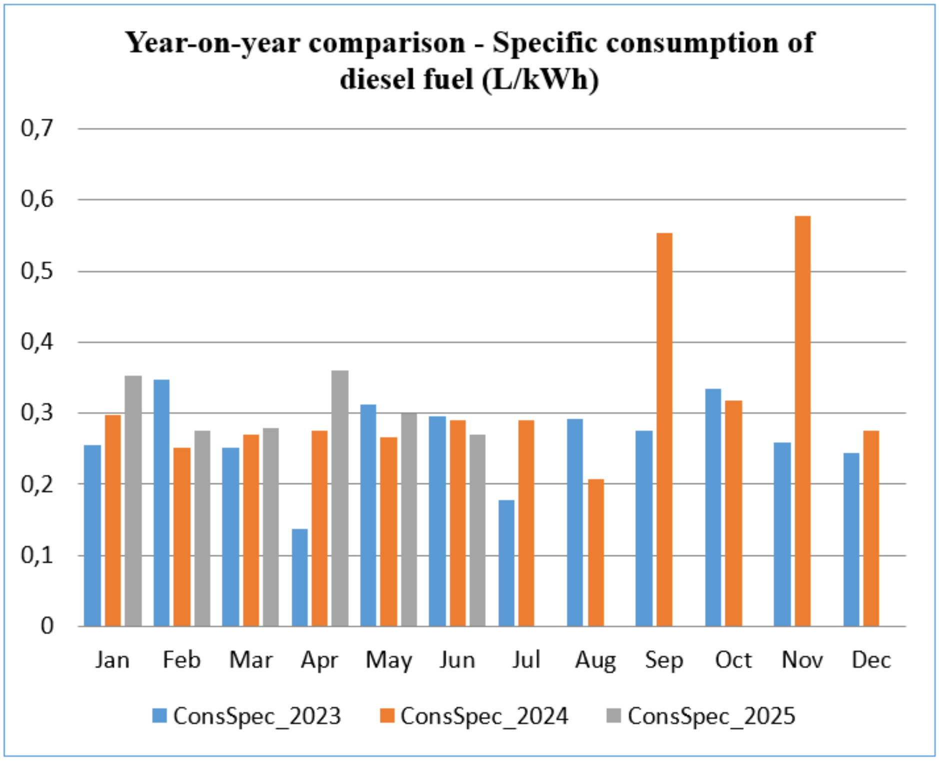

Figure 1: Histogram of the year-over-year comparison of specific diesel fuel consumption

Overall, the values are mostly between 0.20 and 0.35 L/kWh, reflecting relatively stable plant operation. Consumption in 2023 was moderate, with a marked low in April and higher levels in February and May. This variability reflects the sensitivity of energy performance to monthly operating conditions. In 2024, specific consumption was generally higher and more volatile than in other years. Very pronounced peaks appeared in September and November, well exceeding 0.5 L/kWh. These increases indicate a significant degradation in the unit's energy efficiency during these periods. They may be associated with partial load operation, repeated shutdowns, or maintenance constraints. Conversely, 2025 shows relatively consistent and more controlled values. Monthly variations are small, reflecting more stable plant operation. The months of January to June 2025 show consumption levels close to 0.30 L/kWh, without any sudden drops. The year-on-year comparison thus highlights 2024 as the least energy-efficient year. 2023 falls somewhere in between, with a few months of good performance. Overall, 2025 appears to be the most consistent and optimized year in terms of specific fuel consumption. This graph confirms that effective operation and maintenance management is crucial for sustainably reducing specific diesel fuel consumption.

3. 2. Environmental indicators

Figure 2 illustrates the seasonal and interannual variability of CO_2 emission factors between 2023 and 2025.

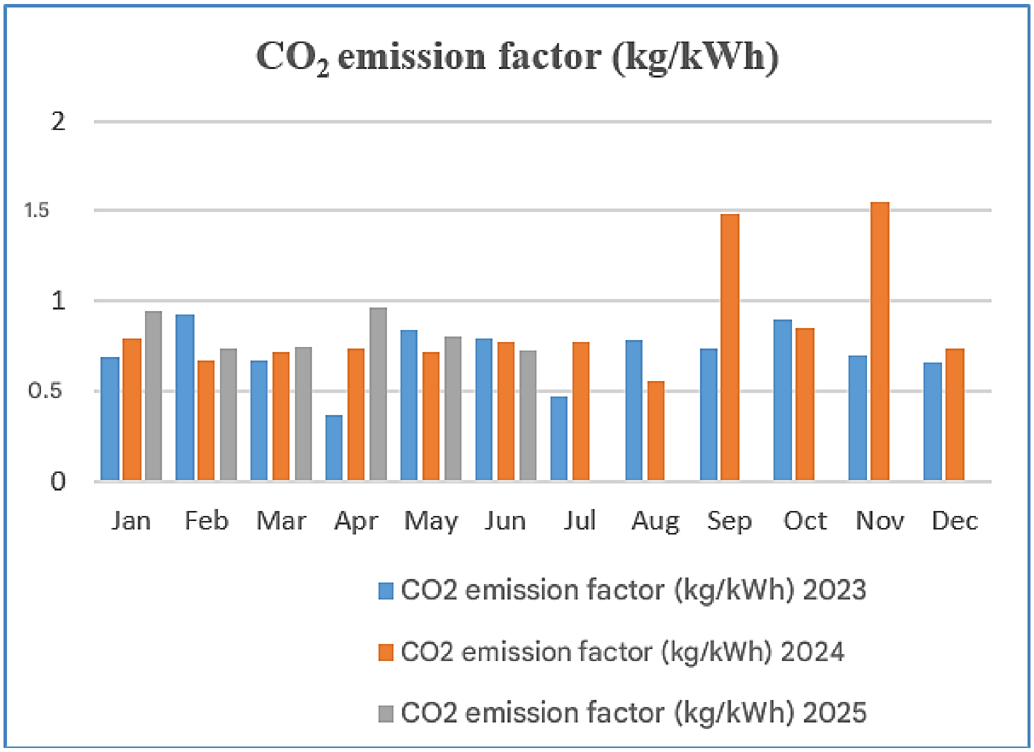

Figure 2: Histogram of interannual comparisons of the emission factor for 2023; 2024; H1 2025

In 2023, monthly emissions remained generally moderate, although there were notable peaks in June and September, reflecting a temporary increase in production activity. Emission factors for 2023 ranged from 0.37 to 0.93 kg CO_2/kWh, indicating fluctuations in energy efficiency from month to month. The year 2024 was characterized by a very sharp increase in absolute CO_2 emissions, particularly between March and June. The exceptionally high values recorded in March, April, and May 2024 suggest a significant intensification of electricity production. Despite this increase in production, emission factors for 2024 remained generally between 0.55 and 0.85 kg CO_2/kWh, reflecting relatively stable average performance. However, very high emission factor values appear in September and November 2024. These peaks, exceeding 1.4 kgCO_2/kWh, reflect a significant decline in energy efficiency during these periods. This situation may be linked to low-load operation, frequent start-ups, or temporary technical failures. In 2025, the available data for the first half of the year show a gradual recovery in emissions starting in March. The months of March to May 2025 show relatively high emissions, indicating sustained activity at the power plant. Emission factors for 2025 remain generally below 1 kgCO_2/kWh, except for a high value observed in January. The year-on-year comparison thus highlights a high variability in CO_2 emissions, primarily driven by the level of electricity production. Conversely, the fluctuations in the emission factor mainly reveal variations in operational performance and quality of operation. Overall, the table shows that 2024 is the most unfavorable period from an environmental point of view, both in terms of emission volume and instability of emission factors.

3. 3. Economic Indicator

Economic analysis allows us to estimate the cost of producing the electricity generated by the power plant, taking into account the cost of fuel (diesel) and lubricant.

• In Burkina Faso, the price of diesel is 675 FCFA per liter. For large consumers, such as industries, diesel is not subsidized, and the price per liter is 1150 FCFA.

• The power plant's engines use 15W-40 engine lubricant. A 208-liter drum costs 350,000 FCFA. This gives a unit price of 1682.6 FCFA per liter of lubricant.

Figure 3 is a histogram comparing the specific cost (FCFA/kWh) on an interannual basis.

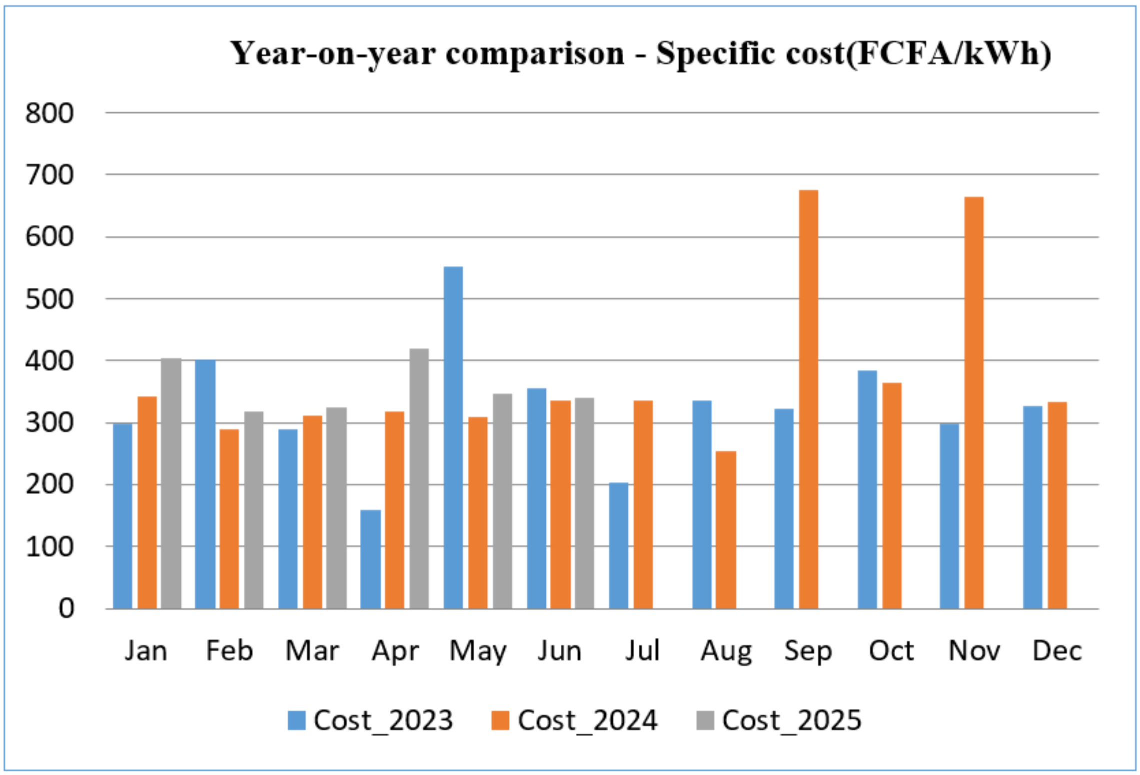

Figure 3: Histogram comparing year-on-year specific cost for 2023; 2024; H1 2025

The economic analysis is based on calculating the specific production cost (FCFA/kWh) from the consumption of diesel and lubricant, relative to the energy actually produced. Over the period from 2023 to half-year 2025, the results show significant variations in the specific cost, with peaks exceeding 350 FCFA/kWh, particularly between September and November 2024. These increases reflect suboptimal operation of the power plant, linked to the underutilization of the units (low load factor), an increase in specific consumption due to fuel quality, and unplanned maintenance shutdowns that disrupted load distribution and reduced overall efficiency. Conversely, certain periods in 2023 and early 2025 show more stable costs, between 250 and 320 FCFA/kWh, indicating improved operational management. These findings highlight the direct impact of operating practices on the power plant's energy efficiency. The lack of optimization results in increased economic costs and higher energy and environmental losses. To address this, it is recommended to streamline operations by improving the load factor, consider a solar-diesel hybrid system to reduce reliance on diesel fuel, and strengthen real-time energy monitoring. These combined actions would stabilize production costs, improve overall efficiency, and reduce the plant's environmental footprint. Furthermore, 2024 saw abnormally high specific cost values in September and November (exceeding 650 FCFA/kWh), associated with very low production levels. These situations typically correspond to periods of suboptimal operation (frequent start-ups, partial plant operation, or technical downtime), during which fixed costs and losses become predominant. Overall, the evolution of the specific cost shows an inverse relationship with the monthly production level: months of high production are characterized by lower and more stable unit costs (generally between 300 and 350 FCFA/kWh), while periods of low production lead to a marked decline in economic performance. These results indicate that the system's profitability is highly dependent on the installation's utilization rate and operational continuity. At the national level, the cost of a kWh of electricity supplied by the grid is approximately 160 FCFA. This demonstrates that local energy production is not profitable; therefore, it must be carefully managed to avoid waste and reduce its impact on cement production costs.

4. Conclusion

This study provided an integrated assessment of the technical, environmental, and economic performance of a diesel power plant supplying a cement manufacturing plant in Bobo-Dioulasso. Analysis of data covering the period from 2023 to the first half of 2025 highlights a strong dependence of the plant's overall performance on actual operating conditions, particularly the load factor and the continuous operation of the generator sets. In terms of energy performance, the results reveal efficiencies generally lower than the reference values established in our initial investigation, and specific diesel fuel consumption often exceeding 0.28 L/kWh, indicating largely suboptimal operation. The observed discrepancies, particularly in 2024, are primarily linked to partial-load operating conditions, frequent start-ups, and maintenance constraints, confirming the existence of significant potential for improving the plant's energy efficiency. Environmental analysis shows that CO_2 emissions directly follow the level of electricity production, while emission factors reflect the operational quality of the installation. The peaks observed in September and November 2024, with emission factors exceeding 1.4 $kgCO_2/kWh$, indicate a temporary but significant degradation in environmental performance, associated with excessive fuel consumption and low generator efficiency. These results highlight that reducing emissions depends primarily on improved management of equipment operation and control. From an economic standpoint, the average specific cost of electricity production remains high and variable, with average values of 343.70 FCFA/kWh in 2023, 377.48 FCFA/kWh in 2024, and 358.64 FCFA/kWh in the first half of 2025. The increase observed in 2024 confirms that higher production does not necessarily guarantee improved profitability when energy efficiency and operational organization are not optimized. The study thus highlights an inverse relationship between the power plant's utilization rate and the unit production cost. Overall, this research demonstrates that the performance of the diesel power plant is highly dependent on the regularity of operation, the quality of maintenance, and the alignment between power demand and installed capacity. Improving the load factor, rigorous maintenance planning, real-time monitoring of performance indicators, and optimizing operating modes are key levers for simultaneously reducing specific energy consumption, greenhouse gas emissions, and production costs. Finally, although this cost is relatively stable, it remains very high compared to that of the national grid. Given the economic and environmental constraints identified, the gradual introduction of hybrid solutions, particularly through the integration of solar photovoltaic production to support the diesel power plant, appears to be a relevant approach for strengthening the site's energy security, reducing dependence on diesel fuel, and sustainably improving the overall performance of the plant's electricity generation system.

Nomenclature

C_g	:	Diesel cost (FCFA)
C_L	:	Lubricant cost (FCFA)
C_S	:	Specific cost (FCFA/kWh)
C_{sg}	:	Specific diesel consumption (L/kWh)
C_{sL}	:	Specific lubricant consumption (L/kWh)
C_{SM}	:	Specific average annual cost (FCFA/kWh)
C_T	:	Total cost (FCFA)
E_{CO_2}	:	CO_2 emissions (kg)
E_P	:	Energy produced (kWh)
F_{CO_2}	:	CO_2 emission factor (kg/kWh)
V_g	:	Diesel volume consumed (L)
V_L	:	Lubricant volume consumed (L)

References

Beccali, M., Cellura, M., & Mistretta, M. (2004). *Technical and economic feasibility of distributed generation systems based on renewable energy sources.* Renewable Energy, 29(12), 2109–2122

Borges, B. T., Silva, C. A., & Tenório, J. A. S. (2018). *Assessment of diesel generator performance in isolated industrial applications.* Energy Reports, 4, 764–774

Gaël Lassina SAWADOGO, Drissa OUEDRAOGO, Yacouba CAMARA, Sory Ibrahim Mickaelou OUEDRAOGO, Serge Wendsida IGO (2026), *Evaluation of the efficiency of a diesel thermal power plant for electricity production at CIMAF Bobo-Dioulasso*, Journal of Chemical, Biological et Physical Sciences, 16 (2), 224-235.

Hosseini, S. E., Wahid, M. A., & Moghaddam, M. P. (2019). *Performance analysis of diesel generators for industrial use.* Journal of Sustainable Energy, 11(3), 145–156.

International Energy Agency (IEA). (2020). *Diesel and Heavy Fuel Oil in Electricity Generation.* IEA Publications.

Hou, D., Li, Y., & Zhu, G. (2021). *Hybrid energy systems for industrial power supply: technical optimization and cost-benefit analysis.* Renewable and Sustainable Energy Reviews, 137, 110600.

Karekezi, S., & Kithyoma, W. (2002). *Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?* Energy Policy, 30(11-12), 1071–1086.

Saidur, R., Rahim, N. A., & Ping, H. C. (2011). *Environmental impact of diesel generator systems in industrial applications.* Journal of Cleaner Production, 19(15), 1726–1735.

Shah, S., et al. (2013). *Air quality and health impacts of diesel generators in urban industrial zones.* Environmental Monitoring and Assessment, 185(4), 3451–3463.

Traoré, A., Sawadogo, L., & Ouedraogo, M. (2017). *Analyse énergétique du secteur industriel du ciment au Burkina Faso.* Revue Burkinabè de Sciences et Techniques, 5(2), 75–89.

Daniel Soto ,Modeling and measurement of specific fuel consumption in diesel

microgrids in Papua, Indonesia, Energy for Sustainable Development

Volume 45, August 2018, Pages 180-185

https://doi.org/10.1016/j.esd.2018.06.013

Hamdan H. Alif; Wangi P. Sari; Bertha M. Sopha; Almas Aprilana; Yun P. Mulyani; Hapsari Tiva W.D. Specific Fuel Consumption Prediction Model for Diesel Engines: A Preliminary Study 2022 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) 10.1109/IEEM55944.2022.9989866

Te Kawanatanga O Aotearoa (2024), Environment, Measuring emissions: Detailed guide New Zealand, 2024.

Bernard Nana, Hamadi Zalle, Issoufou Ouarma, Tizane Daho, Arsène Yonli, Antoine Bere*Assessment of carbon dioxide emission factors from power generation in Burkina Faso*, *Clean Air Journal* (2023).

https://doi.org/10.17159/caj/2023/33/2.15701

Yufei Xi, Lujie Zuo , Meng Chen, Jiansheng Zhang, Lin Cheng, Ioannis Lestas Energy-carbon pricing-guided collaborative optimization for local integrated energy communities with multi-vector electrification consumers Applied Energy

Volume 392, 15 August 2025, 125946, https://doi.org/10.1016/j.apenergy.2025.125946

Katarzyna Joachimiak-Lechman , Jolanta Baran and Joanna Kulczycka, Electricity-Related Emissions Factors in Carbon Footprinting—The Case of Poland,

nergies **2025**, *18*(15), 4092; https://doi.org/10.3390/en18154092

Moses Jeremiah Barasa Kabeyi, Oludolapo Akanni Olanrewaju, he levelized cost of energy and modifications for use in electricity

generation planning, 2023, 495-534 , https://doi.org/10.1016/j.egyr.2023.06.036

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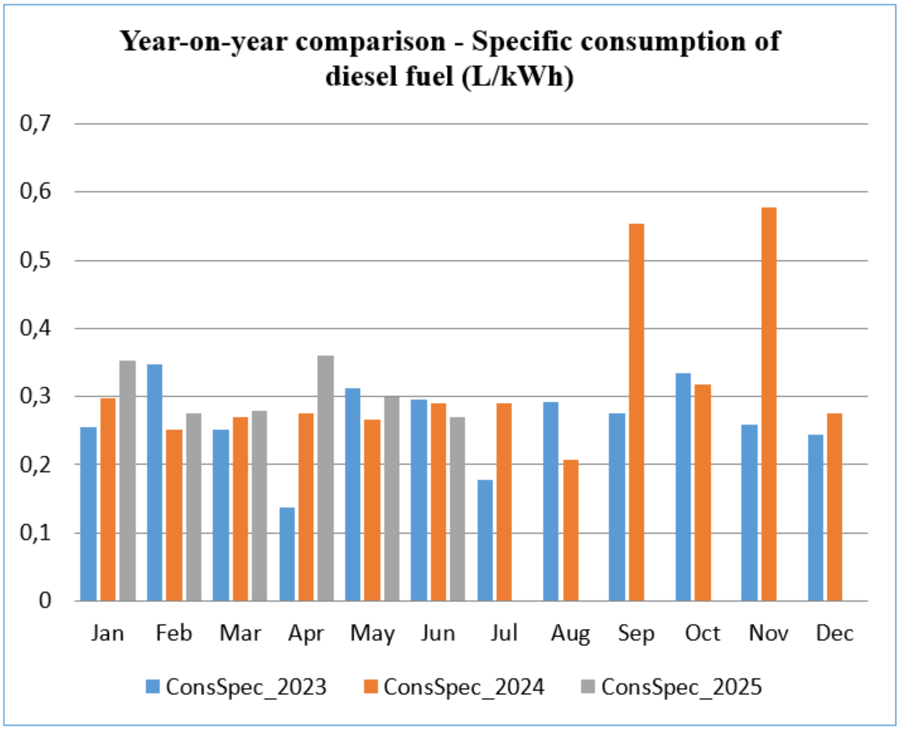
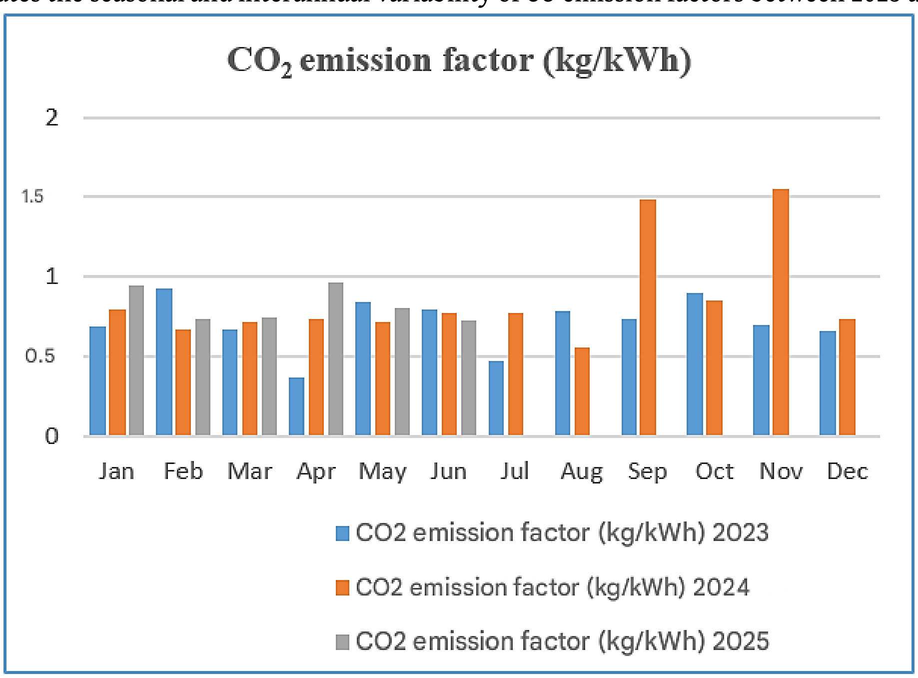


Figure 1: Histogram of the year-over-year comparison of specific diesel fuel consumption

Figure 2 illustrates the seasonal and interannual variability of CO emission factors between 2023 and 2025.



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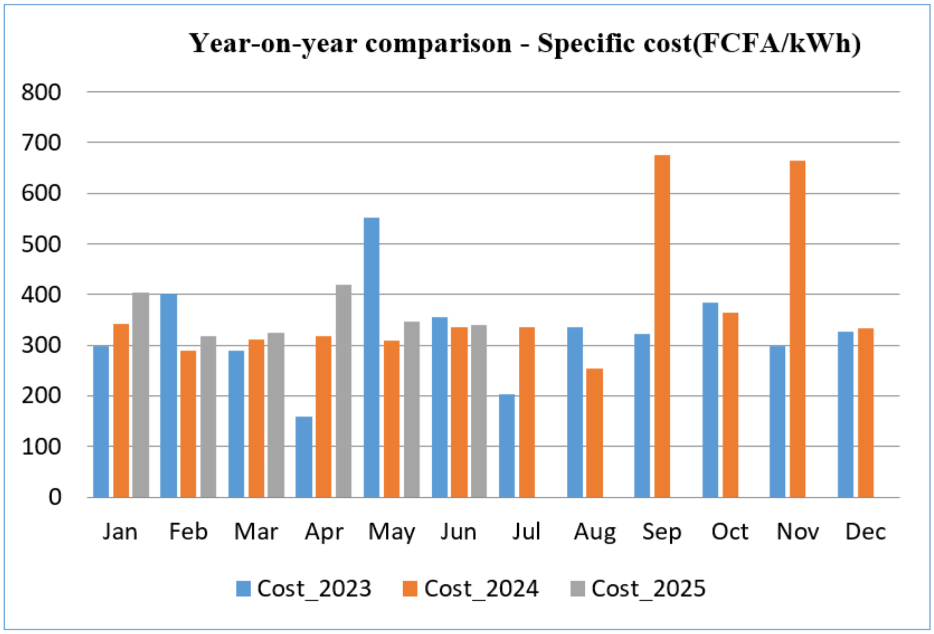

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