The present work was submitted to
the German-Mongolian Institute for Resources and Technology

Smart Cottage Automation: Electrical Installation and calculation, Designing, Possibility of Renewable energy integration

Bachelor's Thesis

By

TAMIRTULGA Ganbold

Study program: Energy and Electrical Engineering

Student ID: B2100511

1st Supervisor / Examiner 1 Mr. Nikita Abramov

2nd Supervisor / Examiner 2 Mr. Bold Enkhbold

Ulaanbaatar/Nalaikh

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Statutory Declaration

Last Name, First Name	Student ID Number
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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

Smart Cottage Automation: Electrical Installation and calculation, Designing, Possibility of Renewable energy integration

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

29/5/2025

Place, Date

Signature

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Abbreviation

IoT - Internet of Things

HAS - Home Automation System

HVAC - Heating, Ventilation, and Conditioning

MPPT - Maximum Power Point Tracking

H-Gateway – Home Gateway

U-Server – User Server

GSM – Global System for Mobile communication

AAC - Autoclaved Aerated Concrete

E-low – Emission low

EPDM – Ethylene Propylene Diene Monomer

SPD – Surge Protective Device

PV - Photovoltaic

GHI – Global Horizontal Irradiance

EMS – Energy Management System

DC – Direct Current

AC – Alternative Current

Acknowledgement

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To my girlfriend, I am especially thankful for being by my side and for giving me the very first idea for this thesis. Your inspiration helped turn this project from a vague thought into a meaningful achievement.

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To all of you, thank you for being part of this chapter in my life.

Abstract

This thesis presents the design and feasibility analysis of a smart, energy-efficient cottage tailored for Mongolia's harsh climate and evolving lifestyle needs. In response to increasing urban overcrowding, air pollution, and a growing interest in countryside living, the project proposes a technologically integrated and sustainable residential model for families of four to six members.

The study covers every core aspect of the cottage from architectural and electrical planning to material selection, energy consumption modeling, and the integration of home automation and renewable energy systems. The design prioritizes energy conservation by using high performance, locally available materials such as MAK Euroblock, triple-glazed Windoor systems, and Mongol Basalt insulation. Electrical loads were calculated across seasonal variations, with detailed planning for wiring, circuit protection, and special loads like oil-based electric heating.

To enhance comfort, security, and efficiency, the cottage incorporates a Tuya-based IoT home automation system, enabling remote control of lighting, heating, and surveillance. A hybrid off-grid energy system, combining solar photovoltaic panels and wind turbines, was sized using real-world climate data from the Global Solar and Wind Atlas. Energy demand modeling, along with storage and inverter sizing, confirms that the system can provide continuous power throughout the year even in the demanding winter months.

While the project demonstrates strong potential for energy independence and smart living, certain aspects remain undeveloped, including plumbing design, detailed interior/exterior architecture, roof structure finalization, and overall construction cost estimation. Nevertheless, the smart cottage stands as a promising and scalable solution that balances modern convenience with environmental sustainability, offering a vision for a more autonomous, efficient, and connected lifestyle in rural Mongolia.

Chapter 1 Introduction

1.1 Background

Home automation has advanced significantly in recent years to improve people's comfort, security, and overall quality of life. A home automation system (HAS) transforms a traditional cottage into a "smart house" by integrating technology that enables intelligent control of appliances, lighting, security, and energy management. By implementing home automation, users can reduce their energy consumption by optimizing usage patterns and utilizing energy-efficient devices and systems.

In recent years, residents of Ulaanbaatar have increasingly sought relief from the city's heavy urban centralization, severe air pollution, massive traffic congestion, and rising stress levels by spending their weekends and holidays in countryside cottages, also known as summer houses. This growing trend has led to a noticeable boom in the cottage and countryside housing market, with rising demand for comfortable, efficient, well equipped, well located, economical, and secure houses outside the city. In response to this demand, the focus of this thesis is the development and design of a smart, energy efficient cottage suitable for a family of four to six members. The house will be designed for year-round use and will include essential features such as an attached garage. It will also be optimized for Mongolia's extreme climate, particularly the harsh winters, using heating technologies powered by electricity.

If the cottage has access to electricity, there are multiple ways to establish an internet connection. For example, Mongolia's cellular companies offer home internet services such as "Ger Internet" and "Manai Internet," which provide reliable connectivity through mobile networks. Alternatively, SpaceX's Starlink service, which operates a constellation of low Earth orbit satellites, is now officially available in Mongolia, offering high-speed internet access even in the most remote areas.

In Mongolia, the connection of a countryside cottage to the electricity grid largely depends on the location. If a cottage is not connected to the grid, establishing an electrical connection often requires significant financial expenditure, as well as navigating complex legal and documentation processes in accordance with national regulations. To address these challenges, incorporating renewable energy sources such as solar power (via photovoltaic panels) and wind power (via kinetic energy conversion) can offer a more sustainable, cost-effective, and environmentally friendly alternative.

This approach not only reduces the initial costs associated with grid connection, but also contributes positively to environmental sustainability by minimizing reliance on conventional fossil fuels.

Additionally, connecting the cottage to renewable energy sources provides the major advantage of eliminating monthly electricity bills, further increasing long-term cost savings for homeowners.

1.2 Objectives of the Study

The primary goal of this thesis is to calculate energy usage and design of a four-season cottage, an electrical system that meets the average consumption needs of a mid-sized family (four to six members), comprising energy-efficient and smart automation systems. The proposed smart cottage will integrate various electrical gadgets and devices with an IoT-based control system to improve usability, efficiency, and sustainability. Renewable energy sources, particularly solar and wind, will be considered for off-grid power supply, and the necessary sizing and performance parameters of these systems will be analyzed and calculated in detail.

Several critical factors were considered in designing a cottage that fits best with a family of medium size, including four to six members. A two-level house with a 6x7 meter footprint was designed to get the maximum use of space and effectiveness. Particular attention was paid to minimizing energy loss and heat loss during the winter, and careful selection of materials to insulate the walls, windows, and roof to maximize insulation and energy efficiency.

To achieve the core objective of energy efficiency, IoT-based home automation technologies were integrated into the design. This will allow homeowners to monitor and control their electricity consumption monthly, enhance security by remotely accessing and managing the house via the internet while faraway, and perform various other control functions through mobile applications.

If the cottage is off grid such as (disconnected from the electric grid), then all electricity needs will be provided by renewable sources (predominantly solar and wind). It is designed to supply reliable and sustainable energy for the smart cottage to be fully self-sufficient and relies on the photovoltaic and wind power systems that are used to generate.

1.3 Significance of the Study

As I said before, in recent years, residents of Ulaanbaatar have increasingly tended to escape the city's air pollution during winter, noise pollution all year round, and high stress levels by spending their holidays and weekends in faraway from city cottages located in quieter, cleaner environments. This shift reflects a residents' capital focus on health, well-being, and quality of life. And on top of that, Mongolia's electricity tariff system has undergone noticeable changes. As of recent regulations, monthly household electricity consumption up to 150 kWh is charged at 175.0 MNT per kWh, consumption between 151 kWh to 300 kWh is charged at 256.0 MNT per kWh and exceeding 300 kWh is charged at 285.0 MNT per kWh. Also, for households who consumption exceeds 300kWh with two-tariff meters, daytime electricity usage (from 6:00 AM to 9:00 PM) is charged at 265.0 MNT per kWh, while nighttime usage (from 9:00 PM to 6:00 AM) is charged at 160.0 MNT per kWh. Then with three-tariff meters, daytime usage (from 6:00 AM to 5:00 PM) is charged at 220.0 MNT per kWh, evening usage (from 5:00 PM to 10:00 PM) at 300.0 MNT per kWh, and nighttime usage (from 10:00 PM to 6:00 AM) remains at 113.0 MNT per kWh. (1)

This study is significant because it proposes a design solution that focuses on creating a smart, energy efficient cottage. Through the integration of IoT-based home automation systems, residents will be able to monitor and control their energy consumption remotely via the Internet even if they're far from home. Let's take an example, during Mongolia's long winters when the heating system typically accounts for the largest share of energy use. However, the ability of smart systems will turn on/off or adjust electric heating systems when not at home, ensuring significant electricity savings. Another example is that motion detection and night vision cameras allow you to ensure and monitor the safety of your house remotely, even when you are not at home or are far away, as long as you have an internet connection. Additionally, installing smoke detectors further enhances security and safety by enabling residents to monitor their cottages remotely and respond quickly to potential emergencies.

Mongolia's geographical location has good potential for renewable energy generation, making this approach feasible and beneficial. Moreover, by integrating renewable energy solutions such as solar and wind power, the cottage can operate independently of the grid, eliminating monthly electricity bills, unexpected power off and reducing environmental impact.

While the selected materials for construction may not represent the lowest financial cost, they are specifically chosen to minimize energy and heat losses, ensuring that the house remains highly energy efficient. Thus, this study not only addresses modern lifestyle needs and environmental sustainability but also offers a financially sound and practical solution for countryside housing in Mongolia.

1.4 Structure of the thesis

This thesis is structured into six chapters, each building upon the previous to systematically develop the design of a smart, energy-efficient cottage integrated with home automation technologies and renewable energy systems.

Chapter 1: Introduction

This chapter introduces the background of the study, highlighting the significance of implementing a Home Automation System (HAS), presenting the initial main idea of the research and discusses the possibilities for internet connectivity and including options for renewable energy integration. The chapter also outlines the main objectives of the study, focused on designing an energy efficient cottage for a mid-sized family, and emphasizes the importance and benefits of energy management for households.

Chapter 2: Literature Review

This chapter presents a comprehensive review of existing technologies related to smart home automation, IoT-based systems, and energy management strategies. It explores how such technologies improve energy efficiency and facilitate the integration of renewable energy sources. Furthermore, this chapter establishes the theoretical principles and operational mechanisms of the key components selected for use in this study.

Chapter 3: Methodology

Explains the calculation used to assess energy consumption, heating demand, and electrical performance. It outlines load estimation techniques, seasonal modeling, heating system sizing, and wiring selection based on standards and real-world assumptions.

Chapter 4: Smart Cottage System Design and Implementation

This chapter details the overall design of the proposed cottage, including architectural planning and selection of construction and electrical materials with a focus on energy loss minimization. It outlines the electrical system layout, wiring designs, installation techniques, and the selection of electrical devices. Each choice is based on energy efficiency, system reliability, and long-term sustainability.

Chapter 5: Calculations and Results

Presents all technical calculations based on the methodology. This includes detailed electrical load analysis, lighting and heating energy consumption, and performance evaluation of the selected components and systems.

Chapter 6: Possibility of Renewable Energy Integration

Based on the results from Chapter 5, this chapter develops a renewable energy solution to meet the cottage's energy needs. It involves the sizing of solar and wind energy systems, component selection, and system configuration. The chapter also evaluates the suitability of the chosen location for renewable energy generation, considering environmental and geographic factors.

Chapter 7: Conclusion

The final chapter summarizes the key findings of the study, discusses the expected benefits of the designed smart cottage, and reflects on the overall effectiveness of integrating IoT-based home automation with renewable energy sources. It also highlights the long-term financial and environmental advantages realized through the proposed design.

Chapter 2 Literature review

2.1 Introduction to literature review

This chapter aims to review research papers and literature to the core themes of this thesis study. It focuses on understanding how smart homes can improve energy efficiency, the technologies involved in home automation, the integration of IoT-based systems with smart home technologies, and the integration of renewable energy sources into cottages. Additionally, it examines how smart homes implement energy management systems to optimize electricity usage.

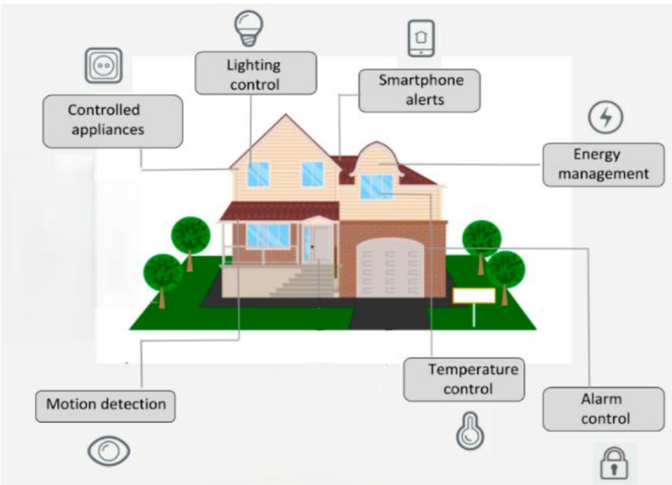
Through this literature review, key concepts, operational principles, and theoretical foundations of the technologies selected for this study will be explored and understood. Special emphasis will be placed on identifying theoretical knowledge and techniques applicable to the design of an energy efficient, smart cottage. By studying existing research papers and extracting essential information, a solid understanding of the necessary systems and components for smart home automation and energy management will be developed.

2.2 Smart Home Automation System (HAS)

Home automation refers to the process of automatically performing everyday functions around the home to save time, energy, and money while simultaneously enhancing comfort and security. The concept of home automation first emerged in the 20th century. One of the early developments was the Electronic Computing Home Operator, created in April 1968 from a set of spare electronic components. (2) Subsequently, the X10 communication standard was developed, allowing transmitters and receivers to broadcast control messages, such as "turn ON" and "turn OFF," over radio frequencies. However, the X10 system had several limitations, including limited speed, reliability, and interference issues. (3)

With the rapid evolution of mobile communication technologies, significant advancements have been made in home automation. Modern home automation systems provide reliable control over household appliances by enabling users to remotely switch devices ON and OFF or adjust their settings via smartphone applications or websites. Typically, these systems involve a combination of embedded hardware and wireless communication modules, such as NodeMCU microcontrollers, Wi-Fi and Bluetooth modules, and relay circuits. Commands sent from a smartphone are received by the Wi-Fi module and transmitted to the relay circuit, which then switches the connected devices accordingly. (4)

Home automation can manage and control various home systems, including:



- ❖ Lighting
- ❖ Appliances
- ❖ Heating systems
- ❖ Security systems
- ❖ Energy management
- ❖ Alarm control

Figure 1. An IoT-based smart home different purposes.

The automation of these systems minimizes human effort, saves time, and improves power efficiency by allowing centralized or remote control within seconds. A smart home enhances the overall quality of life by offering increased convenience, comfort, energy efficiency, and security to its occupants. (4)

Furthermore, the integration of smart systems enables homeowners to manage and monitor their houses remotely. Through Internet connected smartphones, users can control energy meters, lighting, thermostats, irrigation systems, security devices, and other household appliances from anywhere. This not only improves daily living standards but also empowers residents to optimize energy usage and ensure the safety of their homes even when they are away. As smart home technologies continue to advance, their role in promoting sustainable living and enhancing the quality of residential environments becomes increasingly significant. (5)

2.3 Energy Efficiency in Smart Homes

The energy efficiency of smart home technologies, such as solar panels, lighting controls, thermostats, and smart appliances, has been extensively studied. Research shows that notable energy savings can be achieved through energy efficient settings. For example, smart ovens, washing machines, and refrigerators demonstrated average energy consumption reductions of 10% to 15%. The concept of "smart homes," characterized by the integration of automation systems and advanced technologies, provides enhanced security, comfort, and energy efficiency for residents. (6)

Improving the energy efficiency of residential buildings is crucial for promoting environmental sustainability and reducing electricity costs for homeowners. Innovations in energy efficient appliances, advanced energy management systems, and renewable energy sources are rapidly transforming the energy landscape. Smart homes, equipped with a wide range of energy-saving appliances and sensors, are becoming vital contributors to this transition. Both researchers and industry experts recognize that smart technologies possess a strong potential to optimize energy use, leading to greater overall sustainability. (7)

The efficiency of smart home devices has been assessed using a variety of energy efficiency criteria, including

- ❖ Energy Consumption Reduction: Measurement of the energy saved when using smart appliances' energy-efficient settings
- ❖ Energy Star Ratings: Evaluation of appliances and lighting systems based on Energy Star certifications, where applicable.
- ❖ Efficiency of Temperature Control: Analysis of indoor temperature regulation in relation to external environmental factors.
- ❖ Solar Panel Efficiency: Comparison between the actual energy production of solar panels and the predicted output based on local weather conditions. (7)

In addition, Home Automation Systems (HASs), when integrated with the Internet of Things (IoT), represent one of the most promising solutions for achieving higher energy efficiency in residential settings. In such systems, sensors and actuators often embedded within smart devices such as smartphones and tablets serve as the primary components of the network. Based on data collected by the sensors, a HAS is capable of intelligently managing household resources, selecting optimal actions via actuators to enhance energy efficiency and comfort for residents. (7)

2.4 IoT-Based Systems for Smart Homes

The term "Internet of Things" (IoT) was first introduced by Kevin Ashton in 1999. IoT refers to a communication network where objects are interconnected either with each other or with larger systems, converting vast amounts of data collected from everyday devices into usable information. Essentially, IoT enables the process of connecting all physical components and objects on the planet to the internet, creating a global, interactive network. (8)

IoT has evolved into a cutting-edge, cost-effective solution for linking devices and objects across the internet. Modern IoT ecosystems include sensors, microcontrollers, wireless networking technologies, cloud-based services, mobile applications, and web interfaces. Devices within an IoT system can transmit data directly to the internet without human intervention, allowing for automation, real-time monitoring, and enhanced system efficiency. (8)

The integration of IoT technologies in home automation systems offers several significant benefits, including:

- ❖ Monitoring and Control: Remote management of home appliances and systems through mobile devices or web applications.
- ❖ Cost and Energy Savings: Optimization of energy usage, leading to reductions in utility costs.
- ❖ Environmental Impact: Contribution to energy conservation and a reduction in carbon footprints.
- ❖ Improved Safety: Real-time alerts from sensors monitoring gas leaks, fires, and intrusions.
- ❖ Enhanced Comfort: Automation of lighting, temperature, and entertainment systems to match user preferences. (9)

IoT-based home automation systems combine connectivity features with computer vision, online services, and mobile applications to create integrated solutions. These systems utilize sensors, cameras, servo motors, and other actuators to send and receive data and commands between users and home appliances. This approach is particularly effective for continuous home monitoring, controlling devices like lights and HVAC systems, and providing surveillance through night vision cameras, motion detectors, and safety sensors, even when residents are away. (9)

The working principle of IoT involves several stages:

I. Data Collection: Devices are equipped with sensors that gather data from their environment.
II. Data Transmission: The collected data is transmitted over a network, often the internet, to a central server or cloud platform.
III. Data Processing and Action: Software applications analyze the incoming data and, based on user commands or pre-programmed algorithms, trigger appropriate responses or actions.
IV. User Interaction: Users can monitor system status and control devices remotely via smartphone applications or web interfaces. (9)

And another simple example is shown *figure 2*:

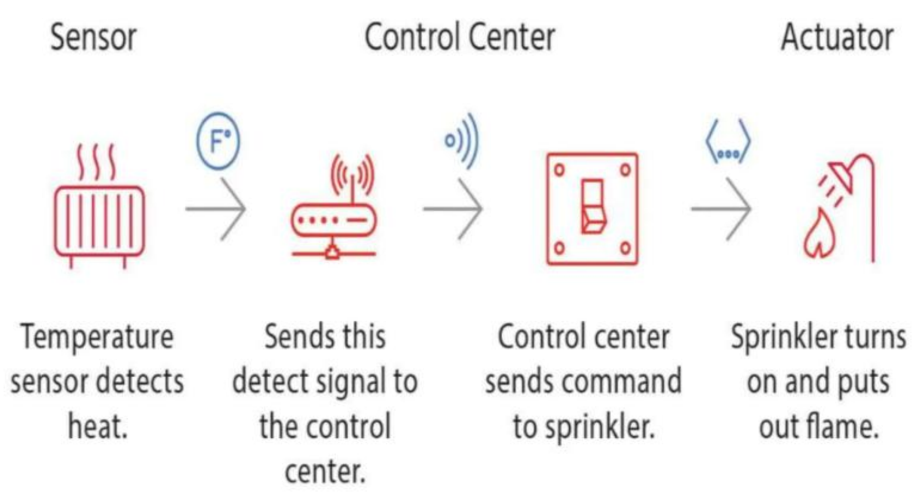


Figure 2. Example of sensor to actuator flow

2.5 Renewable Energy Integration in Smart Homes

The integration of renewable energy sources into smart homes enables multiple benefits. A smart home microgrid, combined with renewable energy, can:

- ❖ Facilitate the use of renewable energy integrated into conventional electricity systems

- ❖ Manage electricity demand through demand response strategies that regulate energy storage and usage
- ❖ Provide detailed reports on energy consumption, demand, supply, and overall efficiency
- ❖ Reduce electricity costs for homeowners
- ❖ Decrease government subsidies for electricity
- ❖ Lower CO_2 emissions by reducing reliance on fossil fuels. (10)

Solar energy is converted into electrical energy using solar panels (photovoltaic) in the form of direct current (DC). Furthermore, it is converted into AC (alternating current) using an inverter to be used directly by the load.

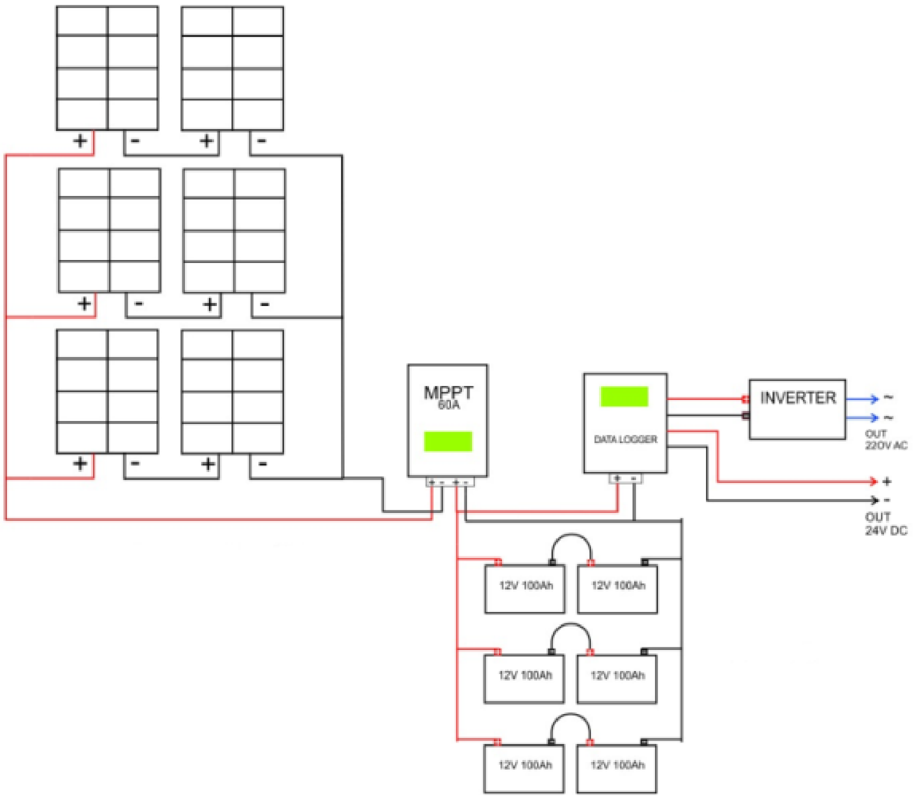


Figure 3. Solar energy grid

The following figure 3 shows a solar energy grid consisting of solar panels, Maximum Power Point Tracking (MPPT), data loggers, batteries and inverters. Solar panels convert solar energy into DC electrical energy. This DC electrical energy is stored in a battery that has previously been regulated by the dynamics of the electric current using MPPT. For example, each solar panel produces DC electricity from sunlight of 100Wp / 12V, which is stored on a battery with a capacity of 100Ah. MPPT as a controller of electricity storage from solar panels to batteries has a capacity of 60A / 150 VDC. The

Off-Grid inverter is used to convert the DC current from the battery to the AC so that it can be used by the load. (10)

The proposed smart home energy management system not only integrates renewable energy sources but also schedules and arranges power flow during peak and off-peak periods. Additionally, a two-way communication protocol is developed, allowing both homeowners and utility providers to optimize energy usage and improve consumption efficiency. (11)

In this system, the Home Gateway (H-Gateway) is an embedded device integrated with a GSM modem, installed at the consumer's premises. The Utility Server (U-Server), a high-end PC, is located at the utility headquarters. Communication between the homeowner and the utility company is achieved through GSM mobile networks. This communication infrastructure supports dynamic energy management, load control, and monitoring.

The functional requirements of the system include:

- ❖ Establishing a two-way communication channel between the H-Gateway and the U-Server using the GSM modem.
- ❖ Receiving forecasted peak demand intervals from the U-Server via the H-Gateway.
- ❖ Storing power consumption data measured by instrument transformers within the microcontroller.
- ❖ Making energy management decisions based on peak interval information, including the optimal use of alternative energy sources.
- ❖ Sending stored power consumption readings from the H-Gateway to the U-Server's database.
- ❖ Hosting a web-based interface at the U-Server, allowing homeowners to view their power consumption patterns.

Battery charging is prioritized whenever solar energy is available. The GSM modem ensures continuous communication between the homeowner and the utility company by utilizing public mobile telephone networks. The U-Server, as a central hub, manages the database and energy management software. Both utility personnel and homeowners are given secured login access with assigned privileges to monitor and manage their respective data via the internet.

Through these mechanisms, smart homes can effectively integrate renewable energy resources, optimize energy consumption, improve efficiency, and contribute significantly to a sustainable energy future. (11)

2.6 Summary of literature review

This chapter reviewed the key concepts and technologies involved in smart home automation, energy efficiency, IoT-based systems, and renewable energy integration. Through the use of smartphones and embedded systems, smart home automation makes it possible for everyday tasks to be completed automatically, enhancing comfort, security, and energy efficiency.

With studies showing notable energy savings from smart appliances, sophisticated thermostats, lighting controls, and solar panels, the significance of energy efficiency in smart homes was underlined. Smart gadgets optimize power use, lower electricity costs, and support environmental sustainability.

The Internet of Things (IoT) plays a central role in smart homes by connecting physical devices, enabling real-time monitoring, remote control, and automation. IoT-based home automation systems integrate sensors, wireless communication, and cloud services to improve energy management, enhance safety, and provide greater convenience.

Furthermore, the integration of renewable energy sources, particularly solar energy, with smart home systems was discussed. Smart microgrids, equipped with solar panels, batteries, and intelligent controllers, not only reduce dependence on the conventional grid but also optimize energy flow and storage.

The body of literature reviews that smart homes, which are fueled by renewable energy and Internet of Things technologies, present a viable way to design more intelligent, efficient, and sustainable living spaces. This foundation will help the way for the design and implementation of the proposed smart home automation system discussed in the next chapters.

Chapter 3. Methodology

3.1 Overview

The methodology of this study was designed to support the technical design and evaluation of a smart, energy-efficient cottage suited for Mongolia’s climate and rural living conditions. This chapter presents the systematic approach used to estimate the electrical energy needs of the proposed cottage, determine appropriate load distributions, and inform the selection of electrical wiring and components. Careful attention was paid to calculating realistic and seasonally adjusted energy loads. This ensured that the resulting electrical design would be both technically reliable and optimized for long term energy efficiency.

All estimations were made using practical usage patterns for a typical family of four to six people. In particular, this involved analyzing the daily use of household appliances, lighting fixtures, and larger energy consumers such as electric stoves and water heating systems. Data was gathered from real product specifications and supplemented with reasonable assumptions to simulate average household behavior. The results of this process provided the foundation for circuit planning, wire sizing, and circuit breaker selection in subsequent design stages. This approach also reflects the increasing relevance of decentralization and smart living technologies, where detailed knowledge of energy use is crucial not only for safety and capacity planning, but also for future integration with renewable energy systems.

3.2 Energy Load Estimation

To calculate the electrical energy needs of the cottage, each room and functional zone was reviewed, and all relevant appliances and fixtures were listed. These included general lighting, sockets for household appliances, kitchen equipment, bathroom fittings, and larger loads such as the electric oil heating system. Each device was assigned a power rating (in watts) and an estimated usage duration (in hours per day), based on typical residential use patterns.

$$Energy(Wh) = Power(W) \times Daily\ Usage(h)$$

To reflect the realities of Mongolia’s climate, energy usage was evaluated on a seasonal basis, as electricity demand fluctuates significantly throughout the year. November to February are the coldest months, requiring continuous use of the electric heating system, increased indoor lighting, and longer appliance usage due to more time spent indoors. March, April, and October are transitional months with moderate heating needs, partial lighting increases, and reduced use of heating systems during the day. May and September are generally warm, with minimal or no heating required; energy use reflects typical non-winter household activity. June, July and August are the warmest months, with no heating demand; energy use may increase slightly due to higher appliance usage during holidays or family gatherings.

This seasonal model provided a more accurate estimate of monthly and annual energy consumption. In addition to load totals, usage patterns were analyzed to identify peak demand times, inform distribution board design, and assist with future renewable energy integration planning.

Diversity factors were applied to avoid overestimation, recognizing that not all appliances operate simultaneously. The results of these estimations formed the basis for wire sizing, breaker selection, and system capacity planning in the following chapters. Once the daily energy usage was determined, weekly and monthly consumption figures were extrapolated. This helped simulate load conditions over time and informed the design of the distribution system, including the number and type of circuit breakers, socket groups, and lighting circuits.

Chapter 4. Smart Cottage System Design and Implementation

4.1 Overview of the House Design

This cottage is thoughtfully designed for a mid-sized family of about 4 to 6 people. The first thing I focused on was making the home feel cozy, functional, and spacious enough without being wasteful. To make everyday living easy and enjoyable, the house includes essential spaces like a kitchen, a dining area, a living room, and enough bedrooms to give each family member their own private retreat. I also made sure to include bathrooms making life more convenient for busy mornings and evenings or when guests come over. Privacy and energy efficiency were equally important. The bedrooms are carefully separated by walls and doors to help save energy to keep the rooms warmer during cold winters and cooler in the heat of summer, without needing too much extra heating or cooling. I aimed to minimize heat loss, especially during the harsh Mongolian winters.

Natural light and fresh air were very important in our design. I placed windows in smart locations so that the house would be filled with sunlight during the mornings, at the noon, and even in the sunsets. I also thought carefully about where to position the garage and it's tucked onto the north side of the house to make the most of ventilation and sunlight.

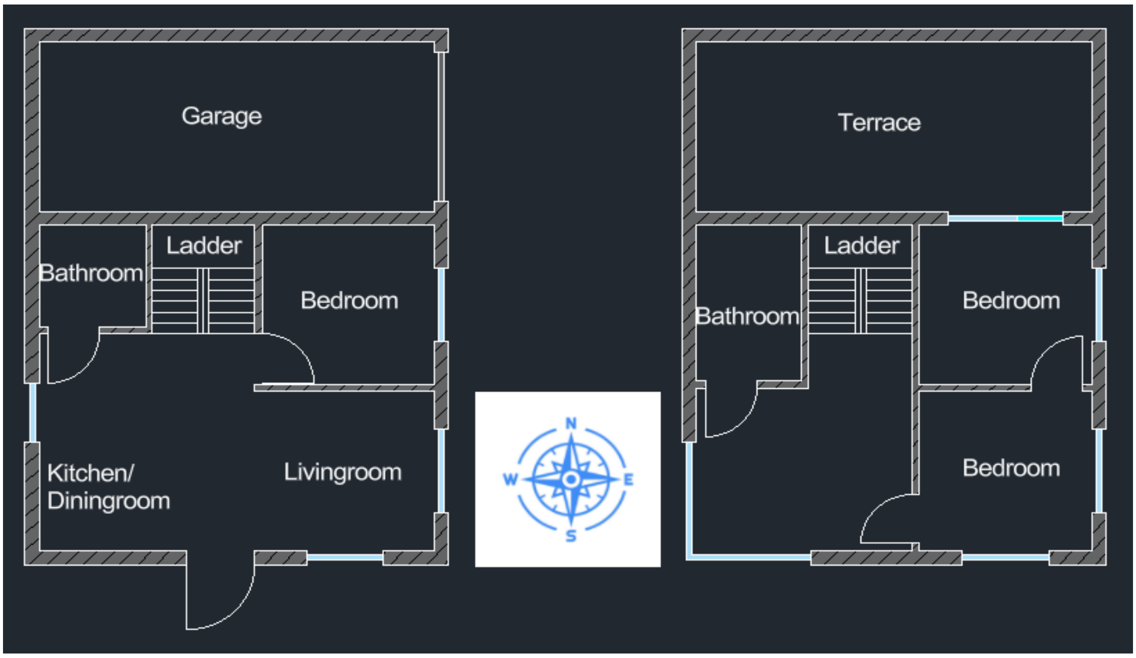


Figure 4. Architectural design of 2-floor 6x7 cottage

After trying out several different size and floor plan options, I decided that a 6x7 meter, two-floor house was the best fit for this project. On the first floor, there's a welcoming living and dining space arranged in an open-plan style, a kitchen, one bedroom, and a bathroom. Upstairs, there are two more bedrooms and another bathroom, as well as a bright open hallway. I added large windows on the second floor to create a relaxing spot where family members can chill out and enjoy the view. Above the garage, we placed a terrace to turn an unused roof area into a perfect outdoor sitting space.

The house is designed so that morning sunlight comes in from the east facing windows (two on each floor), while afternoon and sunsets light flows through windows facing south and west. This way, the home always feels bright and warm without using too much energy for lighting or heating.

Overall, every detail from the room layout to the window placement has been carefully thought out to make the house energy efficient, practical, and, most importantly, a warm and welcoming home.

4.2 Material Selection for Energy Efficiency

When it comes to achieving real energy efficiency, minimizing energy loss and heat loss is absolutely crucial, especially during Mongolia's long, harsh winters. If these losses aren't properly addressed during the design stage, they can have major consequences later on: higher heating costs, less comfortable living conditions, and greater environmental impact. That's why, in this project, I put special focus on solving these challenges right from the beginning.

The first and most important step was selecting the right building materials. Choosing materials that offer excellent insulation and energy performance means that the house will stay warmer in winter, cooler in summer, and require much less energy to maintain a comfortable indoor environment. I wanted to make decisions that support domestic production. Wherever possible, I prioritized materials produced by Mongolian manufacturers aiming for solutions that would be beneficial for both the producer and consumer.

However, simply choosing the right materials is not enough. To truly maximize their efficiency, it's essential that every part from blocks to windows to insulation is installed correctly, according to standards and the best construction practices. Proper installation ensures that all the materials can perform at their full potential, minimizing losses and ensuring long-term durability.

After carefully considering all these factors, we selected these materials MAK Company's Euroblock for the main wall construction, MAK's Argon Gas-Filled Triple Glazed Windows and Doors (Euro Windoor), Mongol Basalt Company's "Stone Wool" and "Sprayed Basalt Wool" used for thermal insulation of walls, roofs, and floors, providing outstanding heat retention. These materials are not only among the best options available in Mongolia today, but they also meet international standards for energy efficiency and building quality.

4.2.1 MAK LLC "Euroblock"

Now, let's discuss the advantages of these materials and some important necessary information about them. Let's start with the 'Euroblock' product from the MAK company. The composition of Euroblock includes: 60% sand, 21% cement,14% quartz lime, and 4% gypsum. Based on its material properties this type of block is named Autoclaved Aerated Concrete (AAC) blocks.

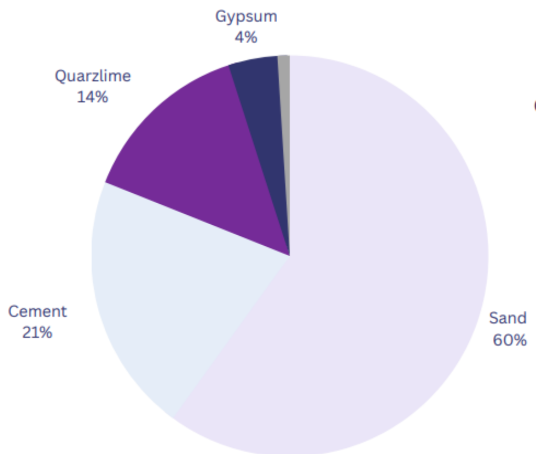


Figure 5. Mixtures of MAK Euroblock

This carefully engineered mix gives the Euroblock several important advantages. Excellent sound reflection properties, lightweight and easy to carry and install, high moisture resistance, ability to adjust indoor humidity, high fire resistance and using special glues that eliminate air leakage through wall joints. One of the most impressive features of the Euroblock is its internal vacuum structure Each block contains 80-90% tiny vacuum bubbles (1-2 mm in size). These tiny air pockets significantly reduce thermal conductivity, providing exceptional insulation and reducing both energy consumption and heat loss.

MAK Euroblock's standard size of 600 mm in length, 250 mm in height, and various width options between 75 mm and 500 mm, I was able to find a perfect fit for my design needs without compromise. After carefully considering different block options, I decided to build both the exterior and interior walls using MAK Euroblock. For the exterior walls, I chose blocks with a 250 mm width and then, for the internal walls, we selected blocks with a 125 mm width. (12)

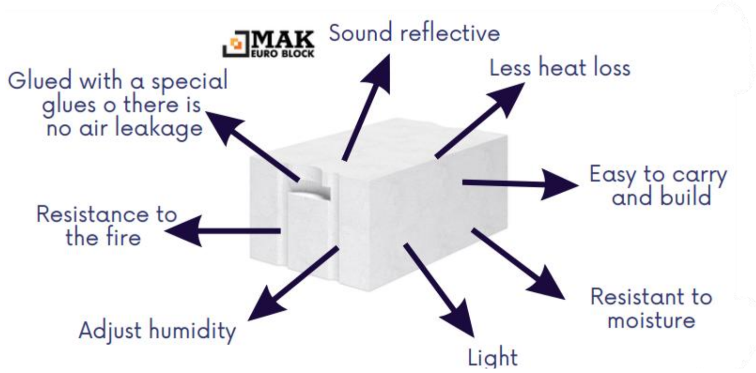


Figure 6. Advantages of MAK Euroblock

4.2.2 MAK Windoor

When I look at the sources of heat loss in buildings, windows account for a significant portion. That's why choosing high-quality windows is one of the most important decisions in my design process.

For my project, I chose MAK Windoor's triple-glazed windows, which are manufactured using German brand profiles under European standards. These windows are filled with argon gas, which has a much lower thermal conductivity than air. This technology is the best solution for keeping indoor heat from escaping, ideal for vacuum-insulated windows for cold climates.

A standout feature of MAK Windoor products is their use of E-Low (low-emissivity) coating, which reflects radiant heat back into the room instead of letting it escape through the glass. This helps to maintain a stable indoor temperature, reducing heating costs and improving year-round comfort. Another key point is their high-quality sealing system. MAK uses EPDM (Ethylene Propylene Diene Monomer) gaskets, which are known for their excellent flexibility, weather resistance, and long-term durability. These seals prevent condensation and cracking, even under extremely cold conditions, and they also contribute to superior air-tightness. In addition to their insulating properties, these triple-glazed windows offer several other benefits that make excellent sound insulation, and special moisture-absorbing materials inside of the window are used inside to prevent fogging and withstand humid conditions. The windows include multi-point locking systems on all four sides for security and tight sealing. They can be custom-made in various sizes and styles to match architectural preferences. (13)

Figure 7. Beneficial of MAK window

4.2.3 Mongol Basalt "Basalt Wool"

When it comes to insulation, especially in Mongolia's harsh winter climate, choosing the right material is crucial not only for minimizing heat loss, but also for long-term durability, fire safety, and indoor comfort. For this project, I selected Mongol Basalt's basalt wool insulation, and spray type basalt wool. Basalt wool is made by melting natural volcanic rock, usually basalt at high temperatures and spinning it into fibrous wool. The result is a highly insulated and fire-resistant insulation material with excellent thermal and acoustic performance.

Key advantages of using basalt wool include its low thermal conductivity, which ensures excellent insulation, keeping the indoor temperature stable and significantly reducing the energy needed for heating or cooling. It is also highly fire resistant, capable of withstanding temperatures over 1000°C making it non-combustible. Unlike some other insulation materials, basalt wool is moisture-resistant and breathable, it doesn't absorb water and allows vapor to pass through, helping prevent mold and rot inside walls. Its dense, fibrous texture provides excellent soundproofing. Additionally, basalt wool is an eco-friendly option, made from natural volcanic rock, recyclable, and free from harmful emissions.

Spray basalt wool was applied in harder to reach areas and around corners to ensure there were no gaps or thermal bridges, maximizing the overall energy efficiency. I plan to use stone wool boards in the exterior walls of the Euroblock structure. Mongol basaltwool standard size of 1000 mm in length, 600 mm in width, and various thick options between 50 mm and 100 mm. I was able to find a perfect fit for my design which is 50 mm thick of 60 kg/m^3 density.

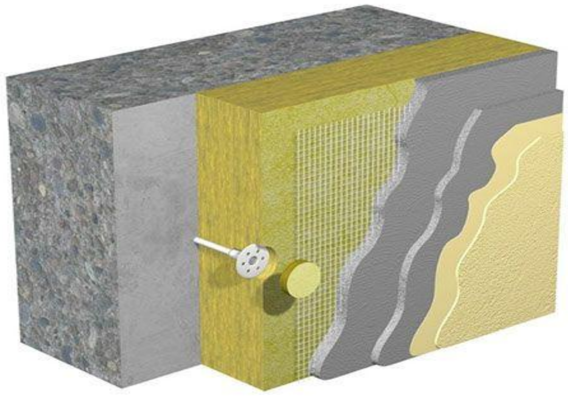


Figure 8. Installation illustration of basaltwool

4.3 Electrical Layout and Installation Plan

In this cottage project, the electrical distribution system is designed with two separate distribution boards one on each floor. This decision was made for two main reasons. First, safety: separating the electrical load by floor ensures lower current per board, minimizing overload risk and simplifying future maintenance or upgrades. Second, it keeps the distribution box compact and tidy, making installation more efficient and aesthetically pleasing.

Lighting System Design

On the first floor, lighting is planned for the garage, bedroom, bathroom, and an open-plan kitchen, dining, and living area. Each room will be equipped with a single ceiling light, except for the garage, which will have two ceiling lights for increased brightness. Additionally, four circular LED lights will be added to the kitchen ceiling to improve illumination during cooking. On the second floor, there are two bedrooms, one bathroom, a hallway, and a terrace. Each bedroom and bathroom will have one ceiling light, but the hallway area has two ceiling lights for the terrace, to ensure a cozy and welcoming atmosphere, ten small circular LED lights will be installed.

In terms of switching, one-way switches will be used for all lights in rooms. Additionally, motion-sensor two lights will be installed at the two sides of main entrance and it will automatically turn on when someone approaches.

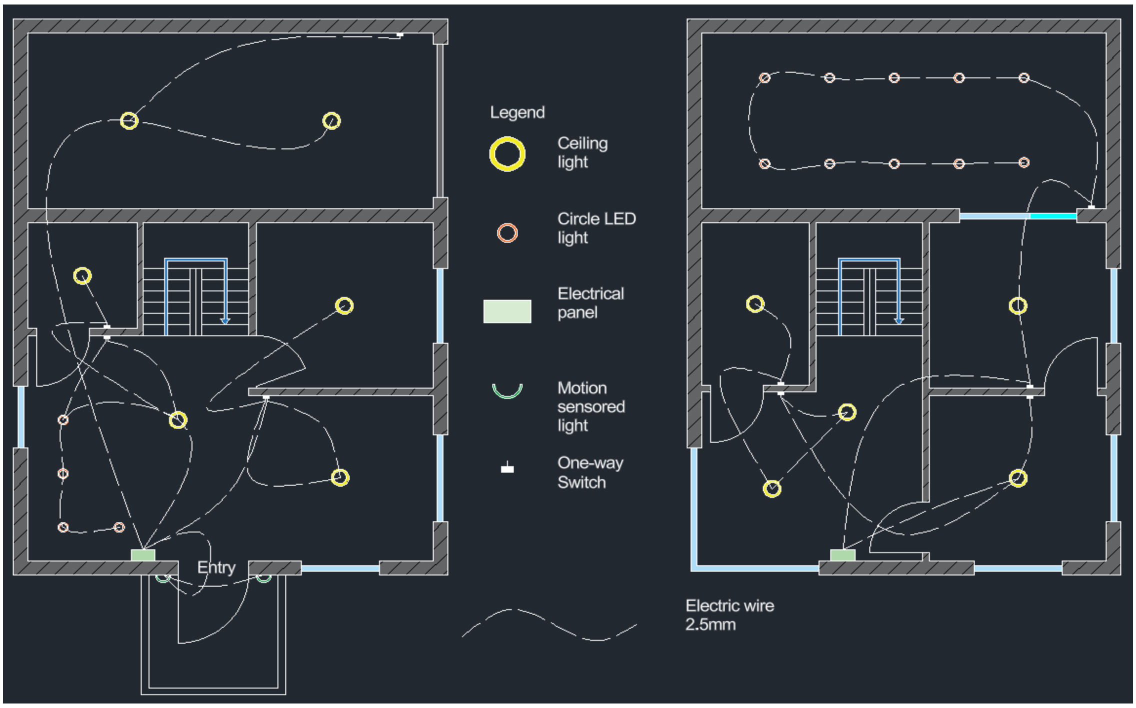


Figure 9. Electrical layout of lights and switches

Socket Layout

Each room on both floors will have three sockets, and the garage and terrace will also include three sockets each. The bathrooms on both floors are planned with two sockets each for appliances like hair dryers or washing machines. To ensure electrical safety, all sockets will be grounded and connected to single-phase system with proper earthing. Grounding helps prevent electrical shock hazards, especially in damp areas like bathrooms and the kitchen, by providing a safe path for leakage currents.

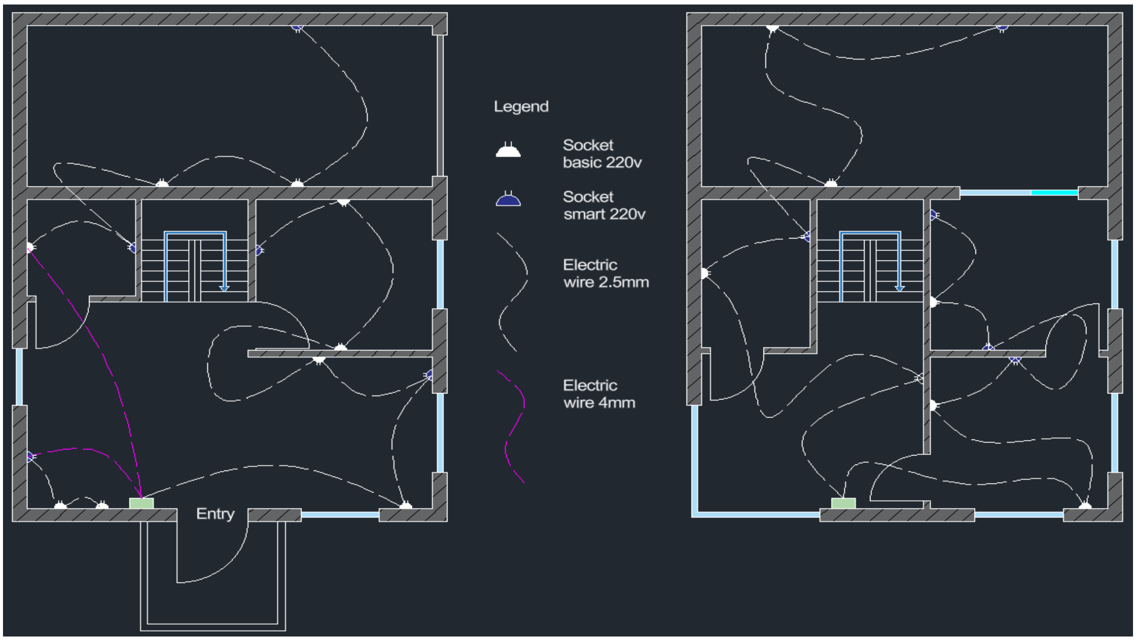


Figure 10. Electrical layout of sockets

Special Loads and Wire Sizing

For high-power appliances such as the electric stove in the kitchen and the electrical heating system located on the first floor, dedicated circuits with thicker cables will be used. These wires will be selected according to relevant electrical standards, ensuring minimal voltage drop and increased durability for heavy loads. For lighting circuits, sockets, and switches, standard wires will be used, ensuring safety and efficiency as per the national electrical code.

4.4 Home Automation System Selection and Security/Safety System.

4.4.1 Home Automation System Selection and Key Devices

In modern energy-efficient building design, Home Automation Systems (HAS) play a vital role in increasing convenience, improving energy savings, and enhancing safety. For this cottage project, a smart home system was selected with the goal of making daily operations easier, reducing unnecessary energy consumption, and enabling remote control and monitoring.

After evaluating multiple platforms such as Tuya Smart, Google Nest, and Amazon Alexa, a decision was made to integrate the Tuya Smart system for the security and safety features. This platform was selected for its flexibility, compatibility with a wide range of devices, and ease of integration with the home automation setup. It supports integration with common smart devices and works seamlessly with mobile apps for iOS and Android. The system includes smart light switches, allowing users to control the lights via phone or schedule-based automation (e.g., lights turn on at sunset). In addition, smart sockets are enabling remote on/off control and energy monitoring for appliances like TVs, kettles, or chargers.

The cottage's heating solution is designed as an energy-efficient hybrid system that uses electrically heated oil to distribute warmth throughout the home. This system ensures steady and comfortable indoor temperatures by combining underfloor radiant heating and traditional radiators, both powered by the same heated oil loop.

Electric oil heater heats oil to the desired temperature, after which the heated oil is pumped through a closed loop system of pipes embedded in the floor and connected to wall-mounted radiators. This method offers multiple advantages, including quiet operation, even heat distribution, and the ability to retain warmth longer than systems using water. The wall mounted radiators provide warmth in key living spaces, while the underfloor heating offers a more uniform and energy efficient heat source, making it ideal for areas like bathrooms, kitchens, and hallways.

For smart functionality, Tuya-compatible smart sockets or smart relays are used to control the oil heater's power and pump operation. While Tuya does not offer a built-in oil heating system, these smart devices allow for remote control, scheduling, and automation of the heating system via the Tuya Smart app. Users can turn the system on/off, adjust heating times, and monitor performance from their smartphone or through smart assistants like Google Home or Amazon Alexa. I can install an electrical oil heater + circulation pump, then plug both or just the master switch into a Tuya smart socket or relay. This gives smart control, even though Tuya doesn't natively produce the whole heating setup.

4.4.2 Security and Safety System

In the design of this cottage, a security and safety system has been integrated to enhance both protection and peace for the residents. This system is designed to provide comprehensive coverage, incorporating surveillance cameras and smoke detection, all managed via a centralized smart platform called Tuya.

The surveillance system is designed to provide both interior and exterior monitoring. An indoor wide-angle camera will be placed above the entrance door, positioned 25-30 cm from the top. This placement allows for a broad view of anyone approaching the door, offering both security and convenience in monitoring visitors. On the exterior, two 360-degree cameras will be installed on the rooftop to cover the entire property. One camera will be positioned at the right top corner, facing north east, while the other will be placed at the left bottom corner, facing south west. This placement ensures that entry points, as well as the surrounding areas, are fully monitored.

The cameras are equipped with high-definition video resolution, enabling clear and detailed footage even in low light conditions. Additionally, these cameras offer features such as motion detection, real time alerts, and remote viewing through a mobile app. The integration with a smart home system allows for convenient control and monitoring from anywhere, adding an extra layer of convenience and security. For fire safety, smoke detectors will be strategically placed throughout the cottage to provide early warnings in case of fire or smoke. These sensors are designed to detect the presence of smoke and sound an alarm when dangerous levels are reached. They will also be linked to the smart system, allowing for real time notifications via a mobile app, ensuring immediate response and action, even when the residents are away from home.

I suggest placement for the smoke sensors includes the kitchen, where the risk of fire is higher due to cooking activities. The hallway near the kitchen is another key area for placing a sensor, as it provides an early detection zone in case of smoke spread. Additional sensors should be installed in the bedrooms and on each floor's hallway, providing maximum coverage for living spaces. Smoke sensors will also be placed near potential electrical hazards, such as near the garage and any rooms with appliances or heating systems.

The smoke detectors used in this system are equipped with advanced sensing technology, ensuring reliable detection while minimizing false alarms. Features include temperature sensors, smart connectivity, and the ability to integrate seamlessly with other home automation devices, allowing the system to send notifications to mobile devices in case of emergencies. The security cameras and smoke sensors are fully integrated into the Tuya Smart home automation system, allowing residents to control, monitor, and receive alerts remotely via the Tuya app. The smoke sensors provide an essential layer of protection, with the ability to instantly alert residents to any fire hazards and provide peace of mind, knowing the home is being actively monitored for safety.

4.4.3 Justification and Benefits

The selection of the smart home system for this cottage project was based on several factors that ensure cost effectiveness, ease of use, and compatibility with existing infrastructure. The goal was to create a system that would not only improve safety but also streamline home management through intelligent automation.

One of the primary advantages of this system is its cost effectiveness. Tuya compatible smart devices such as light switches, sockets, and cameras offer a budget friendly solution compared to more complex automation systems. These devices are not only affordable but are also designed to be easily integrated with existing electrical layouts. Additionally, these devices are designed to be compatible with both local electrical standards and international smart platforms like Google Home, Amazon Alexa, and Tuya, ensuring versatility for future upgrades and expansion.

The Tuya based smart system enhances daily living by automating tasks such as turning lights on and off, controlling heating systems by sockets, and managing household appliances remotely. Smart sockets and switches allow users to control lights or any plugged-in devices via the Tuya app, offering convenient scheduling and energy monitoring. The smart light switches, for instance, can be set to turn on/off automatically based on specific conditions like time of day or residents are not at house, thus optimizing electricity consumption and ensuring that no energy is wasted.

Another key benefit of this system is its ease of maintenance and remote monitoring capabilities. The Tuya system is integrated into a single app that allows homeowners to monitor and manage devices. It also extends to troubleshooting and allows users to reset devices from anywhere with an internet connection. This is particularly advantageous for remote cottages or second homes. Users can check the status of devices, receive alerts about potential issues such as a power surge or device malfunction, ensuring that any issues are addressed promptly before they become more significant problems.

These devices connect via Wi-Fi or Bluetooth. Tuya's app, available on both iOS and Android, provides a user-friendly interface that allows for seamless control of connected devices. Adaptability to Mongolia's electrical infrastructure, combined with the availability of affordable products, makes Tuya an ideal choice for this cottage project.

The cost of Tuya compatible devices varies depending on the device type and functionality. Basic smart sockets and switches typically cost between $10 to $20 USD, while more advanced systems, such as security cameras, may range from $30 to $100 USD. Additionally, Tuya's products are readily available on global e-commerce platforms such as Amazon, AliExpress, and local Mongolian retailers, making them easy to purchase and integrate into the cottage's existing electrical system.

4.4.4 Specific Device Selection and Functional Overview

Smart Socket

The smart socket chosen for this system is the Glomarket Tuya Universal 16A Wi-Fi Smart Wall Socket. This device connects directly to the home's Wi-Fi network and integrates smoothly with the Tuya Smart or Smart Life mobile application. It allows for remote control, real time power monitoring, and customizable scheduling, which can help minimize unnecessary energy consumption. With a current rating of 16A (supporting up to approximately 3680W at 230V), this socket is suitable for powering high energy

Figure 11. Tuya smart wall socket

appliances such as electric stoves and oil-based heaters. Its built-in energy tracking feature makes it a valuable tool for optimizing energy use and improving efficiency. (14)

Smart Light Switch

For lighting control, the Glomarket EU 1/2/3/4 Gang Tuya Smart Switch was selected. This switch is designed with a modern glass touch panel and is available in multiple gang configurations to accommodate different lighting layouts. Once installed, it replaces traditional switches but retains intuitive operation, with the added advantage of remote control and automation via the Tuya Smart app. Users can schedule lighting based on time, presence, or activity, improving both convenience and energy savings. (15)

Figure 12. Tuya smart switches 1/2/3/4 gang

For home security, one wide-angle indoor camera and two outdoor 360° cameras were chosen. Indoor surveillance, the chosen device is the Tuya Dual-Lens Dual-Views 4MP 2K Wireless Indoor Camera. This camera offers dual-lens functionality, providing comprehensive coverage of indoor spaces. It supports high resolution video streaming, motion detection, and night vision, ensuring effective monitoring of the interior environment. (16) Outdoor surveillance, Tuya Solar Powered Smart PTZ Dome Security Camera 355° Ultra: This solar-powered camera offers a nearly 360-degree viewing angle, making it suitable for large area surveillance. It includes infrared LED design for long distance night vision, it is equipped to withstand harsh weather conditions and the solar panel can keep the camera charged, ensuring performance in Mongolia's climate. (17)

Figure 13. Tuya outdoor camera, indoor camera

Smoke Sensor

The safety system includes the SMATRUL Tuya Smart Smoke Detector, which offers Wi-Fi connectivity and multiple sensing functions. In addition to detecting smoke, this device monitors ambient temperature and humidity, providing valuable environmental data. When integrated into the smart system, it sends immediate alerts to the user's mobile device in the event of smoke or unusual temperature fluctuations, allowing for early response and prevention of fire related hazards. (18)

Figure 14. Tuya smart smoke detector

Integration and Interconnectivity

All selected smart devices are managed through the Tuya Smart ecosystem, which offers cross platform mobile app support for both iOS and Android devices. Voice control integration with Amazon Alexa and Google Assistant further enhances user convenience, enabling hands-free commands and automation scenarios. For example, lights and heaters can be turned off automatically when leaving the house, or cameras can be triggered when motion is detected after a certain hour. Many of these products are accessible via international e-commerce platforms that ship to Mongolia, and their reliable performance has been validated by users in similar climates. (19)

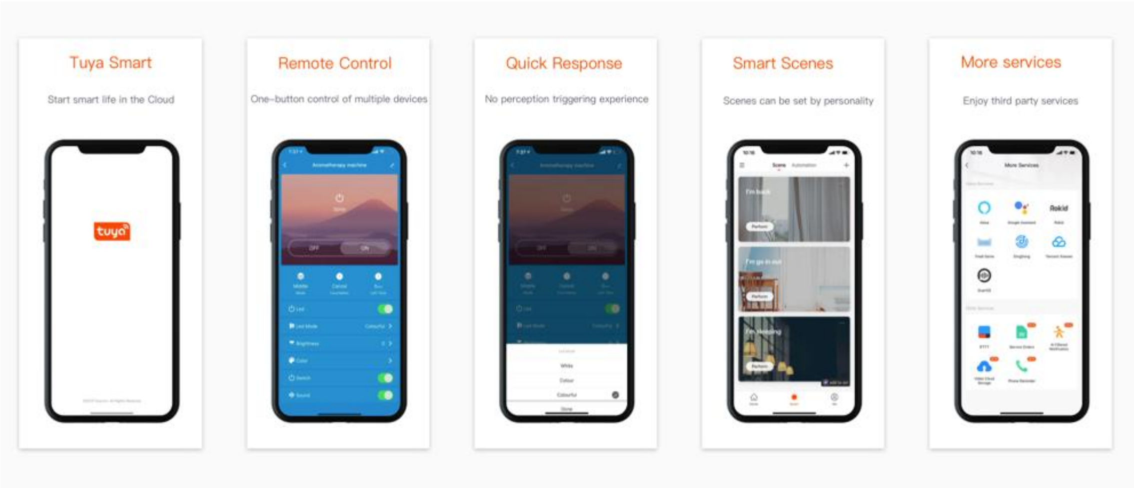


Figure 15. Tuya Smart mobile phone application

4.5 Electrical Component Selection and Specification

In this section, the key electrical components required for the operation of the smart cottage are selected based on performance, safety, smart compatibility, and suitability for Mongolian climate conditions. These components include the electric oil heater, wiring materials, and internet connectivity equipment.

For the heating system, an electric oil heater from Atmor was selected. This device is designed to efficiently heat oil and circulate it through underfloor pipes and radiators, providing steady and reliable heat distribution across the cottage. The heater operates on 220V single-phase voltage and delivers sufficient power output to match the calculated heating demand of the cottage. Its compact design, ease of installation, and compatibility with smart sockets such as Tuya make it an ideal choice. In addition, it features essential safety mechanisms such as automatic overheat protection and a built-in thermostat, ensuring user safety and energy efficiency. (20)

Wiring plays a crucial role in both safety and system efficiency. After careful consideration, high quality Russian made copper cables from Barilga.mn were selected for use in the electrical system. For lighting circuits, 2.5 mm^2 copper wire was chosen as it offers improved durability, lower voltage drops, and better capacity for future upgrades or added loads. For socket circuits, 2.5 mm^2 wire is maintained as standard. For the heater and high-load appliances, 4 mm^2 or 6 mm^2 wire is chosen, depending on the final calculated current. All wires comply with insulation and flexibility standards suitable for Mongolian building environments, ensuring long term performance and fire safety. (21)

Stable internet access is essential for the proper functioning of the smart systems installed in the cottage, including surveillance cameras, sockets, and switches. Three main options were considered for providing connectivity in rural or semi-remote areas: “Manai internet” from Mobicom, “Ger internet” from Unitel, and Starlink satellite internet. Among these, Starlink Mini was selected as the final choice due to its high-speed performance, broad coverage, and strong reliability even in areas with weak terrestrial signal reception. The chosen device, Starlink Mini from PC Mall, ensures seamless communication between the smart systems and the user’s smartphone or control hub, enabling full remote management and monitoring of the house. (22)

The selected components in this chapter serve as the foundation for safe, reliable, and smart enabled electrical operation of the cottage. The Atmor electric oil heater ensures efficient heating, while the use of 2.5 mm^2 and higher-grade copper wiring supports load demands with enhanced safety. Starlink Mini internet guarantees uninterrupted connection for all smart automation features. Each decision was made with long-term functionality, safety, and smart compatibility in mind, tailored specifically for the Mongolian residential environment.

4.6 Summary of Smart Cottage System Design and Implementation

Chapter 3 outlined the practical design and technical implementation of a smart, energy efficient cottage suitable for a mid-sized family. The design approach prioritized energy conservation, modern living standards, and climate adaptability. A 6x7 meter two-floor structure was selected to balance comfort and compactness, incorporating essential household spaces, strategic room orientation, and optimal window placement to maximize solar gain and natural ventilation.

Material selection focused on thermal performance and durability. MAK's Euroblock and triple-glazed Windoor windows, combined with Mongol Basalt's stone wool insulation, were chosen for their high insulation values and ability to withstand Mongolia's extreme winters. Proper installation standards and air tight construction techniques were emphasized to minimize energy and heat loss.

The electrical system was carefully planned with two distribution panels to improve safety and efficiency. Lighting, socket, and special load circuits were designed in compliance with national standards, with particular attention given to heating loads.

A modern Home Automation System (HAS) based on Tuya Smart technology was integrated to enable remote control of lighting, sockets, and heating devices via mobile applications. The smart system also includes essential safety features such as surveillance cameras and smoke detectors, ensuring both comfort and security for the residents.

Finally, key electrical components such as the Atmor oil heater, high quality copper wiring, and Starlink Mini internet were selected based on performance, compatibility, and suitability for off-grid or rural environments. The chapter concludes the cottage's electrical and architectural framework as both sustainable and future-ready.

Chapter 5. Calculations and Result

5.1 Overview

The goal of this analysis is to accurately determine the total electrical energy demand of the proposed smart cottage and ensure that the system design can reliably support the required loads throughout the year. These calculations form the technical basis for both electrical system sizing and the future integration of renewable energy sources.

Using the assumptions and formulas discussed previously, the energy consumption of key household appliances and systems was analyzed in detail. This included common power-consuming devices such as lighting fixtures, kitchen appliances, water heaters and the electric oil-based heating system, etc. For each of these, power ratings (in watts) were paired with estimated average daily usage durations (in hours), depending on the nature of the device and expected behavior of a typical family of four to six members.

The year was categorized into four primary temperature-based segments:

- Winter (November to February) – high heating and lighting demand
- Transitional (March, April, October) – moderate heating and lighting needs
- Warm (May, September) – minimal heating required
- Hot (June to August) – no heating required, stable low to medium energy use

For each seasonal group, a breakdown of one day's typical energy usage was calculated. These values were then extrapolated to estimate monthly energy consumption, and ultimately the annual energy demand of the entire household. This structured seasonal analysis allows for a more accurate prediction of real-world electricity needs. By knowing the detailed yearly consumption pattern, solar or wind generation systems can be more precisely sized, ensuring energy independence, reliability, and cost effectiveness in off-grid or hybrid power scenarios.

5.2 Total Electrical Load Calculation

The energy consumption of the smart cottage was calculated using appliance level data and seasonal variations. Each electrical device and fixture were assigned a power rating (in watts) and an estimated daily usage duration (in hours) for four seasonal groups: Winter, Transitional, Warm, and Hot. This allowed for a more accurate simulation of annual electricity demand based on realistic household behavior and Mongolia's distinct climate patterns.

$$Energy(Wh) = Power(W) \times Daily\ Usage(h)$$

The daily energy consumption for each device was calculated. These daily values were then multiplied by 30 to estimate monthly consumption, which is summarized seasonally in.

Season	**Average Monthly Use (kWh)**	**No. of Months**	**Estimated Seasonal Use (kWh)**
Winter	~2000 kWh	4	~8000 kWh
Transitional	~1500 kWh	3	~4500 kWh
Warm	~670 kWh	2	~1340 kWh
Hot	~415 kWh	3	~1250 kWh
Total		12	~ 15085 kWh/year

Table 1. Monthly energy consumption by seasonally

This analysis revealed that winter months represent the highest electricity demand, driven mainly by the electric oil heating system and extended lighting use. The annual consumption estimate obtained through this method is critical for system design, especially when evaluating the integration of solar or wind based renewable energy systems. It ensures that selected technologies will be able to cover energy needs year-round, even in the most demanding conditions.

5.3 Circuit breaker selection

Circuit breaker selection was based on the calculated electrical load for each circuit and safety requirements in accordance with Mongolian standards.

First Floor Distribution Board

Circuit Type	**Wire Size (mm²)**	**Breaker Type**	**Quantity**	**Images**
General-purpose sockets	2.5	AD12 C50	1	
High-load appliances	4	AD12 C32	2	
Lighting circuits	2.5	BA47-19 C16	3	
Surge Protection	2.5	OPS-1-D SPD	1	

Table 2. Circuit breakers selected in first floor for distribution board

Second Floor Distribution Board

Circuit Type	**Wire Size (mm²)**	**Breaker Type**	**Quantity**	**Images**
General-purpose sockets	2.5	AD12 C50	1	
Lighting circuits	2.5	BA47-19 C16	2	
High-load appliances	2.5	AD12 C25	2	
Surge Protection	2.5	OPS-1-D SPD	1	

Table 3. Circuit breakers selected in second floor for distribution board

5.4 Summary of calculation and result

This chapter presented the system calculations for the smart cottage, covering seasonal energy demand, breaker selection, and wire sizing. The design process began with a detailed energy consumption model based on actual appliances and seasonal usage patterns. Total energy demand was estimated at approximately 15085 kWh per year, with winter months contributing the highest share due to heating and lighting needs.

High demand appliances, including the electric stove, oil heater, and washing machine, were assigned dedicated circuits to maintain stability and safety. All circuits were protected using iEk LLC circuit breakers, with ratings selected according to load calculations. A unified 2.5 mm^2 copper wiring scheme was adopted for both lighting and sockets, while 4 mm^2 wiring was used for high load circuits. Breaker ratings ranged from C16 for lighting, to C25 for sockets, and C32 for high-load appliances, ensuring sufficient protection without over-sizing. Additionally, surge protection devices (SPD) were installed at each floor level distribution board to protect smart electronics and communication systems from voltage disturbances.

Chapter 6. Possibility of Renewable energy integration

6.1 Overview

The goal of this chapter is to design a practical, self-sufficient renewable energy system for the proposed smart cottage based on the total energy consumption calculated in Chapter 5. As outlined, the annual electricity demand of the household is approximately 15,085 kWh, with winter months (November to February) contributing the largest share of energy usage due to electric heating and increased lighting. Specifically, monthly consumption during peak winter periods can reach up to 2,000 kWh.

To address this demand in an off-grid context, two renewable sources will be combined: solar photovoltaic (PV) energy and wind power. During winter, Mongolia experiences both shorter daylight hours and greater heating requirements making it difficult for solar energy alone to meet demand. Therefore, wind energy is introduced as a complementary source, especially considering Mongolia's favorable wind resources in many open steppe and elevated regions.

This chapter uses verified global data platforms called Global Solar Atlas and Global Wind Atlas. These sources provide the necessary climatic and geographic conditions to calculate potential renewable energy generation. Finally, after modeling a fully off-grid system, we will evaluate its technical and financial feasibility.

6.2 Site Resource Assessment

Since the cottage is assumed to be located near Ulaanbaatar, this section examines the renewable energy potential in that area using data from two authoritative sources: The Global Solar Atlas and the Global Wind Atlas. For accurate and citable analysis, data was collected from the geographic coordinates 47.9145°N, 107.4037°E (approximately 20 km east of Ulaanbaatar). This location was selected to represent a typical far away from the capital, where access to the central grid is limited or non-existent, making renewable energy systems more relevant.

6.2.1 Solar Resource Assessment

The most common measure of solar photovoltaic (PV) systems is Global Horizontal Irradiance (GHI), which indicates the total solar energy received per square meter on a horizontal surface over a given period.

According to data retrieved from the Global Solar Atlas, the selected location near Ulaanbaatar receives an average GHI of approximately 1,520 kWh/m²/year. (23)

Map data

Specific photovoltaic power output	PVOUT specific	1731.7	kWh/kWp
Direct normal irradiation	DNI	2000.2	kWh/m^2
Global horizontal irradiation	GHI	1524.3	kWh/m^2
Diffuse horizontal irradiation	DIF	484.8	kWh/m^2
Global tilted irradiation at optimum angle	GTI opta	2023.1	kWh/m^2
Optimum tilt of PV modules	OPTA	46 / 180	°
Air temperature	TEMP	-1.5	°C
Terrain elevation	ELE	1606	m

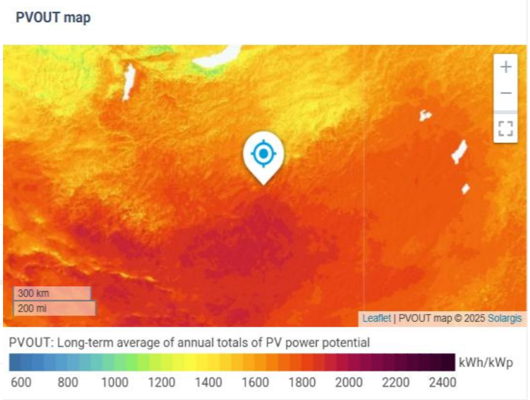


Figure 16. Data from GSA of selected location

6.2.2 Wind Resource Assessment

Wind energy systems generate electricity based on the kinetic energy of moving air. The amount of usable energy depends on wind speed, air density, turbine height, and turbine specifications. Wind speeds are generally higher during the winter months, which aligns well with the periods of reduced solar availability. Using the Global Wind Atlas, the average wind speed at a height of 10 meters above ground level near the chosen location is approximately 7.5 m/s. This value is considered adequate for small to medium-scale wind energy generation. (24)

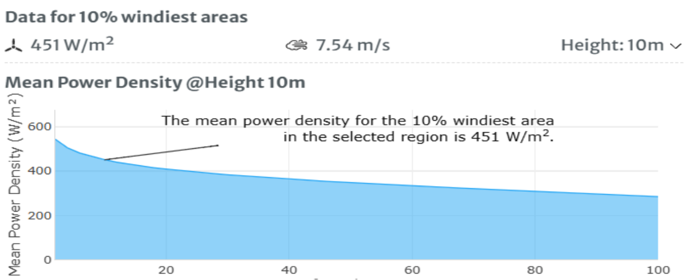


Figure 17. Average wind speed and power density of selected location

6.2.3 Implications for System Design

The analysis clearly shows that neither solar nor wind energy alone can reliably meet the full energy requirements of the cottage throughout the year particularly during

Mongolia's harsh and cloudy winters. By evaluating real world climate data and selecting appropriate technologies, the hybrid system can ensure continuous energy supply, reduce battery storage needs, and improve overall system stability.

6.3 Hybrid Solar and Wind Energy System Design

The system is designed to operate entirely off-grid and independently of the national electricity network. Based on calculations from Chapter 5, the cottage's total annual energy consumption is approximately 15,085 kWh, with a peak monthly usage of around 2,000 kWh during winter (November–February) due to electric heating and increased lighting. Once this peak demand is covered, it becomes significantly easier for the system to manage lower energy needs during the rest of the year. During transitional months (March, April and October), energy usage averages around 1,500 kWh per month, while in warm months (May and September) it drops to approximately 670 kWh, and in hot months (June, July and August) it further decreases to about 415 kWh per month. This "top-down" design approach ensures year-round reliability without seasonal power shortages, a critical consideration for fully off-grid operation in Mongolia's extreme climate.

6.3.1 Solar PV Sizing and Performance

According to the Global Solar Atlas, the project location near Ulaanbaatar receives an average Global Horizontal Irradiation (GHI) of about 1,520 kWh/m²/year. Solar energy availability is strongest between March and September, especially during hot and warm months when energy usage is lowest. To help meet the peak winter demand, solar PV will contribute whenever sunlight is available. However, during the coldest months, its output is limited due to short daylight hours and low sun angles.

To support the year-round 15,085 kWh load, we calculate the necessary PV system size assuming, system efficiency (performance ratio): 0.75, panel efficiency: 18% and target generation: ~15,085 kWh/year.

To estimate the required solar panel capacity, we will use this formula:

$$P_{PV} = \frac{E_{annual}}{GHI \times \eta_{panel} \times PR}$$

Where:

- P_{PV} - Required PV capacity (in kW)

- E_{annual} - Total annual energy consumption (kWh)
- GHI - Global Horizontal Irradiance (kWh/m²/year)
- η_{panel} - Panel efficiency in decimal form
- PR - Performance ratio

$$P_{PV} = \frac{15{,}085}{1.450 \times 0.18 \times 0.75} = \frac{15{,}085}{195.75} \approx 77.05m^2$$

Converting to capacity with standard 400 W panels (~1.9 m² each), the required system size:

$$Number\ of\ panels = \frac{77.05}{1.9} \approx 40.55 \approx 40\ panels$$

$$Total\ PV\ capacity = 40 \times 400W = 16{,}000W = 16kW$$

To meet an annual consumption of 15,085 kWh, you need approximately 15–16 kW of solar panels, or around 38–40 panels rated at 400 W each, assuming good orientation and standard system losses.

6.3.2 Wind Turbine Contribution

To cover the high winter load, wind power plays a crucial role. According to the Global Wind Atlas, the average annual wind speed at 10 meters near the site is about 7.5 m/s, which is excellent for small wind turbine operation.

$$Enrgy\left(\frac{kWh}{month}\right) = Rated\ Power(kW) \times Capacity\ factor \times Hours\ per\ month$$

There are roughly 730 hours in a month, so:

- Low end (15% capacity factor):

$$10kW \times 0.15 \times 730 \approx 1095\ kWh/month$$

- High end (20% capacity factor):

$$10kW \times 0.20 \times 730 \approx 1460\ kWh/month$$

Modern 10 kW turbines operating at 7.5 m/s can produce approximately 1,000–1,400 kWh/month, depending on altitude, air density, and turbulence. A properly cited turbine at 18–24 meters height can reliably provide a large portion of the winter energy requirement, especially at night or on cloudy days when solar is unavailable. Therefore, a single 10 kW wind turbine will act as the backbone of the system during the coldest months.

6.3.3 Battery Storage System

To maintain 24/7 power availability, a large battery bank is required especially for winter when extended periods without sun or wind may occur. Assuming a daily winter load of approximately 66 kWh, with 1 days of autonomy, 80% depth of discharge (for lithium-ion batteries), and a round-trip efficiency of 90%, the battery system must be sized accordingly to meet energy needs during outages.

To calculate the required battery capacity for off-grid autonomy:

$$C_{bat} = \frac{E_{Daily} \times D}{DoD \times \eta_{bat}}$$

Where:

- C_{bat} - Required battery storage capacity (kWh)
- E_{Daily} - Daily energy usage (kWh/day)
- D - Number of autonomy days (e.g., 1 days without sun/wind)
- DoD - Depth of Discharge (e.g., 0.8 for 80%)
- η_{bat} - Battery round-trip efficiency in decimal form

$$Required\ Storage = \frac{66 \times 1}{0.8 \times 0.9} \approx\ 91.6\ kWh$$

To ensure buffer capacity and system longevity, a battery bank of 100 kWh is recommended. While expensive, this size guarantees the house can remain functional even during day periods without sunlight or usable wind which is a realistic scenario in Mongolia’s harsh winters.

6.3.4 System Overview

Component	Value/Rating
Solar PV	15-16 kW (38–40 × 400 W panels)

Wind turbine	10 kW, horizontal-axis, ~1,200 kWh/month
Battery storage	100 kWh, lithium-ion modular system
Mounting	PV on roof and ground; turbine tower: 18–24 m

Table 4. Overview of solar + wind hybrid renewable energy system

This system is sized to cover the worst-case (winter) demand, meaning it will perform comfortably throughout the rest of the year, when energy needs are lower and solar availability is higher.

6.4 System Configuration and Hybrid Operation

6.4.1 System Layout and Power Flow

The system is designed around a shared central battery bank, which receives input from both solar panels and the wind turbine. Each energy source operates through dedicated charge controllers or inverters and supplies DC or AC power based on system design. Power is then routed to the main hybrid inverter, which delivers clean, stable AC electricity to the cottage's internal electrical network.

In this system configuration, solar panels feed into MPPT charge controllers that regulate DC output to charge a shared battery bank, while the wind turbine connects through either a wind charge controller or a wind inverter, depending on whether the setup is DC or AC coupled. Both renewable sources charge the same battery bank, which stores excess energy and serves as the system's power reservoir. A hybrid inverter then converts the stored DC power into 220V/50Hz AC electricity for household use. The control system actively monitors energy generation, load demand, battery state of charge, and overall power flow, intelligently managing whether energy is consumed immediately, stored for later, or curtailed to maintain system stability.

6.4.2 Energy Management Strategy

At the core of the system is a smart hybrid inverter equipped with an integrated energy management system (EMS) that prioritizes energy usage intelligently: real-time solar or wind input is used first to meet immediate demand, battery power is tapped when renewable generation is insufficient, and load shedding or alerts are triggered if battery levels drop critically low and no input is available. This autonomous logic minimizes unnecessary battery cycling while maximizing the use of available renewable energy. During summer, solar production dominates and batteries are easily charged throughout the day, while in winter, wind generation becomes the primary source due to reduced solar irradiance. The battery system plays a crucial role year-round, balancing fluctuations from both energy sources to ensure stable and efficient operation.

6.4.3 Technical Architecture Options

There are two primary configurations for integrating solar and wind in a hybrid system: DC coupling and AC coupling. In a DC coupled system, both solar and wind sources charge the battery directly via DC charge controllers, offering higher efficiency and a simpler setup ideal for off-grid applications but requiring careful voltage matching between the sources and the battery. In contrast, an AC coupled system uses individual inverters for solar and wind to convert power to AC, which is then managed by a central hybrid inverter for battery interaction. This approach provides greater flexibility, easier scalability, and future compatibility with grid-tied or smart home systems, though it is slightly more complex and costly. For this project, both configurations are feasible, but AC coupling is slightly preferred due to its long-term adaptability and integration potential.

6.4.6 Summary of Hybrid Operation

The designed hybrid system is built for fully autonomous operation, seamlessly switching between solar and wind inputs to ensure continuous 24/7 electricity availability through a properly sized battery storage solution. Leveraging modern control systems and smart integration, it delivers year-round energy independence, automatic prioritization of energy sources, and strong resilience against climate variability and potential component faults.

6.5 Cost Estimation and Feasibility

While the hybrid solar and wind system presented so far is technically capable of supplying all the smart cottage's energy needs throughout the year, its economic feasibility must also be considered. Off-grid systems require significant up-front investment, especially when designed for high winter loads like electric heating. This section provides an approximate cost breakdown of the proposed system, examines payback expectations, and compares the fully off-grid solution with a grid-assisted hybrid alternative, which may offer a more cost-effective path for most households.

6.5.1 Cost Breakdown of Full Off-Grid System

The following estimates are based on current 2024–2025 pricing from global based on internet search.

Component	Quantity / Rating	Unit Price (USD)	Subtotal (USD)
Solar Panels (400W)	38 panels	$120	$4,560
Wind Turbine (10 kW)	1 system	$5,000	$5,000
Tower (18–24 m)	1 unit, installed, steel pole	$2,500	$2,500
Lithium Battery Bank	100 kWh	$13,000-15,000	$13,000-15,000
Hybrid Inverter (15 kW)	1 unit	$3,500	$3,500
MPPT & Wind Controllers	2–3 units	$1,000	$2,000

Installation + Wiring	Include safety systems	–	$2,000
Total Estimate			~ $35,000

Table 5. Cost estimation of solar + wind hybrid renewable energy system

These figures illustrate that building a fully off-grid, high load capacity hybrid system is technically feasible but financially demanding particularly.

6.5.2 Proposed Hybrid On-Grid Alternative

To balance autonomy with economic practicality, a hybrid on-grid solution is proposed, featuring an 8–10 kW solar system, a 5–15 kWh battery bank for backup and smart load shifting, and no wind turbine. A hybrid inverter enables both grid interaction and backup functionality, allowing the system to feed excess power to the grid or draw from it when needed. This setup reduces initial costs to approximately $14,000–18,000 by minimizing battery size and avoiding wind tower installation. It offers grid stability, reliable backup during outages, and flexibility for future expansion making modern energy management and renewable integration more accessible without requiring full off-grid independence.

6.5.3 Feasibility Summary

Scenario	Initial Cost	Battery Size	Autonomy	Feasibility
Full Off-Grid	~ $36K	100 kWh	100%	Technically strong, financially weak
Hybrid On-Grid	$12K–18K	5–15 kWh	Partial	Very feasible for most homeowners

Table 6. Difference between renewable energy system off-grid and hybrid on-grid

While the off-grid system aligns with the long-term vision of self-sufficiency and sustainability, its cost is currently impractical for the average Mongolian household.

6.6 Summary

This chapter outlines the technical and financial design of a hybrid renewable energy system for a smart cottage near Ulaanbaatar, designed to meet the household's annual electricity demand of approximately 15,085 kWh, with a focus the seasonal energy challenge during winter months when demand peaks at (~2,000 kWh/month). The proposed off-grid solution includes 15 kW solar photovoltaic, 10 kW wind turbine, 100 kWh lithium-ion battery bank shared by both systems, and a centralized hybrid inverter system for load distribution, charging, and smart monitoring, with an estimated cost of approximately $36,000 USD. As a more practical alternative, a grid assisted hybrid system, combining a smaller solar array and modest battery backup with grid support, reduces costs to (~$14,000–18,000 USD) while maintaining smart automation, renewable integration, and partial energy independence. The grid assisted hybrid system offers a better balance between energy sustainability and affordability, providing a scalable, future proof path toward greener housing in Mongolia's countryside.

Chapter 7. Conclusion

7.1 Summary of the Study

The study began with an in-depth analysis of the growing need for countryside housing (Zuslangiin baishin) in Mongolia, escaping from urban overcrowding and air pollution and the desire for healthier living spaces. This thesis explored the comprehensive design, calculation, and feasibility of a smart, energy efficient cottage tailored for Mongolia's unique climate and modern lifestyle demands. The proposed design includes a comprehensive electrical system fitted to seasonal load consumptions, smart automation features to enhance daily usability, energy efficiency and safety, and the potential integration of renewable energy systems for off-grid capability. Through a combination of literature review, energy load analysis, and component selection, a fully functional smart cottage imagination was developed. It then moved into the technical design phase, which covered architectural planning, material selection for insulation and energy conservation, detailed electrical layout and load calculations, and the selection of devices compatible with modern IoT-based home automation systems.

7.2 Key Findings and Contributions

Furthermore, a hybrid renewable energy system combining solar photovoltaic and wind power was proposed to enable off-grid operation. To support long term sustainability, a hybrid solar wind energy system was designed based on real-world climate data, ensuring the cottage could operate independently from the central grid. All decisions were based on realistic assumptions, local availability of materials, and practical usage patterns for a family of four to six members. By thoughtfully choosing to integrate insulation materials, smart technologies, and renewable energy systems, the project proves that living comfortably is efficient and environmentally responsible. The use of locally available, high-performance materials such as MAK Euroblock, triple-glazed Windoor systems, and Mongol Basalt insulation demonstrated that a well-insulated structure can drastically reduce heat loss and minimize heating demand during Mongolia’s long winters. The smart automation system, based on Tuya technology, adds layers of convenience, safety, and control, allowing residents to manage lighting, heating, and security remotely with ease.

7.3 Technical and Practical Implications

Another key contribution is the development of a detailed seasonal energy load model that reflects actual usage patterns across winter, transitional, and summer months. This enabled more accurate design of the electrical system and informed the sizing of the renewable energy setup. The hybrid solar wind configuration, supported by a centralized battery system, offers a reliable off-grid alternative that aligns with Mongolia’s solar and wind resources. The technical design of the smart cottage demonstrates how energy demands can be reliably met year-round through a combination of efficient construction, intelligent electrical planning, and integrated control systems. The electrical layout inside the house is divided into two well balanced distribution boards, which simplifies maintenance and reduces the risk of overload. Wire sizing and circuit protection were selected in accordance with Mongolian standards, ensuring a safe installation that can handle both general and high-load appliances such as the oil-based heating system. On the practical side, the Tuya based Home Automation System plays a crucial role. It allows for intuitive, remote management of lighting, heating, and security systems using a mobile app. This not only enhances convenience for residents but also reduces electricity waste by enabling scheduled or sensor-based operation of key appliances.

7.4 Economic and Environmental Impact

Moreover, the technical feasibility of operating fully off-grid was confirmed through detailed sizing of solar panels, wind turbines, and energy storage. The system is specifically designed to meet the highest energy demands of winter, with enough buffer to ensure uninterrupted power even during days of poor weather. Environmentally, the smart cottage reduces its carbon footprint by relying on clean, renewable energy sources such as solar and wind. This not only minimizes greenhouse gas emissions but also decreases reliance on coal-fired electricity, which remains a major source of pollution in Mongolia.

7.5 Limitations and Future Considerations

While the proposed smart cottage design offers many strengths, there are also several limitations and practical challenges that should be acknowledged. First, the high initial cost of components, particularly the renewable energy system and battery storage, can be a barrier for many homeowners. Second, while the seasonal load model used in this study is based on realistic assumptions, it is still a simulation. Actual energy consumption can vary based on user habits, occupancy changes, equipment aging, and unexpected weather patterns. Therefore, system flexibility and real-time performance monitoring will be crucial to adapt to real-life usage scenarios. Third, although the Tuya ecosystem was selected for its compatibility and ease of use, its full functionality depends on reliable internet connectivity.

Looking ahead, several areas can be explored for future developments. Smart Grid Integration. If grid power is available, combining it with renewable sources could reduce battery dependence and allow for energy export. Advanced Energy Management. Integration of AI-based systems to further optimize power distribution, appliance scheduling, and fault detection. Improved Battery Technology. As battery prices continue to drop and new chemistries (e.g., sodium-ion) become more available, future systems could achieve higher performance at lower cost.

7.6 Final Thoughts

This thesis was not only a technical project but also a personal journey blending engineering knowledge, design thinking, and real-world context to create something both functional and meaningful. There is still room for growth, innovation, and real-world testing. Several important elements remain unresolved in this version of the design. For example, clean and wastewater plumbing systems have not yet been planned, the interior and exterior design remains incomplete, and although insulation material for the roof has been selected, the full structural design of the roof itself is still pending. Additionally, a total cost estimate for constructing the entire cottage has not been calculated.

In closing, this project offers a glimpse into a smarter, greener, and more independent way of living. And for anyone looking to take a break from the stress of the city without sacrificing comfort or connectivity, this smart cottage may just be the perfect place to call home.

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Appendix

Column 1	No.	Item	Location(s)	Quantity	Power rating (W)	#	Daily duration (h)	Energy (1 Day) consumption (Wh)	Montly E consumption (kWh)
A. Lighting Fixtures	1	Ceiling LED light	Bedrooms, Living Kitchen, Garage	6	15		8	720	21.6
	2	Circular LED downlights	Kitchen, Terrace	14	7		4	392	11.76
	3	Ceiling lights	Hallways Bathrooms	4	12		3	144	4.32
	4	Outdoor motion-sensor lights	Main entrance	2	10		0.5	10	0.3
B. General socket based appliances	5	Phone/Laptop charger	Bedrooms, Living	4	20		3	240	7.2
	6	Vacuum cleaner	All areas	1	1000		0.5	500	15
	7	Hair dryer	Bathroom	1	1500		0.2	300	9
	8	Iron	Living/Storage	1	1200		0.3	360	10.8
	9	Water kettle	Kitchen	1	1500		0.5	750	22.5
	10	Television	Living room	1	100		4	400	12
	11	Wi-Fi Router (Starlink Mini)	Living room	1	30		24	720	21.6
C. Kitchen Appliances	12	Electric stove	Kitchen	1	2000		2	4000	120
	13	Rice cooker	Kitchen	1	700		0.5	350	10.5
	14	Microwave oven	Kitchen	1	1200		0.1	120	3.6
	15	Refrigerator	Kitchen	1	120		24	2880	86.4
	16	Coffee machine	Kitchen	1	1000		0.5	500	15
	17	Toaster (optional)	Kitchen	1	800		0.2	160	4.8
D. Bathroom Appliances	18	Washing machine	Bathroom/ Garage	1	1000		0.3	300	9
	19	Electric water heater	Bathroom	1	2000		0.3	600	18
	20	Shaver socket/light	Bathroom	1	10		0.2	2	0.06
E. Heating System	21	Electric oil heater	Central	1	2000		24	48000	1440
	22	Circulation pump	Heating line	1	100		24	2400	72
F. Security Devices	23	Smoke detectors	Kitchen Hallways	4	1		24	96	2.88
	24	Surveillance cameras	2 Outdoor 1 Indoor	3	5		24	360	10.8
Total								64304	1929.12

Annex 1. Estimated energy consumptions of daily and monthly during winter

Column 1	No.	Item	Location(s)	Quantity	Power rating (W)	Daily duration (h)	Energy (1 Day) consumption (Wh)	Monthly E consumption (kWh)
A. Lighting Fixtures	1	Ceiling LED light	Bedrooms, Living Kitchen, Garage	6	15	7	630	18.9
	2	Circular LED downlights	Kitchen, Terrace	14	7	4	392	11.76
	3	Ceiling lights	Hallways Bathrooms	4	12	3	144	4.32
	4	Outdoor motion-sensor lights	Main entrance	2	10	0.5	10	0.3
B. General socket based appliances	5	Phone/Laptop charger	Bedrooms, Living	4	20	3	240	7.2
	6	Vacuum cleaner	All areas	1	1000	0.5	500	15
	7	Hair dryer	Bathroom	1	1500	0.2	300	9
	8	Iron	Living/Storage	1	1200	0.3	360	10.8
	9	Water kettle	Kitchen	1	1500	0.5	750	22.5
	10	Television	Living room	1	100	4	400	12
	11	Wi-Fi Router (Starlink Mini)	Living room	1	30	24	720	21.6
C. Kitchen Appliances	12	Electric stove	Kitchen	1	2000	2	4000	120
	13	Rice cooker	Kitchen	1	700	0.5	350	10.5
	14	Microwave oven	Kitchen	1	1200	0.1	120	3.6
	15	Refrigerator	Kitchen	1	120	24	2880	86.4
	16	Coffee machine	Kitchen	1	1000	0.5	500	15
	17	Toaster (optional)	Kitchen	1	800	0.2	160	4.8
D. Bathroom Appliances	18	Washing machine	Bathroom/ Garage	1	1000	0.3	300	9
	19	Electric water heater	Bathroom	1	2000	0.3	600	18
	20	Shaver socket/light	Bathroom	1	10	0.2	2	0.06
E. Heating System	21	Electric oil heater	Central	1	2000	16	32000	960
	22	Circulation pump	Heating line	1	100	16	1600	48
F. Security Devices	23	Smoke detectors	Kitchen, Hallways	4	1	24	96	2.88
	24	Surveillance cameras	2 Outdoor 1 Indoor	3	5	24	360	10.8
Total							47414	1422.42

Annex 2. Estimated energy consumptions of daily and monthly during transitional

Column 1	No.	Item	Location(s)	Quantity	Power rating (W)	Daily duration (h)	Energy (Day) consumption (Wh)	Monthly E consumption (kWh)
A. Lighting Fixtures	1	Ceiling LED light	Bedrooms, Living Kitchen, Garage	6	15	6	540	16.2
	2	Circular LED downlights	Kitchen, Terrace	14	7	4	392	11.76
	3	Ceiling lights	Hallways Bathrooms	4	12	3	144	4.32
	4	Outdoor motion-sensor lights	Main entrance	2	10	0.5	10	0.3
B. General socket based appliances	5	Phone/Laptop charger	Bedrooms, Living	4	20	3	240	7.2
	6	Vacuum cleaner	All areas	1	1000	0.5	500	15
	7	Hair dryer	Bathroom	1	1500	0.2	300	9
	8	Iron	Living/Storage	1	1200	0.3	360	10.8
	9	Water kettle	Kitchen	1	1500	0.5	750	22.5
	10	Television	Living room	1	100	4	400	12
	11	Wi-Fi Router (Starlink Mini)	Living room	1	30	24	720	21.6
C. Kitchen Appliances	12	Electric stove	Kitchen	1	2000	2	4000	120
	13	Rice cooker	Kitchen	1	700	0.5	350	10.5
	14	Microwave oven	Kitchen	1	1200	0.1	120	3.6
	15	Refrigerator	Kitchen	1	120	24	2880	86.4
	16	Coffee machine	Kitchen	1	1000	0.5	500	15
	17	Toaster (optional)	Kitchen	1	800	0.2	160	4.8
D. Bathroom Appliances	18	Washing machine	Bathroom/ Garage	1	1000	0.3	300	9
	19	Electric water heater	Bathroom	1	2000	0.3	600	18
	20	Shaver socket/light	Bathroom	1	10	0.2	2	0.06
E. Heating System	21	Electric oil heater	Central	1	2000	4	8000	240
	22	Circulation pump	Heating line	1	100	4	400	12
F. Security Devices	23	Smoke detectors	Kitchen, Hallways	4	1	24	96	2.88
	24	Surveillance cameras	2 Outdoor 1 Indoor	3	5	24	360	10.8
Total							22124	663.72

Annex 3. Estimated energy consumptions of daily and monthly during warm

Column 1	No.	Item	Location(s)	Quantity	Power rating (W)	Daily duration (h)	Energy (1 Day) consumption (Wh)	Monthly E consumption (kWh)
A. Lighting Fixtures	1	Ceiling LED light	Bedrooms, Living Kitchen, Garage	6	15	5	450	13.5
	2	Circular LED downlights	Kitchen, Terrace	14	7	4	392	11.76
	3	Ceiling lights	Hallways Bathrooms	4	12	3	144	4.32
	4	Outdoor motion-sensor lights	Main entrance	2	10	0.5	10	0.3
B. General socket based appliances	5	Phone/Laptop charger	Bedrooms, Living	4	20	3	240	7.2
	6	Vacuum cleaner	All areas	1	1000	0.5	500	15
	7	Hair dryer	Bathroom	1	1500	0.2	300	9
	8	Iron	Living/Storage	1	1200	0.3	360	10.8
	9	Water kettle	Kitchen	1	1500	0.5	750	22.5
	10	Television	Living room	1	100	4	400	12
	11	Wi-Fi Router (Starlink Mini)	Living room	1	30	24	720	21.6
C. Kitchen Appliances	12	Electric stove	Kitchen	1	2000	2	4000	120
	13	Rice cooker	Kitchen	1	700	0.5	350	10.5
	14	Microwave oven	Kitchen	1	1200	0.1	120	3.6
	15	Refrigerator	Kitchen	1	120	24	2880	86.4
	16	Coffee machine	Kitchen	1	1000	0.5	500	15
	17	Toaster (optional)	Kitchen	1	800	0.2	160	4.8
D. Bathroom Appliances	18	Washing machine	Bathroom/ Garage	1	1000	0.3	300	9
	19	Electric water heater	Bathroom	1	2000	0.3	600	18
	20	Shaver socket/light	Bathroom	1	10	0.2	2	0.06
E. Heating System	21	Electric oil heater	Central	1	2000	0	0	0
	22	Circulation pump	Heating line	1	100	0	0	0
F. Security Devices	23	Smoke detectors	Kitchen, Hallways	4	1	24	96	2.88
	24	Surveillance cameras	2 Outdoor 1 Indoor	3	5	24	360	10.8
Total							13634	409.02

Annex 4. Estimated energy consumptions of daily and monthly during hot