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Demand-side management: Load profile analysis and energy efficiency strategies for university facilities

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Abstract

This study investigates energy consumption across a campus to identify major energy-consuming units and optimize energy efficiency. Key loads, including HVAC systems, lighting, office and classroom equipment, cafeteria appliances, lab instruments, and miscellaneous devices, were analyzed to determine their contributions to overall energy usage. Time-series data were utilized to examine daily and weekly consumption patterns, identifying peak demand periods and high-consumption areas. The findings highlight critical energy-intensive zones and operational inefficiencies, offering actionable insights for implementing targeted energy-saving strategies. This approach supports sustainable energy management and contributes to reducing operational costs while promoting environmental stewardship on campus.

Keywords: Energy consumption, energy efficiency, HVAC systems, load profile analysis, sustainable energy management

Introduction

Demand-side management (DSM) is a robust concept introduced by Clark Gellings of EPRI in 1984, well before the widespread liberalization of the electricity industry. Despite its impressive track record in promoting the efficient use of energy resources, DSM faced challenges during the era of market liberalization. However, it has re-emerged as a vital tool in addressing climate change and achieving carbon neutrality [1].

Effective energy management plays a crucial role in conserving energy within organizations. The importance of energy savings is driven by the global imperative to reduce energy consumption. This necessity influences energy prices, emissions targets, and regulations, providing compelling reasons for organizations to prioritize energy efficiency [2].

Without a clear vision of the future and a proper understanding of the past, overproduction of electricity can lead to unnecessary investments, while inadequate electricity supply can lead to unwanted social and economic impacts. Energy policy has socio-economic impacts, such as its impact on consumers' incomes and so on their social welfare. In addition, energy policy here in the Philippines is closely associated with political debates. So, an In-depth knowledge of the electricity industry and electricity consumption is essential for effective energy policy formulation. A serious obstacle to an effective energy policy is the lack of accurate knowledge and adequate studies of the determinants of electricity loads and demand, as well as of modeling and forecasting. This study provides an empirical analysis of electrical load in USTP, and policy recommendations that will assist USTP in its future investment and energy management decisions. This study will also facilitate more efficient usage of electricity by the consumer.

Electrical devices have paved the way for convenient living and give comfort, productivity, and security in day to day living of end users of electricity. However, electrical devices use electricity to provide these services even in its standby mode and the demand to upgrade these electrical devices or equipment is rapidly increasing, with that electricity consumption also increases and with the increasing rate of energy available on the market, there is a great opportunity in reduction of energy consumption due to end-used energy efficiency implication.

Objective of this Study

- Identify all major energy-consuming units and loads across the campus, including HVAC, lighting, office/classroom equipment, cafeteria appliances, lab instruments, and miscellaneous equipment.
- Analyze energy usage patterns daily, weekly, to pinpoint peak demand periods, the energy consumption per day, and high-consumption areas.
- and identify areas where energy-saving opportunities can be implemented.

Scope and Limitations

This study utilizes data from a prior energy audit, as well as detailed energy consumption data measured at 15minute intervals from a smart meter provided by the utility, to analyze energy usage patterns at USTP. The scope includes reviewing the energy consumption of major systems such as HVAC, lighting, office and classroom equipment, cafeteria appliances, and lab instruments documented in the audit data. Specifying equipment and detailing their wattages is essential for creating a more efficient and accurately defined list of electrical consumption.

The limitations of this study include its reliance on previously collected audit data and smart meter readings over a limited timeframe of nearly one month. This period may not fully capture seasonal or operational changes over the long term.

Literature Review

Previous research highlights the value of equipment-specific energy consumption analysis in demand-side management

(DSM), as demonstrated by a study at the University of Science and Technology of Southern Philippines, which found that air conditioning accounted for 51% of energy usage, followed by other equipment at 40% and lighting at 9% [2]. While that study did not assess individual wattage, this DSM study intends to take a more detailed approach by calculating the wattage and kWh consumption per equipment. This deeper analysis will enable more accurate and targeted strategies, addressing specific high-demand equipment to optimize energy use and manage costs more effectively.

A conclusion drawn from the study on the classification of daily load profiles highlights the complexities involved in analyzing energy consumption across various building types on a campus. Specifically, while teaching, research, library, and gymnasium buildings exhibited clear clusters based on day types; office buildings did not, indicating that day-typebased classifications may not always be reliable. This finding underscores the limitations of relying solely on electric demand data for load profile classification, as additional metadata is necessary for a comprehensive analysis [3]. Similarly, in this study on demand-side management, the researchers aim to perform a detailed breakdown of wattage and kWh consumption per equipment to identify specific energy usage patterns. By integrating such granular data, including the number of hours each piece of equipment operates, researchers hope to develop tailored energy-saving strategies that address the unique consumption profiles of different equipment within the university.

A study titled" Smart Building Energy Inefficiencies Detection through Time Series Analysis and Unsupervised Machine Learning" shows that employing time series analysis and unsupervised learning can identify timeslots to reduce HVAC consumption, potentially saving up to 6% in energy [4]. These findings highlight the value of advanced analytical methods in energy management, aligning with my research goals of breaking down wattage and kWh consumption per equipment to develop demand-side management strategies.

The study" Analysis of the Energy Usage in University Buildings: The Case of Aristotle University Campus" analyzed energy consumption in eight buildings using 15-minute signal data from a medium-voltage metering system. It highlighted significant electricity usage patterns that contribute to high bills and identified frequent inefficiencies in energy use, underscoring the need for further research on daily load profiling [5]. These insights align with my study's objective to break down wattage and kWh consumption per equipment for effective demand-side management strategies.

Despite the effectiveness of demand-side management (DSM) strategies in reducing energy consumption and enhancing grid reliability, challenges persist in optimizing load distribution and integrating renewable energy sources. Current predictive models often struggle with real-time demand and supply fluctuations, and while machine learning (ML) shows promise for peak demand forecasting, it requires further refinement for improved accuracy. The integration of energy storage systems (ESS) into distributed generation faces technical and economic hurdles, particularly concerning long-term cost-effectiveness. Future research should focus on developing advanced ML algorithms for demand prediction, improving the incorporation of renewable energy sources into DSM strategies, and creating adaptive frameworks that can dynamically respond to evolving grid conditions, particularly within smart grid contexts

Methodology

a. Flow Diagram Data Collection and Processing

In this section describe the methodology to obtain the data, the original sources of the data, and how this information is used throughout the analysis. The same sources are used for the qualitative descriptions of electrical load characterization methodologies.

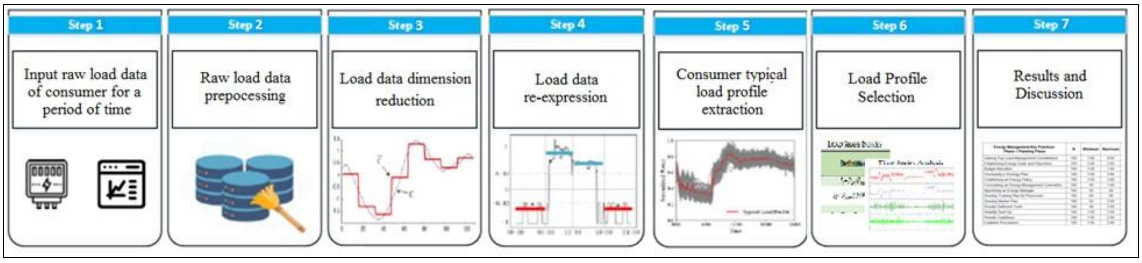


Fig 1: Flow Diagram of the Study

Figure 1 show the step by step processing of the data. First is the data gathered is being loaded into the Matlab software. The preprocessing is transforming the raw data to understandable format (Chart, table, graph). From the preprocess data a data dimension reduction method is applied without affecting the important properties of the data to make further analysis easier. Then a data re-expression method is applied in the data to make it more suitable for further analysis. From preprocessing of data to re-expression of the data we can extract the consumer typical load profile. And by load profile selection using load indices and time series analysis it can reflect the characteristic of the typical load profile of consumer, lastly result and discussion is the last step.

b. Data Gathering and Processing

In this study, energy consumption data were collected every 15 minutes by a single smart meter installed across the campus and provided by the Distribution Utility (DU). This dataset reflects the real net electricity consumption figures of USTP, excluding transmission and distribution losses. The DU supplied pre-adjusted data to ensure that losses were excluded, enhancing the reliability of the dataset. Additionally, further processing may be needed to account for external factors, such as varying building functions and occupancy levels, to ensure consistent analysis of consumption patterns.

From the data collected a series of statistical analysis then is use to process the data. Time series analysis is used to the data to determine the behavior of the data. The data is analyzed using computer software to give graphic and numerical output and the output of the analysis would tell more about the real-life condition. Time series data has four aspects of behavior, trends, cycles, seasonality and unexplained variation. There can also be irregularities or outliers in the data, which can be related back to real-world occurrences.

1. Technical Design Setup for Data Gathering

The technical setup described is designed for gathering, processing, analyzing, and visualizing data from smart meters used by utility companies. Smart meters collect detailed electricity usage data from customers at frequent intervals. A detailed explanation of each component of the technical setup is as follows:

a. Data acquisition

The goal of data acquisition is to Collect detailed electricity consumption data from customers. The main Components for data acquisition are Smart Meters: These devices are installed at customer premises to measure electricity consumption and transmit the data to a central system. Communication Network: A reliable network (e.g., cellular, Wi-Fi, Zigbee) to transmit data from smart meters to the central server.

These are the Steps for data acquisition. Install smart meters at the test sites. Set up the communication network to ensure continuous data flow from meters to the server, and deploy data collection software to aggregate data from smart meters in real-time or at regular intervals [6]. *b) Data Storage:*

The purpose of data storage is to store the collected data securely and efficiently for processing and analysis. The Components needed for data storage are, Servers or Cloud Storage Choose between on premise servers or cloud storage solutions (e.g., AWS S3, Google Cloud Storage) based on data volume and access requirements. and Database Management System (DBMS): Use robust DBMS like PostgreSQL, MySQL, or NoSQL databases like MongoDB to store data in a structured format. These are the Steps for data storage: first set up a database schema to store the smart meter data, ensuring it captures all necessary fields like timestamp, meter ID, and consumption values. And second implement data ingestion scripts to push data from the collection software to the database [6].

2. Data Processing and Mathematical Formula for Statistical Method

Data processing refers to the collection and manipulation of data to produce meaningful information. It involves a series of operations that transform raw data into a usable format. *a) Descriptive analysis:*

Provides a summary of the main features of a dataset, usually involving measures of central tendency and variability.

- **Mean**

The mean is the average of a set of numbers

$$Mean(\mu) = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (1)$$

where N is the number of observations, and xi are the individual values.

- **Standard Deviation**

The standard deviation measures the amount of variation or dispersion in a set of values.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \qquad (2)$$

where σ is the standard deviation, μ is the mean, and xi are the individual values.

- **Maximum and Minimum**

The maximum is the largest value in a dataset, and the minimum is the smallest value [7].

- **Data Frequency**

Data frequency refers to the number of times a particular value or range of values occurs in a dataset. Example: If collecting a weekly data, it might count how many times a specific energy consumption value occurs within a week. Weekly data aggregates measurements or observations taken on a weekly basis. Weekday analysis examines data patterns specifically on weekdays, excluding weekends [8].

- **Cross-Validation**

Cross-validation is a resampling technique used to assess how well a model generalizes to an independent dataset. The idea is to split the data into subsets, train the model on some subsets, and validate it on others, repeating this process multiple times. The most common form is k-fold cross-validation.

Formula of k-Fold Cross-Validation:

1. Split the data into k equal-sized” folds” (subsets).
2. For each fold i=1, 2, k;
    - Train the model on the remaining k - 1 folds.
    - Validate it on the iii-th fold.
3. Calculate the validation metric for each fold, and then average the results over all k folds.

Mathematically

$$CVError = \frac{1}{k}\sum_{i-1}^{K} E_i \qquad (3)$$

where Ei is the error metric (e.g., Mean Squared Error, accuracy) for the i-th fold.

- **Auto-correlation Coefficient**

The auto-correlation coefficient measures the correlation of a time series with a lagged version of itself.

Formula:

$$\rho_k = \frac{\sum_{t=1}^{N}(x_t - \mu)(x_{t+k} - \mu)}{\sum_{i=1}^{N}(x_t - \mu)^2} \qquad (4)$$

where ρk is the auto-correlation coefficient at lag k, xt are the values at time t, and μ is the mean [8].

Statistical methods such as mean, standard deviation, and autocorrelation are essential for load management as they provide insights into average consumption patterns, variability in energy usage, and temporal relationships, enabling facility managers to optimize energy planning, identify peak demand periods, and implement effective demand response strategies.

b. Load shape indices

Load Shape Indices are quantitative measures used to describe the variations in electrical load over a specific period. These indices provide insights into the patterns of energy consumption, helping to identify peaks, valleys, and periods of stable demand. Key Load Shape Indices are, Load Factor (LF), Maximum Utilization Rate (MUR), PeakValley Difference Ratio (PVDR), Peak Load Factor (PLF), Valley Load Factor (VLF), and Flat Load Factor (FLF) [9].

- **Load Factor (LF)**

Load Factor is the ratio of the average load over a given period to the peak load during that period Formula:

(5)

$$LF = \frac{AverageLoad}{Peakload}$$

A higher load factor indicates more efficient use of the electrical infrastructure, as it suggests a smaller difference between average and peak loads. It helps in assessing the capacity utilization of the energy generation and distribution system.

- **Maximum Utilization Rate (MUR)**

Maximum Utilization Rate is the ratio of the total energy consumed over a given period to the maximum possible energy consumption if the peak load had been maintained throughout the period.

Formula:

$$MUR = \frac{TotEnergyConsumed}{MaxPossibleEnergy} \quad (6)$$

This index helps in understanding the extent to which the available capacity is utilized. It can identify periods of underutilization and potential for load shifting to improve efficiency.

- **Peak-Valley Difference Ratio (PVDR)**

Peak-Valley Difference Ratio is the ratio of the difference between peak and valley loads to the peak load.

Formula:

$$PVDR = \frac{Peakload - ValleyLoad}{PeakLoad} \quad (7)$$

It measures the variability in load, which is crucial for designing demand-side management strategies. A lower PVDR indicates a more stable load profile, reducing the need for additional capacity to handle peak loads [8].

- **Peak Load Factor (PLF)**

Peak Load Factor is the ratio of the average load during peak hours to the maximum load.

Formula:

$$PLF = \frac{AverageLoadDuringPeakHours}{MaximumLoad}$$

(8)

Peak Load Factor helps in understanding the intensity of peak demand periods, and aids in planning for peak load management and ensuring that the infrastructure can handle peak demands without failure [10].

- **Valley Load Factor (VLF)**

Valley Load Factor is the ratio of the average load during valley (low demand) hours to the maximum load.

Formula:

$$VLF = \frac{AverageLoadDuringValleyHours}{MaximumLoad}$$

(9)

Valley Load Factor provides insights into the efficiency of energy usage during low-demand periods, and helps in identifying opportunities for load balancing and utilizing off-peak energy more effectively [10].

- **Flat Load Factor (FLF)**

Flat Load Factor is the ratio of the average load during flat (medium demand) periods to the maximum load.

Formula:

$$FLF = \frac{AverageLoadDuringFlatHours}{MaximumLoad} \quad (10)$$

Flat Load Factor indicates the stability of energy consumption during non-peak and non-valley times and assists in ensuring consistent energy generation and supply, improving overall system reliability [10].

c. Site Investigation

A comprehensive energy assessment was conducted at the University of Science and Technology of Southern Philippines. The study surveyed major energy loads, including air conditioning, lighting, computers, and laboratory equipment, to estimate energy consumption. Each building was thoroughly analyzed, with power ratings documented and detailed load distribution maps developed.

The primary goal of the study is to create load profiles that enable targeted measures such as load scheduling, minimizing disruptions, and identifying inefficient energy usage. By refining load patterns, the study aims to reduce the risk of exceeding demand limits and power interruptions. Special attention was given to high-energy-consuming equipment to enhance overall efficiency.

Results and Discussion

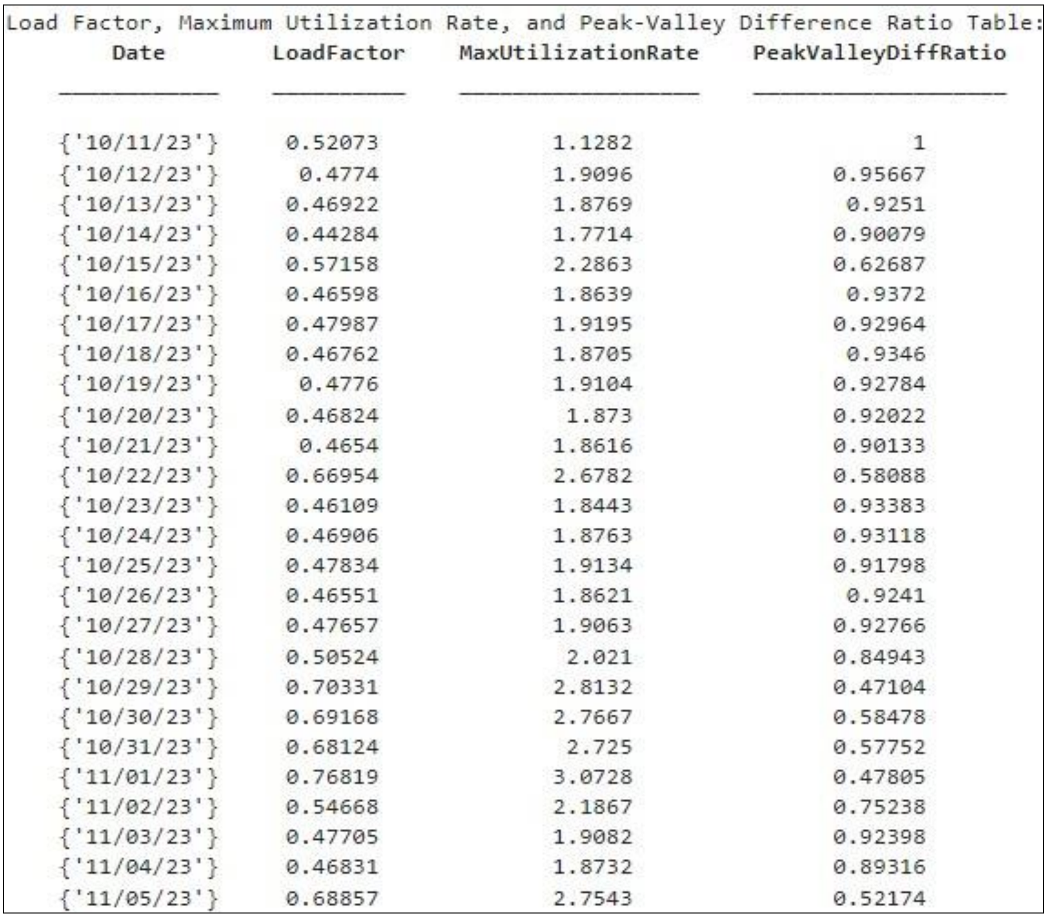
a. Load Shape Indices

The load shape indices refer to the load characteristic indices commonly used in the power system, such as load factor, peak-valley difference, mean load and other 15 indices. These indices can capture reflect the characteristics and power consumption behaviors of consumer. In this paper, we have selected 6 load shape indices, including load factor, maximum utilization rate, the peak-valley difference ratio, peak load factor, flat load factor and valley load factor, which can comprehensively reflect the power consumption behaviors of various consumers.

Figure 2, shows the values of these metrics for each date in the dataset. For example, on October 22, 2023, the Load Factor is 0.66954, indicating that the average power consumption is about 66.95 percent of the maximum power consumption for that day. The Maximum Utilization Rate is 2.6782, suggesting that the actual energy consumed is about 267.82 percent of the maximum possible energy that could have been consumed. The peak-to-valley difference ratio on October 22, 2023, is

0.58088, indicating a relatively low variation in power consumption throughout the day, with the consumption dropping to around 58.08 percent of the maximum at its lowest point.

Overall, the indicators for October 22, 2023, point to a day with a larger peak demand relative to average usage and a lower load factor, along with notable variations in power consumption between peak and off-peak times. This can be the result of particular activities or events that took place that day and raised the demand for electricity during particular times of the day.



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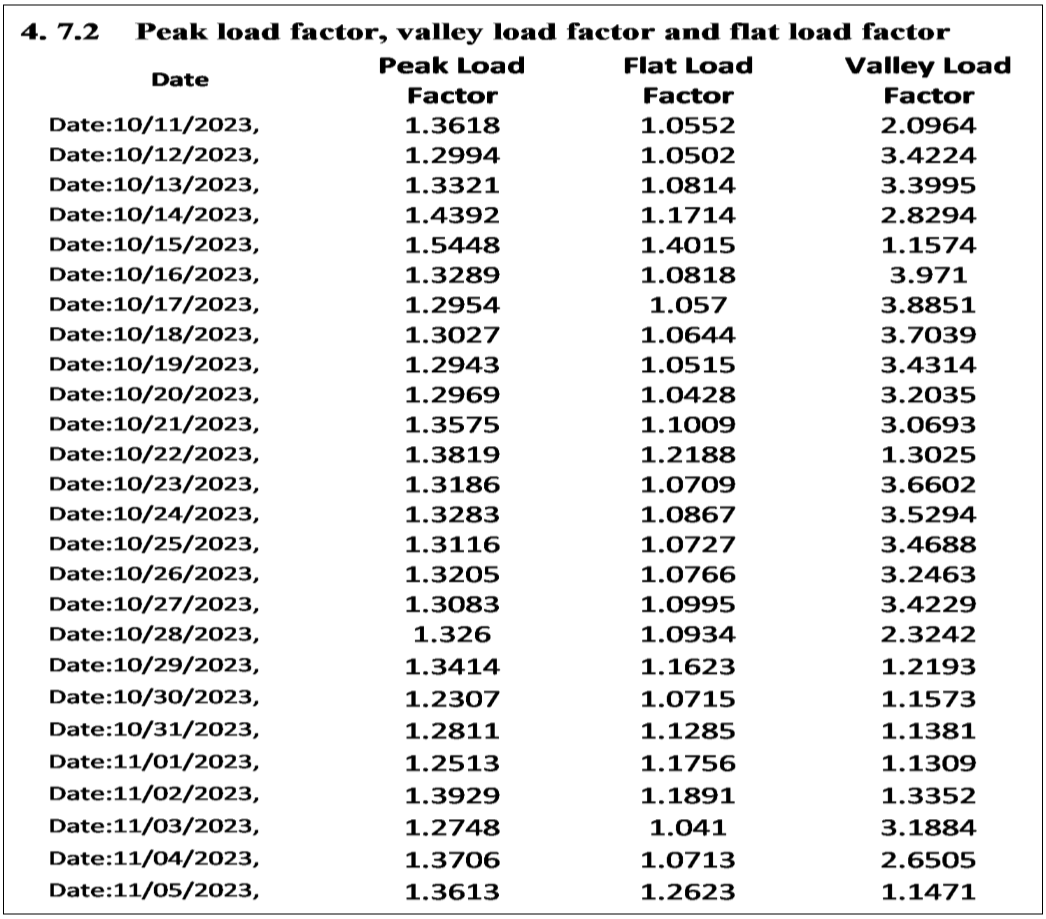
Load Factor, Maximum Utilization Rate, and Peak-Valley Difference Ratio Table:
       Date        LoadFactor    MaxUtilizationRate    PeakValleyDiffRatio
   ____________    __________    __________________    ___________________

   {'10/11/23'}     0.52073            1.1282                      1
   {'10/12/23'}      0.4774            1.9096                0.95667
   {'10/13/23'}     0.46922            1.8769                 0.9251
   {'10/14/23'}     0.44284            1.7714                0.90079
   {'10/15/23'}     0.57158            2.2863                0.62687
   {'10/16/23'}     0.46598            1.8639                 0.9372
   {'10/17/23'}     0.47987            1.9195                0.92964
   {'10/18/23'}     0.46762            1.8705                 0.9346
   {'10/19/23'}      0.4776            1.9104                0.92784
   {'10/20/23'}     0.46824             1.873                0.92022
   {'10/21/23'}      0.4654            1.8616                0.90133
   {'10/22/23'}     0.66954            2.6782                0.58088
   {'10/23/23'}     0.46109            1.8443                0.93383
   {'10/24/23'}     0.46906            1.8763                0.93118
   {'10/25/23'}     0.47834            1.9134                0.91798
   {'10/26/23'}     0.46551            1.8621                 0.9241
   {'10/27/23'}     0.47657            1.9063                0.92766
   {'10/28/23'}     0.50524             2.021                0.84943
   {'10/29/23'}     0.70331            2.8132                0.47104
   {'10/30/23'}     0.69168            2.7667                0.58478
   {'10/31/23'}     0.68124             2.725                0.57752
   {'11/01/23'}     0.76819            3.0728                0.47805
   {'11/02/23'}     0.54668            2.1867                0.75238
   {'11/03/23'}     0.47705            1.9082                0.92398
   {'11/04/23'}     0.46831            1.8732                0.89316
   {'11/05/23'}     0.68857            2.7543                0.52174
```

Fig 2: Load factor, Maximum utilization rate, and Peak-valley difference



4. 7.2 Peak load factor, valley load factor and flat load factor

Date	Peak Load Factor	Flat Load Factor	Valley Load Factor
Date:10/11/2023,	1.3618	1.0552	2.0964
Date:10/12/2023,	1.2994	1.0502	3.4224
Date:10/13/2023,	1.3321	1.0814	3.3995
Date:10/14/2023,	1.4392	1.1714	2.8294
Date:10/15/2023,	1.5448	1.4015	1.1574
Date:10/16/2023,	1.3289	1.0818	3.971
Date:10/17/2023,	1.2954	1.057	3.8851
Date:10/18/2023,	1.3027	1.0644	3.7039
Date:10/19/2023,	1.2943	1.0515	3.4314
Date:10/20/2023,	1.2969	1.0428	3.2035
Date:10/21/2023,	1.3575	1.1009	3.0693
Date:10/22/2023,	1.3819	1.2188	1.3025
Date:10/23/2023,	1.3186	1.0709	3.6602
Date:10/24/2023,	1.3283	1.0867	3.5294
Date:10/25/2023,	1.3116	1.0727	3.4688
Date:10/26/2023,	1.3205	1.0766	3.2463
Date:10/27/2023,	1.3083	1.0995	3.4229
Date:10/28/2023,	1.326	1.0934	2.3242
Date:10/29/2023,	1.3414	1.1623	1.2193
Date:10/30/2023,	1.2307	1.0715	1.1573
Date:10/31/2023,	1.2811	1.1285	1.1381
Date:11/01/2023,	1.2513	1.1756	1.1309
Date:11/02/2023,	1.3929	1.1891	1.3352
Date:11/03/2023,	1.2748	1.041	3.1884
Date:11/04/2023,	1.3706	1.0713	2.6505
Date:11/05/2023,	1.3613	1.2623	1.1471

Fig 3: Peak load Factor, Flat Load Factor, and Valley Load Factor

Figure 3 show the Peak load Factor, Flat load Factor and Valley load Factor. Greater peak load factors that is, those above 1.0; signify that the maximum power demand for example, during October 15, during that period is substantially larger than the average power demand. The peak load factor of 1.5448 on October 15, 2023, indicates that the maximum power demand on that day is 1.5448 times more than the average power demand. The flat load factor measures how evenly distributed power consumption is during a flat, consistent load period, such as business hours. For instance, on October 29, 2023, the flat load factor is 1.1623, suggesting that power consumption during that period is relatively stable. The ratio of the maximum power demand during off-peak hours to the average power demand during those hours is represented by the valley load factor. For example, on October 22, 2023, the valley load factor is 1.3025, indicating that there are fluctuations in energy demand during off-peak hours.

b. Load Distribution

An efficient approach to studying a building's power usage over a specific period is to categorize power consumption based on different load types. Each load type has its own unique load profile, resulting in varying levels of power consumption. During each operating session, multiple load types are integrated to ensure optimal performance.

Figure 4 displays a pie chart illustrating the breakdown of load distribution, encompassing lighting, computers, airconditioning, ceiling fans, and others. Machinery or laboratory equipment operation often introduces significant variability in power consumption due to differing modes of operation. Therefore, to ensure fair justification in load distribution, consistent loads with stable consumption profiles are examined to analyze their cumulative power usage over a defined timeframe, typically aligned with standard working hours from 0800 to 1700 hours or beyond.

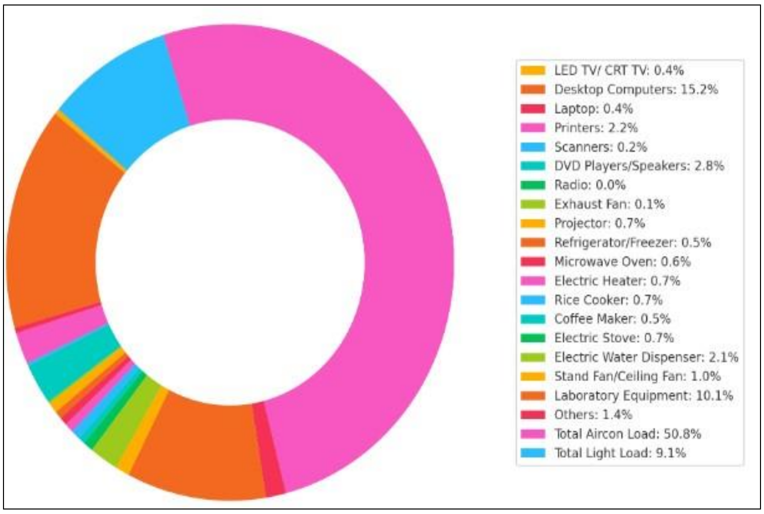


Fig 4: Load distribution per equipment in percentage

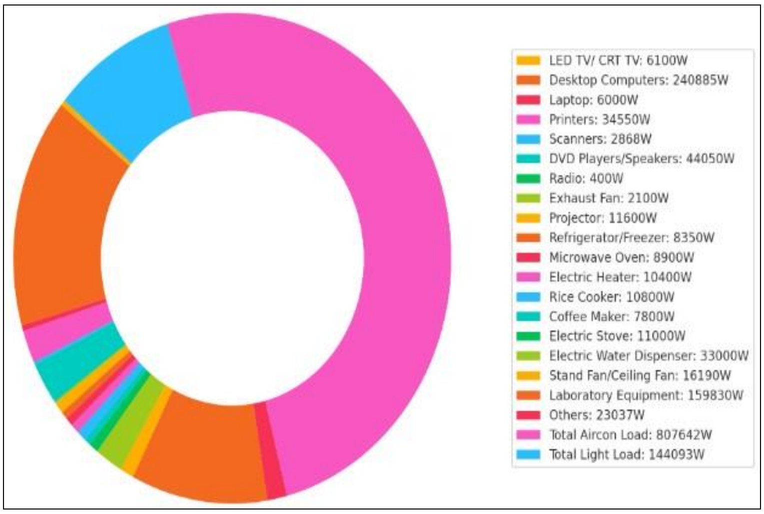


Fig 5: Load distribution per equipment in Watts

This data is from the study conducted within the university entitled development of energy management policy in university of science and technology of southern philippines version 2.0 [2]. the study also did a survey within the university asking how many hours this equipment is being used during operational hours. Figure 5 shows that the top 3 equipment with the highest contribution to energy consumption within the university, namely the air conditioner, due to its considerably high power rating, accounts for the majority of the load distribution which is 50.8 percent of the total load wattage, followed by desktop computer indicating 15.2 percent of the total load wattage and the next is the laboratory equipment contributes 10.1 percent of the total load wattage indicating room for potential reduction in energy consumption in this areas. Furthermore, the operation of other loads is synchronized with the air conditioner, occurring simultaneously during each working hour. While these additional loads may not individually consume as much power as the air conditioner, their interdependence allows for the possibility of regulation and control to improve overall energy efficiency.

From this data the kWh used per equipment can be calculated, the step by step process is stated in Chapter 3. The total kWh for equipment is 12441.9 kWh, applying standard demand factor of 0.8 for all equipment assuming not all equipment operates at its maximum capacity. The new total kWh of all equipment is 9952.95 kWh per day. This is higher compared to the daily energy consumptions computed from the utility meter data which ranges from 4800-8800 kWh per day.

c. Energy Management strategies

Energy management strategies optimize energy use to reduce costs, enhance efficiency, and support sustainability. By minimizing waste, integrating renewable, and using smart technologies, they lower emissions, improve system reliability, and comply with regulations. These strategies also strengthen resilience to supply disruptions, balance demand through Demand-Side Management, and provide a competitive edge while aligning with sustainability goals. Below is the step by step process for the proposed strategies based from Energy Star Guidelines for Energy Management.

Step 1: Baseline Assessment and Energy Audit

1. **Inventory Energy-Consuming Equipment**
   - Catalog all equipment, including HVAC, lighting, office electronics, laboratory instruments, appliances, and infrastructure loads.
   - Use sub-meters to measure energy consumption for each building.

2. **Analyze Consumption Patterns**
   - Review energy usage data (daily, weekly, and monthly) from utility meters.
   - Identify peak demand periods, seasonal variations, and inefficient systems.

3. **Assess Renewable Energy Potential**
   - Conduct feasibility studies for solar; wind, considering roof space, and wind conditions.

Step 2: Optimize Energy Efficiency

4. **Upgrade Equipment**
   - Replace traditional lights with LEDs.
   - Transition to inverter-type air conditioners and energyefficient office equipment.
   - Upgrade old laboratory and appliances to models with higher energy ratings.

5. **Automate Energy Controls**
   - Install smart meters, motion sensors, and building management systems to monitor and control energy use.
   - Use programmable thermostats for HVAC systems to adjust based on occupancy.

6. **Improve Operational Schedules**
   - Schedule energy-intensive tasks during off-peak hours to reduce demand on the grid.
   - Use load-shifting strategies to align with renewable energy availability (e.g., daytime solar energy production).

Step 3: Integrate Renewable Energy Systems

7. **Install Solar PV Systems**
   - Deploy rooftop solar panels on academic buildings, and high-consumption facilities.
   - Incorporate solar-powered outdoor lightings.

8. **Explore Wind Energy Options**
   - Evaluate wind turbine installation in open areas or rooftops with consistent wind flow.

9. **Engage in Power Purchase Agreements (PPAs)**
   - Partner with renewable energy providers to purchase clean energy directly from the grid.

Step 4: Promote Behavioral and Cultural Change

10. **Raise Awareness**
    - Launch campaigns to educate students, staff, and faculty about energy conservation practices.
    - Display dashboards showing real-time energy usage and renewable energy contributions.

11. **Encourage Participation**
    - Introduce competitions and reward systems to incentivize energy-saving behaviors.

Step 5: Develop Policies and Governance

12. **Establish an Energy Management Committee**
    - Assign roles to oversee implementation, monitoring, and periodic review of strategies.

13. **Adopt Green Building Standards**
    - Require energy-efficient and renewable-ready designs for all new construction projects.

14. **Implement Institutional Policies**
    - Mandate the use of energy-saving devices and regulate the operation of high-energy equipment during noncritical hours.

Step 6: Secure Funding and Partnerships

15. **Apply for Grants and Incentives**
    - Seek funding from government programs, energy grants, and international sustainability initiatives.

16. **Collaborate with Energy Providers**
    - Partner with private firms for renewable energy installations under shared-investment or cost-sharing models.

Step 7: Monitor, Evaluate, and Maintain

17. **Regular Maintenance**
    - Establish a schedule for maintaining renewable energy systems, HVAC units, and automated controls.

18. **Continuous Monitoring**
    - Use data from smart meters to identify areas for further improvement.
    - Conduct annual energy audits to assess progress and update strategies.

19. **Evaluate and Scale**
    - Review the effectiveness of implemented measures and scale successful initiatives to other parts of the campus.

d. Potential Saving Estimation

The potential savings estimation highlights the importance of targeting high-consumption equipment, air conditioners, lighting load, desktop computers and laboratory equipment with proven efficiency measures. By implementing these, organizations can significantly reduce energy usage and costs while contributing to sustainability goals.

1. Air-conditioning unit

The total energy usage for the air-conditioning unit is 7268.78 kWh/day. Upgrading the old units to inverter models and setting the temperature to optimal thermostats setting which is 24-26 degrees will have an efficiency gain of 20% base from the U.S Department of Energy (DOE). 20% of 7268.78 kWh/day, the estimated saving for air-condition unit is 1453.76 kWh per day

2. Desktop Computer

The total energy usage for the desktop computers is 1927.08 kWh/day. Enabling sleep mode and reducing idle time will have an efficiency gain of 30% base from the Energy Star: Computer Power Management. 30% of 1927.08kWh/day, the estimated saving for desktop computer unit is 578.12 kWh per day.

3. Lighting Loads

The total energy usage for the lighting load is 1296.84 kWh/day. Replacing old lighting with LED will have an efficiency gain of 40% base from the International Energy Agency (IEA): Energy Efficiency in Lighting. 40% of 1927.08kWh/day, the estimated saving for lighting load is 518.74 kWh per day.

4. Laboratory Equipment

The total energy usage for the laboratory equipment is 958.98 kWh/day. Optimizing equipment scheduling and maintenance will have an efficiency gain of 20% base from University of California Energy Programs: Sustainable Laboratory Practices. 20% of 958.98kWh/day, the estimated saving for lighting load is 191.8 kWh per day.

Conclusion and Recommendation

Conclusion

This study analyzed organizational energy consumption data using MATLAB, focusing on load indices, visualization, and identifying consumption patterns. The analysis revealed peak demand occurring between 9:00 AM and 3:00 PM, with daily energy usage ranging from 4,800 to 8,800 kWh. Lowconsumption days, such as October 15, October 22, October 29, and November 5, correspond to possible weekends or holidays.

The load profile analysis identified air-conditioning units (50.8%), desktop computers (15.2%), laboratory equipment (10.1%), and lighting (9.1%) as the top energy-consuming loads. A deeper investigation into equipment usage revealed these top contributors account for 90.59% of total consumption, with air-conditioning alone contributing 57.5%. The estimated load profile is 10,056.51 kWh/day, 14.28% higher than the utility's peak reading of 8,800 kWh/day, likely due to overestimated usage patterns, equipment diversity, and demand factor limitations.

By targeting the top four energy-consuming loads, a potential daily energy savings of 2,742.42 kWh can be achieved, supporting operational efficiency and cost reduction.

Recommendation

The recommendations align with the existing Energy Management Policy (EMP) and Energy Management Plan (EMPlan) to enhance efficiency and sustainability. Air conditioning, accounting for 57.5% of energy consumption, should be optimized through temperature controls, scheduling, and maintenance. Desktop computers (15.24%) can benefit from energy-saving modes and automated shutdowns, while lighting (10.26%) should be upgraded to LEDs with motion sensors and better use of natural daylight. Laboratory equipment (7.59%) should follow strict usage protocols and regular audits. To address peak demand periods (9:00 AM–3:00 PM), load scheduling and staggered operations should be implemented. Discrepancies between calculated and measured energy usage highlight the need for refining assumptions and improving monitoring. Targeted measures for the top energy consumers can save 2,742.42 kWh per day. Integrating these strategies into the EMPlan ensures measurable progress toward reducing energy consumption, costs, and environmental impact.

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