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Simulation of Electrical Energy Requirements for the CPO Pump House at PT Pelindo Energi Logistik

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ABSTRACT

Electricity consumption in industrial pumping systems plays an important role in supporting operational efficiency, particularly in facilities that operate continuously. The motor and pump system used in the Crude Palm Oil (CPO) pump house at PT Pelindo Energi Logistik requires a stable and reliable electricity supply to ensure optimal pumping operations. Therefore, analyzing the electrical energy demand of the system is essential to understand its energy consumption characteristics and to support more efficient energy management. This study aims to analyze the electrical energy demand of the motor and pump system in the CPO pump house by evaluating the pattern of energy consumption during the analyzed operational period. The research methodology involves collecting technical and operational data related to the motor and pump system. The data are then analyzed using several key parameters, including the average annual energy consumption, minimum and maximum energy consumption values, and the standard deviation of energy usage. These parameters are used to simulate and evaluate the energy consumption pattern of the system during the operational period. The results show that the motor and pump system has an average electricity consumption of approximately 131.77 MWh per year with a relatively stable consumption pattern. The findings provide insights into the characteristics of electricity usage in industrial pumping systems and can serve as a basis for improving energy management and operational efficiency.

1. Introduction

Global electricity consumption has shown a consistently increasing trend in line with the growth of economic activities, technological advancements, and the rising dependence of modern society on reliable and sustainable electrical systems [1,2]. This increase in consumption creates strategic challenges in energy resource management, particularly related to the limited reserves of fossil energy and the significant environmental impacts resulting from their intensive utilization [3,4]. These conditions encourage various stakeholders to accelerate the transition toward renewable energy utilization as part of long-term energy security and sustainability strategies [5,6]. One

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renewable energy technology that has experienced significant development is solar panels or photovoltaic (PV) systems, which are capable of directly converting solar radiation into electrical energy through the photovoltaic effect mechanism [7,8]. Therefore, comprehensive studies on the potential utilization of solar energy are becoming increasingly crucial in supporting the transformation of energy systems toward greater sustainability, efficiency, and adaptability to future energy dynamics [9,10].

The utilization of solar energy through photovoltaic systems has gained increasing urgency, particularly in Indonesia, which is geographically located in a tropical region with relatively high and evenly distributed solar radiation throughout the year [11,12]. This potential provides substantial opportunities for the industrial and port logistics sectors to begin integrating renewable energy technologies into existing electrical systems in order to improve energy efficiency while simultaneously reducing operational carbon emissions [13]. In addition to environmental benefits, the implementation of solar panels also offers long-term economic advantages through the reduction of conventional electricity costs, which tend to be volatile [14]. However, the deployment of renewable energy systems requires accurate and representative data-driven planning to ensure that the designed system capacity truly matches the load characteristics in the field. Therefore, electrical load profile analysis becomes a fundamental stage that must be carried out prior to considering the integration of renewable energy technologies in industrial facilities [15].

From the perspective of port logistics operations, the distribution of liquid commodities represents a process with relatively high electricity consumption intensity because it involves various electromechanical equipment that supports the fluid transfer process. In the Crude Palm Oil (CPO) distribution system, the pump house functions as a critical node that bridges the transfer of fluid from storage tanks to ship loading facilities through an integrated piping network [16]. Within the operational environment of PT Pelindo Energi Logistik, the CPO pump house operates following loading and unloading schedules that are fluctuating and highly dependent on vessel arrival and departure dynamics. These operational conditions cause the pump electric motors to become the dominant load component contributing significantly to the total electricity consumption of the logistics facility [17]. Therefore, a comprehensive understanding of the electrical power requirements of the pump house is a crucial aspect in maintaining the reliability and efficiency of the port logistics electrical system.

Without adequate electrical load profile analysis, facilities are at risk of experiencing power capacity mismatches, energy waste, and suboptimal electrical system planning that may ultimately affect operational reliability. Therefore, electrical energy requirement analysis is an important step in industrial energy management, particularly for identifying peak loads, monthly operating patterns, and estimated monthly energy consumption in a more accurate and structured manner. Software-based simulation approaches offer advantages because they can dynamically model load behavior based on actual operational data available in the field. One of the software tools widely used in energy system studies is HOMER Pro, which has the capability to comprehensively simulate electrical load profiles and energy requirements. Through this approach, the energy system planning process for the CPO pump house at PT Pelindo Energi Logistik is expected to be carried out more systematically, data-driven, and with a higher level of accuracy.

As summarized in table 1, previous studies indicate that techno-economic simulation approaches based on HOMER and similar software have been widely applied to evaluate the integration of photovoltaic and hybrid systems across various sectors, generally demonstrating potential reductions in energy costs and improvements in system performance. Based on these conditions, it can be emphasized that the urgency of renewable energy development, particularly solar panel technology, is becoming increasingly relevant in supporting improved efficiency and sustainability of

energy systems in the industrial and port logistics sectors. On the other hand, the operational characteristics of the CPO pump house at PT Pelindo Energi Logistik, which exhibits significant electricity consumption, require accurate, comprehensive, and data-driven electrical power demand analysis. Simulation approaches using software such as HOMER Pro provide an appropriate solution for obtaining a more detailed and dynamic picture of the electrical load profile. The results of this analysis are expected to serve as a strong foundation for the planning, evaluation, and development of a more optimal electrical system. Therefore, the synergy between electrical demand analysis and future renewable energy utilization opportunities is expected to support the creation of industrial operational systems that are more reliable, efficient, and sustainable.

Table 1

Literature review of techno-economic analysis of on-grid Photovoltaic (PV) systems

| References | Method | Research Focus | Key Results |
|------------|--|--|--|
| [18] | Techno-economic modeling using HOMER for grid-connected PV | On-grid rooftop PV cost-reliability trade-off in developing economies (including unserved energy simulation) | Systems with maximum PV capacity show lower NPC and reduced grid requirements for on-grid systems |
| [19] | Stochastic assessment with MATLAB, PVsyst & HOMER Grid | Techno-economic performance evaluation of large industrial grid-connected rooftop PV systems | Sensitivity to grid tariffs, inflation, and PV degradation is identified, providing an economic strategy for grid-PV systems |
| [20] | Prefeasibility techno-economic analysis of HGIRES with HOMER Pro | Optimal design of HRES for rural electrification | An optimal configuration with low NPC and COE was found, demonstrating 100% renewable source KEOH |
| [21] | Techno-economic & simulation HOMER Pro | Grid-connected PV systems for medium-sized buildings (Algeria) | The optimal configuration is able to meet institutional loads and outperform conventional solutions |
| [22] | PV-Wind + grid hybrid simulation using optimization | Integration of solar and wind energy for desalination stations | Grid + PV + wind integration significantly reduces the energy costs of the desalination process |
| [23] | Techno-economic hybrid PV + DG + grid | Analysis of hybrid PV + grid + generator for telecom BTS | Results show a significant reduction in NPC and COE with PV integration |
| [24] | Techno-economic & environmental optimization | Optimization of grid-connected microgrids with geothermal + PV + WT sources | Reducing GHG emissions, optimizing NPC and proportion of renewable energy |
| [25] | Comparison of three HOMER based hybrid systems | Feasibility analysis of PV + BES + WT + grid systems in various cities | Feasibility analysis of PV + BES + WT + grid systems in various cities |
| [26] | Microgrid hybrid systems feasibility | Feasibility study of hybrid hydrogen & PV systems in residential buildings | On-grid optimal with COE 0.09 CA\$/kWh; higher off-grid |
| [27] | Techno-economic hybrid microgrid optimization | Integration of PV, WT, Battery, DG with optimization algorithm | The PV + WT + BESS + DG configuration shows high reliability and competitive LCOE |

2. Methodology

2.1 HOMER Pro-Driven Energy System Simulation

This research methodology begins with the systematic collection of technical and operational data of the CPO pump house to obtain an accurate representation of the actual electrical conditions, as illustrated in figure 1. The next stage involves determining the study location at PT Pelindo Energi

Logistik by incorporating geographical parameters, solar radiation data (solar GHI), ambient temperature, and the characteristics of the PLN electricity supply as the basis for system modeling. Subsequently, a daily load consumption profile is developed based on the main equipment such as pump motors and air conditioning systems, with specifications including installed power, operating voltage, operating hours, load factor, and equipment efficiency. The validated data are then modeled using HOMER Pro software to analyze energy production, energy consumption, and the techno-economic performance of the system based on parameters such as Net Present Cost (NPC) and Cost of Energy (COE). The simulation results are finally used as the basis for evaluation and for formulating recommendations to develop a more optimal, efficient, and sustainable energy system.

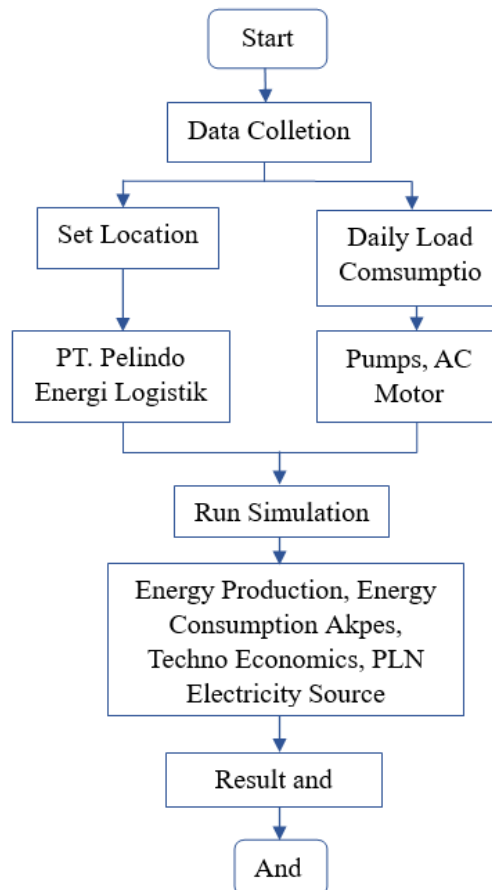


Fig. 1. Research methodology flowchart

2.2 Data Collection

Figure 2 illustrates the configuration of a Solar Power Plant (PV system) integrated with the grid and a battery bank to supply an electric pump load. On the AC side, the grid functions as a power source from the PLN utility network and is connected to the AC bus as the alternating current distribution line [28]. Electrical energy from the AC bus is then delivered to operate the electric load represented by a pump. On the DC side, the LR6-60BK solar panel module converts solar radiation into electrical energy in the form of direct current (DC). This DC electrical energy can be stored in the battery bank as an energy storage system to maintain power availability. Furthermore, the converter acts as an interface between the DC bus and the AC bus by converting DC power into AC power, allowing electrical energy from the solar panels and batteries to be utilized to supply the pump load. The mathematical formulation of the power balance in the hybrid system is expressed as follows (1)

$$P_{load}(t) = P_{PV}(t) + P_{grid}(t) + P_{battery}(t) \tag{1}$$

This equation explains that $P_{load}(t)$ is the power required by the pump, meanwhile $P_{PV}(t) + P_{grid}(t) + P_{battery}(t)$ respectively is the power that comes from solar panels, the PLN electricity network, and batteries. These three energy sources are used together to meet the pump power requirements so that the system can operate properly.

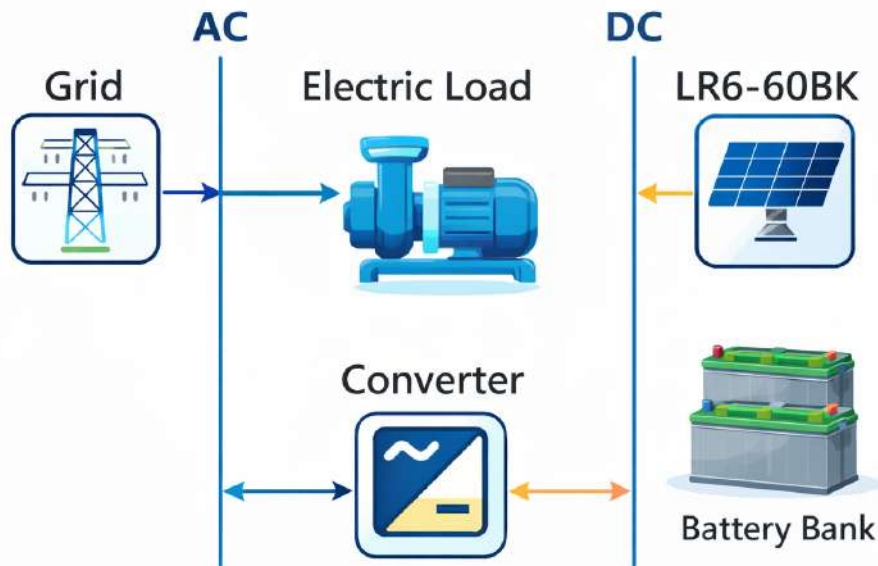


Fig. 2. Grid–PV–battery hybrid energy system configuration for pump operation

Figure 3 shows the monthly solar radiation profile over one year expressed in kWh/m²/day. The horizontal axis (X) represents the months from January to December, while the vertical axis (Y) indicates the amount of solar radiation received each day. Based on the graph, the annual average solar radiation is approximately 5.17 kWh/m²/day, which is indicated by the dashed line representing the annual average value. The highest solar radiation occurs in September with a value of 6.05 kWh/m²/day, while the lowest value occurs in June at 4.73 kWh/m²/day. In general, the solar radiation begins to increase from July and reaches its peak in September, then gradually decreases toward the end of the year. These data indicate that the solar energy potential at the study location is relatively stable throughout the year, making it suitable for supporting the implementation of a Photovoltaic (PV) solar power system at the site.

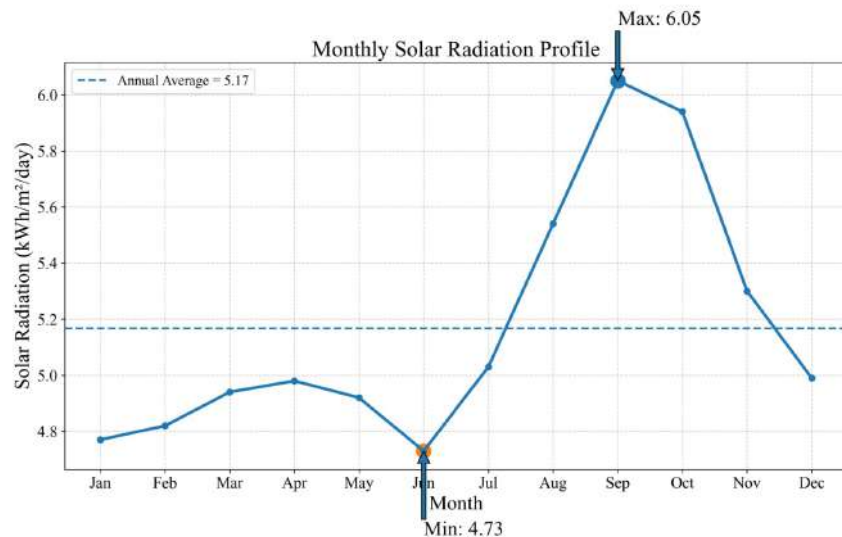


Fig. 3. Monthly solar radiation profile at the study location

Table 2 presents the technical parameters used as the basis for system design in this study. The pumping system consists of six centrifugal pump units manufactured by Siemens & Hirsch GmbH with models D-3357862, D-3357864, and series D-96-00637 [29]. Each pump has a nominal flow rate of 45 m³/h, resulting in a total system flow rate of 270 m³/h with a total head of 35 m and a pump efficiency of approximately 72%. The pumps operate at a rotational speed of 1,450 rpm with a daily operating volume of about 2,160 m³/day to support a production capacity of 2,200 MT per month. These specifications are used to determine the pumping system characteristics and to estimate the electrical energy requirements during operation.

The pump driving system uses three-phase induction motors with an installed power of 7.5 kW per unit, resulting in a total motor capacity of 45 kW. The motors operate at a nominal voltage of 380 V with a frequency of 50 Hz and a power factor of 0.88 [30]. The motor efficiency is approximately 90% with an IP55 protection class that provides protection against dust and water splashes. The motors are designed to operate continuously with an S1 duty cycle for 8 hours per day. Based on this operating duration, the electrical energy consumption required to operate the six motors reaches approximately 360 kWh per day or about 10,800 kWh per month.

The solar power generation system uses LONGi Solar LR6-60BK modules based on monocrystalline technology with a rated power output of 295 Wp per module. The modules have an efficiency of approximately 18% with a temperature coefficient of -0.41 %/°C, indicating performance reduction as temperature increases. Each module requires an installation area of approximately 1.635 m², which requires sufficient space for system installation. The PV system capacity design is based on a daily energy demand of 360 kWh while considering system losses of about 20%. Based on these calculations, the optimal PV system capacity is estimated at 54 kWp with approximately 183 modules and a total installation area of about 299 m².

The inverter used in this system is a grid-tied or hybrid type with a capacity of 60 kW and a capacity margin of around 10%. The inverter has an efficiency of approximately 96% and functions to convert electrical energy from direct current (DC) into alternating current (AC) so that it can be used by electrical loads. In addition, the inverter acts as the interface between the solar panel system and the electrical system supplying the pump load. The system cost parameters include a PV module price of Rp 10,000/Wp and an inverter price of Rp 2,000,000/kW with annual operation and maintenance costs of about 1.5%. The total initial investment cost of the solar power system is estimated at Rp

660,000,000, and the system is capable of generating approximately 350–380 kWh of electricity per day, which is sufficient to meet the operational energy requirements of the pumping system.

Table 2
 Data on pump systems and solar power generation systems specifications

| Categories | Parameter | Value | Units |
|---|-------------------------------------|---|----------------------|
| Pump System (Installed Equipment) | Number of Centrifugal Pumps | 6 | units |
| | Pump Brand | Siemens & Hinsch GmbH | – |
| | Pump Model | D-3357862; D-3357864; D-96-00637 series | – |
| | Pump Type | Centrifugal Pump | – |
| | Nominal Discharge (per pump) | 45 | m ³ /hour |
| | Total System Discharge | 270 | m ³ /hour |
| | Total Head (per pump) | 35 | m |
| | Pump Efficiency | 72 | % |
| | Pump Rotation | 1,450 | rpm |
| | Daily Operating Volume | 2,160 | m ³ /hour |
| | Production Capacity | 2,200 | MT/month |
| Motor System (Requirements & Operation) | Motor Type | 3 Phase Induction Motor | – |
| | Installed Motor Power (per unit) | 7.50 | kW |
| | Total Motor Power (6 units) | 45 | kW |
| | Nominal Voltage | 380 | V |
| | Frequency | 50 | Hz |
| | Power Factor (cos ϕ) | 0.88 | – |
| | Motor Efficiency | 90 | % |
| | Protection Class | IP55 | – |
| | Duty Cycle | S1 (Continuous) | – |
| | Operating Time | 8 | hour/day |
| | Daily Energy Consumption (6 motors) | 360 | kWh/day |
| | Monthly Energy Consumption | 10,800 | kWh/month |
| Solar PV Module | Module Type | LONGi Solar LR6-60BK | – |
| | Cell Technology | Monocrystalline | – |
| | Power per Module | 295 | Wp |
| | Module Efficiency | 18 | % |
| | Temperature Coefficient | -0.41 | %/°C |
| | Area per Module | 1.635 | m ² |
| PV System (Sizing – Recalculated) | Daily Energy Requirements | 360 | kWh/ day |
| | System Loss Factor | 20 | % |
| | Optimal Installed PV Power | 54 | kWp |
| | Number of PV Modules | 183 | units |
| | Total PV Area | 299 | m ² |
| Inverter System | Inverter Type | Grid-tied / Hybrid | – |
| | Inverter Capacity | 60 | kW |
| | Capacity Margin | 10 | % |
| | Inverter Efficiency | 96 | % |
| Cost Parameters (Updated) | PV Module Prices | 10,000 | Rp/Wp |
| | Inverter Price | 2,000,000 | Rp/kW |
| | O&M costs | 1.5 | %/ year |

| | | | |
|----------------------------------|---|-----------------------|---------|
| CAPEX Summary (Updated) | PV Cost (54 kWp × IDR 10,000/Wp) | 540,000,000 | Rp |
| | Inverter Cost (60 kW × Rp. 2,000,000/kW) | 120,000,000 | Rp |
| | Total CAPEX of PV–Inverter System | 660,000,000 | Rp |
| System Output & Compatibility | Daily Energy Generated PV | 350–380 | kWh/day |
| | Suitability for Pump–Motor Loads | Fulfil | – |
| | System Operating Mode | Direct load (daytime) | – |

3. Results

The system performance analysis was carried out by evaluating the solar fraction, which represents the percentage contribution of electrical energy generated by the Photovoltaic (PV) system to the total energy demand of the pumping system. This parameter is used to determine the extent to which solar energy can replace electricity supplied from the conventional grid during the operational period. Based on the available data, the solar fraction at the beginning of the operational period shows a relatively high contribution from solar energy. In the first year, the solar fraction reached 55.50% with a standard deviation of approximately 2.23%, indicating that more than half of the system's energy demand can be supplied by the PV system. Figure 4 illustrates the trend of solar energy contribution from the PV system over a 25-year operational period, where the solar fraction gradually decreases from approximately 52.67% in year 12 to about 49.72% in year 25, although the PV system is still capable of supplying nearly half of the total energy demand indicating that the system remains effective for long-term operation.

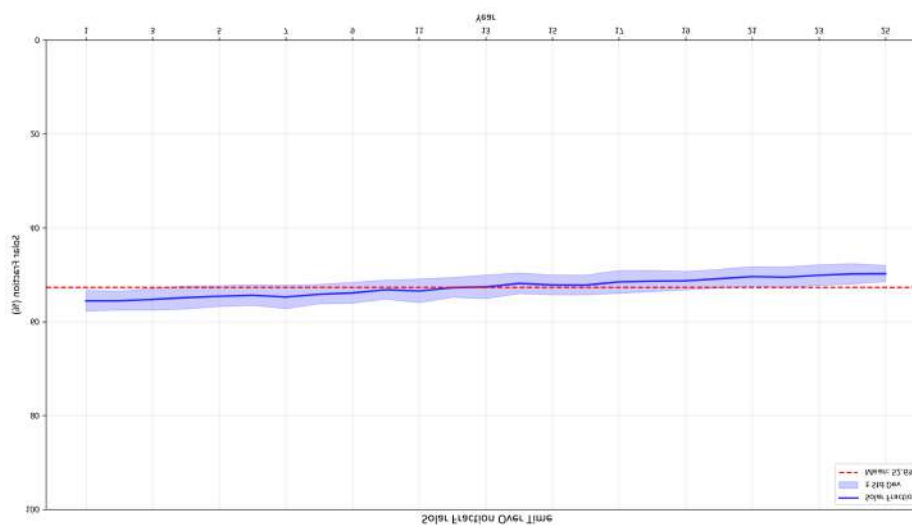


Fig. 4. Solar energy fraction of the PV system during a 25-year operational period

The evaluation of the energy system was conducted by comparing the annual energy production of the Photovoltaic (PV) system and the electricity consumption from the grid over a 25-year operational period. The data used consist of four main parameters, namely annual PV energy production (MWh/year), the standard deviation of PV production, grid energy consumption, and the standard deviation of grid consumption. These parameters are used to assess the stability of energy production from the solar power system as well as the level of system dependence on the conventional electricity grid. Figure 5 shows the comparison between the annual energy production of the PV system and electricity consumption from the grid during the system's operational period. The graph indicates a gradual decrease in PV energy production from approximately 73 MWh/year

in the first year to around 65.23 MWh/year in the 25th year, while grid electricity consumption gradually increases from about 58.70 MWh/year to approximately 66.05 MWh/year at the end of the operational period.

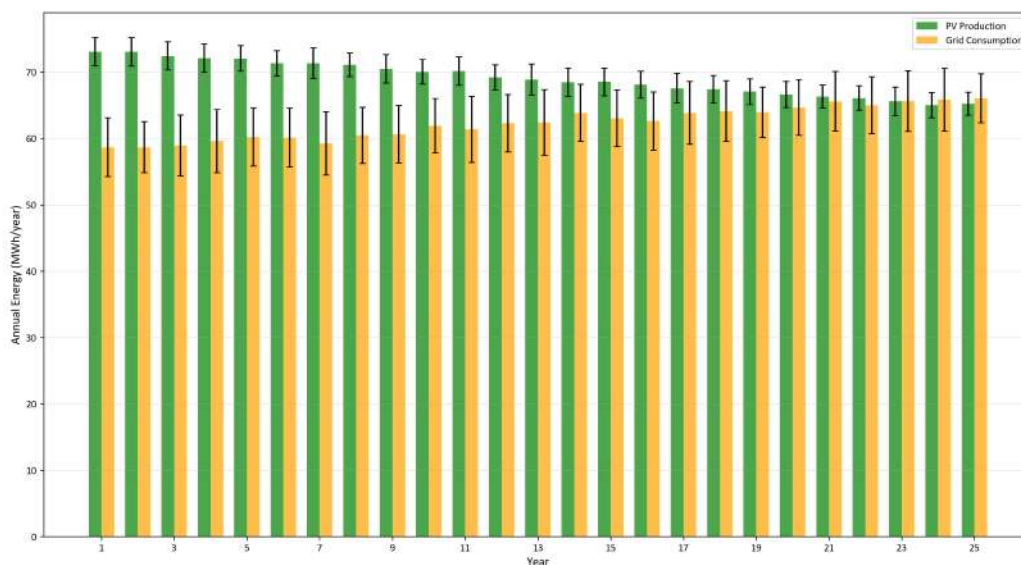


Fig. 5. Annual energy production comparison between PV system and grid consumption over a 25-year operational period

The energy consumption of the motor and pump system is described using annual energy demand data over a 25-year operational period. The data used consist of four main parameters, namely the average annual energy consumption of the motor and pump system (MWh/year), the standard deviation of energy consumption, the minimum energy consumption value, and the maximum energy consumption value that occurs in each year of operation. Based on these data, the average energy consumption of the system is around 131.77 MWh/year in the first year with a standard deviation of approximately 4.11, a minimum value of about 119.98 MWh/year, and a maximum value of about 142.02 MWh/year. The average energy consumption of the system during the observation period tends to remain stable in the range of 130–132 MWh/year, indicating that the energy demand of the motor and pump system remains relatively constant throughout the operational period. Figure 6 shows the pattern of annual energy consumption changes of the motor and pump system during the 25-year operational period, where the red line represents the sample data of motor and pump energy consumption, the blue line represents the average annual energy consumption of the system, the light blue area indicates the ± 1 standard deviation range from the average energy consumption value, and the dashed line represents the rated load of the system, with the horizontal axis (X) showing the operational years of the system from year 1 to year 25 and the vertical axis (Y) showing energy consumption in MWh/year, indicating that although there are fluctuations in energy consumption in several years, the values remain within a reasonable deviation range and the system can be considered to have good operational stability during the observation period.

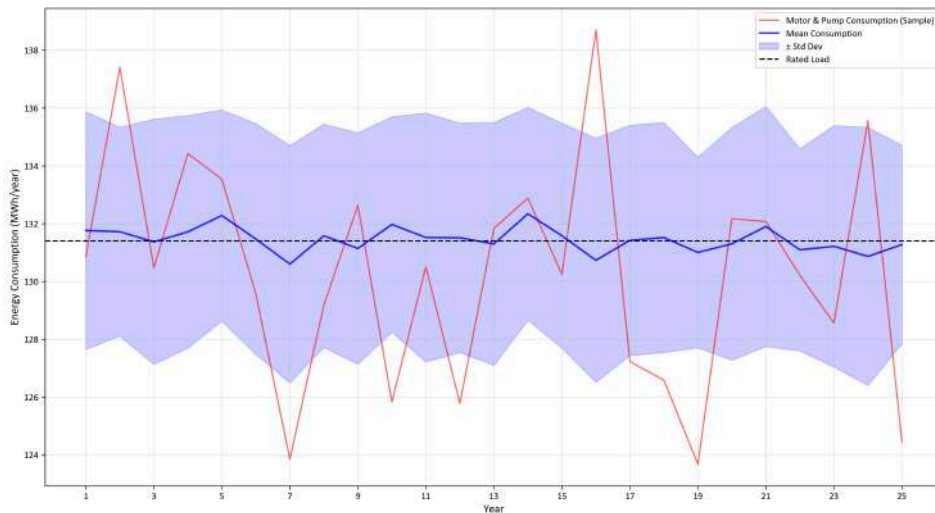


Fig. 6. Annual energy consumption pattern of the motor and pump system over a 25-year operational period

The assessment of system reliability was conducted using the capacity shortage parameter, which represents the ratio of energy capacity shortage to the total energy demand of the system during the operational period. This parameter is used to determine the extent to which the power generation system can continuously meet the energy demand of the load without experiencing electricity supply shortages. Based on the available data, the capacity shortage value during the 25-year operational period ranges from 0.994 to 1.007, with an average value close to 1.000 each year. A value close to one indicates that the available generation capacity is able to meet the system's energy demand with a very high level of reliability. Figure 7 shows the statistical distribution of annual system energy consumption over the 25-year operational period in the form of a boxplot, where each box represents the distribution of annual energy consumption in each operational year with the middle line indicating the median value of energy consumption, the upper and lower boundaries of the box indicating the first and third quartile ranges, the vertical lines indicating the minimum and maximum energy consumption values, the horizontal axis (X) representing the system operational years from year 1 to year 25, and the vertical axis (Y) representing the annual energy consumption in MWh, indicating that the distribution of energy consumption remains relatively stable from year to year with relatively small variations and suggesting that the energy system has good operational stability in the long term.

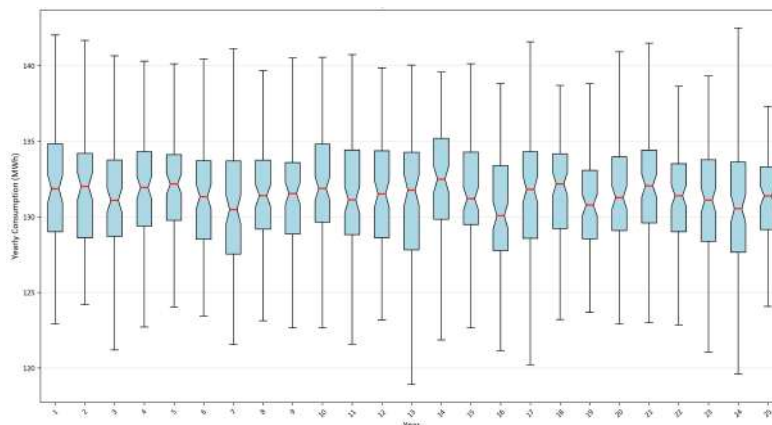


Fig. 7. Statistical distribution of annual system energy consumption during a 25-year operational period

The load variation factor values range between 0.994 and 1.007, indicating that the deviation from the reference value of 1 is very small and reflects relatively stable system operating conditions.

The difference between the highest and lowest values is only around 0.013, which indicates that changes in energy demand during the analysis period remain very limited. This condition shows that the energy consumption pattern of the system tends to be consistent with only minor variations in load demand. In the middle of the analysis, figure 8 presents the Load Duration Curve (LDC) which illustrates the relationship between electricity load magnitude and the percentage of time the load is exceeded during the operational period. The curve shows a load distribution ranging from approximately 119 to 145 MWh/year, where the beginning of the curve represents peak load, the middle section represents average load, and the end of the curve represents base load, indicating a stable and consistent energy consumption pattern throughout the system operation.

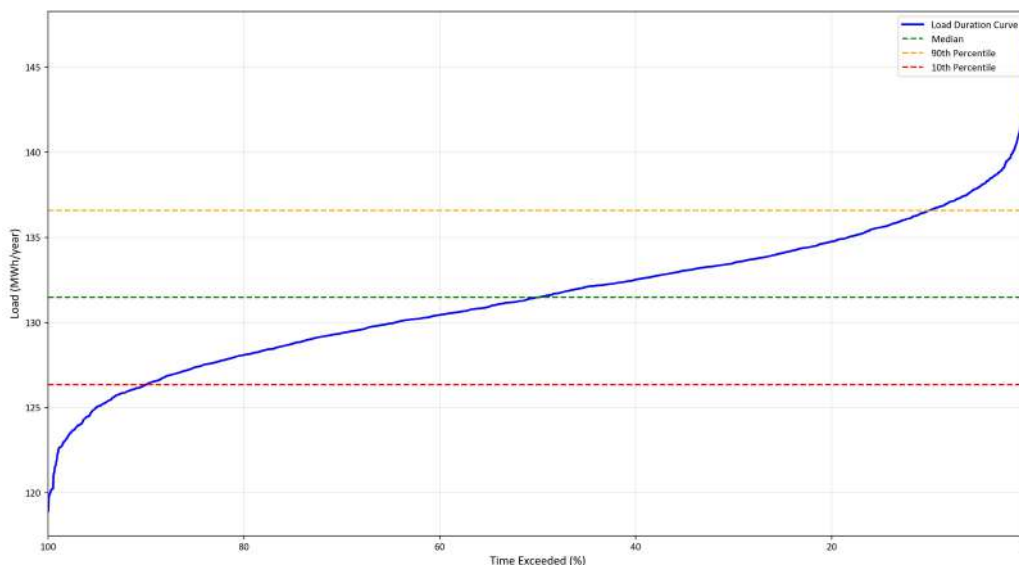


Fig. 8. Annual energy system Load Duration Curve (LDC)

The economic parameters of the system show that the Net Present Value (NPV) ranges from approximately 608.61 to 660.54 million rupiah, indicating that the system provides financial benefits throughout its operational period. The Levelized Cost of Energy (LCOE) ranges from 459.84 to 474.99 Rp/kWh, indicating that the cost of electricity production from the system remains relatively stable and at a competitive level. In addition, the Simple Payback Period ranges from approximately 4.88 to 5.04 years, indicating that the initial investment of the system can be recovered within a relatively short time. In the middle section of the discussion, figure 9 presents the comparison of the average values of several economic indicators, namely NPV of about 630.56 million rupiah, LCOE of 468.05 Rp/kWh, Simple Payback Period of about 4.96 years, Discounted Payback Period of about 8.97 years, and B/C Ratio of about 1.66. A B/C Ratio greater than one indicates that the economic benefits obtained from the system are higher than the investment costs incurred, suggesting that the system has good economic feasibility for long-term implementation.

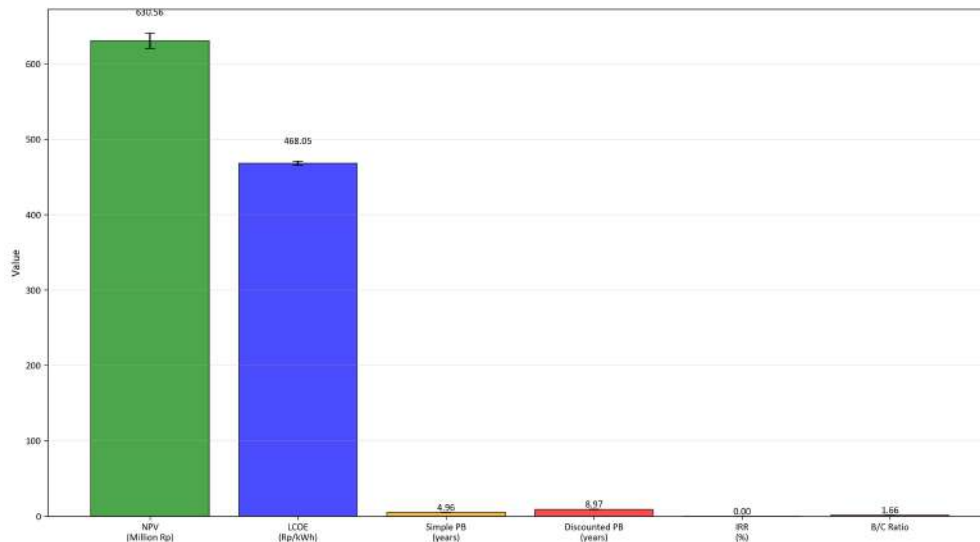


Fig. 9. Comparison of economic feasibility parameters of the energy system (NPV, LCOE, Payback Period, IRR, and B/C Ratio)

The Net Present Value (NPV) obtained from the system simulation ranges from approximately 608.61 to 660.54 million rupiah, indicating that the energy system project has the potential to generate economic benefits during its operational period. The distribution of these values is derived from various calculation scenarios that produce relatively close NPV values, indicating the stability of the system's economic performance. In the middle section of the discussion, figure 10 illustrates the probability distribution of NPV values in the form of a histogram showing the frequency of NPV occurrences from all simulation results. The graph shows that most NPV values are concentrated in the range of approximately 620 to 650 million rupiah, with an average value of about 630.56 million rupiah, and all values remain positive above the breakeven point. This condition indicates that the system has good economic feasibility since the probability of financial loss is very low and the economic benefits generated tend to remain stable under various calculation scenarios.

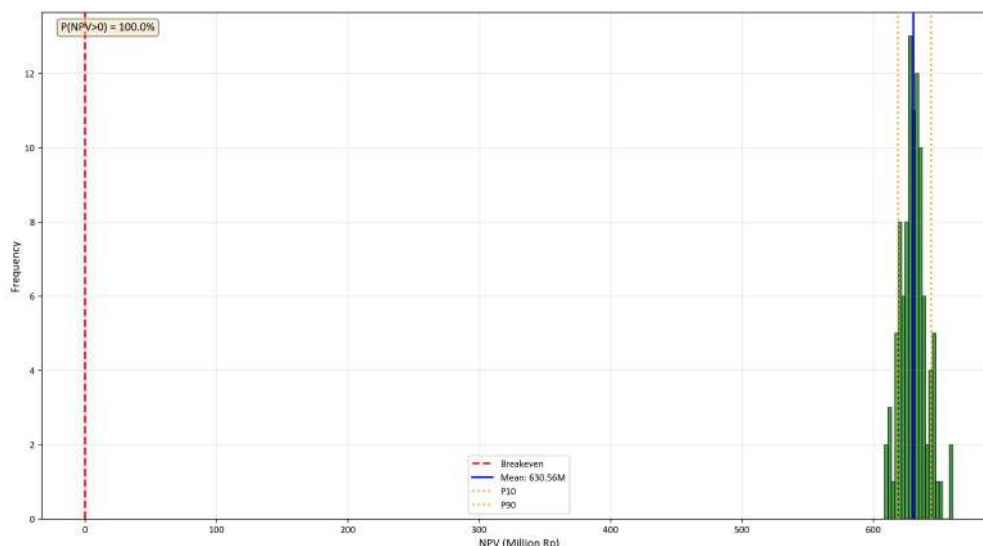


Fig. 10. Histogram distribution of Net Present Value (NPV) of the energy system during the operational period

The economic performance of the system was analyzed based on simulation data covering several key parameters, namely Net Present Value (NPV), Levelized Cost of Energy (LCOE), Simple Payback

Period, Discounted Payback Period, and Benefit Cost Ratio (B/C Ratio). Based on the obtained data, the NPV ranges from approximately 608.61 to 660.54 million rupiah, the LCOE ranges between 459.84 and 474.99 Rp/kWh, and the Simple Payback Period ranges from 4.88 to 5.04 years, indicating that the system investment can be recovered within a relatively short time. In addition, the B/C Ratio ranges from 1.63 to 1.69, which indicates that the economic benefits obtained are greater than the investment costs incurred. In the middle section of the discussion, figure 11 shows the increase in cumulative cashflow from negative values at the beginning of the investment to more than 2,200 million rupiah in year 25, with the Simple Payback Period occurring around year 5 and the Discounted Payback Period around year 9. This condition indicates that after passing the investment payback point, the system is able to generate continuously increasing economic benefits, making the energy project feasible for long-term implementation.

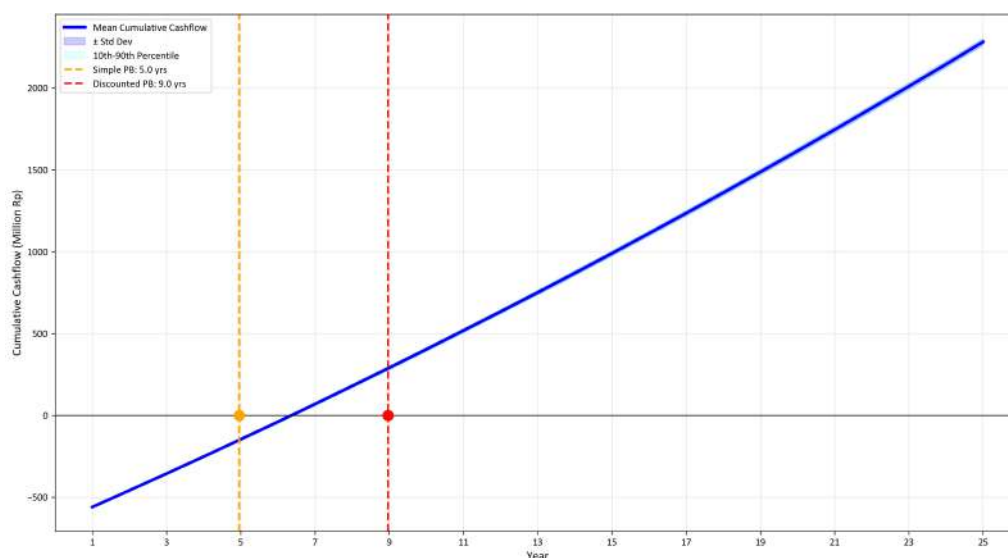


Figure 11. Trend of Cumulative Cashflow and Payback Period of the Energy System

4. Conclusions

Based on the results of the study, it can be concluded that the motor and pump system at the CPO pump house of PT Pelindo Energi Logistik has a significant electrical energy demand with a relatively stable consumption pattern throughout the analyzed operational period. The analysis conducted using parameters such as average annual energy consumption, minimum and maximum values, as well as standard deviation, provides a comprehensive understanding of the system's energy consumption characteristics. The simulation results indicate that the average electrical energy consumption of the motor and pump system is approximately 131.77 MWh per year. This value demonstrates that the pumping system is one of the main components contributing to the overall electricity demand in the facility. Therefore, understanding the energy consumption pattern of the system is essential to support more effective and efficient energy management in industrial operations.

Overall, this study demonstrates that a simulation-based approach can be effectively used to analyze the long-term electrical energy demand of motor and pump systems. The findings of this research can serve as a useful reference for facility managers in evaluating system performance and developing strategies to improve energy efficiency. In addition, this study contributes to providing insights into the characteristics of energy consumption in continuously operating industrial pumping systems. A better understanding of the system's energy demand can help identify opportunities for

optimizing operational performance and reducing potential energy losses. For future research, it is recommended to conduct a more comprehensive analysis by considering the integration of renewable energy sources and evaluating the efficiency of motor and pump components to further enhance the sustainability and performance of the electrical system.

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References

- [1] Acedo, Clementina. "Skills for inclusive and sustainable development: Perspectives from the Asia Pacific region and beyond." *Prospects* 44, no. 2 (2014): 137-140. <https://doi.org/10.1007/s11125-014-9314-1>
- [2] Ahmad, Shabir, Sabina Umirzakova, Ghulam Mujtaba, Muhammad Sadiq Amin, and Taegkeun Whangbo. "Education 5.0: requirements, enabling technologies, and future directions." *arXiv preprint arXiv:2307.15846* (2023). <https://doi.org/10.1007/s10639-023-11785-y>
- [3] Aryawati, N. P. A., Harahap, T. K., Yanti, N. N. S. A., Mahardika, I. M. N. O., Widiniarsih, D. M., Ahmad, M. I. S., Mattunruang, A. A. & Amali, L. M. (2023). *Manajemen keuangan*. Penerbit Tahta Media.
- [4] Baharuddin, Suhana, Muhammad Saqib Iqbal, and Nooriza Ibrahim. "TVET Education for Community Education 5.0 in Malaysia." *Semarak International Journal of Innovation in Learning and Education* 4, no. 1 (2024): 27-41.
- [5] Baharuddin, Suhana Binti, Zulhasni Abdul Rahim, and Muhammad Saqib Iqbal. "Impact of Data Mining Techniques and Self-Regulated Learning (SRL) in Predicting TVET Student Performance: A Review."
- [6] Biggs, J. & Tang, C. (2021). *Teaching for quality learning at university: What the student does* (5th edn.). McGraw-Hill Education.
- [7] Carlisle, Sheena, Karam Zaki, Mohamed Ahmed, Louise Dixey, and Emmet McLoughlin. "The imperative to address sustainability skills gaps in tourism in Wales." *Sustainability* 13, no. 3 (2021): 1161. <https://doi.org/10.3390/su13031161>
- [8] Cebrián, Gisela, and Mercè Junyent. "Competencies in education for sustainable development: Exploring the student teachers' views." *Sustainability* 7, no. 3 (2015): 2768-2786. <https://doi.org/10.3390/su7032768>
- [9] Kolb, D.A. (2022). *Experiential Learning: Experience as the source of learning and development* (2nd ed.). Pearson Education.
- [10] LAMBINA, REGINA, RAMLEE MUSTAPHAB, and MP ROSLIN MD SHARIFC. "Identification of vocational well-being taxonomy for TVET sustainable growth: an initial review." *Journal of Contemporary Issues in Business and Government* | Vol 27, no. 2 (2021): 1434. <https://doi.org/10.47750/cibg.2021.27.02.155>
- [11] A Lei, M., & Abidin, N. Z. (2024). Exploring the relationship between the Sustainable Development Goal (SDG) of the United Nations and Technical and Vocational Education and Training (TVET). *International Journal of Advanced Research in Education and Society*, 6(2), 591–601.
- [12] Moore, Jonathan H., Luke Gibson, Zachary Amir, Wirong Chanthorn, Abdul Hamid Ahmad, Patrick A. Jansen, Calebe P. Mendes, Manabu Onuma, Carlos A. Peres, and Matthew Scott Luskin. "The rise of hyperabundant native generalists threatens both humans and nature." *Biological Reviews* 98, no. 5 (2023): 1829-1844.
- [13] Murnawan, Murnawan, Sri Lestari, Rosalim Samihardjo, and Deshinta Arrova Dewi. "Sustainable educational data mining studies: Identifying key factors and techniques for predicting student academic performance." *Journal of Applied Data Sciences* 5, no. 3 (2024): 1325-1342. <https://doi.org/10.47738/jads.v5i3.347>
- [14] Organisation for Economic Cooperation and Development (OECD). (2023). *The role of education in climate resilience and the development of green skills*. OECD Publishing. <https://doi.org/10.1787/1c12a07b-en>
- [15] Paryono. "The importance of TVET and its contribution to sustainable development." In *AIP Conference Proceedings*, vol. 1887, no. 1, p. 020076. AIP Publishing LLC, 2017. <https://doi.org/10.1063/1.5003559>

- [16] Peng, C., Liu, Z., Yang, W., & Lv, C. (2023). Green Vocational Education Implementation Path in Guangxi Under the Background of Rural Revitalisation: Taking Civil Engineering Major as an Example. *Journal of Contemporary Educational Research*, 7(12), 344-350. <https://doi.org/10.26689/jcer.v7i12.5846>
- [17] Ramli, Syarina, Mohamad Sattar Rasul, and Haryanti Mohd Affandi. "Fourth Industrial Revolution (4IR)." *International Journal of Academic Research in Business and Social Sciences* 8, no. 9 (2018). <https://doi.org/10.6007/ijarbss/v8-i9/4682>
- [18] Spada, Irene, Vito Giordano, Filippo Chiarello, Antonella Martini, and Gualtiero Fantoni. "Text mining on green policies for integrating sustainability in higher education." *The International Journal of Management Education* 23, no. 2 (2025): 101126. <https://doi.org/10.1016/j.ijme.2024.101126>
- [19] Srivastava, Sidharth, Sandeep Kumar Dey, Savita Sharma, and Mark Ratilla. "Adoption of sustainable practices by Asian hotels: gaps in academia." *Worldwide Hospitality and Tourism Themes* 15, no. 3 (2023): 220-230. <https://doi.org/10.1108/whatt-01-2023-0009>
- [20] Thevathas, V. A. P., & Zakaria, A. (2024). Relationship Between the Importance of Technical and Vocational Education and Training (TVET) Programmes and Their Contributions Towards Sustainability of Society's Development Among Kuala Lumpur Technical Secondary Students. *International Journal of Academic Research in Business and Social Sciences*, 14(7). <https://doi.org/10.6007/ijarbss/v14-i7/21057>
- [21] United Nations Educational, Scientific and Cultural Organisation (UNESCO). (2023). Education for sustainable development: A roadmap. UNESCO Publishing. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf00000374802>
- [22] World Bank. (2022). Climate education and workforce transformation: Policy strategies. World Bank Group. Retrieved from <https://openknowledge.worldbank.org/handle/10986/37268>
- [23] World Economic Forum (WEF). (2023). Transitions to a green workforce and circular economy models. WEF Publishing. Retrieved from <https://www.weforum.org/reports/green-workforce-transitions-and-circular-economy-models>
- [24] Safin, Rais S., and Evgeny A. Korchagin. "Vocational training of Russian students within educational cluster." *Rev. Eur. Stud.* 7 (2015): 168. <https://doi.org/10.5539/res.v7n5p168>