Visualizing Electricity Usage Using Power BI: A Case Study In An Automotive Manufacturing Plant

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ABSTRACT

Aims: This study aims to examine current electricity monitoring practices in an automotive manufacturing plant and to demonstrate how electricity usage data can be visualized using Microsoft Power BI to support better energy-related decision-making.
Study design: This research adopted a qualitative case study design.
Place and Duration of Study: The study was conducted at an automotive manufacturing plant, using electricity consumption data collected over a one-year period.
Methodology: A qualitative approach was employed using multiple data sources. Data were collected through semi-structured interviews, direct observations, and analysis of existing documents. Based on the collected data, an interactive Power BI dashboard was developed to visualize electricity consumption.
Results: The developed dashboard included total electricity consumption, monthly usage trends, electricity usage per unit of production, plant-level comparisons, and electricity supply sources. The developed Power BI dashboard improved the visibility of electricity consumption patterns and enabled easier identification of inefficiencies and usage trends. The visualization supported more structured energy monitoring and enhanced management understanding of electricity usage across different production areas.
Conclusion: This study demonstrates that data visualization using Power BI can support data-driven decision-making and sustainability efforts in automotive manufacturing. The findings highlight the practical value of interactive dashboards as a tool to improve electricity monitoring practices in manufacturing environments.

Keywords: Data visualization; Energy monitoring; Electricity usage; Power BI; manufacturing

1. INTRODUCTION

The increasing environmental awareness has raised concerns related to sustainable development (Ellili, 2024). In a manufacturing environment, the sustainability topic has become the organizational focus as manufacturers are now under pressure to reduce the environmental impact while still maintaining their operational efficiency (Uddin et al., 2023). In sustainability, energy consumption, particularly electricity usage, is one of the most significant challenges in manufacturing due to its direct relationship with operational costs and carbon emissions (Min et al., 2022; Uddin et al., 2023). The United Nations General Assembly put out the Sustainable Development Goals (SDGs) as a framework for sustainable development in 2030 towards climate action, increasing the need for manufacturers to adopt data-driven approaches that support energy efficiency and transparent monitoring practices.

The manufacturing industry must remain competitive in a challenging market with applicable strategic methods, and manufacturers must progress and improve to be sustainable. In Malaysia, the manufacturing sector contributes approximately 23% of the national gross domestic product (GDP) and has been the second-largest economic contributor for the past two decades (Perkins et al., 2022). The automotive industry is recognized as a strategic sector supporting industrialization and technological advancement (Monye et al., 2023). Automotive manufacturing plants are characterized by high capital intensity and extensive automation, where electricity is a critical enabler of production activities (Zehra et al., 2024). Operations such as robotic welding, material handling, painting, and assembly depend heavily on electrically powered systems to sustain continuous and high-volume production (Pothamsetti, 2024). Consequently, electricity consumption constitutes a substantial portion of operating costs and plays a significant role in the environmental footprint of automotive manufacturing facilities.

This study was conducted in an automotive manufacturing plant, referred to as Company X, which operates using automated and electricity-intensive production systems. Despite the growing emphasis on sustainability and energy efficiency, the electricity data compiled from the national grid bill were not used to construct an effective data visualization. Without data visualization, raw electricity data provides limited information related to consumption patterns, demand behavior, and the monthly target of energy usage. This limits the ability of organizations to translate energy usage into the actions required by manufacturing plants to support energy management and continuous improvement initiatives. To address this gap, this study explores the visualization of electricity usage data through the development of an interactive dashboard tailored to an automotive manufacturing environment. By transforming electricity consumption and production data into a visualization, this study aims to enhance the visualization of energy usage patterns, support sustainability-oriented decision-making, and improve electricity monitoring practices within daily operations. Specifically, the objectives of this study are:

1. To examine current practices of electricity usage recording and monitoring in an automotive manufacturing plant.
2. To develop and demonstrate a dashboard-based visualization approach for analyzing electricity usage to support energy-related decision-making in the case company.

This study contributes to both industrial practice and academic literature. From an industrial perspective, the proposed dashboard provides a practical tool to improve transparency of electricity consumption, support energy efficiency initiatives, and strengthen data-driven decision-making in manufacturing operations. From a scholarly perspective, this study contributes to sustainability and manufacturing research by demonstrating how electricity usage data can be operationalized through visualization to generate actionable insights within a real industrial context.

2. LITERATURE REVIEW

2.1 Sustainability Development Goals (SDGs)

The United Nations set up the Sustainable Development Goals (SDGs), encouraging all countries to create a better future for everyone by 2030. 17 goals aim to eliminate poverty, being responsible for the environment for the future generation. SDG 7 highlights affordable and clean energy, which promotes affordable, reliable, sustainable, and contemporary energy (Shafik, 2025). In the automotive manufacturing industry, an energy usage visualization approach can be used to monitor the electricity usage, hence informing the necessary steps for the organization to take actions such as a strategy to encourage cleaner energy, low carbon technology, and reduce the reliance on non- renewable energy sources (Alimin et al., 2025). SDG 9, as stated by the UN, aimed to build resilient infrastructure, enhance sustainable and inclusive industrialization, and increase innovative technologies (Aziz et al., 2025). The introduction of dashboard supports this goal by introducing a digital and innovative method to monitor the electricity usage. This technology transforms the data into a visualization to better understand the energy usage pattern and operational performance. This supports efficient and sustainable industrial operations by improving transparency and encouraging data-driven decisions.

2.2 The Automotive Manufacturing Industry

The automotive manufacturing sector is a significant part of the global economy, producing vehicles such as cars, trucks, and buses for markets all over the world (Dakić et al., 2024). This industry relies significantly on new technology, robotics, and efficient manufacturing processes to meet rising demand while maintaining quality (Aripin et al., 2023). As competition increases and sustainability becomes more important, automotive manufacturers are adopting new technologies and energy-saving methods to improve productivity and reduce costs (Zeng et al., 2022). These approaches help automotive manufacturers stay competitive while addressing environmental concerns and changing customer expectations (Dakić et al., 2024).

The automotive industry, which began in the late 19th century, has undergone some changes over time (de Souza et al., 2022). The global automotive landscape experienced a significant shift towards globalization in the late 20th century. This marked a significant shift in automotive manufacturing, targeting to reduce operational costs and known in the global market (Dakić et al., 2024). In addition, the integration of robotics in the automotive process has increased the productivity and quality of production. Automated assembly lines have become the main assurance of companies’ competitiveness. Robots can handle repetitive and hazardous tasks with precision and consistency while ensuring that defects are minimized, resulting in higher-quality products (Pereira et al., 2022).

Electricity is essential in automotive production, powering a variety of operations from raw material preparation to final vehicle assembly (Mohd Aripin et al., 2025). Additionally, energy is needed to operate heavy machinery and automated robotics, as well as critical systems like ventilation, heating, lighting, and quality control equipment. According to Dehning et al. (2017) automotive manufacturing needs more electricity than most other manufacturing industries. The body shop section, according to Konstantinidis et al. (2023) consumes between one-quarter and one-third of the plant's total electric power for its operations, such as welding and stamping. This high energy usage is primarily attributed to resistance spot welding and laser welding technologies (Pittner & Rethmeier, 2022).

2.3 Visualizations

Data Visualization is a process of making data through a visual context, and it is a part of analytics (Atobatele et al., 2022). There are various techniques to visualize data, including interactive and dynamic options. These techniques utilize several elements such as graphs, slicers, histograms, tables, and other types of visual representations. Microsoft Power BI is a comprehensive business intelligence and analytics platform that enables users to analyze data, share insights, and obtain timely answers through interactive data visualization (Molke et al., 2024). Using visuals and filters helps the user understand the data more easily. The general operations of Microsoft Power BI are as follows: 1) Get the Data from Required Data Source, 2) Analyze the data by means of connectors and gateways of organization, 3) Build the Report by means of Different Visuals and Filters, 4) Publish the Report into web through Power BI Desktop, 5) Edit the report if any changes are needed and make shareable by means of publishing on to web option for creating embed URL, 6) Access the report data from different applications of Microsoft, and 7) Refresh the data using different gateways of organization for updating the dashboard.

Previous researchers have demonstrated improvements in data analysis and decision-making through the use of dashboards. Molke et al. (2024) investigated the role of Microsoft Power BI in enhancing real-time data visualization for organizational decision-making. The study focused on data collection, transformation, analysis, and dashboard development to support performance monitoring, particularly for small and medium-sized enterprises. The findings showed that interactive dashboards improved data clarity, reduced analysis time, and enabled users to identify trends and performance gaps more effectively. The use of Power BI also enhanced user interaction through customizable visuals and filters, supporting informed, timely, and data-driven decisions across organizational levels. In addition, Naikwadi and Shende (2025) emphasized the growing importance of interactive data visualization tools in procurement and financial analytics. Prior research has shown that business intelligence platforms enhance organizations' ability to monitor spending behavior, evaluate supplier performance, and support strategic sourcing decisions. The use of dashboard-based visualization enables decision-makers to identify inefficiencies, detect cost overruns, and improve budget control more effectively. These studies also highlight that real-time analytics supports proactive decision-making rather than reactive responses.

3. METHODOLOGY

3.1 Research Design

This study adopts a qualitative case study research design to explore how electricity usage data are monitored, managed, and visualized to support decision-making in an automotive manufacturing environment. A qualitative approach is appropriate as the study focuses on understanding real operational practices, data handling processes, and decision-making challenges within their natural industrial context rather than testing hypotheses or establishing causal relationships. According to Yin (1994), case study research is suitable for investigating phenomena where contextual conditions are integral to the phenomenon under investigation. In this study, energy usage, production activities, and data utilization practices are closely interconnected, making a case study approach suitable for generating in-depth and practice-oriented insights.

3.2 Case Company and Informants

The company referred to as Company X is an automotive manufacturing organization that operates electricity-intensive production equipment. The company produces passenger vehicles and relies on electrically driven systems such as welding equipment, robotic stations, conveyors, and supporting utilities. Electricity usage data are routinely recorded for reporting purposes; however, the absence of structured visual monitoring limits the effective use of these data for operational and strategic decision-making. Company X was selected using convenience sampling based on its relevance to the research objectives, accessibility, and willingness to participate.

Informants were selected based on their direct involvement in electricity monitoring and production operations. Selection criteria included holding operational or technical roles, having at least five years of experience in the company, and possessing practical knowledge of electricity usage practices. Two key informants participated in the study, representing production and maintenance functions respectively, providing complementary perspectives on electricity consumption and operational challenges.

3.3 Data Collection Methods

Multiple qualitative data collection methods were employed to ensure a comprehensive understanding of electricity usage monitoring practices in Company X. Data were collected through semi-structured interviews, direct observation, and document analysis. The use of multiple sources enabled data triangulation, thereby enhancing the credibility and robustness of the research findings Donnelly et al. (2023). Semi-structured interviews with the respondents were conducted to obtain in-depth insights into current electricity monitoring practices, data recording procedures, and challenges in interpreting electricity usage information. The interview protocol focused on two main themes: current practices of electricity usage monitoring and effective energy visualization and decision-making. This approach allowed flexibility to explore emerging issues while maintaining alignment with the research objectives.

Following that, direct observation was carried out during on-site visits to examine actual electricity monitoring and operational practices. Observation enabled the researcher to verify interview findings and to understand how electricity data were recorded, compiled, and used in daily operations. The observation revealed that electricity usage data were primarily recorded manually and analyzed using spreadsheet-based tools, limiting the ability to quickly identify abnormal consumption patterns or relate electricity usage to production activities. In addition, document analysis was conducted to review electricity usage records, production reports, and Excel-based monitoring files used by the company. These documents provided evidence of existing data structures, reporting frequency, and limitations in current electricity monitoring practices.

3.4 Data Analysis Process

Data analysis followed a systematic qualitative approach by integrating findings from interviews, observations, and document analysis. Electricity usage data obtained from Company X covered the period from January to December 2024 and included structured data such as monthly electricity consumption (kWh) and semi-structured data such as production records and shift schedules. The analysis process consisted of three main stages: data preparation, data organization, and data interpretation.

During data preparation, electricity and production data were cleaned, standardized, and aligned to ensure consistency and usability. Spreadsheet functions such as pivot tables and data matching techniques were used to organize the data by time period, plant, and production output. This process enabled the identification of electricity usage trends, variations across months, and differences in energy efficiency between production plants.

Qualitative insights from interviews and observations were then synthesized with the analyzed electricity data to identify key issues in current monitoring practices and to determine relevant indicators for visualization. These indicators included total electricity consumption, time-based usage trends, production output, and electricity usage per unit.

3.5 Dashboard Development

Based on the analysis findings and literature review, an interactive electricity usage dashboard was developed using Microsoft Power BI. The dashboard development focused on transforming processed electricity and production data into clear and interpretable visual elements, including charts, key performance indicators, and interactive filters. Power BI was selected due to its compatibility with spreadsheet-based data, accessibility, and capability to support interactive analysis.

The dashboard was designed to enhance visibility of electricity consumption patterns, support comparison across time periods and production plants, and facilitate data-driven decision-making. Emphasis was placed on clarity, simplicity, and usability to ensure that the dashboard could be effectively used by management and operational personnel. The final dashboard was presented to Company X's respondents along with their management for validation and feedback to confirm its practicality and relevance in supporting electricity usage monitoring and sustainability-related decisions.

4. RESULT AND DISCUSSION

4.1 Electricity Usage Data Management

Electricity usage data in the automotive manufacturing plant were manually recorded and compiled using Microsoft Excel after each reporting period. Each record contained basic information such as electricity consumption values (kWh), reporting period, production volume, plant or section identifier, and source of electricity supply. These records were stored in multiple spreadsheet files and primarily used for reporting purposes. While this practice enabled basic documentation of electricity usage, the data were not structured for integrated analysis or operational monitoring. As a result, management and operational personnel faced difficulties in identifying electricity usage trends, peak consumption periods, and variations in energy efficiency across time and production units. The absence of structured summaries, such as comparative consumption across plants or electricity usage per unit, limited visibility of overall energy performance, and constrained the ability to support proactive energy management decisions. Consequently, electricity monitoring relied heavily on periodic reporting rather than data-driven analysis.

4.2 Dashboard Visualization Results

Based on the consolidated electricity usage data obtained from spreadsheet records, a dashboard was developed to visualize electricity consumption performance in the automotive manufacturing plant, as shown in Figure 1. To protect data confidentiality, sensitive numerical values in the dashboard were intentionally blurred before publication. The dashboard integrates key electricity usage indicators into a single interface to enhance visibility of energy consumption patterns and support structured energy monitoring and decision-making.

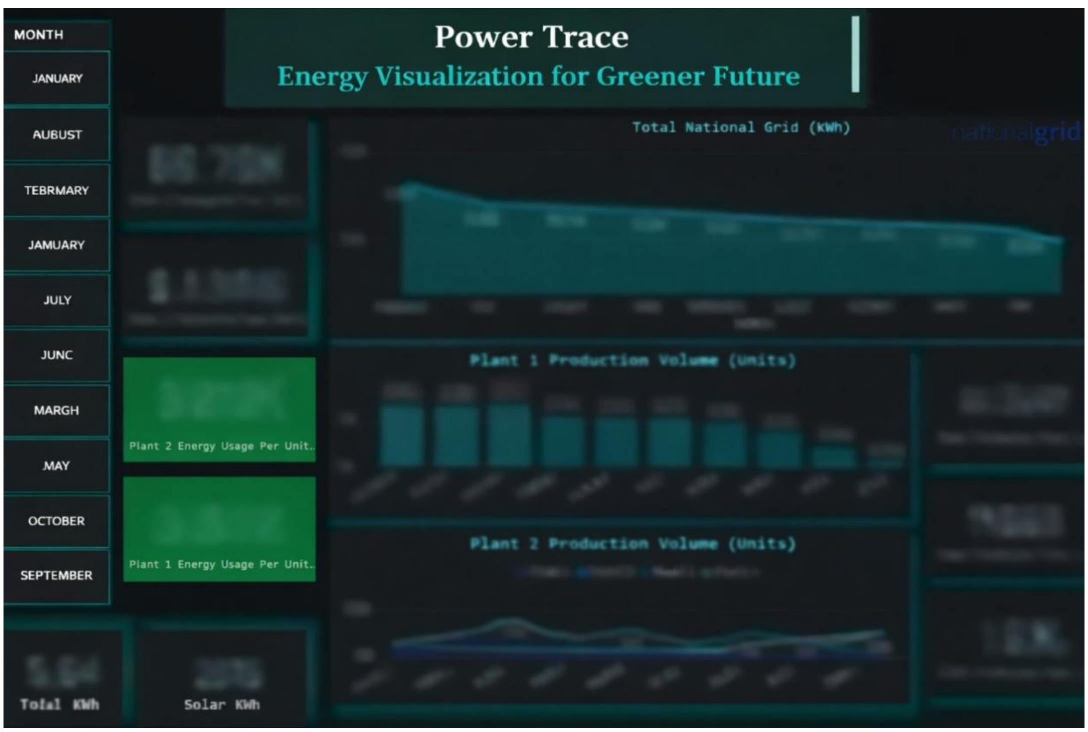

Fig. 1. Electricity Usage Dashboard for Automotive Manufacturing Plant

The developed dashboard integrates several key indicators, as described below:

1. **Plant and Time Period Selection**
   The dashboard includes filtering functions based on plant and time period. These selection features allow users to analyses electricity usage data for specific plants and selected months. This functionality supports focused analysis by enabling users to examine electricity consumption trends without the need to manually review multiple spreadsheet files.

2. **Electricity Consumption by Plant**
   Electricity consumption is visualized by the plant using bar charts to highlight differences in total electricity usage between production plants. This visualization enables direct comparison of electricity consumption levels and helps identify plants with relatively higher energy demand, supporting prioritization of energy efficiency initiatives.

3. **Total Electricity Consumption**
   Total electricity consumption is presented as a key performance indicator representing cumulative electricity usage within the selected period. This indicator provides a clear overview of overall energy demand and allows management to assess electricity consumption relative to production output and internal energy targets.

4. **Time-Based Electricity Usage Trend**
   Electricity usage trends across different months are displayed using a line chart. This visualization supports the evaluation of consumption behavior over time. Increasing trends may indicate rising energy demand or inefficiencies, while stable or decreasing trends may reflect improved energy management practices.

5. **Electricity Usage per Unit of Production**
   Electricity usage per unit of production is displayed as a key efficiency indicator. This metric enables comparison between plants by relating electricity consumption to production output. Visual cues are used to highlight acceptable and higher-than-expected energy usage levels, supporting quick identification of inefficiencies and areas requiring further investigation.

6. **Electricity Supply Source Contribution**
   The dashboard also presents the contribution of electricity sources, such as the national grid supply, to overall electricity consumption. This indicator provides insight into the company's dependency on external electricity sources and supports the evaluation of potential energy diversification or sustainability strategies.

5. CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

This study explored the management and visualization of electricity usage data in an automotive manufacturing plant through a qualitative case study approach. The findings indicate that although electricity consumption data were routinely recorded, the absence of a structured visual monitoring system limited the effective use of these data for operational and sustainability-related decision-making. Electricity usage information was primarily used for reporting purposes, resulting in limited visibility of consumption trends, energy efficiency variations, and the relationship between electricity usage and production performance.

The development of an interactive dashboard using Power BI demonstrated the potential of data visualization to transform raw electricity usage data into meaningful and actionable insights (Gonçalves et al., 2023). By integrating key indicators such as total electricity consumption, time-based usage trends, electricity usage per unit of production, and plant-level comparisons, the dashboard enhanced transparency and supported more structured energy monitoring. The visualization allowed management and operational staff to easily identify patterns, detect inefficiencies, and connect electricity consumption behavior to production activities. This facilitates a transition from reactive, report-based energy monitoring to a more data-driven, sustainability-focused approach.

From a practical perspective, the study highlights the value of dashboard-based visualization as a decision-support tool for energy management in automotive manufacturing environments. Improved visibility of electricity usage can support energy efficiency initiatives, cost control efforts, and alignment with organizational sustainability objectives. The findings suggest that even with existing data sources, significant improvements in energy monitoring and decision-making can be achieved through effective data structuring and visualization. From a theoretical perspective, this study contributes to the manufacturing and sustainability literature by demonstrating how electricity usage data can be operationalized through visualization within a real industrial context. While existing studies often emphasize energy audits or predictive energy models, this research provides empirical evidence of the role of visualization in bridging the gap between available electricity data and practical decision-making in manufacturing operations.

5.1 Limitations And Suggestions For Future Research

Despite its contributions, this study has several limitations that provide opportunities for future research. First, the study was conducted in a single automotive manufacturing plant, which may limit the generalizability of the findings. Future studies could extend the analysis to multiple plants or different manufacturing sectors to validate the applicability of dashboard-based electricity visualization across diverse industrial contexts. Second, this study focused on descriptive and diagnostic analysis of historical electricity usage data. Future research could incorporate predictive and prescriptive analytics, such as forecasting electricity demand or simulating the impact of energy-saving initiatives, to further enhance the decision-support capability of energy dashboards. In addition, future studies may explore the integration of real-time electricity monitoring systems and Internet of Things (IoT) technologies to enable continuous and automated data collection. Such integration could support real-time alerts, anomaly detection, and more proactive energy management strategies. Overall, this study demonstrates that effective visualization of electricity usage data can play a significant role in improving energy monitoring, supporting informed decision-making, and advancing sustainability objectives in automotive manufacturing environments.

CONSENT (WHERE EVER APPLICABLE)

Written informed consent was obtained from the respondents. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

Not Applicable

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