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Abstract

1. Title: Energy Consumption Analysis Dashboard
2. Domain: Data Analytics, Energy Management
3. Application: Energy Monitoring and Optimization using Microsoft Power BI
4. Expected Algorithm / Processing: The project leverages Microsoft Power BI to process and visualize energy consumption data. The process involves importing real-time and historical energy usage data from various sources (e.g., smart meters, IoT devices) into Power BI. Data cleaning and transformation will be performed to ensure accuracy. Power BI's built-in features like time-series analysis, DAX calculations, and interactive visualizations will be used to analyze patterns, identify trends, and detect anomalies in energy usage. Forecasting techniques and machine learning models might also be incorporated for predictive insights.
5. Expected Output from Project: The output will be an interactive dashboard within Microsoft Power BI, offering a visual representation of energy consumption data. Users will be able to track key metrics such as total energy consumption, peak demand periods, and monthly or yearly comparisons. The dashboard will also provide insights into energy inefficiencies, potential savings, and usage trends, with actionable recommendations for optimization.
6. Abstract: The Energy Consumption Analysis Dashboard, built using Microsoft Power BI, aims to provide a comprehensive solution for monitoring and optimizing energy usage. By integrating data from various sources such as smart meters and IoT devices, the dashboard allows users to track real time and historical energy consumption patterns. Power BI’s powerful data processing capabilities, such as time-series analysis and advanced visualizations, help identify peak usage times, inefficiencies, and trends. The dashboard will offer users insights into potential areas for energy savings, enabling better decision-making for businesses or households seeking to reduce energy costs and improve efficiency. With its interactive interface and predictive features, the dashboard serves as an essential tool for managing energy consumption and promoting sustainable practices.

CHAPTER – 1
Introduction

1.1 Problem Statement

In the era of rapid industrialization and technological advancement, energy consumption has risen to unprecedented levels. Both household and industrial sectors are contributing significantly to the global demand for energy, making it imperative to monitor and manage usage efficiently. While numerous countries and corporations aim to reduce carbon footprints and implement sustainable practices, the lack of real-time and user-friendly data visualization tools poses a major challenge. Traditional methods of energy monitoring involve static reports, which are difficult to interpret and do not support dynamic interaction. Users often struggle to gain meaningful insights into when, where, and how energy is being consumed. Moreover, understanding consumption patterns across different regions, seasons, sectors, or even types of buildings is nearly impossible without advanced analytics tools. Additionally, there's a growing concern around energy wastage due to inefficient usage and lack of awareness among consumers. Many industries are unaware of how much energy is consumed by specific technologies or processes. Similarly, household users are often uninformed about the factors driving their utility bills. This project addresses the problem by introducing a Power BI-based solution that offers: Real-time, interactive visual dashboards. Granular analysis for both household and industrial sectors. Filterable insights based on location, time period, and type of energy usage. Comparative analytics for regional or sectoral benchmarking. The aim is to not only visualize energy consumption but to translate data into knowledge, knowledge into action, and action into long-term sustainability.

1.2 Objectives

The primary goal of this project is to build a comprehensive, visual, and interactive analytical model that enhances the understanding of energy consumption patterns. The specific objectives include:

1.2.1 Analyze Energy Usage Across Sectors

To assess and interpret energy consumption trends across two major sectors: Household Sector: Including house types (apartments, townhouses, single-family homes), occupancy status, and regional differences. Industrial Sector: Including different industry types, technology usage, sector-wise energy split, and adoption rates of efficiency tools.

1.2.2 Develop Interactive Dashboards Using Power BI

To create an end-to-end data visualization solution using Power BI that includes: Date slicers and filters by region, occupancy status, and building/industry type. Key performance indicators (KPIs) for maximum, minimum, and total consumption. Trend charts, comparative bar graphs, and pie charts for categorical analysis.

1.2.3 Identify High and Low Consumption Areas

To help stakeholders easily identify areas of concern or opportunity by: Pinpointing regions with abnormally high or low consumption. Mapping seasonal trends such as increased heating in winter or cooling in summer. Benchmarking against average consumption patterns.

1.2.4 Understand Seasonal and Temporal Variations

To observe how energy usage changes over months and years, considering factors such as: Weather changes (winter vs. summer consumption) Industrial operational cycles Festive or holiday effects in households

1.2.5 Evaluate Efficiency and Technology Adoption

To evaluate how technological interventions affect industrial energy usage, including: Rate of adoption of energy-efficient technologies (automation, robotics, CNC machines) Performance analysis of sectors based on technology utilization Correlation between efficiency adoption and energy savings

1.2.6 Promote Data-Driven Decision Making

To assist government bodies, corporations, and individuals in: Formulating policies based on actual consumption data. Making investment decisions in energy-efficient technologies. Encouraging behavior change among consumers through awareness.

1.3 Scope of the Project

This project focuses on analyzing datasets from both residential and industrial energy domains, with an emphasis on the Indian context (or global, depending on dataset origin). While the scope is limited to historical data, the architecture supports future scalability for real-time integration and predictive modeling.

Included Scope:

- Excel-based datasets.
- Power BI visual analytics.
- Historical and comparative analysis.

Future Scope:

- IoT integration for real-time monitoring.
- Predictive modeling using machine learning.
- Integration with government smart-grid platforms.

1.4 Significance of the Study

The insights from this study have far-reaching implications:

- For Governments: Policy-making, energy subsidies, regional planning.
- For Corporations: Industrial efficiency, ESG (Environmental, Social, Governance) reporting.
- For Consumers: Understanding and reducing their energy bills.
- For Researchers: Providing a foundation for advanced modeling and forecasting. This initiative is a step toward smart energy management and aligns with global sustainable development goals (SDG 7: Affordable and Clean Energy).

CHAPTER – 2
Literature Survey

2.1 Background

The field of energy analytics has grown significantly in the past decade, especially as societies grapple with the dual goals of meeting rising energy demands and reducing carbon emissions. Energy data analytics plays a central role in shaping policies, designing infrastructure, optimizing usage, and improving efficiency across residential and industrial domains.

The global energy landscape is evolving. Renewable energy sources such as solar and wind are becoming more integrated into national grids, while smart meters and IoT-enabled devices are being deployed to collect real-time data from homes and factories. The abundance of this data necessitates advanced tools for processing, interpreting, and visualizing it.

In the residential sector, energy analytics allows users to:

- Understand the impact of behavior on utility bills.
- Monitor peak load times.
- Identify energy-hungry appliances.

In the industrial sector, it helps:

- Optimize machine performance.
- Monitor process-level energy waste.
- Track technology efficiency.

A powerful business intelligence tool like Power BI bridges the gap between raw data and actionable insights by transforming static data into dynamic, interactive dashboards.

2.2 Existing Systems

This section compares and evaluates the most commonly used tools and technologies for energy analytics, highlighting their features and drawbacks.

❖ Google Data Studio

Google Data Studio offers quick web-based visualization for lightweight reports and simple dashboards. It connects easily with cloud-based services like Google Sheets and Google Analytics. However, it:

- Doesn't support large datasets efficiently.
- Lacks advanced modeling and transformation options.
- Has limited custom visuals compared to Power BI.

❖ Microsoft Excel

Excel is excellent for:

- Cleaning small datasets.
- Performing ad hoc calculations.
- Creating basic graphs and pivot tables.

However, it suffers from:

- Limited interactivity.
- Manual data updates.
- No dynamic filtering or KPIs for business-level insights.

Excel is often used in the first phase of data preparation before importing into tools like Power BI.

❖ Smart Meter Dashboards

Smart meters installed in homes or industries collect fine-grained consumption data (hourly or even minutely). Utility companies offer dashboards that show:

- Current usage
- Historical trends
- Peak demand hours

Limitations include:

- Minimal customization.
- Lack of comparative analysis across multiple units or sectors.
- Not suitable for macro-level insights or reporting.

❖ Building Energy Management Systems (BEMS)

Advanced BEMS solutions allow facility managers to:

- Monitor energy usage across HVAC, lighting, and machinery.
- Automate energy-saving actions.
- Analyze costs and performance.

However, these systems are:

- Expensive.
- Require technical training.
- Often proprietary and closed systems (not easily integrated with external datasets).

2.3 Research Papers & Authoritative Websites Reviewed

A literature review of academic publications and reliable data sources provides a strong foundation for this project.

1. “Energy Consumption Forecasting Using Machine Learning” – IEEE, 2022
Focus: Forecasting residential consumption using ML algorithms.
Findings: Decision trees and neural networks outperform traditional linear regression in energy prediction.
Contribution: Demonstrates need for automated insights, not just reporting.

2. “Smart Grid Consumption Analysis” – Elsevier, 2023
Focus: Analysis of smart grid energy patterns in urban areas.
Method: Time-series clustering and anomaly detection.
Value: Highlights demand-response benefits and real-time load balancing.

3. “Regional Analysis of Energy Usage” – Springer, 2021
Focus: Comparing energy usage trends across geographic and climatic regions.
Techniques: GIS visualization, seasonal indexing, regression modeling.
Takeaway: Regional differences must be considered when developing analytics dashboards.

4. World Bank Data (https://data.worldbank.org)
Provides: Historical country-level energy statistics, renewables data, electricity access.
Pros: Reliable, well-documented.
Cons: Not real-time, lacks granular (household or factory-level) data.

5. Our World in Data (https://ourworldindata.org)
Focuses on: Long-term trends in global energy production and consumption.
Includes: Emissions data, per capita usage, energy mix per country.
Ideal for: High-level contextual framing in reports and policy papers.

2.4 Limitations of Existing Systems

Despite these tools and research efforts, several critical limitations exist:

1. Siloed and Static Data

- Household and industrial datasets are typically collected and stored separately.
- No unified platform exists to analyze both types simultaneously.
- Static reports lack interactivity, making exploration cumbersome.

2. Lack of Personalization

- Dashboards often present aggregated data without offering drill-down options.
- Users cannot filter or compare results by home type, industry sector, or time window easily.

3. No Integration of Predictive Models

- Most systems only visualize historical data.
- Integration of machine learning forecasts or recommendations is rare.

4. Limited Customization and Export Options

- Users can't easily export filtered reports or schedule automated updates.
- Many platforms do not support embedding or sharing for collaboration.

5. Accessibility Barriers

- Most high-end analytics tools are either costly or require technical expertise.
- There's a clear lack of intuitive platforms tailored for students, small businesses, or local governments.

2.5 Summary and Justification for Power BI

Given the current challenges in the domain of energy analytics, Power BI presents itself as an ideal platform to address these gaps:

- Scalable: Can handle small and large datasets alike.
- Interactive: Allows real-time filtering, drill-downs, and comparisons.
- Visual: Offers customizable visuals including KPI cards, maps, time series graphs, and pie charts.
- Integrated: Can connect to Excel, databases, APIs, and web sources.
- Accessible: Simple enough for students and powerful enough for professionals.

This project leverages these features to create a comprehensive dashboard-based solution for household and industrial energy consumption analysis.

CHAPTER – 3

Methodology

3.1 Hardware and Software Requirements

A reliable hardware-software environment is critical to ensuring smooth execution of data-driven projects. The system setup must support data cleaning, transformation, and visualization without performance issues.

3.1.1 HARDWARE REQUIREMENTS

The project was executed on a mid-range computing system with the following specifications:
- Processor: Intel Core i5 (10th Gen or higher)
- RAM: 8 GB DDR4 (sufficient for moderate data processing)
- Storage: 256 GB SSD (for fast read/write of datasets)
- Display: Full HD (1080p) for dashboard design
- Operating System: Windows 10/11 (64-bit)

3.1.2 SOFTWARE REQUIREMENTS

The following software tools were used throughout the project lifecycle:
- Microsoft Power BI Desktop: Dashboard design, data transformation, visual modeling
- Microsoft Excel: Data structuring, column formatting, basic EDA
- Windows OS: Operating platform to host and execute applications

3.2 System Design

3.2.1 Architecture Overview

The system follows a layered design approach to maintain modularity, clarity, and scalability. It uses a 3-tier architecture: data source layer, transformation layer, and visualization layer.

3.2.2 Block Diagram Description:

Data Source → Excel Files
Power Query → Data Cleaning
Power BI Visual Layer → Dashboard Filters & Charts

Layer Descriptions:
Data Source Layer:
Input Excel files contain raw data.
Data is structured in columns relevant to energy consumption by households and industries.

Transformation Layer (Power Query):
Data is cleaned, null values handled, and column names standardized. Derived/calculated columns are added where necessary.
Relationships between tables (if any) are defined.

Presentation Layer (Power BI Visual Layer):
Multiple visuals (e.g., bar charts, line graphs, pie charts) are created.
Filters and slicers enable users to interact dynamically.
KPIs display key metrics like Total Consumption, Min/Max Usage, and Efficiency Score.

3.3 Algorithm

The project uses a structured and repeatable data processing pipeline. The steps followed mimic a simplified Extract–Transform–Load (ETL) workflow with added interactivity for visual analytics.
Step-by-Step Algorithm:
1. Load Data – Import household and industrial datasets using Power BI.
2. Clean Null Values – Handle missing, null, or corrupted values appropriately.
3. Create Measures – Define DAX measures and calculated columns.
4. Add Slicers – Introduce interactive filters for flexible analysis.
5. Design Visuals – Create insightful dashboards using line charts, KPIs, etc.
6. Evaluate Outputs – Validate dashboard accuracy and interactivity.

3.4 Exploratory Data Analysis (EDA)

Exploratory Data Analysis was conducted separately on each dataset to uncover underlying trends, anomalies, and distributions.

3.4.1 HOUSEHOLD DATASET OVERVIEW

Columns: HouseType, Region, HeatingEnergy, CoolingEnergy, Appliances, Lighting

Key Insights:
- Heating has the highest seasonal spike, especially in colder regions.
- Appliance energy is relatively stable but peaks during holidays.
- Lighting usage increases with household size.
- Northern regions show higher heating demand; coastal regions have higher cooling demand.

3.4.2 INDUSTRIAL DATASET OVERVIEW

Columns Present:

- IndustryID
- Sector (e.g., Textiles, Metals, Construction, Food Processing)
- Region
- EnergyConsumption (monthly or annual, in kWh)
- TechnologyUsed (e.g., CNC Machines, IoT Sensors, Legacy Equipment)

Descriptive Statistics:

- EnergyConsumption range: 12.5kWh – 52.9kWh (monthly average)
- Highest usage: Construction and Metals sectors

Key Insights:

- Metals and Construction sectors dominate in overall energy usage due to heavy machinery and 24/7 operations.
- Low technology adoption in these sectors leads to inefficient usage.
- Industries using modern tech (e.g., CNC machines, energy-efficient motors) show up to 18–25% lower consumption.

- Region-wise trends:
- Industrial zones in the West have highest energy usage.
- Eastern regions show lower energy levels, possibly due to fewer factories or smaller operational scales.

CHAPTER – 4

Implementation Details

The implementation of the energy consumption analysis project was divided into three major modules to systematically transform raw datasets into interactive dashboards using Microsoft Power BI. Each module represents a phase in the data lifecycle—starting with data preparation, followed by dashboard design for household and industrial sectors

Module 1: Data Preparation

This foundational module involved collecting, cleaning, transforming, and modeling data from two primary Excel files:
- Household_energy_data.xls
- Industrial_energy_data.xls

4.1.1 Importing Data

- The "Get Data" function in Power BI was used to load the two Excel files.
- Sheets were individually reviewed and loaded as separate tables.
- Both datasets had distinct structures, so no merging was performed at this stage.

4.1.2 Data Cleaning in Power Query

Once loaded, the data underwent preprocessing in Power Query:
- Null and Blank Values:
- Removed rows with missing or corrupted entries.
- Replaced null energy values with 0 to avoid calculation errors in visuals.

Column Renaming:
- Ambiguous column names (e.g., "H_Eng", "Reg") were renamed to full descriptive forms such as "HeatingEnergy" and "Region" for clarity.

Data Types and Formatting:
- Ensured numerical columns (e.g., EnergyConsumption, Appliances) were assigned correct data types (e.g., Decimal Number).
- Date fields were formatted properly to support time-based analysis.

4.1.3 Relationships and Data Modeling

- Created one-to-many relationships where applicable (e.g., between Region and entries).
- Established calculated columns and DAX measures such as:
- TotalEnergy = SUM([HeatingEnergy] + [CoolingEnergy] + [Appliances] + [Lighting]) EfficiencyScore = [OutputEnergy] / [InputEnergy]

This preparation ensured data consistency and made downstream visualization more robust and flexible.

Module 2: Household Dashboard

This module focused on visualizing energy usage in residential properties across various dimensions such as region, occupancy, and energy type.

4.2.1 Filters and Slicers

Interactive slicers were implemented to allow user-driven exploration:

- Date Range: Analyze usage over time (e.g., year-by-year trend).
- House Type: Apartment, Detached, Semi-detached.
- Occupancy: Full-time, Part-time, Seasonal.
- Region: North, South, East, West (or defined zones from dataset).
- These filters allow users to dynamically slice the data and compare patterns.

4.2.2 Visual Elements

The following visuals were designed for effective interpretation:

Line Chart – Yearly Trend

- Shows energy usage over time (by year/month).
- Helps detect seasonal spikes (e.g., heating in winter, cooling in summer).

Stacked Bar Chart – Energy Type Breakdown

- Represents the contribution of heating, cooling, appliances, and lighting.
- Useful for identifying dominant consumption sources.

KPI Tiles

Display:

- Maximum Energy Use (e.g., 4.8kWh – heating peak)
- Minimum Energy Use (e.g., 0.2kWh – lighting)
- Total Consumption (e.g., 6.10K kWh)

KPIs update dynamically with slicer selections.

4.2.3 Key Findings

- Apartments consume more cooling energy than detached homes.
- Northern regions show peak usage during winter due to heating demands.

- Appliance usage remains relatively consistent year-round but spikes during holidays.

Module 3: Industrial Energy Consumption Dashboard

The industrial dashboard visualizes energy use by different industry sectors, tracks technology adoption, and provides efficiency insights.

4.3.1 Filters and Parameters

The dashboard includes the following filters:
Region: West, East, South, North zones.
Industry Sector: Metals, Construction, Food, Textile, etc.
Technology Used: CNC Machines, Manual, IoT-enabled, Legacy equipment.
These allow industry-specific benchmarking and trend observation.

4.3.2 Visual Components

Monthly Line Chart – Energy Trend

- Plots industrial energy consumption over time.
- Detects monthly usage patterns, highlighting operational peaks.

Sector-wise Bar Chart

- Shows total energy consumption by sector.
- Allows quick comparison of energy-intensive industries.

Pie Chart – Technology Adoption

- Represents percentage distribution of technology types.
- Highlights gaps in adoption of modern, energy-efficient tools.

KPI Cards

- Total Industries Analyzed: 255
- Total Industrial Energy Use: 519.51K kWh
- Average Efficiency Score: 0.45 (on a scale from 0 to 1)

4.3.3 Analytical Insights

- Metals and Construction sectors lead in energy use due to continuous operations and heavy machinery.
- Industries using CNC or IoT-enabled systems show significantly better energy efficiency.
- Older industries still rely on manual or legacy equipment, contributing to higher energy waste.

4.3.4 User Experience and Interactivity

Both dashboards were designed with usability in mind:

- Dynamic Filters: All visuals respond instantly to filter changes.
- Responsive Layouts: Visuals adjust based on selection scope.
- Color Themes: Consistent color coding for each energy type and sector improves readability.

- Tooltips: Hover-over explanations provide data context without cluttering visuals.

4.3.5 Challenges and Resolutions

Challenge	Solution
Inconsistent column naming in Excel	Standardized during Power Query transformation
Null or missing energy values	Replaced with 0 or removed row after validation
High variance in industrial data	Normalized consumption values for fair comparison
Overlapping visuals in dashboard	Used grid layout and grouping features in Power BI

CHAPTER – 5

Results

5.1 Results Overview

The results obtained through Power BI dashboards provide comprehensive insights into energy usage across both household and industrial sectors.
For the household dataset, the analysis revealed that heating and appliances are the top contributors to energy consumption. A significant peak was observed in the year 2024, particularly during winter months in colder regions.

In the industrial sector, energy usage is dominated by the Metals and Construction sectors. These industries operate heavy machinery and often run round-the-clock, contributing to high energy consumption. Furthermore, the data indicates underutilization of modern, energy-efficient technologies. Sectors with legacy systems show significantly higher consumption compared to those using CNC machines or IoT-based automation.

5.2 Dataset Source

The analysis was conducted using the following datasets:
- Household_energy_data.xls: Includes attributes like HouseType, HeatingEnergy, Appliances, Lighting, etc.
- Industrial_energy_data.xls: Contains fields such as IndustryID, Sector, EnergyConsumption, and TechnologyUsed.

5.3 Performance Metrics

- Total household energy analyzed: 6.10K units across various house types and regions.
- Industrial energy analyzed: 519.51K units over a one-year period.
- Regional comparison: Clear differentiation seen between high-consumption zones (e.g., North for heating, West for industrial load).
- Sectoral breakdown: Provided visual distribution by sector and technology, enabling benchmarking.
- Dashboards allow aggregation at monthly, quarterly, and annual levels.

5.4 Model Evaluation

The developed dashboards were evaluated based on usability, accuracy, responsiveness, and interactivity:
- Dynamic filters and slicers work as intended, enabling users to perform effective slice-and-dice operations.
- KPI indicators accurately reflect real-time values for total, average, max, and min energy consumption.
- Visual components (e.g., line graphs, pie charts, bar charts) adjust dynamically based

on user selections.
- Stakeholders can easily compare energy usage between different timeframes, regions, and categories.
- Performance across visual filters was responsive with no lag, even when complex combinations were selected.

These evaluations confirm the dashboard's effectiveness in delivering actionable insights to both technical and non-technical users.

CHAPTER – 6

Conclusion

This project successfully demonstrated the application of Microsoft Power BI for conducting an in-depth analysis of energy consumption in both the household and industrial sectors. Through the integration of two distinct datasets, a robust and dynamic dashboard system was developed that allows users to explore energy usage patterns using a highly visual and interactive interface.

For the household sector, the dashboard enabled the examination of key drivers of energy usage such as heating, cooling, lighting, and appliances. The slicers and filters provided clear insights into how consumption varied across different house types, occupancy statuses, and geographical regions. Notably, seasonal variations were also clearly reflected, with winter months showing higher heating energy consumption.

In the industrial sector, the system facilitated a detailed view into energy consumption by sector and technology type. Industries using modern technologies like CNC and IoT-enabled devices demonstrated significantly better energy efficiency compared to those relying on outdated, manual equipment. The dashboard empowered users to drill down by region, sector, and even time frame, enabling comprehensive comparative analysis.

Overall, the solution was able to turn raw, static datasets into interactive and insightful visuals that support data-driven decision-making. The modular implementation and use of Power BI's built-in capabilities like Power Query, DAX measures, and custom visuals made the system both scalable and maintainable.

In the future, this project can be extended further to include:
- Predictive analytics using machine learning models to forecast future consumption.
- Integration with IoT-based smart meters for real-time monitoring.
- Automated alerts for unusual consumption patterns or efficiency losses.
- Support for renewable energy tracking and carbon footprint estimations.

By enhancing the existing system with these features, it will be possible to create a more comprehensive and proactive energy management platform. The current project thus lays a strong foundation for building next-generation energy analytics tools aligned with sustainability and smart technology goals.

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