

Household Electricity Consumption Analytics Using Google Cloud Platform Services

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Abstract—The increasing consumption of electrical energy at the household level has created a need for efficient monitoring and analytical systems capable of identifying consumption patterns and supporting energy management. Conventional electricity monitoring approaches often provide limited analytical capabilities and primarily present periodic consumption summaries. This paper proposes a cloud-based Household Electricity Consumption Analytics System using Google Cloud Platform (GCP) services. The proposed architecture integrates Google Cloud Storage for scalable data storage, Google Cloud Functions for automated data processing, Google BigQuery for analytical processing, and Looker Studio for interactive visualization. Household electricity consumption data in CSV format is uploaded to cloud storage and processed through an Extract, Transform, and Load (ETL) pipeline. The data is validated, cleaned, transformed, and subsequently loaded into BigQuery for SQL-based analysis. The system focuses on identifying consumption trends, peak usage periods, monthly consumption, and estimated electricity costs. The analytical results are presented through interactive dashboards to improve the understanding of electricity usage. The proposed approach provides a scalable and cloud-oriented framework for household electricity analytics and can serve as a foundation for future extensions involving forecasting, anomaly detection, and real-time monitoring.

Index Terms—Household Electricity Consumption, Google Cloud Platform, Cloud Computing, BigQuery, Google Cloud Storage, Cloud Functions, Looker Studio, Energy Analytics

I. INTRODUCTION

Electricity is an essential component of modern household life, with increasing dependence on electrical appliances, smart devices, and digital infrastructure. As household electricity consumption continues to increase, effective monitoring and analysis of energy usage have become important for identifying inefficient consumption, reducing unnecessary energy usage, and supporting sustainable energy management.

Traditional electricity monitoring systems generally provide limited information regarding detailed consumption patterns. Monthly or periodic billing information may indicate the total amount of electricity consumed, but it does not provide sufficient analytical insight into peak usage periods, consumption trends, or variations in energy demand.

The availability of cloud computing technologies provides an opportunity to develop scalable systems for storing and analyzing large volumes of electricity consumption data. Google Cloud Platform (GCP) provides several services that can be integrated to create an end-to-end data analytics pipeline.

The proposed system utilizes Google Cloud Storage (GCS) for storing raw electricity consumption data, Google Cloud Functions for automated data processing, Google BigQuery for analytical querying, and Looker Studio for visualization. The complete architecture enables the collection, processing, analysis, and visualization of household electricity consumption data.

The primary contributions of the proposed work are:

- Development of a cloud-based framework for household electricity consumption analytics.
- Integration of multiple GCP services into a unified analytical pipeline.
- Automated data validation, cleaning, and transformation using cloud-based processing.
- Analysis of electricity consumption trends and peak usage periods using BigQuery.
- Development of interactive dashboards for visualizing electricity consumption patterns.

II. RELATED WORK

Research in household electricity analytics has evolved through the integration of smart meters, Internet of Things (IoT), cloud computing, and machine learning techniques.

Hart introduced Non-Intrusive Load Monitoring (NILM), which focuses on identifying individual appliance-level electricity consumption from aggregate household power measurements. This work established an important foundation for residential energy monitoring and appliance analysis.

Smart grid research has further explored advanced metering infrastructure, demand response, and intelligent energy management. These approaches enable electricity providers and consumers to obtain more detailed information regarding energy usage.

Cloud computing has introduced scalable infrastructure for storing and processing large datasets. Cloud-based energy management systems can provide remote access, automated processing, and centralized data management. Google Cloud services such as BigQuery provide scalable analytical processing, while visualization platforms such as Looker Studio can convert analytical results into interactive dashboards.

Despite these developments, many existing approaches focus on individual aspects such as forecasting, smart-meter deployment, IoT-based monitoring, or cloud infrastructure.

The proposed work focuses on integrating cloud storage, automated processing, analytical querying, and visualization into a unified framework specifically for household electricity consumption analytics.

III. PROPOSED SYSTEM

The proposed system is designed as a cloud-based data analytics pipeline for household electricity consumption. The architecture integrates Google Cloud Storage, Google Cloud Functions, BigQuery, and Looker Studio.

The overall workflow consists of the following stages:

- 1) Data Collection
- 2) Cloud Storage
- 3) Data Processing and Transformation
- 4) Analytical Processing
- 5) Data Visualization
- 6) Decision Support

A. System Architecture

The proposed architecture provides an end-to-end flow from raw electricity consumption data to analytical dashboards.

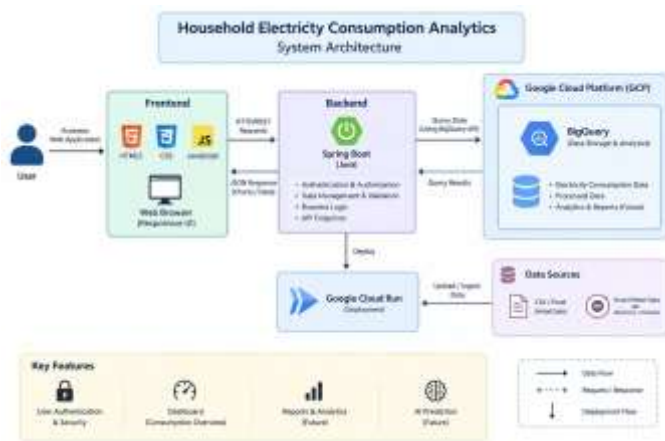


Fig. 1. Architecture of the Proposed Household Electricity Consumption Analytics System

The raw electricity consumption dataset is provided in CSV format and uploaded to Google Cloud Storage. The uploaded data is processed by a Java-based Google Cloud Function, where validation, cleaning, duplicate removal, missing-value handling, and transformation are performed. The processed dataset is subsequently loaded into Google BigQuery for analytical processing.

The analytical results are connected to Looker Studio, where interactive dashboards and charts are generated for interpreting household electricity consumption.

B. Data Collection and Storage

The system uses household electricity consumption data in CSV format. The raw dataset is uploaded to Google Cloud Storage, which provides scalable cloud-based storage and enables integration with downstream processing services.

The storage layer separates raw data from processed analytical data, thereby supporting an organized data processing workflow.

C. ETL Processing

The proposed system implements an Extract, Transform, and Load (ETL) pipeline using Google Cloud Functions.

During the transformation stage, the dataset undergoes:

- Data validation
- Duplicate record removal
- Missing-value handling
- Invalid-value handling
- Data transformation
- Structural standardization

After transformation, the processed dataset is loaded into Google BigQuery for analytical processing.

D. Data Analysis

Google BigQuery is used for SQL-based analytical processing of the transformed electricity consumption data.

The proposed analysis includes:

- Identification of electricity consumption trends
- Identification of peak consumption periods
- Monthly electricity consumption analysis
- Estimation of electricity costs

E. Data Visualization

Looker Studio is integrated with BigQuery to transform analytical results into interactive dashboards.

The dashboards provide graphical representations of electricity consumption patterns, allowing users to interpret the data more effectively.

IV. METHODOLOGY

The proposed research follows an experimental methodology for analyzing household electricity consumption using GCP services.

The complete methodology is divided into six stages.

A. Data Extraction

The household electricity consumption dataset is collected in CSV format and uploaded to Google Cloud Storage.

B. Data Transformation

Google Cloud Functions are triggered to process the uploaded data. The dataset is validated, duplicate records are removed, missing and invalid values are handled, and the data is transformed into a structured format.

C. Data Loading

The transformed dataset is loaded into Google BigQuery. The data is organized into analytical tables to support efficient SQL queries.

D. Data Analysis

SQL queries are executed in BigQuery to analyze consumption trends, peak-hour usage, monthly consumption, and estimated electricity costs.



Fig. 2. System Architecture of the Proposed Method

E. Data Visualization

BigQuery is connected to Looker Studio to generate interactive dashboards, charts, and reports.

F. Decision Support

The generated analytical insights can be used to understand household electricity usage, identify inefficient consumption patterns, and support energy-efficient decision-making.

V. TECHNOLOGIES USED

TABLE I
TECHNOLOGIES AND THEIR FUNCTIONS

Technology	Purpose
Java	Application development and business logic implementation
Google Cloud Storage	Storage of raw household electricity consumption datasets
Google Cloud Functions	Automated ETL processing, validation, and transformation
Google BigQuery	Data storage and SQL-based analytical processing
SQL	Querying and analyzing electricity consumption data
Looker Studio	Interactive dashboards and data visualization
Git and GitHub	Version control and source code management

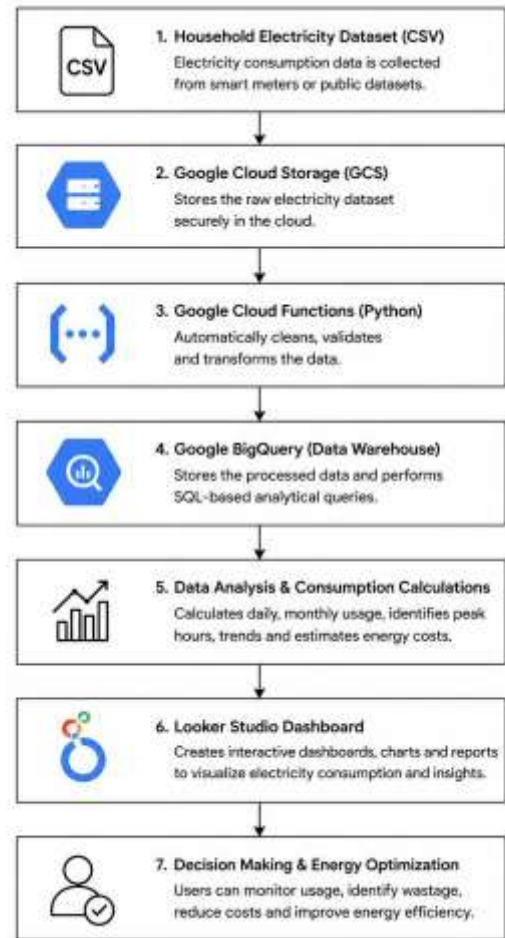


Fig. 3. ETL and Analytics Workflow

VI. SYSTEM WORKFLOW

The overall workflow of the proposed system is illustrated in Fig. 3.

The workflow begins with the collection of electricity consumption data. The raw dataset is stored in Google Cloud Storage. Cloud Functions then perform automated processing and transformation. The processed dataset is loaded into BigQuery, where SQL queries are used for analytical processing. Finally, Looker Studio presents the analytical results through interactive dashboards.

VII. RESULTS AND ANALYSIS

The proposed system provides a structured cloud-based environment for processing and analyzing household electricity consumption data.

The developed system is intended to provide the following analytical capabilities:

- Household electricity consumption monitoring.
- Identification of consumption trends.
- Detection of peak usage periods.

- Monthly consumption analysis.
- Estimation of electricity costs.
- Interactive visualization of analytical results.

The project implementation currently includes several modules related to authentication, dashboard functionality, electricity consumption management, administration, reporting, AI prediction, GCP integration, and testing.

TABLE II
PROJECT MODULE IMPLEMENTATION STATUS

Module	Status
User Authentication	Completed
Dashboard	Completed
Electricity Consumption Management	Completed
Admin Panel	Ongoing
Reports and Analytics	Remaining
AI Prediction	Remaining
GCP Integration	Remaining
Testing, Deployment and Maintenance	Remaining

VIII. DISCUSSION

The proposed architecture demonstrates the integration of cloud services for household electricity analytics. The separation of storage, processing, analytical querying, and visualization provides a structured workflow for handling electricity consumption datasets.

Google Cloud Storage provides the storage layer, while Cloud Functions automate data transformation. BigQuery provides scalable analytical processing, and Looker Studio provides an interactive visualization layer.

The architecture also provides flexibility for future extensions. Additional analytical and machine learning components can be integrated into the existing pipeline without significantly changing the overall system structure.

IX. CHALLENGES AND LIMITATIONS

The development and implementation of the proposed system involve several challenges.

A. Data Quality

Electricity consumption datasets may contain missing, duplicate, or incorrect values. Such data-quality issues can affect the accuracy of analytical results.

B. Cloud Service Integration

The integration of multiple GCP services requires appropriate configuration, authentication, and testing.

C. Large Dataset Processing

Increasing dataset size may increase processing and query execution time. Efficient data management is therefore required for large-scale analysis.

D. Data Security

Household electricity consumption information must be protected from unauthorized access during storage and processing.

E. Internet Dependency

The proposed cloud-based architecture depends on stable network connectivity for accessing GCP services.

F. Dataset Dependency

The quality and completeness of analytical results depend on the quality of the input electricity consumption dataset.

X. FUTURE SCOPE

The proposed system can be extended in several directions.

First, machine learning techniques can be integrated to forecast future electricity consumption. Second, anomaly detection techniques can be implemented to identify unusual consumption patterns.

The system can also be extended to support real-time electricity monitoring through smart-meter or IoT integration. Mobile-based notifications and automated energy-saving recommendations can further improve the practical usefulness of the system.

Future research can also investigate the integration of advanced energy optimization techniques and smart-grid infrastructure.

XI. CONCLUSION

This paper presented a cloud-based Household Electricity Consumption Analytics System using Google Cloud Platform services. The proposed architecture integrates Google Cloud Storage, Google Cloud Functions, Google BigQuery, and Looker Studio to provide an end-to-end pipeline for storing, processing, analyzing, and visualizing household electricity consumption data.

The system performs data validation, cleaning, transformation, and analytical processing before presenting the results through interactive dashboards. The proposed approach provides a structured and scalable framework for understanding household electricity consumption patterns.

The system can be further enhanced through machine learning-based forecasting, anomaly detection, and real-time monitoring. These extensions can provide additional analytical capabilities for supporting efficient and sustainable energy management.

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