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# Towards an Approach for Household Energy Monitoring and Visualisation to Enable Sustainable Peer-to-Peer Energy Trading

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**Abstract**

Energy systems are currently undergoing a rapid generational and non-reversible change from centralised fossil fuel power plants with national grid distribution to renewable, decentralised systems that are both sustainable and resilient. One promising area of activity is the development of microgrids that can be established on-demand in areas where the power supply is inadequate/ not available. Microgrids enable the possibility of peer-to-peer energy trading and exchange between physically closely located groups of households/ buildings. To achieve this, not only the physical infrastructure but also the supporting software and systems need to be developed and investigated. In this paper, we propose an architecture to allow the monitoring of energy generation and consumption in the household, which is the first step to enabling peer-to-peer energy trading. We demonstrate that with current off-the-shelf technology, it is feasible to monitor and present the current state of a household's energy resources. The ultimate goal is to provide insights and recommendations for the effective deployment and operation of distributed energy resources in future smart grid systems.

***Index Terms*—Distributed energy resources, smart grids, modelling, simulation, and optimization.**

## I. Introduction

The electric power industry is evolving rapidly as new technologies emerge and the adoption of renewable energy sources accelerates [1]. Microgrids, small-scale power distribution systems that can operate in parallel with the main power grid or independently in "island mode", are becoming increasingly popular as they offer numerous benefits such as increased energy efficiency, reliability, and security [2]. Furthermore, microgrids have the potential to support the integration of renewable energy sources and foster a more sustainable energy system [3].

The growing interest in microgrids has led to the exploration of novel approaches to energy trading, such as peer-to-peer (P2P) energy trading, which allows participants to exchange energy directly with each other without relying on traditional energy markets and intermediaries [4]. P2P energy trading can increase self-sufficiency, promote the use of renewable energy sources, and reduce energy costs for participants [5]. Effectively implementing and managing P2P energy trading in microgrids requires the development of advanced control strategies, communication infrastructure, and data management approaches [6].

To achieve peer-to-peer energy sharing, supporting software and systems are needed to enable households to monitor and understand their energy generation and consumption. The research presented in this paper takes a practical approach to evaluating the current state-of-the-art technologies to manage home energy data collection, visualisation and analysis. We present an architecture that can use off-the-shelf energy monitoring equipment to collect and visualise the current energy production and consumption of a home. This architecture allows a user to explore their energy needs live. The research goal is to provide insights into the first step towards enabling peer-to-peer energy trading to allow the creation of distributed energy resources in future smart grid systems.

The paper is organized as follows. Section II presents background information on the topic of microgrids and P2P energy trading. Section III discusses the framework of the Energy Monitoring Dashboard. Section IV details the experimental setup for the energy dashboard. Section V evaluates the performance of the proposed artefact and discusses its implications for the future of microgrids and P2P energy trading. Finally, Section VII concludes the paper and outlines potential avenues for future research in this area.

## II. Background

Microgrids and peer-to-peer energy sharing are innovative concepts that can be used in the field of energy distribution and management to enable various benefits including energy sustainability, efficiency, and resilience. This section provides an overview of each of these concepts highlighting the challenges in the implementation.

### A. Microgrids

Microgrids are small-scale power distribution systems designed to provide energy for local loads, either in parallel with the main power grid or operating independently in "island mode" [3]. They typically consist of distributed energy resources, energy storage systems, and advanced control strategies [7]. Some benefits of microgrids include increased energy efficiency, reliability, and security, as well as the potential to support the integration of renewable energy sources [8].

*1) Fundamental Aspects of a Microgrid:* A microgrid is a small, localized power system that consists of several key components, including power generation sources, energy storage devices, and energy-consuming loads [3]. The power generation sources within a microgrid can be renewable energy systems such as solar panels and wind turbines, or conventional fossil fuel generators [7]. Figure 1 indicates a simplified layout schematic of a typical microgrid system. Energy storage devices, such as batteries and flywheels, play a crucial role in balancing supply and demand within the microgrid [9]. Microgrids can be connected to the main grid, allowing them to draw power from or supply power to the grid depending on local energy demand and generation [8]. In addition, they can operate autonomously or in "island mode", which is particularly useful during grid disturbances or emergencies when the main grid is unavailable [10].

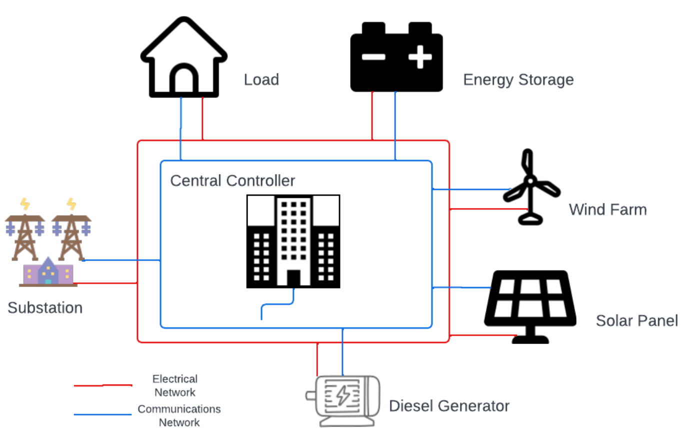


Fig. 1. Simplified Microgrid Schematic

*2) Microgrid Control Strategies:* Effective control strategies are crucial for the optimal operation and stability of microgrids [11]. These strategies can be classified into three main categories: hierarchical, centralized, and decentralized [3]. Hierarchical control schemes employ multiple layers of control, with each layer responsible for a specific function, such as voltage regulation, frequency control, or load balancing [12]. This type of control scheme allows for coordination and decision-making at various levels, providing a flexible and scalable solution for microgrid management [13].

Centralized control strategies rely on a single central controller that manages the entire microgrid, making decisions about generation, storage, and consumption [14]. This approach provides a global view of the system and allows for efficient coordination, but may be vulnerable to communication failures and single points of failure [15].

Decentralized control approaches use multiple local controllers that communicate and collaborate to achieve optimal operation of the microgrid [11]. This type of control strategy can be more resilient to communication failures and provides better scalability [3]. It may require more sophisticated coordination mechanisms and communication infrastructure to ensure reliable operation [13].

*3) Microgrids in Australia:* In Australia, the adoption of microgrids has been gaining momentum due to the country's abundant renewable resources, such as solar and wind power, and the potential for improved energy resilience in remote areas [16]. Microgrids can help address some of the challenges faced by the Australian energy sector, including the need to modernize aging infrastructure, reduce dependence on fossil fuels, and ensure energy security in the face of growing demand and extreme weather events [17]. Several microgrid projects have been implemented across Australia, including the King Island Renewable Energy Integration Project [18] and the DeGrussa Solar Project [19], which showcase the potential benefits of microgrid technology in the Australian context.

### *B. Peer-to-Peer Energy Trading*

Peer-to-peer energy trading in microgrids represents a paradigm shift in the way energy is exchanged, allowing consumers to buy and sell energy directly with one another, bypassing traditional energy markets and intermediaries [6], [20]. P2P energy trading can increase self-sufficiency, promote the use of renewable energy sources, and reduce energy costs for participants [20]. Various P2P trading mechanisms have been proposed in the literature, including auctions, bilateral contracts, and double-sided auctions [21]. Some P2P energy trading platforms also employ blockchain technology to enable secure, transparent, and decentralized transaction management [22]. This subsection discusses various aspects of P2P energy trading, including methods, hardware and software requirements, and architectural considerations.

*1) Methods:* Various methods have been proposed for P2P energy trading, including auctions, bilateral contracts, and double-sided auctions [23]. Figure 2 depicts different methods of engaging in 'peer to peer' and 'peer to grid' energy trading. Each method has its own strengths and weaknesses, and the choice of method will depend on the specific goals and requirements of the microgrid [24]. Some P2P energy trading platforms also employ blockchain technology to enable secure, transparent, and decentralized transaction management [22].

*2) Hardware/Software Requirements:* Implementing P2P energy trading in a microgrid requires a combination of hardware and software components, including smart meters for monitoring and recording energy generation and consumption data [25], communication infrastructure for enabling the exchange of information between participants [26], [27], and software platforms for facilitating the trading process [22]. There has much interest and recent advances in energy monitoring of activities [28], [29] and the use of this information for

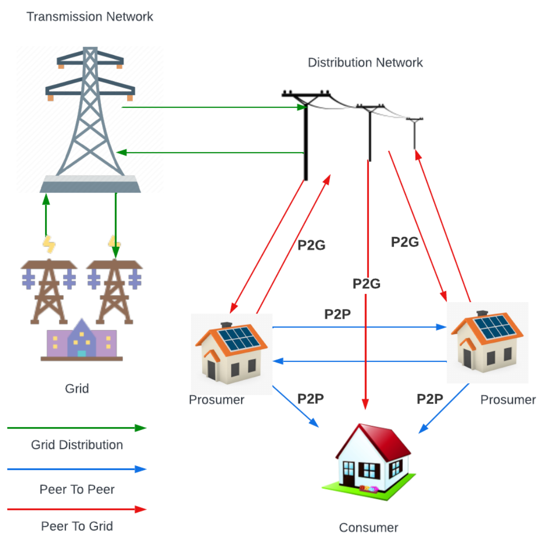


Fig. 2. P2G and P2P types of energy trading in a network

decision making [30]–[33]. Advanced metering infrastructure (AMI) is often used to support P2P energy trading, as it enables real-time data collection and communication between consumers, prosumers, and the energy management system [34].

*3) Architecture:* The architecture of a P2P energy trading system can be centralized, decentralized, or hybrid, depending on the specific requirements and objectives of the microgrid [6]. Centralized architectures rely on a central entity, such as a utility or an aggregator, to manage the trading process [35], while decentralized architectures allow participants to directly trade with one another without the need for intermediaries [4]. Hybrid architectures combine elements of both centralized and decentralized approaches, with some functions managed by a central entity and others handled by individual participants [6].

In summary, microgrids are a promising solution for the modern power system, offering various benefits for both individual users and the overall power system. Microgrids also face several challenges, such as the high initial cost of deployment and the lack of regulatory frameworks in many regions [36]. To address these challenges, it is important to develop policies and incentives that support the development and deployment of microgrids, as well as to invest in research and development to improve the technology and lower the costs [37]. Peer-to-peer energy trading has the potential to increase the efficiency of electricity markets and enable a more decentralized energy system. There are also a number of challenges that must be addressed in order for it to be implemented on a larger scale. These challenges include developing approaches for monitoring energy usage and generation in Microgrids and methods that can be used to accurately simulate and test community energy systems.

## III. Comprehensive Energy Monitoring Dashboard Framework

The objective of this research is in the recognition of a pressing problem - the lack of efficient and effective tools for analysing and understanding energy data from smart homes and microgrid communities. The envisioned solution was a comprehensive energy monitoring dashboard, capable of leveraging Internet of Things (IoT) devices and sensors to measure and analyse energy consumption. This innovative framework aimed to facilitate improved energy management by providing users with immediate, intricate insights into their energy usage patterns.

The preliminary phase of the research was governed by the goal to create a digital environment that could accurately capture and present a wide spectrum of energy data, including but not limited to voltage, current, power, energy inflow (e.g., solar photovoltaic inputs), and energy outflow (usage). The aspiration was to design a user-friendly dashboard that could articulate this data effectively, offering an overarching network view, scaled views and entity comparisons, and a historical perspective for deeper, longer-term operation analysis.

In the blueprint of the energy monitoring dashboard, three main components were perceived as fundamental: the frontend web application, a backend for data processing, and an interface for seamless communication with IoT devices and sensors.

### A. The Web Application

At the heart of the planned energy monitoring dashboard was the web application, which was seen as a key point of interaction between users and their energy data. Envisioned as an intuitive, easy-to-use platform, the web application was meant to serve as a bridge between the complex world of IoT data and the end-users, translating intricate patterns into understandable, actionable insights.

To accomplish this, the web application was imagined as a visually-appealing display that represented energy usage data through dynamic graphs and charts. This design was expected to make it easier for users to identify and understand their energy consumption patterns over time, facilitating data-driven decisions to improve energy efficiency and conservation.

The web application was also planned to have interactive features that would enable users to manipulate the visualized data. For example, users could filter the displayed data by date, time, or specific devices, allowing for a more personalized, detailed examination of energy use patterns.

### B. The Backend

The backbone of the dashboard framework was the backend, the operational core responsible for the collection, processing, and management of the incoming data from the IoT devices. Given the magnitude and complexity of the data, the backend had to be robust and efficient to ensure seamless operation.

The backend's primary function was to communicate with the IoT interface, fetching raw data in real-time, and processing it into a format that could be used for visualization on the

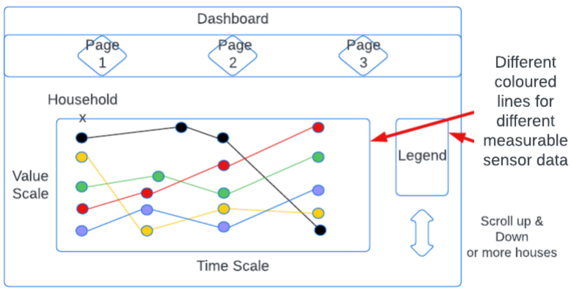


Fig. 3. Design of Frontend Web Interface

web application. Moreover, it was also expected to perform computations to generate insights such as energy consumption trends and comparisons among different households or devices.

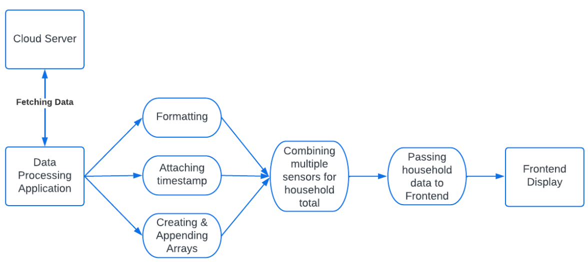


Fig. 4. Design of Backend

### C. The IoT Interface

The IoT interface was seen as the crucial link between the IoT devices and the dashboard. As the direct connection to the IoT devices in each household, this interface had to effectively and efficiently fetch and transmit the data back to the backend for processing.

This interface was planned to gather various metrics from the IoT devices, including voltage, current, power, energy inflow and outflow, and total daily energy consumption. These metrics were crucial in painting a comprehensive picture of energy consumption patterns in each household.

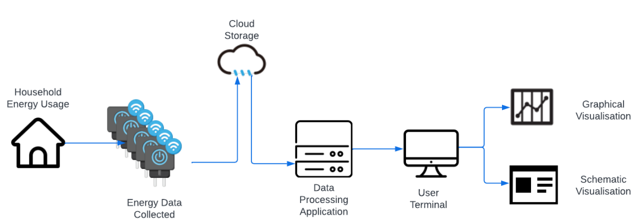


Fig. 5. Design of IoT interface

In summary, the planning and conceptual design of the energy monitoring dashboard was a meticulously detailed process. The ultimate objective was a comprehensive system capable of seamless data collection, effective processing, and intuitive visualization. By offering real-time and historical data on energy consumption patterns in an engaging and interactive format, the dashboard was intended to equip users with the information needed to make educated decisions about their energy consumption. This proactive approach towards energy management was perceived as a significant step towards a more sustainable future and a substantial reduction in the environmental impact of energy consumption.

## IV. Energy Monitoring Dashboard Experiment Setup

To assess the efficiency and efficacy of the energy monitoring dashboard for smart homes, a series of experiments have been conducted using varying configurations. A configuration was set up using standard IoT devices and sensors. The energy monitoring dashboard's architecture, as described in Figure 6, was implemented using Flask and Dash for web development and Home Assistant API for interfacing with IoT devices. Figure 6 details these connections.

The primary goal of this experiment is to evaluate the functionality and user interaction aspects of the energy monitoring dashboard for smart homes. The main functionalities to be assessed include:

- Displaying live data, ensuring it corresponds to the output from multiple Athom HLW8032 Smart Plugs.
- Presenting historical data for different households.
- Providing a schematic representation of grid-microgrid interactions, with the ability to adjust the number of solar panels in the network to determine surplus generation or power deficit, and the reliance on the main grid.

For the experiment, the setup consists of (i) an Acer Nitro 5 laptop as the server for the web application, (ii) a Raspberry Pi 3 as the Home Assistant server, (iii) multiple Athom HLW8032 Smart Plugs, and (iv) various household devices connected to the smart plugs. The Raspberry Pi 3 Model B features 1 GB LPDDR2 SDRAM, Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC at 1.2 GHz. The Acer Nitro 5 laptop is equipped with an Intel Core i9 processor, 16 GB RAM, and a GeForce RTX 3060 GPU. The Athom HLW8032 Smart Plugs are WiFi-enabled devices that can measure and monitor energy consumption in real-time. Figures 7 and 8 illustrate the experiment setup, which includes IoT devices/ Athom HLW8032 Smart Plugs, and Home Assistant server (RPi 3B), respectively.

During the experiment, the energy monitoring dashboard acquires and processes data from multiple Athom HLW8032 Smart Plugs connected to various household devices. The Home Assistant server running on the Raspberry Pi 3 interacts with the smart plugs to collect real-time data, including voltage, current, power, energy, and total daily energy consumption. The Flask backend on the Acer Nitro 5 laptop

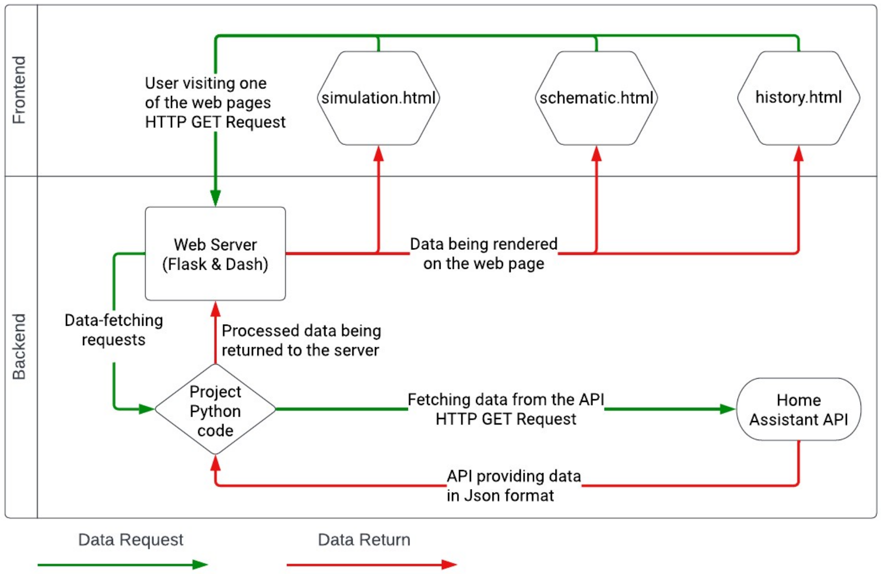


Fig. 6. Energy Monitoring Dashboard Architecture

processes this data and forwards it to the web application for visualization and user interaction.

The dashboard's performance is assessed based on its ability to display live and historical data accurately and effectively, as well as its capacity to represent grid and microgrid interactions. These performance indicators will be used to determine the dashboard's effectiveness in facilitating informed decisions and promoting efficient energy management in smart homes.

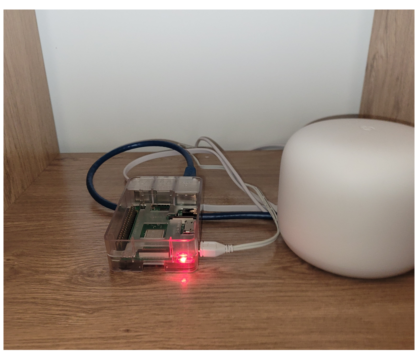

Fig. 7. Raspberry Pi3

Fig. 8. Athom HLW8032 Smart Plugs

Throughout the experiment, the Acer Nitro 5 laptop initiates communication with the Home Assistant server (Raspberry Pi 3) via the Home Assistant API. The API enables data retrieval from the Athom HLW8032 Smart Plugs in JSON format, which is then processed by the Flask backend. The processed data is sent to the web application, where it is visualized through interactive charts and graphs, allowing users to interact with and assess the energy data.

As the experiment progresses, the performance of the energy monitoring dashboard is continually monitored and analyzed to identify potential areas for optimization and improvement. This analysis will help confirm the dashboard's effectiveness in supporting energy management in smart homes and contribute to the development of more sustainable and efficient energy consumption practices.

In summary, the focus of this experiment is to evaluate the core functionalities of the energy monitoring dashboard, such as live data display, historical data representation, and grid/microgrid schematic interactions, rather than time latency, UI response, or visualization data accuracy. The results of this experiment will provide valuable insights into the energy monitoring dashboard's capacity to facilitate informed decisions and encourage better energy management in smart homes, ultimately promoting more sustainable and efficient energy consumption habits.

# V. Evaluation

## A. Evaluation Criteria

The evaluation of the developed energy monitoring dashboard for smart homes focuses on the following criteria:

- Live data display: Examining the dashboard's capability to showcase live energy consumption data accurately and effectively in comparison to the output from the integrated smart home devices.
- Historical data representation: Assessing the dashboard's ability to display historical data for different households in a clear and meaningful manner.
- Grid and microgrid interactions: Evaluating the dashboard's effectiveness in providing a schematic representation of grid and microgrid interactions, allowing users to adjust the number of solar panels and determine surplus generation or power deficit.
- User experience: Evaluating the usability, accessibility, and responsiveness of the web application interface across various devices and screen sizes.

## B. Evaluation Results

*1) Live Data Display:* The energy monitoring dashboard's live data display was evaluated by comparing the energy consumption data from the Athom HLW8032 Smart Plugs with the data displayed on the dashboard. The results showed that the dashboard effectively displayed live data, without deviation from the actual readings. This level of accuracy ensures that users can rely on the dashboard to provide real-time insights into their energy consumption patterns, allowing them to make informed decisions about their energy usage.

*2) Historical Data Representation:* The dashboard's ability to display historical data for different households was evaluated by reviewing the clarity and effectiveness of the presented information. The evaluation demonstrated that the dashboard effectively displayed historical data in a clear and meaningful manner, allowing users to understand their past energy consumption patterns and make informed decisions for future energy management.

*3) Grid and Microgrid Interactions:* The dashboard's effectiveness in providing a schematic representation of grid and microgrid interactions was assessed by examining its ability to allow users to adjust the number of solar panels and determine surplus generation or power deficit. The evaluation results showed that the dashboard successfully represented grid and microgrid interactions, enabling users to understand the impact of their solar panel configuration on their energy balance and reliance on the main grid.


Fig. 9. Live Data Trending

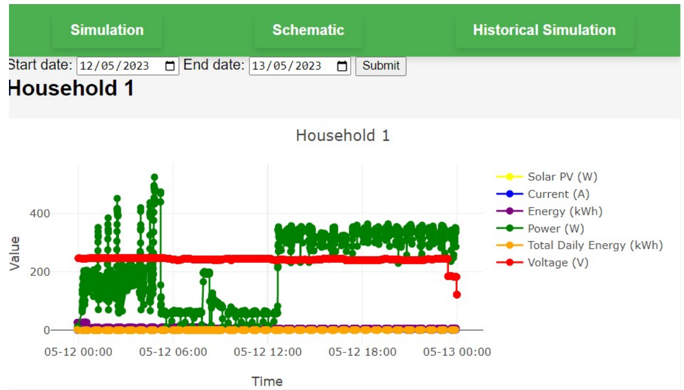


Fig. 10. Historical Data Trending

*4) User Experience:* The user experience of the energy monitoring dashboard was evaluated through user feedback gathered from a small group of participants who used the dashboard to monitor their energy consumption. The participants found the dashboard intuitive and straightforward to use, with a clear and concise layout that facilitated easy access to essential information. The interactive visualizations were highly appreciated, enabling users to explore and analyze their energy consumption data effectively.

## C. Summary

The evaluation of the energy monitoring dashboard for smart homes demonstrates its effectiveness in meeting the criteria of live data display, historical data representation, grid and microgrid interactions, and user experience. The dashboard provides accurate and reliable data collection from integrated smart home devices, showcases historical data effectively, and offers a schematic representation of grid and microgrid interactions, allowing users to understand the impact of their energy management choices.

There are areas for potential improvements, such as refining the user interface and navigation, offering additional customization options, and integrating additional smart home devices or energy management systems. Overall, the energy monitoring dashboard for smart homes represents a valuable tool for users seeking to better understand and manage their home energy systems and make informed decisions about their energy consumption.

The evaluation results validate the effectiveness of the dashboard in providing real-time insights into energy consumption patterns and facilitating informed decisions about energy management in smart homes. The dashboard can contribute to more sustainable and efficient energy consumption practices, ultimately benefiting both users and the environment.

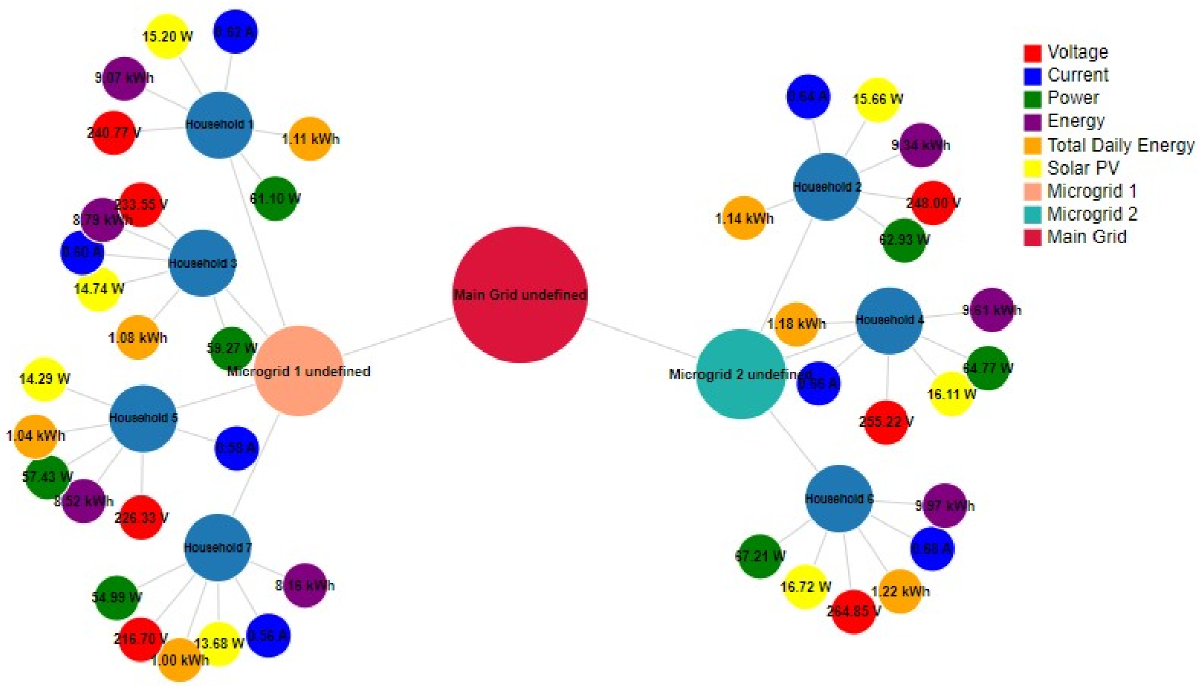


Fig. 11. Schematic Overview

## VI. Conclusion and Future Work

This paper has argued for the need for an energy monitoring dashboard for smart homes to inform homeowners of their energy impact. It has presented the design, development and evaluation of a prototype dashboard that aims to provide users with real-time insights into their energy consumption and support informed decision-making regarding energy management. The approach integrates with the Home Assistant platform and smart home devices to offer a versatile platform for users to monitor and manage their home energy systems. The contributions of this research are as follows.

- A comprehensive review of existing energy monitoring solutions, identifying their strengths and limitations, and highlighting the need for more user-friendly and accessible tools.
- The design and implementation of a web application that integrates with the Home Assistant platform and various smart home devices, providing users with a powerful tool to monitor and manage their energy consumption.
- The development of customizable visualizations and interactive features for users to tailor the application according to their specific needs and preferences.
- The evaluation of the web application using various user testing scenarios, demonstrating its capabilities in providing accurate data, ensuring a positive user experience, and effectively representing grid and microgrid interactions.

There are several directions for future work, as suggested by the limitations of the current research and the rapidly evolving smart home and energy management domains. Some potential avenues for further research include:

- Conducting more extensive user testing with diverse user groups and home energy system configurations to gain a better understanding of the application's performance and usability in various real-world contexts.
- Expanding the evaluation criteria to include factors such as scalability, performance optimization, and integration with other smart home components, to assess the application's suitability for large-scale deployment and its potential impact on the wider energy system.
- Enhancing the application's integration capabilities with various smart home devices and energy management systems, developing standardized APIs or plugins for seamless connectivity, and incorporating more advanced analytics and machine learning techniques to optimize energy management strategies.
- Investigating the potential of the application to support predictive analytics and optimization, using machine learning algorithms to provide insights into future energy consumption patterns and help users optimize their energy usage.
- Refining the user experience and accessibility of the application by incorporating user feedback and best practices from HCI and inclusive design, to ensure a seamless user experience for distinct user groups.

In conclusion, this research presented in this paper has demonstrated the value of the energy monitoring dashboard in providing real-time insights into energy consumption patterns and facilitating informed decision-making for energy management in smart homes. As the energy sector and smart home industry continue to evolve, the need for user-friendly, accessible, and customizable tools to support energy management will only grow, enabling the design and deployment of innovative solutions for sustainable and efficient energy consumption practices that benefit both users and the environment.

## References


[1] C. Wang, B. Zhou, and Z. Chen, "A comprehensive review of microgrid and its multi-objective planning," *Energy Strategy Reviews*, vol. 24, pp. 42–58, 2019.

[2] P. Lombardi, M. Liserre, J. Rajasekharan, V. G. Monopoli, A. Benigni, and T. Huang, "Microgrid technologies: A review," *IEEE Industrial Electronics Magazine*, vol. 14, no. 2, pp. 6–22, 2020.

[3] N. Hatziargyriou, "Microgrids: Architectures and control," *John Wiley & Sons*, 2014.

[4] E. Sorin, K. Leiviskä, and S. Pulkkinen, "Peer-to-peer energy trading in a prosumer-based community microgrid: A game-theoretic model," *International Journal of Electrical Power & Energy Systems*, vol. 104, pp. 471–479, 2018.

[5] E. Mengelkamp, J. Gärttner, K. Rock, S. Kessler, L. Orsini, and C. Weinhardt, "Designing microgrid energy markets: A case study: The brooklyn microgrid," *Applied Energy*, vol. 210, pp. 870–880, 2018.

[6] T. Morstyn, N. Farrell, S. J. Darby, and M. D. McCulloch, "Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants," *Nature Energy*, vol. 3, no. 2, pp. 94–101, 2018.

[7] P. Lombardi, S. C. Bhattacharyya, and M. V. Rocco, "Distributed generation and microgrids," *Energy*, vol. 36, no. 2, pp. 1290–1301, 2011.

[8] C. Marnay, S. Chatzivasileiadis, C. Abbey, A. Hirohisa, K. Hirose, Y. Matsuoka, B. Nordman, V. Vossos, H. Kühn, and R. Kühn, "Microgrids: An emerging paradigm for meeting building electricity and heat requirements efficiently and with appropriate energy quality," *Energy and Buildings*, vol. 43, no. 8, pp. 1975–1982, 2012.

[9] H. Zhang, L. Xu, M. Ouyang, L. Lu, and J. Li, "Energy management strategies comparison for electric vehicles with hybrid energy storage system," *Applied Energy*, vol. 169, pp. 110–118, 2016.

[10] R. Palma-Behnke, C. Benavides, F. Lanas, B. Severino, L. Reyes, S. López, and A. Aguayo, "A distributed approach for the optimal dispatch of distributed energy resources," *IEEE Transactions on Smart Grid*, vol. 3, no. 2, pp. 1138–1146, 2012.

[11] A. Bidram and A. Davoudi, "Distributed control and management of microgrids," *IEEE Transactions on Smart Grid*, vol. 4, no. 4, pp. 2170–2183, 2013.

[12] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuña, and M. Castilla, "Hierarchical control of droop-controlled ac and dc microgrids—a general approach toward standardization," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 1, pp. 158–172, 2011.

[13] A. L. Dimeas and N. D. Hatziargyriou, "Operation of a multiagent system for microgrid control," *IEEE Transactions on Power Systems*, vol. 24, no. 3, pp. 1447–1455, 2009.

[14] F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, "Microgrid management," *IEEE Power and Energy Magazine*, vol. 6, no. 3, pp. 54–65, 2008.

[15] A. Andreotti, M. Benini, L. Piegari, and P. Tricoli, "Overview and modeling of microgrid systems," *Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC), 2014 International Conference on*, pp. 1–6, 2014.

[16] P. Bronski and T. James, "Microgrids in australia: An overview of the current status and future potential," *Rocky Mountain Institute*, 2015.

[17] B. Elliston, M. Diesendorf, and I. MacGill, "Simulations of scenarios with 100% renewable electricity in the australian national electricity market," *Energy Policy*, vol. 45, pp. 606–613, 2018.

[18] S. Gartner, M. Negnevitsky, G. Ledwich, and L. Wang, "King island renewable energy integration project: A holistic approach to maximising renewable penetration," *Power Engineering Conference (AUPEC), 2014 Australasian Universities*, pp. 1–6, 2014.

[19] D. Rogers, "Degrussa solar project: 10.6 mw solar pv with 6 mw battery storage," *ARENA*, 2016.

[20] P. Siano, "A review of demand side management business models in the electricity market," *Renewable and Sustainable Energy Reviews*, vol. 104, pp. 438–458, 2019.

[21] Y. Zhang, J. Wen, and X. Zhang, "Blockchain technology in energy internet: A survey on applications, challenges, and approaches," *IEEE Access*, vol. 6, pp. 46 876–46 886, 2018.

[22] E. Mengelkamp, B. Notheisen, C. Beer, D. Dauer, and C. Weinhardt, "A blockchain-based smart grid: towards sustainable local energy markets," *Computer Science-Research and Development*, vol. 33, no. 1-2, pp. 207–214, 2018.

[23] H. Farag and H. A. Gabbar, "A survey on peer-to-peer energy trading," *International Journal of Electrical Energy*, vol. 6, no. 4, pp. 169–180, 2018.

[24] C. Long, J. Wu, Y. Zhou, and N. Jenkins, "Peer-to-peer energy sharing through a two-stage aggregated battery control in a community microgrid," *Applied Energy*, vol. 233, pp. 832–843, 2019.

[25] V. C. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella, C. Cecati, and G. P. Hancke, "Smart grid technologies: Communication technologies and standards," *IEEE Transactions on Industrial Informatics*, vol. 9, no. 4, pp. 2270–2291, 2013.

[26] Z. Fan, P. Kulkarni, S. Gormus, C. Efthymiou, G. Kalogridis, M. Sooriyabandara, Z. Zhu, S. Lambotharan, and W. H. Chin, "Smart grid communication networks," *Computer Networks*, vol. 67, pp. 74–88, 2014.

[27] B. Amarasekara, C. Ranaweera, R. Evans, and A. Nirmalathas, "Dynamic scheduling algorithm for lte uplink with smart-metering traffic," *Transactions on Emerging Telecommunications Technologies*, vol. 28, no. 10, p. e3163, 2017.

[28] M. Warade, K. Lee, C. Ranaweera, and J.-G. Schneider, "Monitoring the energy consumption of docker containers," in *2023 IEEE 47th Annual Computers, Software, and Applications Conference (COMPSAC)*, 2023, pp. 1703–1710.

[29] M. Warade, J.-G. Schneider, and K. Lee, "Measuring the energy and performance of scientific workflows on low-power clusters," *Electronics*, vol. 11, no. 11, 2022. [Online]. Available: https://www.mdpi.com/2079-9292/11/11/1801

[30] R. Fereira, C. Ranaweera, K. Lee, and J.-G. Schneider, "Energy efficient node selection in edge-fog-cloud layered iot architecture," *Sensors*, vol. 23, no. 13, 2023. [Online]. Available: https://www.mdpi.com/1424-8220/23/13/6039

[31] M. Warade, K. Lee, C. Ranaweera, and J.-G. Schneider, "Optimising workflow execution for energy consumption and performance," in *2023 IEEE/ACM 7th International Workshop on Green And Sustainable Software (GREENS)*, 2023, pp. 24–29.

[32] R. Fereira, C. Ranaweera, J.-G. Schneider, and K. Lee, "Optimal node selection in communication and computation converged iot network," in *2022 IEEE Intl Conf on Parallel & Distributed Processing with Applications, Big Data & Cloud Computing, Sustainable Computing & Communications, Social Computing & Networking*, 2022, pp. 539–547.

[33] M. Warade, K. Lee, C. Ranaweera, and J.-G. Schneider, "Energy aware adaptive scheduling of workflows," in *2022 IEEE Intl Conf on Parallel & Distributed Processing with Applications, Big Data & Cloud Computing, Sustainable Computing & Communications, Social Computing & Networking*, 2022, pp. 562–570.

[34] V. Giordano, G. Fulli, and M. Sánchez Jiménez, *Demand Response: A Different Electric Grid Paradigm*. Joint Research Centre, Institute for Energy and Transport, 2013.

[35] A. Pahwa and S. Bansal, "Centralized and decentralized architectures for peer-to-peer energy trading in smart grid," *2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, pp. 1–6, 2019.

[36] G. Kamath, J. Chandy, and P. S. Mohapatra, "Microgrids: A review of the state-of-the-art," *Renewable and Sustainable Energy Reviews*, vol. 47, pp. 442–454, 2015.

[37] D. Schnitzer, D. S. Lounsbury, J. P. Carvallo, R. Deshmukh, J. Apt, and D. M. Kammen, "Microgrids for rural electrification," *United Nations Foundation: New York, NY, USA*, 2014.