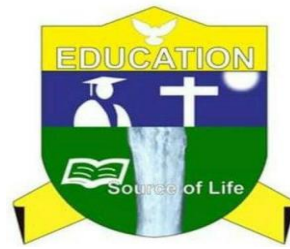


RUAHA CATHOLIC UNIVERSITY



RUCU

FACULTY OF INFORMATION COMMUNICATION TECHNOLOGY

DEPARTMENT OF COMPUTER SCIENCE

PROJECT PROPOSAL

**TITLE: A SMART ELECTRICITY METERING AND BILLING SYSTEM FOR
SHARED ACCOMMODATION**

SUBMITTED

BY

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February, 2026

CERTIFICATION

I, the undersigned certify that, I have read and here by recommend for acceptance by the Ruaha Catholic University (RUCU) Examiners Board of Field Attachment Report done at Ruaha Catholic University in fulfillment of the requirement for the award of Bachelor Degree.

Supervisor's name: Mr. Abdallah Ali

Supervisor's signature.....

Date:

DECLARATION

We, Alexander Amsi, Deocles Joseph, Michael Mbughi, hereby declare that this project proposal titled *A Smart Electricity Metering and Billing System for Shared Accommodation* is our original work and has been prepared uniquely by us. We further declare that this work has not been submitted, either in part or in full, for any academic award at this or any other institution.

All sources and references used in the preparation of this proposal have been duly acknowledged.

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LIST OF ABBREVIATION

AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
ICT	Information Communication Technology
IDs	Identifications
IoT	Internet of Things
RUCU	Ruaha Catholic University

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CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

Electricity metering systems serve as the foundational infrastructure of modern power distribution networks, functioning as the primary interface for energy measurement, financial accounting, and granular consumption analysis [1]. Historically perceived as passive "cash registers" for utility providers, these devices have evolved into sophisticated intelligence hubs that facilitate a bidirectional flow of both electricity and information [2]. This transition is essential for maintaining the operational integrity and financial sustainability of the contemporary electrical grid, as it allows utilities to transition from manual estimation to precise, data-driven management [3].

The evolution of metering technology is characterized by three distinct generations that mark a progressive shift from mechanical sensing to digital intelligence. The first generation, conventional electromechanical meters, utilizes electromagnetic induction to rotate a metal disc at a speed proportional to power consumption [4]. While well-known for their extreme durability and independence from software vulnerabilities, they are fundamentally limited by the requirement for manual on-site readings and an inherent lack of time-stamped data, which prevents modern dynamic pricing [5]. The second generation consists of basic electronic or "static" meters, which replaced moving mechanical parts with integrated circuits and digital displays [6]. These systems offer enhanced precision and the capacity to monitor complex electrical parameters such as reactive power and peak demand; however, many of these devices still lack integrated remote communication capabilities, remaining localized in their data delivery [7].

The current state-of-the-art is represented by Smart Meters and Advanced Metering Infrastructure (AMI), which integrate two-way communication modules to enable automated meter reading (AMR), remote service disconnection, and real-time outage notifications [8]. Despite these technological advancements, the standard deployment strategy often encounters practical limitations in dense urban settings. Conventional and even smart meters are typically designed to measure aggregate energy usage at a single point of supply for a single legal entity [9]. While this "single-point" model is effective for isolated residential units, it is

fundamentally not suited for shared accommodation, a housing trend driven by rapid urbanization and rising costs, particularly in developing nations [14]. In these environments, electricity is frequently billed through equal cost-sharing or manual estimation by landlords, methods that are inherently inaccurate and often precipitate interpersonal disputes, a lack of transparency, and inefficient energy use [10].

To mitigate these challenges, contemporary research has explored Smart Grid technologies and Data Analytics. For instance, while smart grid communications enable real-time monitoring and system interoperability, such systems require significant infrastructure investment and high-level technical overhead, making them economically unviable for small-scale shared housing or low-resource settings [11]. Similarly, studies by Alahakoon and Yu [12] demonstrated that data analytics can reveal consumption patterns to support demand-side management; however, these software-centric approaches provide awareness without providing a mechanism for enforcement or individual financial autonomy among multiple occupants sharing a single supply.

Emerging IoT-based monitoring systems and physical sub-metering have attempted to bridge this gap, yet both face critical functional obstacles. IoT solutions, such as those proposed by Rahman et al. [13], offer automated billing but often rely on continuous internet connectivity and centralized cloud dependencies, which may be unreliable in the very environments where shared housing is most prevalent. Conversely, while physical sub-metering improves transparency at the room level [9], these systems remain critically dependent on the main meter. Under current configurations, if the primary meter's credit is depleted, all sub-meters lose power regardless of individual payment status [10]. This creates a "collective failure" scenario where responsible occupants are penalized for the insolvency of others, thereby failing to resolve the fundamental billing disputes that both IoT and analytics overlook.

The limitations identified in these existing approaches underscore a critical gap in multi-user energy management. There is an urgent need for a **Smart Electricity Metering and Billing System for Shared Accommodation** that transcends these boundaries. By integrating occupant-level measurement with independent electricity purchasing capabilities, the proposed system ensures that individual payment directly guarantees individual access. This approach effectively resolves persistent billing disputes and eliminates the power-dependency issues inherent in traditional shared electricity supplies, providing a scalable and equitable solution for modern urban living.

1.1 Problem Statement

The central challenge in modern energy management for shared accommodation is the structural misalignment between aggregate metering infrastructure and individual consumption patterns. Existing electricity billing systems are fundamentally designed for single-consumer households, measuring energy usage at a solitary point of entry [9], [10]. In multi-tenant environments such as hostels and communal rental units, this technical limitation forces a reliance on arbitrary billing methods, including equal cost-sharing or manual estimation by landlords. These practices fail to reflect actual individual usage, leading to a "tragedy of the commons" where low-consumption occupants effectively subsidize those with higher energy demands. This lack of granularity not only precipitates frequent interpersonal disputes and a deficit in financial transparency but also eliminates the incentive for responsible energy conservation.

Furthermore, while the introduction of physical sub-metering has provided a layer of transparency, it fails to offer functional autonomy. Current sub-metering configurations remain tethered to the operational status of the primary utility meter [9]. Because these devices lack independent credit management and purchasing capabilities, a "collective failure" occurs whenever the main meter is depleted. In this scenario, all occupants suffer a total loss of power regardless of their individual payment history or credit balance [10]. This systemic dependency undermines the principles of fair billing and personal accountability, as an individual's access to a vital utility is dictated by the fiscal behaviour of their neighbours or the landlord.

While advancements in IoT-based billing and Smart Grid technologies have improved overall accuracy and real-time monitoring [11], [12], [13], these solutions remain optimized for centralized utility-scale deployment or isolated single-household applications. There is a persistent technological gap: existing systems do not adequately address the need for occupant-level billing autonomy within a shared supply framework. Consequently, there is a critical need to design and develop a smart electricity metering and billing system that empowers occupants to independently purchase electricity and monitor consumption in real time. The problem to be addressed is the absence of a localized, autonomous infrastructure that ensures occupants pay strictly for their actual usage while operating under a shared main supply.

1.2 Objectives of the Study

1.2.1 Main Objective

To design and implement smart electricity metering and billing system for individual occupants within shared accommodation environments.

1.2.2 Specific Objectives

- i. To design a hardware sensing unit to accurately measure electricity consumption for each individual room or apartment.
- ii. To develop a payment mechanism that lets occupants buy electricity independently using unique user IDs.
- iii. To implement a credit-management algorithm to link purchased energy units to specific user.
- iv. To create a user interface for web that allows occupants to track their real-time usage, remaining credit, and billing history.
- v. To test and evaluate the system to ensure its accuracy in resolving billing disputes and encouraging energy saving in shared housing.

1.3 Significance of the Study

The proposed system is expected to enhance fairness in electricity billing within shared accommodation by ensuring that each occupant pays strictly according to actual electricity consumption. Traditional aggregate metering systems measure total household usage without differentiating individual consumption, which often leads to inaccurate cost allocation in multi-occupant settings [9], [10]. By associating electricity consumption with specific occupants, the proposed system directly addresses this structural limitation.

The system will contribute to reducing billing disputes among occupants and minimizing conflicts between tenants and landlords. Studies on smart metering systems indicate that improved billing transparency and automated consumption tracking enhance trust and reduce disagreements related to estimated or shared billing practices [12], [13]. By introducing automated room-level measurement and individualized credit management, the proposed solution strengthens accountability and transparency in shared environments.

In addition, the system promotes responsible electricity usage by increasing consumption awareness. Research on smart meter data analytics shows that access to detailed consumption information influences user behaviour and supports energy conservation efforts [12]. When

occupants can monitor their own electricity usage and remaining credit, they are more likely to adopt energy-efficient practices.

Furthermore, the proposed system offers a cost-effective alternative to installing multiple independent utility meters. Smart grid and advanced metering infrastructure deployments typically require significant investment and centralized infrastructure [11]. In contrast, the proposed approach operates under a shared main supply while providing occupant-level measurement and billing functionality. This makes the system particularly suitable for shared accommodation in developing regions, where affordability, scalability, and simplicity are essential considerations.

Overall, the study contributes to practical energy management solutions by bridging the gap between aggregate metering systems and occupant-level billing autonomy in shared accommodation environments.

1.4 Scope of the Study

This study focuses on the design and implementation of a localized smart electricity metering and billing system personalized for shared accommodation environments. The scope includes the measurement of electricity consumption at room or apartment level, the development of a mechanism for independent electricity purchasing, automated billing based on actual usage, and provision of consumption monitoring interfaces for occupants.

The system will be implemented as a functional prototype suitable for small-scale shared residences such as hostels and rental houses. The design will operate under a shared main electricity supply and will emphasize affordability, modularity, and ease of deployment in low-resource settings.

The study does not cover integration with national utility smart grid infrastructure or advanced metering infrastructure (AMI) deployments. Large-scale smart grid communication architectures and utility-level billing frameworks require extensive centralized infrastructure and investment [11], which fall outside the objectives of this project. Additionally, issues related to national grid optimization, transmission-level control, and regional demand-side management are beyond the scope of this study.

The primary focus remains on occupant-level electricity measurement and billing independence within a shared supply framework.

1.5 Chapter Summary

This chapter presented the background of the study by outlining the challenges associated with electricity billing in shared accommodation environments. It explained how reliance on aggregate metering systems leads to unfair cost allocation, limited accountability, and frequent disputes among occupants. The problem statement clearly defined the limitations of existing billing approaches and highlighted the absence of occupant-level billing autonomy under a shared main electricity supply.

The chapter further outlined the main and specific objectives of the study, established its significance in promoting fair and transparent electricity usage, and defined the scope of the proposed system. Collectively, these elements justify the need for the design and implementation of a smart electricity metering and billing system personalised specifically for shared accommodation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides a comprehensive examination of the theoretical and empirical literature surrounding electricity metering, automated billing architectures, sub-metering methodologies, and energy management technologies within residential and shared accommodation contexts. The primary objective of this review is to evaluate prior research, synthesize key technological contributions, and identify systemic limitations regarding occupant-level energy management.

Smart electricity metering has emerged as a transformative technology for enhancing billing precision and consumption transparency [9], [12]. Unlike conventional electromechanical meters that merely record aggregate consumption at a single point of entry, smart meters integrate advanced sensing, digital processing, and bidirectional communication modules. These functionalities facilitate automated data acquisition, remote monitoring, and sophisticated billing mechanisms that can handle complex tariff structures [9], [11]. Deployment of these technologies at the utility and household levels has demonstrated significant success in enabling real-time usage tracking, thereby empowering consumers to make informed energy-efficiency decisions and providing utilities with granular data for load forecasting [12], [13].

To address the complexities of multi-tenant environments, sub-metering approaches have been adopted to improve transparency and allocate costs based on granular consumption data [9], [10]. These systems function by installing secondary measurement devices downstream of the primary utility meter to capture the energy footprint of specific circuits or rooms. While these systems provide better visibility into room-level usage patterns, they often remain structurally and legally dependent on the primary utility meter. This dependency frequently restricts the occupant's autonomy in independent credit acquisition, as the "master" meter remains the sole point of financial transaction with the utility [10], [15]. Consequently, while sub-metering provides data, it often lacks the integrated payment gateways necessary to fully resolve the social friction and billing disputes inherent in shared living environments.

Furthermore, the integration of Internet of Things (IoT) frameworks has catalyzed the development of automated measurement and cloud-based billing platforms. By utilizing embedded microcontrollers and precision sensors, these solutions leverage data analytics to

support demand-side management and consumer awareness [13]. However, a critical analysis of current IoT-based systems reveals a preoccupation with single-household deployments or a heavy reliance on persistent high-bandwidth connectivity and centralized cloud infrastructure [12]. Such requirements may prove impractical in low-resource shared accommodation settings, where internet stability is inconsistent and the cost of cloud maintenance can undermine the economic benefits of the system [13].

The synthesis of existing literature highlights a significant research gap: while smart metering has advanced considerably, there is a distinct lack of solutions specifically engineered for the socio-technical dynamics of shared accommodation. Prevailing systems are largely utility-centric, designed for single-family units, or constrained by a lack of independent credit management functionality. This creates a "split-incentive" problem where neither the landlord nor the individual tenant is fully empowered to manage energy efficiently. This gap underscores the necessity for a localized, cost-effective smart metering and billing system that offers occupant-level autonomy, decentralized credit management, and fair cost distribution under a shared infrastructure.

The subsequent sections of this chapter will critically evaluate conventional and smart metering architectures, communication protocols, and sub-metering paradigms to establish a robust foundation for the proposed system's design and implementation. This review ensures that the proposed solution addresses identified limitations while meeting the specific needs of multi-occupant living environments.

2.2 Empirical Review

2.2.1 Study by Willis (2004)

Willis [9] provides a comprehensive overview of power distribution planning and conventional electricity metering. The study emphasizes the role of meters in measuring aggregate consumption at a single supply point. While effective for single-family households, Willis notes that conventional meters lack granularity and are not designed for multi-tenant environments, making fair billing in shared accommodation difficult.

2.2.2 Study by Short (2014)

Short [10] examines practical challenges in electricity billing and highlights inefficiencies associated with manual or equal-cost allocation in multi-occupant buildings. The study

identifies disputes and lack of accountability as common problems arising from aggregate metering, echoing the need for more transparent occupant-level measurement systems.

2.2.3 Study by Gungor et al. (2011)

Gungor et al. [11] discuss smart grid communication technologies that support real-time monitoring, system interoperability, and scalability. Although their study shows that smart grids improve energy management, it notes that such systems are costly and infrastructure-intensive, limiting applicability to small-scale shared residences.

2.2.4 Study by Alahakoon and Yu (2016)

Alahakoon and Yu [12] explore the use of smart electricity meter data for energy intelligence, demonstrating that data analytics can reveal consumption patterns and support energy conservation. However, their study focuses on household-level applications, not occupant-level billing autonomy in shared settings.

2.2.5 Study by Tejwani et al. (2020)

Tejwani et al. [13] propose an IoT-based smart energy meter and billing system, highlighting real-time monitoring and automated billing. While effective for single households, the system depends on continuous internet connectivity and cloud infrastructure, making it less suitable for low-resource shared accommodation environments.

2.2.6 Study by the United Nations (2018)

The United Nations [14] reports on the growth of urbanization and shared housing worldwide, emphasizing that electricity billing issues in multi-tenant buildings are increasingly relevant in developing countries. This contextualizes the practical need for occupant-level metering solutions.

2.2.7 Study by Roosefart et al. (2017)

Roosefart et al. [15] examine fault location in smart meters using wavelet-based techniques. While their work focuses on technical reliability, it reinforces the importance of meter-level monitoring for accuracy and transparency in billing systems.

2.2.8 Study by Depuru et al. (2011)

Depuru et al. [16] highlight the benefits of smart meters in enhancing billing accuracy and consumer trust. Their study supports the use of smart metering for automated consumption tracking but mainly considers utility-scale deployment rather than shared occupancy settings.

2.2.9 Study by Rahman et al. (2019)

Rahman et al. [17] present an IoT-based smart energy monitoring and billing system capable of automated measurement and real-time billing. While promising, the system primarily addresses single-household deployment and assumes continuous network connectivity, limiting its suitability for shared accommodation.

2.3 Related Works

2.3.1 Conventional Electricity Metering

Traditional electricity meters, as discussed by Willis [9] and Short [10], are designed to measure aggregate energy consumption at a single point of supply. These devices primarily record the total electricity usage of an entire household or building without distinguishing individual consumption among multiple users. In single-family households, this approach is generally sufficient for billing purposes, as the electricity demand comes from a single consumption entity. However, in shared accommodations such as hostels, rental houses, or multi-tenant apartments, occupants have varying electricity usage patterns, which conventional meters cannot capture.

Because these meters provide only total consumption data, landlords or building managers often rely on equal cost-sharing or manual estimation to allocate electricity expenses among tenants [10], [15]. This approach can lead to multiple issues, including billing inaccuracies, disputes between occupants, and inequitable cost distribution. High-consuming tenants may benefit at the expense of low-consuming tenants, discouraging responsible energy behavior. Moreover, reliance on manual readings introduces the potential for human error, further compromising the accuracy of billing [9].

Willis [9] emphasizes that conventional meters lack flexibility and do not provide real-time or user-specific consumption data, limiting their usefulness in environments where consumption monitoring at an individual level is needed. Short [10] notes that in developing countries, shared accommodation often relies on such aggregate billing methods, which exacerbates conflicts and reduces transparency. The United Nations [14] further highlights that

urbanization has increased demand for shared living spaces, making the shortcomings of conventional electricity metering systems a growing concern in both developed and developing regions.

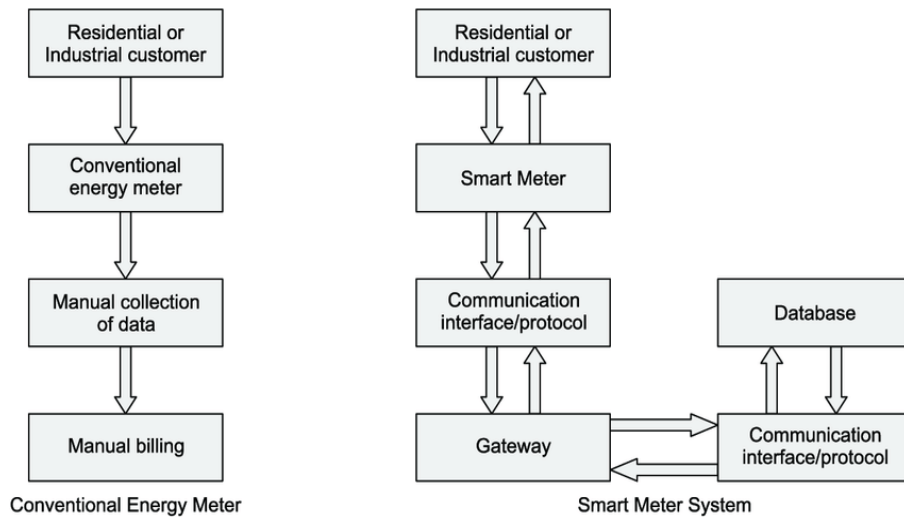


Figure 1. Functional Difference between Conventional and Smart Electricity Metering Systems.

Overall, the literature demonstrates that while conventional electricity meters are reliable for measuring total consumption, they are insufficient for ensuring fair and transparent billing in multi-occupant settings. This limitation motivates the need for systems that can provide occupant-level monitoring, automated billing, and independent electricity management.

2.3.2 Smart Meters and Advanced Metering Technologies

Smart meters represent a significant advancement over conventional electricity meters by integrating sensing, processing, and communication functionalities. These devices enable automated meter reading, remote data collection, real-time monitoring of electricity consumption, and more accurate billing [9], [11], [12], [16]. The automation provided by smart meters reduces human error associated with manual meter readings and ensures more reliable data reporting, which is critical for both utilities and consumers.

Depuru et al. [16] emphasize that smart meters enhance trust between consumers and electricity providers by providing transparent and verifiable consumption data. This transparency not only reduces disputes over billing but also promotes accountability among users. Alahakoon and Yu [12] extend this perspective by demonstrating that smart meter data analytics can uncover consumption patterns, identify peak usage periods, and facilitate energy efficiency initiatives.

Such analytics allow both users and utility providers to optimize electricity usage, contributing to demand-side management and cost reduction.

Despite these advantages, several limitations remain in the context of shared accommodation. Most smart metering systems are designed for centralized utility-scale deployment or single-household applications [9], [11], [12]. Their architectures typically assume a single consumer per meter, and the billing and monitoring features are not tailored for multiple occupants sharing a single electricity supply. Consequently, these systems do not provide the granular, occupant-level control required for independent electricity purchasing or real-time tracking in multi-tenant environments. This lack of individual autonomy limits their effectiveness in reducing billing disputes or promoting responsible energy behaviour among shared accommodation residents.

Furthermore, while smart meters can support advanced billing methods such as time-of-use tariffs or dynamic pricing, the infrastructure and cost requirements are often prohibitive for low-resource or small-scale shared residences [11], [16]. Without adaptations for these settings, the benefits of smart metering accuracy, transparency, and consumption awareness cannot be fully realized at the occupant level.

In summary, while smart meters offer superior monitoring and billing capabilities compared to conventional meters, their current implementations are not optimized for the unique challenges of shared accommodation. There is a clear need for a system that combines the technological strengths of smart meters with features that allow independent, occupant-level electricity management under a shared main supply.

2.3.3 Sub-Metering in Multi-Tenant Buildings

Sub-metering systems have been widely adopted as a means of improving electricity billing transparency in multi-tenant buildings. These systems measure electricity consumption at the room or apartment level, providing a more granular view of usage compared to conventional aggregate meters [9], [10]. By capturing individual consumption data, sub-meters allow landlords or building managers to allocate costs more accurately and reduce disputes among occupants. This feature also promotes accountability, as tenants become aware of their actual energy usage and can be billed accordingly.

Despite these benefits, sub-metering systems have notable limitations. Sub-meters are typically dependent on the main electricity supply; if the main meter is depleted or disconnected, all

connected sub-meters lose power regardless of the individual consumption or payment status [10], [15]. This dependency creates a structural constraint, as tenants cannot fully control their electricity access even when they have paid for their usage. Additionally, traditional sub-metering systems do not support autonomous electricity purchasing or credit management at the occupant level [9], [10]. Occupants are still reliant on the landlord or building manager to manage billing and electricity supply, which limits fairness and autonomy.

Roosefart et al. [15] highlight technical challenges in sub-metering, such as fault detection and accuracy maintenance, particularly when systems are deployed across multiple tenants. Failures in individual sub-meters or issues in the main supply can propagate quickly, affecting multiple users and undermining billing transparency. Moreover, sub-metering systems often lack integration with digital monitoring or automated billing platforms, which restricts their potential for real-time consumption tracking or data-driven energy optimization.

In summary, while sub-metering provides a step toward fairer electricity billing in multi-tenant settings, it remains constrained by its dependence on the main meter and limited support for occupant-level autonomy. These limitations underscore the need for a more advanced system that allows independent electricity purchasing, real-time monitoring, and fair cost allocation under a shared main supply, bridging the gap between traditional sub-metering and modern smart metering solutions.

2.3.4 IoT-Based Electricity Monitoring Systems

The integration of Internet of Things (IoT) technologies into electricity metering has introduced significant improvements in automated monitoring, billing, and energy management. IoT-based systems use connected sensors, smart meters, and communication networks to collect real-time consumption data, which can then be processed locally or in the cloud to generate accurate bills and provide consumption insights [13], [17]. These systems enable features such as automated meter reading, real-time alerts, energy usage visualization, and data-driven recommendations for energy conservation.

Rahman et al. [17] proposed an IoT-based smart energy monitoring and billing system that allows for automated measurement of electricity consumption and real-time generation of bills. Their system demonstrated high accuracy and reduced the need for manual readings, enhancing billing transparency. Similarly, Tejwani et al. [13] highlighted that IoT-enabled monitoring

allows users to track energy usage remotely and adjust consumption behavior accordingly. Such features increase consumer awareness and promote energy-efficient practices.

Despite their advantages, IoT-based systems face practical limitations in shared accommodation settings. Most existing implementations are designed for single-household environments and rely heavily on continuous internet connectivity and cloud infrastructure [13], [17]. In low-resource settings, these requirements may be difficult to maintain due to unstable network connections, high data costs, or limited technical support. Additionally, while IoT systems can provide detailed consumption data, they do not typically support independent electricity purchasing or credit management for individual occupants under a shared main supply. This limits their ability to ensure fair billing and autonomous control over electricity usage in multi-tenant buildings.

Furthermore, the deployment of IoT-based monitoring systems often involves higher costs and technical complexity compared to conventional or sub-metering solutions. Installation, maintenance, and integration with user interfaces or billing platforms require technical expertise, which may be inaccessible in small-scale shared accommodations [13]. These challenges indicate that while IoT systems are technologically advanced, adaptations are necessary to make them practical, affordable, and fully functional for occupant-level electricity management in shared living environments.

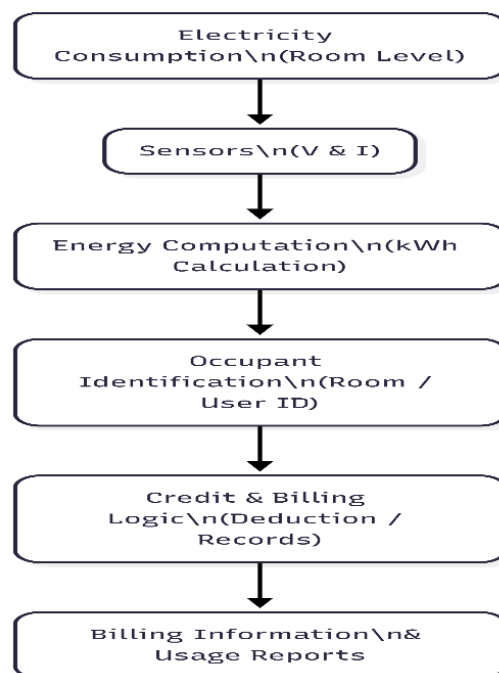


Figure 2. Data-Flow Diagram of Electricity Consumption and Billing System

In summary, IoT-based electricity monitoring systems provide real-time data, automated billing, and enhanced consumption awareness. However, their dependence on network connectivity, single-household design, and lack of occupant-level purchasing functionality limit their applicability in shared accommodation contexts. This highlights the need for a cost-effective, localized IoT-enabled solution that enables independent monitoring, fair billing, and occupant autonomy under a shared main supply.

2.4 Research Gap

From the reviewed empirical studies and related works, it is evident that existing smart electricity metering and billing systems primarily focus on either large-scale utility deployments or single-household residential environments. These systems emphasize automated meter reading, real-time monitoring, and advanced billing mechanisms, which improve accuracy and transparency at the household or utility level. However, they do not adequately address the unique challenges of shared accommodation settings, where multiple occupants share a single electricity supply but require independent control over consumption and billing. In multi-tenant or shared housing environments, residents often face inequities in electricity billing due to aggregate metering practices or reliance on landlord-managed cost-sharing. Although sub-metering systems provide a partial solution by measuring electricity at room or apartment level, they remain dependent on the main meter, and occupants cannot independently purchase electricity or manage their own credit. This dependency undermines the fairness and autonomy of electricity usage, leaving occupants vulnerable to power interruptions caused by issues in the main supply or non-payment by other tenants. Additionally, IoT-based and smart metering solutions, while technologically advanced, rely heavily on continuous internet connectivity, cloud infrastructure, and higher installation costs. Such requirements limit their practical adoption in small-scale, low-resource shared accommodations, especially in developing countries where network reliability and financial resources may be constrained. Furthermore, these systems rarely integrate tenant-specific billing with real-time consumption monitoring in a way that empowers occupants to make informed energy use decisions and pay strictly according to actual consumption. These limitations collectively indicate a significant gap in current research and technology, highlighting the need for a localized, cost-effective, and scalable smart electricity metering and billing system designed specifically for shared accommodation. Such a system should support occupant-level autonomy, fair billing, real-time monitoring, reliability under a shared supply, and affordability for low-resource environments. Addressing these gaps forms the empirical

justification for the proposed study and underscores the importance of developing a solution that promotes transparency, accountability, and responsible energy consumption among multiple occupants.

2.5 Chapter Summary

This chapter provided a comprehensive review of empirical studies and related works on conventional electricity metering, smart metering, sub-metering, and IoT-based electricity monitoring and billing systems. The review highlighted the advantages of automated meter reading, real-time consumption tracking, and data analytics in improving billing accuracy, transparency, and energy awareness. However, it also identified key limitations in existing approaches, particularly their inability to support independent electricity purchasing, occupant-level credit management, and real-time monitoring in shared accommodation settings. Sub-metering systems, while improving transparency, remain dependent on the main meter, and IoT-based or smart metering solutions often require infrastructure and connectivity that may not be feasible in low-resource environments. These gaps underscore the need for a localized, cost-effective, and scalable system tailored specifically for multi-occupant residences. The findings of this chapter provide the empirical and theoretical foundation for the design and methodology of the proposed smart electricity metering and billing system, which will be presented in the next chapter.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter outlines the research methodology adopted for the design and implementation of the proposed smart electricity metering and billing system for shared accommodation. The methodology provides a structured approach to achieving the objectives of the study, ensuring that the system is designed, developed, and evaluated in a systematic and rigorous manner. It describes the research design, system architecture, data collection methods, hardware and software components, and the procedures followed for system development and testing. The chapter also explains how the methodology addresses the gaps identified in the literature, particularly the need for occupant-level electricity monitoring, independent purchasing, and fair billing under a shared main electricity supply. By providing a clear and detailed methodological framework, this chapter lays the foundation for the practical implementation of the system and the evaluation of its effectiveness in enhancing transparency, accountability, and energy management in shared living environments.

3.1 Project Approach

The project will adopt a structured system development approach to design and implement the proposed smart electricity metering and billing system. The approach involves sequential phases, including requirement analysis, system design, hardware and software development, system integration, and comprehensive testing. Each phase will ensure that the system meets the functional and non-functional requirements, addresses the identified gaps in occupant-level electricity monitoring, and provides a reliable and user-friendly solution for shared accommodation environments.

3.2 Project Methods

The system will utilize a combination of hardware and software components to achieve occupant-level electricity measurement and billing. Hardware components will include smart electricity meters, current and voltage sensors, and a microcontroller to collect and process consumption data at the room or apartment level. The software platform will manage the association of electricity usage with individual occupant IDs, enable independent electricity purchasing, generate accurate billing, and provide real-time or periodic consumption monitoring through a user interface. Data from the hardware will be processed in the software

to ensure transparency, accuracy, and fairness in billing, while promoting energy awareness among occupants.

3.3 System Architecture

The proposed smart electricity metering and billing system for shared accommodation is designed using a layered architecture to ensure modularity, scalability, and reliability. The system integrates sensing, processing, communication, and billing functionalities, following the general principles of smart metering architectures described by Depuru et al. [9] and Rahman et al. [13]. Unlike conventional systems designed for single households or utility-scale deployments, this architecture specifically supports occupant-level identification and billing while operating under a shared main electricity supply.

3.3.1 Architecture for Smart Electricity Metering

The conceptual system consists of several key components. Each room or apartment is equipped with current and voltage sensors that measure electricity consumption at the local level. These sensors are connected to a microcontroller that processes raw energy data, calculates usage, and associates it with a unique occupant identifier. The processed data is then forwarded to a centralized billing and credit management module, which handles electricity credit allocation, generates invoices, and maintains consumption records. Occupants access their usage data and manage electricity purchasing through a user interface, which can be implemented as a web or mobile application. By localizing data processing and billing functions, the system reduces reliance on large-scale smart grid infrastructure, making it cost-effective and suitable for small-scale shared accommodations.

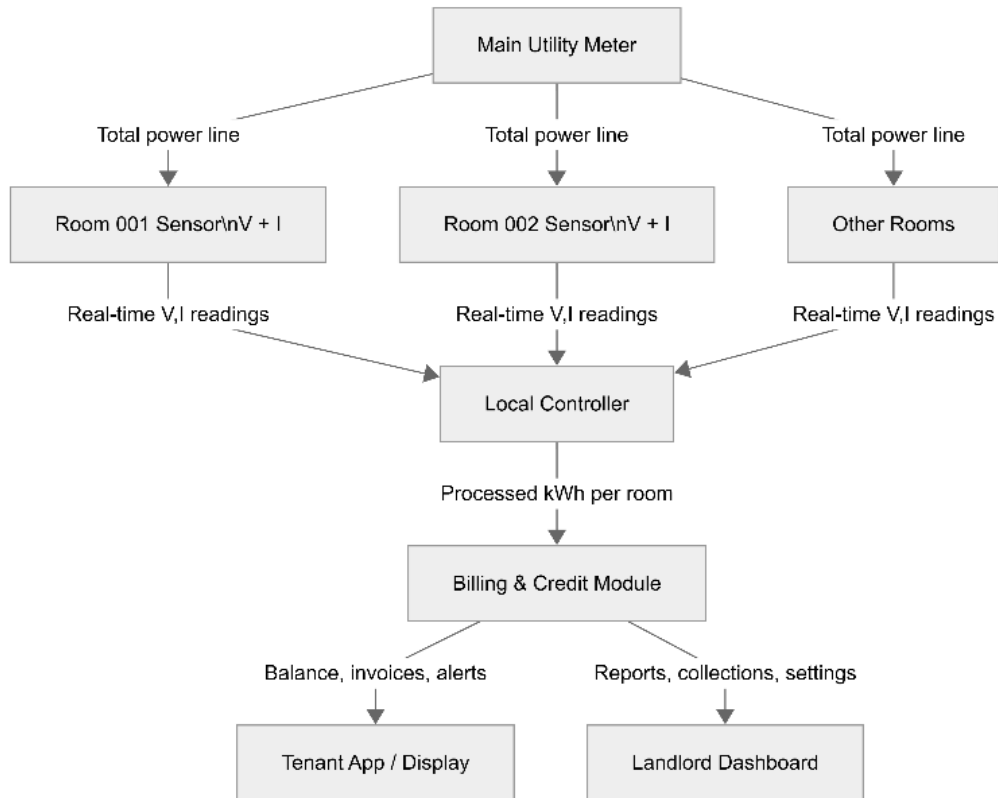


Figure 3. Conceptual System Architecture of a Smart Electricity Metering and Billing System

3.3.2 Architecture for Billing System

The billing system architecture is an integral part of the overall design, providing the functionality necessary for independent electricity management. It consists of three main modules: a credit management module, a consumption monitoring module, and a billing interface. The credit management module tracks the electricity purchased by each occupant and deducts consumption in real time, ensuring that billing is strictly proportional to individual usage. The consumption monitoring module collects and visualizes energy usage data, enabling occupants to track their consumption patterns and remaining credits. Finally, the billing interface generates invoices and provides notifications for low credit or consumption thresholds, promoting transparency and accountability. This architecture ensures that each occupant can independently manage their electricity usage while the landlord or system administrator maintains overall monitoring and system control.

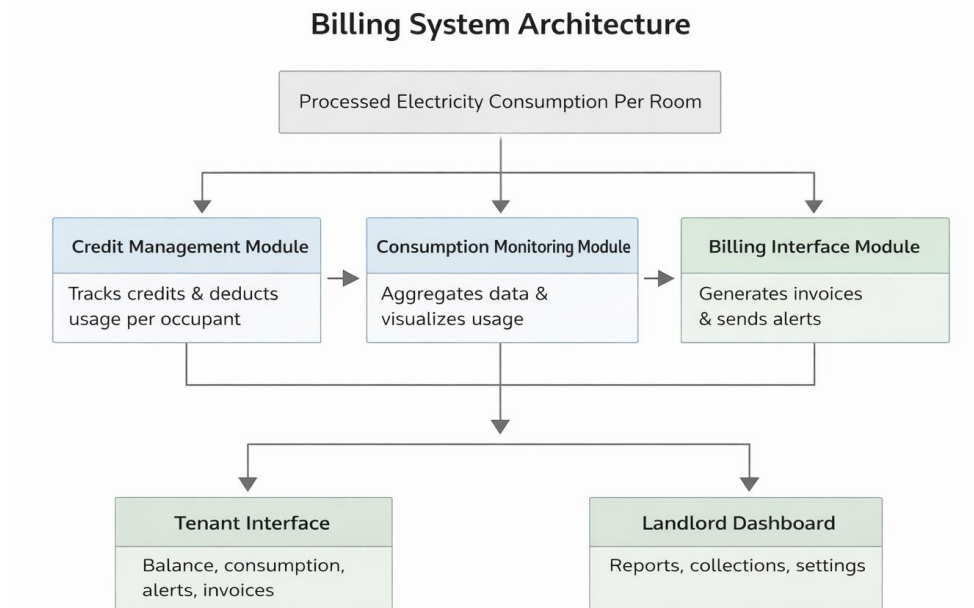


Figure 4. Conceptual System Architecture of a Billing system

Overall, the layered and modular system architecture allows for efficient integration of hardware and software components, ensures accurate occupant-level billing, and provides a scalable framework that can be deployed in various shared accommodation environments. By combining real-time monitoring, credit management, and user interfaces within a localized system, the architecture addresses the gaps identified in conventional metering, sub-metering, and existing smart metering solutions, offering a practical and affordable approach to fair electricity management in multi-tenant residences.

3.3 Area of the Study

The study will be conducted in shared accommodation settings such as rental houses, hostels, and small-scale multi-tenant buildings within the local community. These settings were chosen because they typically face challenges in fair electricity billing and occupant-level consumption monitoring, making them ideal for testing the practicality and effectiveness of the proposed system. The study will focus on small-scale implementations to ensure affordability, ease of deployment, and relevance to low-resource environments.

3.4 Ethical Considerations

The study will adhere to strict ethical standards to ensure the responsible and secure use of electricity consumption data collected from occupants in shared accommodations. All data will be treated as confidential, and access will be restricted to authorized personnel involved in the

system’s development and evaluation. Personal information associated with occupants, including identification and consumption history, will not be disclosed to third parties without explicit consent. Additionally, participants will be informed about the purpose of the study, the type of data collected, and how it will be used, ensuring transparency and voluntary participation. Measures will also be taken to protect the data from unauthorized access, loss, or misuse, including secure storage, encrypted communication between hardware and software components, and anonymization where necessary. These ethical practices are essential for maintaining the trust of participants, safeguarding privacy, and ensuring that the system promotes fairness and accountability without compromising the rights of occupants.

3.5 Study Timeline

The study timeline outlines the planned activities, milestones, and duration of each phase of this project. It serves as a roadmap to ensure that the project is completed systematically and within the allocated time frame. Each activity has been carefully scheduled to optimize resource utilization and ensure timely completion, while allowing for periodic evaluations and adjustments where necessary. This timeline reflects the logical sequence of tasks, from initial research and data collection to analysis, implementation, and final reporting.

Table 1. Detailed Schedule of Project Activities and their Expected Timeframes.

S/N	Activity	MAR	APR	MAY	JUN	JUL
1.	Requirements Analysis					
2.	System Design					
3.	Hardware Implementation					
4.	Software Development					
5.	System Integration					
6.	Testing and Evaluation					
7.	Documentation					

3.6 Budget Estimate

This section provides an overview of the estimated financial requirements for the successful completion of the project. The budget covers all necessary expenses, including materials, equipment, software, personnel, and other operational costs. The estimates are prepared to ensure that resources are allocated efficiently, and that the project can be executed within the planned financial limits.

Table 2. Estimated Budget for each Major Component of the Project.

S/N	Item	Quantity	Unit Cost (TZS)	Total (TZS)
1.	Arduino/ESP32	5	65,000	325,000
2.	ACS712 Current Sensors	10	20,000	200,000
3.	ZMPT101B Voltage Sensors	5	25,000	125,000
4.	LCD Display 16x2	5	40,000	200,000
5.	Wi-Fi/GSM Modules	3	30,000	90,000
6.	Software Tools	-	65,000	65,000
7.	Hosting & Domain	-	70,000	70,000
8.	Miscellaneous	-	100,000	100,000
Total		28	415,000	1,175,000/=

3.7 Chapter Summary

This chapter presented the methodology adopted for the design and implementation of the proposed smart electricity metering and billing system for shared accommodation. It outlined the project approach, including requirement analysis, system design, hardware and software development, integration, and testing, ensuring a structured process to achieve the study objectives. The chapter also described the methods and tools employed, such as smart electricity meters, current and voltage sensors, a microcontroller, and a software platform for occupant-level monitoring and billing. The study area was identified as shared accommodation settings, including rental houses and hostels within the local community, providing a practical

context for implementation and evaluation. Ethical considerations were emphasized, ensuring the confidentiality of occupant data, restricted access to authorized users, and voluntary participation. Additionally, the chapter highlighted planning elements such as the project timeline and budget, which support the systematic execution of the study. Overall, the methodology provides a comprehensive framework for developing, testing, and evaluating a localized, cost-effective system that promotes fair billing, transparency, and responsible electricity consumption among multiple occupants.

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