EAST WEST UNIVERSITY
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Project Title:

IoT based real-time energy monitoring and dashboard development.

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1. Executive Summary

This project presents the design and development of a real-time smart energy monitoring system using a smart plug. The primary goal was to track the power consumption of a household's electric items and log its energy usage continuously.

The project began with a detailed planning and research phase, during which various devices were considered for monitoring. A refrigerator was selected due to its 24/7 operation, consistent load behavior, and practical relevance. A smart plug was chosen for its affordability, safety, and compatibility. By using a smart plug, we collected 24 hours of data over 6 days.

Energy data was collected every five minutes and stored in a structured Excel file, which contains data, time, power, voltage, and current. The system data were collected from July 26 to August 2. With a 24-hour data collection on August 1, 2025, we successfully identified power cycles and idle periods.

The stored data helped estimate daily consumption, and a thorough review was conducted of safety, data quality, scalability, environmental impact, and business potential. The solution was found to be cost-effective, reliable, and scalable for broader use in homes. Overall, the project not only demonstrates the technical feasibility of submetering through smart plugs but also highlights how such solutions can contribute to energy efficiency and sustainable practices under the scope of Green Computing

2. Brief description of the work

The project followed a step-by-step approach, starting from planning and research to final data presentation. The goal was to measure the real-time energy usage of a refrigerator using a smart plug. The steps are :

- **Planning:**
  Explored feasible measurement options and selected a refrigerator for its consistent energy use. Select a smart plug that is available and capable of handling safe current. Verified power compatibility using calculated current ratings.

- **Purchasing & Setup:**
  Bought a smart plug, installed the Smart app, and connected the plug to Wi-Fi. Retrieved the device's local key and IP for communication. Figure 1 shows the smart plug with its box.

Figure 1: Smart plug.

- **Development:**
  Built a Flask-based dashboard that collects and displays power, voltage, and current data. Enabled manual ON/OFF control and timer-based switching.

- **Testing:**
  Verified connectivity, accurate data logging, and smooth interaction with the device. Ensured reliability of real-time updates and local communication.

- **Measurement:**
  Monitored the refrigerator for a full 24 hours (1st August). Logged electrical parameters continuously to capture complete usage behavior.

- **Data Preprocessing:**
  Converted raw values into standard units (W, V, A) using scaling operations, and stored cleaned data in an Excel file for easy access.

3. Detailed description of the steps

- **Planning:**
  The first step of this project involved identifying a suitable electrical device for continuous energy monitoring, as well as exploring viable tools to log its energy consumption effectively. The key planning considerations were centered around device selection, measurement method, and data access strategy.

To measure real-world energy usage, we consider a refrigerator as a personal appliance that runs continuously throughout the day. As a refrigerator continuously operates 24/7 with a periodic cycle, that's why we chose it as a data collection device.
Enabling uninterrupted data collection that captures natural fluctuations in power usage, compressor behavior, and temperature regulation. Its practical relevance as a common household appliance with a notable impact on electricity bills makes it an ideal candidate for generating meaningful insights into daily consumption and potential efficiency improvements. Being a personal device, it offered safe and exclusive access for setup without interfering with shared infrastructure. Moreover, its moderate and variable power draw allowed for observing useful consumption trends without the extremes of high-power appliances like air conditioners or the minimal load of devices like LED bulbs. These factors made the refrigerator the most practical and data-rich choice for this study.

➢ **Execution:**

To measure every single detail according to the time, we bought a smart plug with monitoring capability. The smart plug provides real-time data with low latency in its free application. No data leaves the local network, offering higher control and privacy. The system works even without an internet connection, as long as the device and server are on the same Local Area Network. Figure 2 shows the connection of the refrigerator using a smart plug.

Figure 2: Smart plug installation.

To ensure safety, first, we verified our refrigerator's power draw. Where

- **Power** = 250 W
- **Voltage** = 220 V

- **Power Factor** = 0.8
- **Safety Margin** = 20%

Step-by-step calculation:

- Base current = 250 / 220 = **1.136 A**
- Adjusted for power factor: 1.136 / 0.8 = **1.42 A**
- With 20% safety margin: 1.42 × 1.2 = **1.70 A**

So the smart plug needs to handle at least 1.7A, which is below a 20A-rated plug, which makes the process safe. Figure 3 illustrates the measured device (refrigerator).

Figure 3: Measured Device.

➢ **Configuration:**

To begin, I installed the Smart app from the Play Store and registered an account. The smart plug was then added to the app and connected to my local Wi-Fi network, allowing

it to be recognized by the system. Although this is required for initial setup, I ultimately chose to communicate with the device locally.

- **Testing:**
  Before deploying for full-day data collection, I tested the dashboard and smart plug under controlled conditions:
  - Verified device connectivity and response times.
  - Confirmed accurate logging of energy data with proper time stamps.
  - Ensured local communication was stable.

- **Data Measurement:**
  We collected data from (26th July- 2nd August). On **August 1, 2025**, we connected the smart plug to a refrigerator and ran the system for a full 24 hours.
  - The dashboard logged **voltage, power, and current** every five minutes. Logging conditions ensured that data was saved when values changed significantly or at regular intervals.
  - A complete dataset was generated, capturing the fridge's energy profile across day and night every five minutes.

- **Analysis:**
  We used the dashboard's History section to load and visualize the collected data, where we observed the fridge's compressor cycling behavior, idle power draw, and voltage fluctuations. This helped quantify energy consumption patterns and identify peak usage periods. Through the application and the application dashboard, we can easily measure the power consumption with a timestamp, which is shown in figure 4 below.

Figure 4: App Interface.

- **Data Preprocessing:**
  The raw data from the smart plug device was reported in scaled integers. Power and Voltage in tenths and current in thousandths. To convert them into standard SI units, we applied: Current = raw ÷ 1000 (A)
  The converted values were stored in an Excel file.

- **Result:**
  Through the experiment, we noticed that our measured device consumes 306.6W of power, 227.4V voltage, and 1.338A current in its peak time. On the other hand, when it

becomes an idea, then it consumes 0 in each field. Table 1 shows a sample dataset of our observed data.

Date	Time	Power	Voltage	Current	Total (KWh)
2025-08-01	5:50:57	83.6	234.4	0.619	0.0069
2025-08-01	5:54:40	161.4	234	1.133	0.0134
2025-08-01	5:58:38	163.5	233.5	1.147	0.0136
2025-08-01	6:04:57	159.6	233.5	1.053	0.0133
2025-08-01	6:09:48	0	233.5	0	0
2025-08-01	6:16:27	82.2	233.5	0.571	0.0068
2025-08-01	6:20:27	96.7	233.5	0.696	0.008
2025-08-01	6:24:37	97.5	234	0.702	0.0081
2025-08-01	6:28:48	97.4	213.7	0.701	0.0081
2025-08-01	6:33:18	97.4	213.7	0.701	0.0081
2025-08-01	6:39:48	97.4	213.7	0.701	0.0081
2025-08-01	6:44:07	97.4	213.7	0.701	0.0081
2025-08-01	6:48:27	97.4	213.7	0.701	0.0081
2025-08-01	6:52:50	97.4	213.7	0.701	0.0081
2025-08-01	6:57:10	97.4	213.7	0.701	0.0081
2025-08-01	7:01:27	97.4	213.7	0.701	0.0081

Table 1: Sample dataset.

Here, we tried measuring the total (kWh) for each five-minute interval by using the formula of

$$Total\ (KWh) = \frac{Power\ (W) \times \frac{5}{60}}{1000}$$

Here, power is the value of the power column. 5/60 is the conversion of 5 minutes into hours, and dividing by 1000 converts the value from Wh to kWh.

4. Results and graphs:

For the sample here, we added current, power, and voltage graphs to understand the consumption of the refrigerator. Figure 5 shows the sample graph of the collected data.

Figure 5: Sample of voltage, current, and power consumption graph.

Graphs and charts for the collected data:

Here is the power consumption chart for the 24 hours (01st August) according to the data collection. Figure 6 illustrates the power consumption graph of the observed graph data for 24 hours. The graph illustrates the power consumption of your refrigerator over 24 hours, showing both sharp peaks and low valleys. The peaks represent moments when the refrigerator's compressor is actively cooling, while the valleys indicate periods of low energy use when the cooling cycle is off. The frequency and intensity of these peaks suggest how often the refrigerator engages its cooling mechanism, which typically occurs in cycles. Overall, the graph helps assess the refrigerator's energy efficiency by

showing patterns in power usage, including potential periods of excessive energy consumption. The power consumption graph of your refrigerator over 24 hours reveals a cyclical pattern of energy use, characterized by varying peak levels:

High Peaks: These represent the refrigerator's cooling cycles when the compressor is working at full capacity. High peaks are typically seen when the internal temperature of the fridge is higher than the desired setting, requiring intense cooling. This could happen due to factors like placing warm food inside, frequent door openings, or changes in ambient room temperature. These spikes are the moments when the fridge consumes the most energy.

Medium Peaks: These moderate spikes indicate that the refrigerator's compressor is still running but at a lower intensity, maintaining the internal temperature. These peaks are less frequent and show the refrigerator operating efficiently to preserve the desired temperature without needing full power.

Low Peaks/Valleys: During these periods, the refrigerator is using minimal power. This occurs when the cooling system is off, and the fridge is maintaining its internal temperature without active cooling. These low points are most commonly observed when the fridge has reached the target temperature and is in an idle or energy-saving state.

Overall Pattern:

- The graph shows regular cycles, where the refrigerator switches between high and low power consumption. The high peaks, which are followed by moderate peaks, suggest the refrigerator is working efficiently to keep the internal temperature steady.
- **Energy-efficient operation**: The periods of low consumption indicate that the refrigerator is entering an idle state or consuming very little power once the desired temperature is achieved.
- **Potential inefficiencies**: If the high peaks are too frequent or last too long, it might indicate a problem, such as the fridge struggling to maintain temperature, which could be due to insulation issues, an overfilled fridge, or incorrect temperature settings.

Figure 6: Power consumption graph for 24 hours.

Figure 7 shows the current consumption graph of your device over 24 hours, with the data presented in red. The graph highlights distinct fluctuations in current usage throughout the day:

High Peaks: These sharp, tall spikes in current consumption are indicative of periods when the device is drawing significant power, likely corresponding to active operation or intense usage. The current readings peak at values slightly above 1 ampere, suggesting that the device is operating at full capacity during these times.

Medium Peaks: Moderate spikes in current are observed between the high peaks. These are periods when the device is still consuming more power, but at a reduced rate compared to the high peaks. This could indicate the device entering a lower operational mode or being in the process of completing certain tasks that don't require full power.

Low Valleys: The troughs or valleys in the graph represent times when the current consumption drops significantly, possibly when the device is idle or in standby mode. These periods show minimal power draw, as the device is not actively working or is in a low-energy state.

Pattern Analysis:

- The graph displays **repetitive cycles** of high and low current consumption, which is typical for devices that operate in cycles of activity and rest. The device might be performing tasks intermittently, with high consumption during task execution and low consumption during idle or standby periods.

- The frequency of the high peaks suggests **regular operation** cycles, which may correspond to specific tasks, processes, or cooling cycles.

- The sharpness and frequency of the high peaks indicate **intense usage** during certain periods, potentially leading to higher energy consumption during those times.

Overall, the current consumption graph reveals that the device follows a regular cycle of operation, with higher power consumption during active periods and lower consumption during idle periods. Monitoring these fluctuations can help assess the efficiency of the device and identify any irregularities in its power usage.

Figure 7: Current consumption graph for 24 hours.

5. Challenges and issues:

Issue: Planning and researching

The core idea behind this project was to explore energy monitoring in a way that is both practical and scalable. Refrigerators are common household appliances that run continuously and consume significant electricity. Monitoring its energy usage in real time allowed me to:

- Understand baseline energy consumption
- Visualize how usage fluctuates throughout the day
- Explore potential areas for energy savings

It also aligns with Green Computing principles by promoting awareness about energy efficiency in everyday electronics.

I initially considered monitoring devices like:

Desktops or Laptops – Usage varies widely depending on user behavior and power settings.

Printers or Routers – These typically have low or idle energy usage most of the time.

Computer Lab Devices – Difficult to access consistently and ethically since shared by multiple Users.

In contrast, a refrigerator:

- Runs 24/7, ensuring a continuous data stream
- Shows real-world periodic cycling due to compressor behavior
- Offers safe, personal access without disturbing shared resources

Smart plugs with energy monitoring were found to be widely available

Issue: Wattage for the chosen device

Calculate the AC rating that the equipment can handle. Use Power Factor 0.8 and a 20% safety factor.

- Power = 250 W
- Voltage = 220 V
- Power Factor = 0.8
- Safety Margin = 20%

Step-by-step calculation:

- Base current = 250 / 220 = 1.136 A
- Adjusted for power factor: 1.136 / 0.8 = 1.42 A
- With 20% safety margin: 1.42 × 1.2 = 1.70 A

Thus, the plug must handle at least 1.7 A, which is well below a 20A-rated plug, making it a safe and suitable choice

6. Discussion on issues:

Checklist of Issues	Remarks (if any)
*Planning and researching?	Completed thoroughly. Device selection, feasibility, and measurement methods were carefully evaluated before purchase.
Data Collected?	Power (W), Voltage (V), and Current (A) data were collected at 5-minute intervals over 24 hours.
Data Stored?	Data was stored in a structured Excel file locally, with timestamps and preprocessed units.
Data displayed in the dashboard?	Real-time and historical data visualized with line charts.

Checklist of Issues	Remarks (if any)
*Real-time or stored data?	Both
*Wattage of the chosen device?	197 W. For more safety, consider 250 W.
*Wattage of the measuring equipment?	20 A * 220 V = 4400 W
*AC Power: Why/not apparent power? Why/not Instantaneous Power? AC power vs. DC power?	Instantaneous active power was logged (Watt). Apparent power (V A) wasn't used, as the power factor was assumed standard (0.8). AC power is chosen since the device runs on alternating current; DC power is irrelevant here.
*Documentation	Properly documented everything
*Safety: Electrical Insulation and Isolation?	Commercial smart plug used, rated for insulation, surge protection, and proper isolation—avoided DIY circuits for safety.
*Caution with overclocking/flushing	Not applicable
*API Issues: Did you get it? How? If not, how did you solve this problem?	Used Local Key for device communication. Solved access via tinytuya local key and network configuration.
*UI/UX issues? Standard components of an energy dashboard?	N/A
*User Manual?	N/A
*Future Extensions and Limitations?	Could integrate multiple devices, cloud sync, and mobile apps and use API and buy a domain. Currently limited to one device and local control.
*Installation, Operation and Maintenance?	Simple local setup using Flask, no complicated hardware maintenance. Needs stable power and network.

Checklist of Issues	Remarks (if any)
*Recurring costs	None. One-time plug purchase and free Cloudflare Tunnel setup.
*Cost Accounting?	BDT 1100
*Business Aspects? Cost savings and ROI? Value of this product/service? Justification?	High value for households and small businesses. Helps reduce energy wastage and monitor costs. Potential for commercial dashboard offering.
*Reliability? Never failed? Any fail-safe mechanisms?	The system was tested for continuous 24-hour operation without failure. Conditional logging, stable local communication, and the use of reliable commercial smart plugs ensured consistent performance and uninterrupted data collection.
*Accuracy? Calibration?	No external calibration used. Relied on built-in calibration of Tuya plug. Sufficient for non-industrial use.
*Data quality? Sampling rate? Crosstalk and interference? Accuracy and calibration?	Sampled every 300 seconds. No interference or signal loss.
*Scalability?	Scalable by adding more smart plugs and routes. Backend modular for multi-device extension.
*Interoperability?	N/A
*Data Security? Important or not in this case?	Medium importance here. Local-only access with no cloud dependency ensures privacy and LAN-only exposure
*Compliant with regulations?	For personal use, no regulatory compliance is needed. Uses CE-certified smart plug.

Checklist of Issues	Remarks (if any)
*Environmental Impacts? PESTLE analysis?	Encourages energy conservation and reduces unnecessary power consumption. Positive sustainability use-case.

Table 2: Summary of the observation.