Proposal Documentation

Empowering Consumers with 5G-Enabled Earth2Us Plug for Greener Energy Practices

Prepared By

Earth2Us

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Prepared For

ZTE NextGen 5G Hackhaton

1 Participant Background

1.1. Group Details

Group Name: Earth2Us

Total Member: Solo (1 Member)

1.2. Member Details

Full Name: Nur Inqsyira Binti Zamri

Age: 21 years old

University: Multimedia University, Cyberjaya

Student ID: 1211103098

Current Study Level: Third trimester of second year

Degree: Bachelor of Computer Science with Specialization in Cybersecurity (Hons.)

1.3. Roles in Project

- Project Manager
- Developer
- Designer
- Analyst

1.4. Background and Motivation

Recently, I encountered my first academic setback, which prompted me to reflect and seek unique opportunities for growth. Discovering this hackathon felt like the perfect moment to stop self-sabotaging and take control of my progress. Determined to overcome procrastination and the belief that time would always be on my side, I decided to proceed with my plan to join the hackathon, even though my fellow friend could not make it.

The solution I propose may not directly align with my background in computer science and cybersecurity, but my eagerness to learn and adapt has driven me to explore new areas and develop the skills necessary to tackle this challenge. I believe that a commitment to continuous learning is just as important as technical expertise, and this mindset has helped me approach this project with confidence.

Through this project, I aim to push myself beyond my comfort zone, leveraging my passion for problem-solving to create a solution that benefits to the betterment of humanity while setting a new, higher baseline for my personal and professional growth.

2 Problem Statement

As Malaysia progresses toward digital modernization, the rising demand for electricity exacerbates environmental concerns, particularly with household consumption accounting for approximately 72% of global greenhouse gas emissions (Abdullah et al., 2022). Current energy management systems, such as TNB's smart meter initiative, lack detailed insights into specific appliance usage, limiting the ability of homeowners and businesses to implement targeted energy-saving measures. By aligning appliance schedules with renewable energy availability, users can lower their electricity bills and reduce carbon emissions, contributing to Malaysia's goal of sourcing 70% of its energy from renewables by 2050 (Take, 2023).

3 Overview of the Solution

3.1. Overview of the Solution

The Earth2Us Plug leverages 5G technology, AI predictive analytics, and IoT integration to optimize energy consumption at the consumer level. The system schedules appliances based on carbon emission data and local renewable energy availability, helping users reduce electricity costs and strain on the energy grid. The 5G-enabled Earth2Us Plug, paired with a mobile app, offers real-time energy consumption reports for each connected appliance.

3.2. Key Features

3.1.1. Real-Time Energy Monitoring

Provides detailed insights into energy consumption for each connected appliance, accessible via the mobile app.

3.1.2. AI-Driven Predictive Analytics

Uses AI to predict optimal energy usage times and offer recommendations based on local carbon emission data and renewable energy availability.

3.1.3. Remote Control via Earth2Us Mobile App

Users can monitor and control appliances remotely, turning them on or off through the app.

3.1.4. User-Centric Scheduling

Incorporates user priorities and schedules appliance operation for optimal energy efficiency.

3.1.5. Emission Visualization

A friendly interface with visual elements like trees to represent emission reductions, promoting environmentally conscious behaviour.

3.1.6. Renewable Energy Awareness

Provides insights into local fluctuations in renewable energy production, encouraging users to adjust consumption based on availability.

3.3. Benefits

3.2.1. Increased Energy Efficiency

Helps users reduce energy wastage by optimizing appliance usage based on real-time data and presence detection.

3.2.2. Lower Electricity Bills

AI-powered recommendations and scheduling help users lower their energy consumption and costs, particularly during peak non-renewable energy times.

3.2.3. Sustainability

Encourages sustainable living by offering suggestions based on carbon emissions and renewable energy availability, supporting Malaysia's decarbonization goals.

3.2.4. Convenience

Remote monitoring and control via the mobile app provide flexibility and ease of use, allowing users to manage their energy consumption from anywhere.

3.2.5. Personalized Experience

Incorporates user preferences for energy scheduling, ensuring the system adapts to individual needs and habits.

4 Target User / Industry

4.1. Target Users

4.1.1. Residential Homeowners

Homeowners looking to reduce their energy consumption and electricity bills will benefit greatly from the Earth2Us Plug. By providing real-time monitoring, automated control, and tailored energy-saving recommendations, the device helps them make informed decisions about their energy usage, promoting sustainable living.

4.1.2. Apartment Dwellers

Individuals living in apartments often have limited control over their overall energy consumption but can still manage the energy use of specific appliances. The Earth2Us Plug enables apartment dwellers to optimize their usage of high-

consumption devices such as air conditioners or washing machine, helping them save on energy costs.

4.1.3. Small Businesses

For small business owners, energy consumption during peak hours can significantly impact operational costs. The Earth2Us Plug's scheduling and predictive features help businesses avoid high demand charges by managing appliance usage during non-peak hours, reducing their energy bills and contributing to more sustainable operations.

4.2. Target Industry

4.2.1. Smart Home Technology

The Earth2Us Plug integrates seamlessly into the broader smart home ecosystem, aligning with the growing trend of IoT-based home automation. By enabling energy efficient management of appliances, it complements other smart devices like thermostats, lights, and security systems, enhancing overall home automation.

4.2.2 Energy Management

With a focus on optimizing energy usage and promoting sustainable practices, the Earth2Us Plug directly addresses the needs of the energy management sector. The device provides valuable insights into energy consumption and helps consumers adopt more efficient energy habits, contributing to reduced grid demand and lower carbon emissions.

4.2.3. Green Energy Solutions

As the world transitions toward greener energy sources, there’s a growing need for technologies that help consumers adapt to the fluctuations in renewable energy availability. The Earth2Us Plug supports this shift by promoting energy usage during times when renewable energy is more abundant, aligning with the goals of decarbonization and climate-friendly initiatives.

5 Hardware Stack

5.1. Hardware Components Used for the Prototype

No	Category	Component Name	Description
1.	Microcontroller	Raspberry Pi 4 Model B (1GB)	The main microcontroller is used to manage and control the plug's functions. Provides processing power and interfaces for sensors and modules.
2.	Storage	MicroSD Card (32GB) with Pre-installed Raspberry Pi OS	Storage for the operating system and software applications needed to run the Raspberry Pi.
3.	Relay Module	2 Channel 5V Active Low Relay Module	Used to control the power to load appliances. Can switch on and off high voltage devices.
4.	Prototyping	Breadboard (8.5 x 5.5 cm)	A prototyping board used for assembling the circuit without soldering. Optional use for testing connections.
5.	Tools	Electric Soldering Iron (60W)	Used for soldering connections and components on the board.
6.	Power Supply	Power Supply Model S-60-12 DC 12V 5A	Provides power to the components of the circuit, ensuring they operate correctly.
7.	Sensor	ACS712 Hall Current Sensor Module (5A)	Measures the current flowing through the connected load to monitor power consumption.
		AC Voltage Sensor Module ZMPT101B (Single Phase)	Measures the AC voltage of the connected load, providing data for voltage monitoring
		ADS1115 Analog-to-Digital Converter	Provides precise measurement of analog signals from sensors, enhancing the accuracy of data collection.
8.	Cable	Micro HDMI to HDMI Full HD Cable (1.5m)	Connects the Raspberry Pi to a monitor for setup and troubleshooting.
9.	Tools	Soldering Lead (0.2mm)	Used in conjunction with the soldering iron to create permanent electrical connections.
10.	Clips	45mm Alligator Crocodile Clip with Lead (Super Duty)	Used for temporary connections during prototyping and testing.
11.	Wires	Male-to-Male Dupont Wire	Used for connecting components on the breadboard or to the Raspberry Pi.
		Male-to-Female Dupont Wire	
		Female-to-Female Dupont Wire	

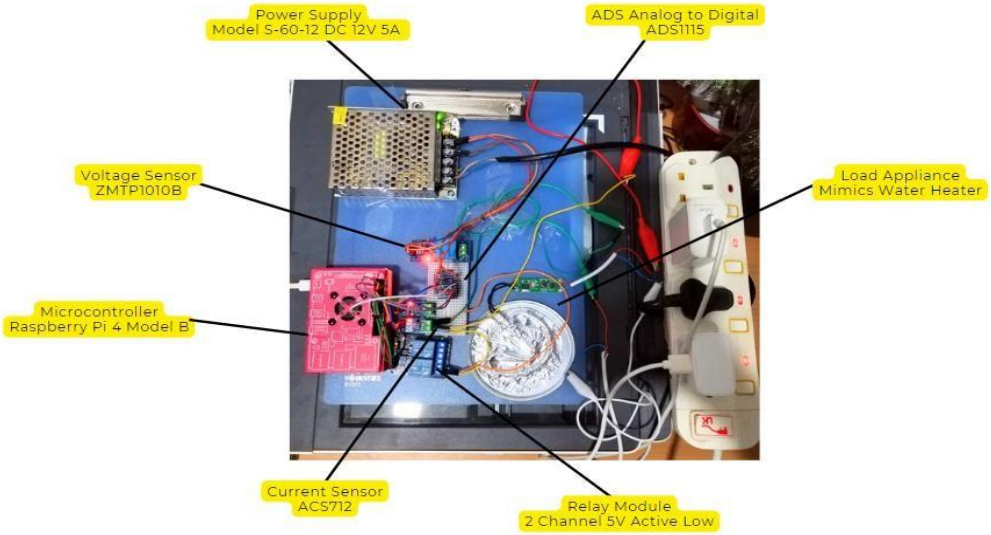

Figure 1: Plane view of the hardware stack

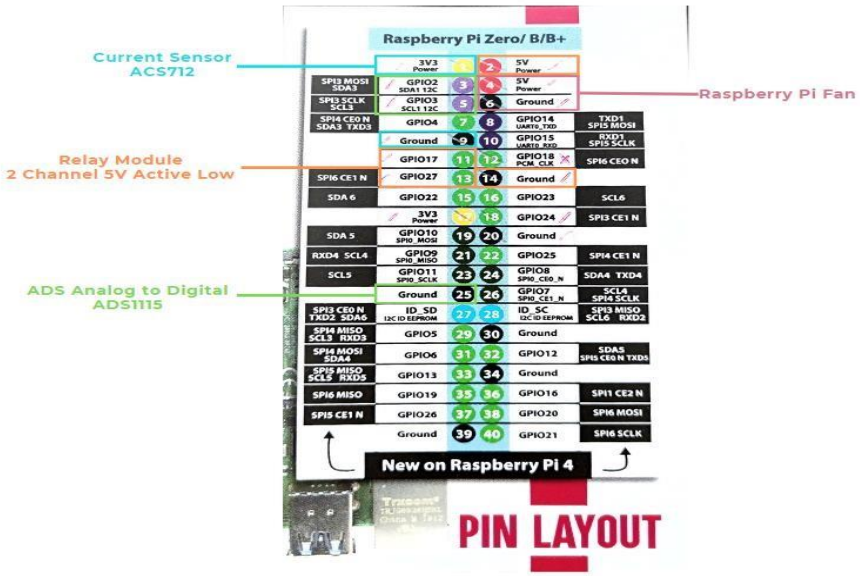

Figure 2: Raspberry Pi Pin Usage

The figure 1 and 2 shows the hardware layout and the raspberry pi pin connections for the Earth2Us Plug prototype. The ACS712 current sensor connects to the Raspberry Pi via an Analog-to-Digital Converter (ADS1115) using the I2C interface (SDA and SCL pins) since the Raspberry Pi lacks built-in ADC capabilities. This setup enables the Pi to read the current measurements from the ACS712. The relay module is connected to the GPIO pins (e.g., GPIO4 and GPIO17) and controls the power state of a connected load, such as a water heater, by switching it on or off. The ADS1115 converts analog signals from the ACS712 into digital data for the Pi. A Raspberry Pi fan is connected to the 5V and GND pins to keep the system cool. Additional components like the power supply provide the necessary voltage to power the relay and sensors. Together, these components allow the Raspberry Pi to monitor power consumption and control the appliance efficiently.

6 Software Stack

6.1. Software Architecture (Free-Tier Plan)

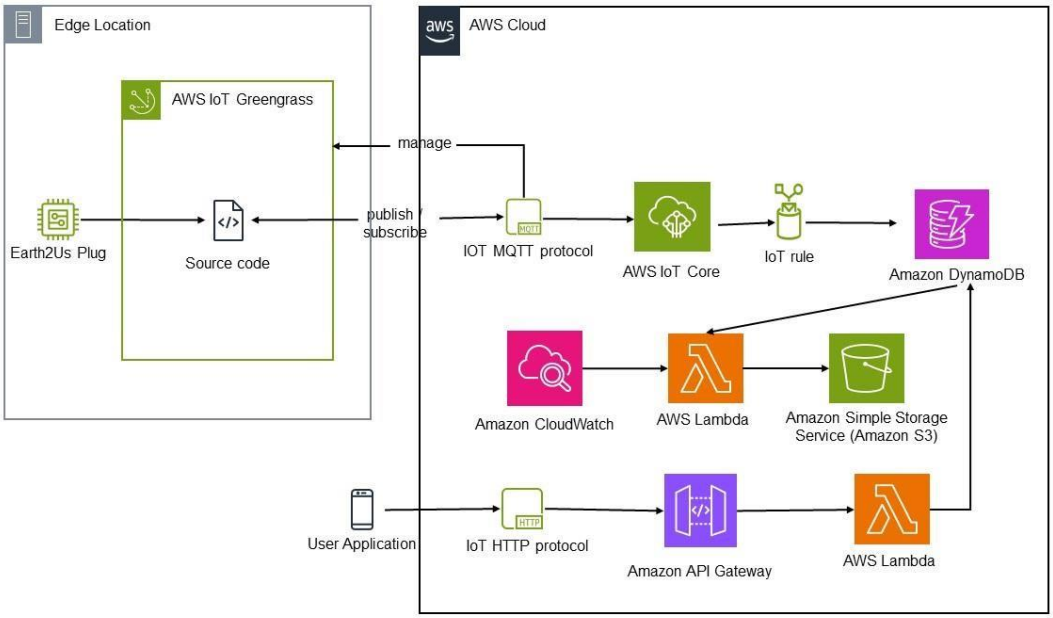

Figure 3: Software Architecture for Earth2Us Plug

Figure 3 shows the software stack for the Earth2Us Plug leverages AWS IoT services to enable real time monitoring, data archiving, and efficient data retrieval. The system is designed with specific goals: it is serverless, has no fixed costs, supports multiple sensors, handles any data rate, and archives all data for future use. The Earth2Us Plug runs AWS IoT Greengrass at the edge, sending readings every 30 seconds to AWS IoT Core using MQTT. Upon receiving data, an IoT rule writes the raw readings to a DynamoDB table, happening 2880 times a day to ensure that no data is lost. AWS IoT's Basic Ingest feature is used here to save costs by directly sending the data to DynamoDB without the need for multiple consumers.

To manage long-term storage efficiently, a CloudWatch rule triggers a Lambda function nightly. This function retrieves the previous day's readings from DynamoDB, compresses them into a Gzipcompressed CSV file, and archives it to Amazon S3. This approach keeps storage costs low and simplifies the retrieval of historical data. A second Lambda function powers a GraphQL API, providing data access to the web dashboard and the Ionic app, facilitating user interaction and real time data visualization.

This architecture is designed to be serverless, cost-effective, and scalable. It should be able to handle multiple sensors and high data rates while ensuring that no data is discarded. The combination of DynamoDB for short-term storage and S3 for long-term archiving ensures efficient use of resources and quick data retrieval. This approach allows the system to operate within the AWS free tier, incurring no costs unless storage requirements exceed the free tier limits.

6.2. Software Architecture (Subscription Plan)

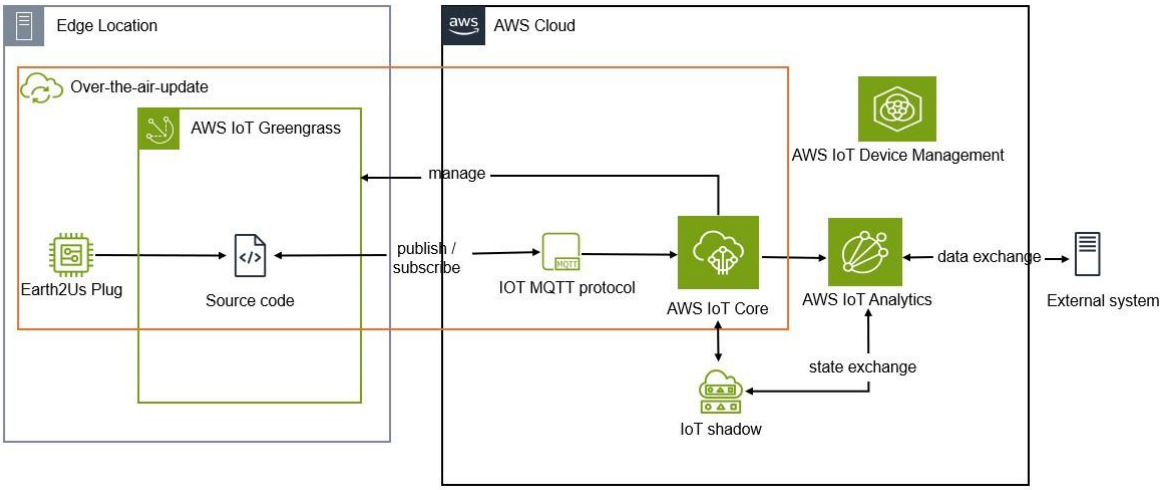

Figure 4: Advanced Software Architecture for Earth2Us Plug

The subscription plan enhances the basic Earth2Us Plug architecture by introducing AWS IoT Device Management for efficient remote monitoring, secure over-the-air updates, and lifecycle management of devices. AWS IoT Greengrass continues to run at the edge, but now allows for real time local processing and over-the-air updates to ensure scalability. Data is still sent to AWS IoT Core using MQTT, but the addition of AWS IoT Analytics enables advanced data processing and insights, such as anomaly detection and predictive analysis. This architecture also integrates external systems for enhanced reporting and data exchange, while IoT Shadows provide a virtual representation of devices to ensure real-time sync with cloud apps. These upgrades make the system more scalable, automated, and capable of handling complex data while ensuring device health and long-term management.

6.3. Source Code Explanation

6.3.1 Libraries and Toolchain

AWS SDKs, including AWS SDK for Python (Boto3), are utilized for interacting with AWS services, specifically for data retrieval and processing in Lambda functions. For the GraphQL API, libraries such as Apollo Server for Node.js are employed, integrating seamlessly with AWS Lambda. Data compression is managed using the Gzip algorithm, implemented through libraries like Python's gzip module or similar in other programming languages.

6.3.2 SDKs and Programming Languages

The AWS IoT Greengrass SDK is used for running code locally on the device and managing connectivity with AWS IoT Core. Lambda functions are written in languages such as Python, Node.js, or Java. The GraphQL API is developed using JavaScript or TypeScript, often with Node.js. The Ionic framework, which involves JavaScript/TypeScript, is used for developing the mobile app.

6.3.3 Communication Protocols

MQTT (Message Queuing Telemetry Transport) is employed for sending data from AWS IoT Greengrass to AWS IoT Core, providing a lightweight, publish-subscribe protocol suitable for high-latency or unreliable networks. HTTPS is used to ensure secure communication between the web dashboard, Ionic app, and the GraphQL API.

6.3.4 Algorithms

6.3.4.1. Data Compression

The Gzip algorithm is used to compress historical data before archiving, helping to reduce storage costs.

6.3.4.2. Anomaly Detection and Predictive Analysis

AWS IoT Analytics facilitates advanced data processing, including anomaly detection and predictive analysis, through statistical or machine learning algorithms.

6.3.4.3. Energy Generation Prediction

Machine learning algorithms are employed to predict energy generation from raw weather data forecasts. This system targets users without smart home connections to smart grids, helping them optimize their energy usage. By estimating energy production from weather data and local energy plant distribution, the system suggests the optimal times for users to perform energy-consuming tasks from a sustainability perspective. The use of historical data and machine learning models enables accurate predictions of renewable energy for future days and allows for region-specific energy forecasts due to the varied distribution of renewable energy plants.

7 Potential Adoption of 5G Technology

7.1. Integration of 5G Technology in Earth2Us Plug

7.1.1 Real-Time Data Transmission

5G's high-speed, low-latency network will ensure immediate transmission of energy usage data to cloud services. This capability allows for precise monitoring and instant feedback, enhancing our energy management system's effectiveness.

7.1.2. Enhanced Connectivity

The vast capacity of 5G networks will support a high density of smart plugs in a single area without network congestion. This ensures that every smart plug can reliably send and receive data, making it feasible to deploy our solution on a large scale in urban environments.

7.1.3. Improved Data Analytics

The increased data throughput of 5G will facilitate advanced analytics, enabling us to detect energy consumption patterns and forecast potential issues, thus optimizing energy use.

7.1.4. IoT Integration

5G enhances the integration of IoT devices by providing faster and more reliable communication between smart plugs and other smart home devices. This facilitates a more connected and automated home environment.

7.1.5. Challenges and Mitigation

Potential issues include 5G coverage limitations. We will address this by incorporating multi-connectivity options, such as fallback to 4G/LTE in areas with weak 5G signals, ensuring consistent performance.

8 Impact / Effectiveness

8.1. Expected Impact and Effectiveness in Earth2Us Plug

8.1.1. Energy Efficiency

By providing real-time insights into energy consumption, Earth2Us Plug helps users optimize their energy use. This leads to lower electricity bills and reduced energy waste. The ability to monitor and control energy usage more precisely directly supports the reduction of overall energy consumption.

8.1.2. Environmental Benefits

Lower energy consumption contributes to a decrease in greenhouse gas emissions. By integrating renewable energy data, Earth2Us Plug encourages the use of green energy sources, aligning with Malaysia's goal to achieve net zero emissions by 2025.

8.1.3. Urban Sustainability

Earth2Us Plug supports the development of more sustainable urban environments. It helps residents and businesses reduce their carbon footprint, contributing to cleaner air and a healthier environment. This aligns with the goal of creating more resilient and sustainable cities.

8.1.4. Innovation in Energy Management

The deployment of 5G technology enhances the effectiveness of Earth2Us Plug providing cutting-edge solutions for energy management. This drives innovation in infrastructure and supports the development of smart cities.

9 Cost Breakdown

9.1. Earth2Us Plug Project Development and Implementation Costs

Component Type	Component	Function	Quantity	Estimated Cost (MYR)
Hardware	Microcontroller (RaspberryPi 4) and kit	Central control and processing	1	232.00
	ACS712 Hall Current Sensor Module 2A	Measures current consumption	2	13.00
	AC Voltage Sensor Module ZMPT101B	Measures voltage	1	8.90
	ADS1115 Analog-to-Digital Converter	Measures analog signals from sensors	1	10.99
	2 Channel 5V Active Low Relay Module	Controls the switching of appliances	1	5.50
	Universal Adapter Transformer DC Power Supply 12V – 5A	Provides necessary power to the components	1	6.84
	Breadboard 8.5 x 5.5 cm (400 holes)	Connects and holds the components	1	2.70
	Micromini HDMI to HDMI Full HD Cable 150cm	Programming the microcontroller	1	5.90
	Solder Lead and Electric Soldering Iron Gun 60 W	Soldering connections and components	1 / 2m	7.46
	Male-Male Dupont / Male Female Dupont / Female – Female Dupont	Wires, connectors, etc.	40	4.99
	Alligator Crocodile Clip Lead Jumper Wire	Wires, connectors, etc.	3	2.70
3D Printing	3d Printing Earth2Us Plug	To properly enclose the plug	1	TBD
		Total		300.98

Note: The costs listed above do not include the 3D printing of the Earth2Us Plug.

10 Revenue or Plan for Sustainability

10.1. Revenue Generation and Sustainability Plan for in Earth2Us Plug

10.1.1. Direct Sales

Generate revenue through the sale of "Earth2Us Plug" devices. The devices are designed for lifespan of 5–7 years with minimal hardware degradation. The plug will be developed using durable materials, ensuring that they can withstand regular use and environmental conditions. Minimal physical maintenance is required for hardware, and most updates will be delivered through over-the-air (OTA) software updates, reducing the need for manual interventions.

10.1.2. Subscription Services

Offer a subscription-based service for premium features like advanced analytics, cloud storage, and integration with other smart home systems. The subscription model provides steady recurring income, supporting continuous updates, server maintenance, and R&D. With cloud-based services, server uptime and software stability are prioritized. The system can operate without human intervention for extended periods, with regular software patches ensuring long-term functionality.

10.1.13. Partnerships and Collaborations

Partner with energy providers and smart home solution companies to offer Earth2Us Plug as part of their service packages, creating additional revenue channels. Strategic partnerships ensure a continuous influx of customers and distribution, allowing for wider adoption, which increases product relevance and longevity. Partnerships will drive continuous demand for the product, helping to maintain product availability and expand the lifespan through bulk deployment and corporate integration.

10.1.4. Data Monetization

Analyse aggregated data to provide insights and recommendations to businesses and energy providers, creating a revenue stream through data analysis services. Aggregated data can provide predictive analysis for energy consumption trends and optimization strategies, which can evolve into consulting services or market insights for third-party organizations. This is a low-maintenance, high-revenue model that can run continuously with minimal human oversight.

10.1.5. Grants and Incentives

Seek grants and incentives from governments and environmental organizations supporting clean technology and energy efficiency projects. Continuous funding from these sources can support long-term R&D efforts and reduce the need for price increases. Such funding will help improve product resilience and reduce the overall cost of hardware and services for consumers. Funds can be

allocated to improving hardware longevity and reducing the cost of cloud-based services, ensuring the plug remains relevant and sustainable for years.

10.1.6. Continuous Innovation

Ongoing research and development will help integrate new technologies such as AI and machine learning into the plug, which will allow it to offer more accurate predictive analysis and energy-saving recommendations over time. As new features are added, the product will stay relevant in the market, and regular software updates will extend its lifespan. Innovation in hardware design ensures the product remains robust and compatible with emerging technologies like 5G. Most updates and optimizations can be done automatically through OTA updates, which will require minimal human intervention, ensuring long-term operation without physical hardware adjustments.

10.2. Conclusion

In summary, the hardware Earth2Us is expected to last 5–7 years with minimal physical maintenance. Continuous software improvements and predictive analysis features will help extend the overall lifespan of the product. Besides, the maintenance costs are kept low through:

- Remote software updates via OTA.
- Low maintenance of cloud-based systems.
- Reliable hardware design using durable materials.
- Predictive analysis to foresee and mitigate failures, reducing the need for physical repairs.

The project can operate for long periods without human intervention, thanks to automation, reliable hardware, and self-sustaining revenue streams. The use of predictive analytics, cloud services, and partnerships will ensure continuous growth and operational sustainability, with minimal need for physical maintenance.

11 References

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