ENERFLY PROJECT REPORT

CBI4AI - TEAM 3

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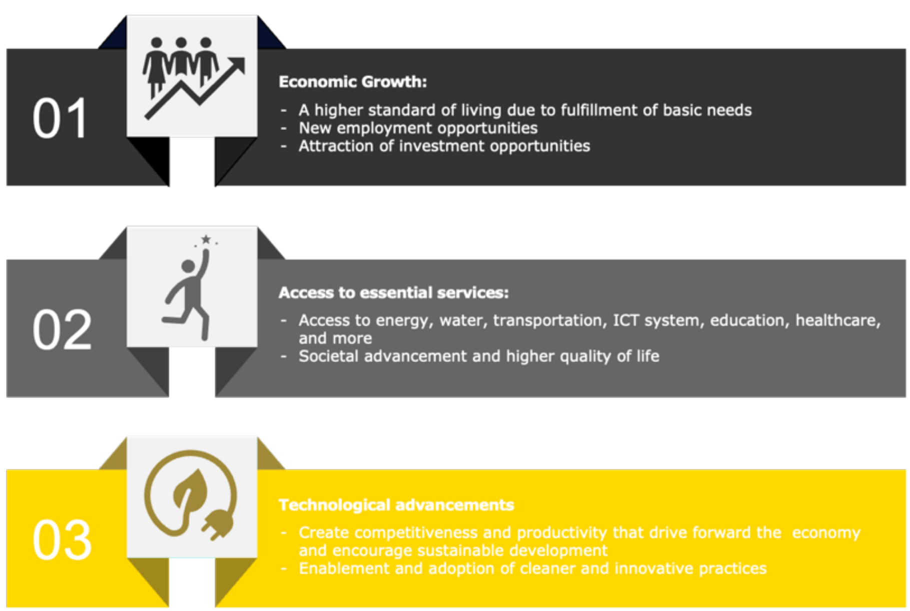
SDG Challenge (SDG 9)

1.1 Overview of SDG 9

SDG number 9 is based on three main pillars: Industry, innovation, and infrastructure. In terms of industry, SDG 9 aims to make the process of industrialization more inclusive and sustainable. It aims to increase the impact of manufacturing and the industrial's sector on the GDP, foster innovation and better practices in manufacturing that could help mitigate the negative environmental effects and support the growth of small to medium enterprises. Above all, it encourages sustainable growth in manufacturing through the efficient use of resources and new technologies that aid in the reduction of waste. Innovation, as one of the main pillars, is considered a crucial steppingstone towards sustainable development. This section of SDG 9 calls for increased capacity in encouraging innovation and more funding for research and development. There is a focus on new technology applications that allow for more efficient energy management solutions. Lastly, infrastructure refers to resilient and sustainable physical and digital infrastructures, particularly in developing countries where economic growth and social advancement are hindered by a lack of basic infrastructure. Developing a reliable infrastructure is defined as one resistant to internal and external shocks and allows access to different resources be it physical or digital. In the digital world, SDG 9 promotes access to digital resources and digital literacy for all demographic groups to obtain maximal benefit from the opportunities online.

1.2 Importance and Relevance of SDG 9



1.3 Key Objectives and Targets of SDG 9

Problem to be solved

2.1 Identification of the Problem

Access to reliable and efficient energy is still a significant challenge in many developing countries due to fractured and underdeveloped infrastructure. The lack of effective energy management systems results in frequent blackouts, energy peaks, and high losses in the energy distribution network. Additionally, the untapped potential of renewable energy resources remains largely unexplored.

The objective of our device is to address these challenges by developing an innovative energy management device. The device leverages the capabilities of Attract technologies such as UltraRAM making the device more robust and persistent in cases of blackouts, and Random Power enabling the most secure data encryption possible as well as simulations that aid in accurate analysis of energy consumption patterns. By predicting energy peaks and identifying potential blackouts, the device aims to assist in managing energy distribution more effectively and reducing losses in the network.

2.2 Significance and Impact of the Problem

Access to reliable energy sources is a fundamental right that can highly impact the standard of living, economic activity, and societal advancement, particularly in developing countries with weak infrastructures and power grids. For the great impact it could have in the citizen's life, the development of an energy management device for improving energy distribution and utilization in developing countries carries great significance in allowing sustainable development and higher standard of living. By addressing the challenges of energy peaks, blackouts, and losses in the distribution network, our device has the potential to revolutionize energy management practices. It can empower governments and energy providers to efficiently allocate limited resources, minimize disruptions in energy supply, and enhance overall energy access for communities. Moreover, the integration of renewable energy resources through this device presents an opportunity to leverage sustainable and clean sources of power, leading to reduced dependence on fossil fuels and contributing to a more environmentally friendly energy landscape. Ultimately, the successful implementation of this project can uplift lives, foster economic development, and pave the way for a more resilient and sustainable energy future in developing countries.

2.3 Relationship of the Problem to SDG 9

Our device's functionalities align closely with Sustainable Development Goal 9, which focuses on building resilient and reliable infrastructure. By improving energy management, reducing losses, and predicting energy peaks, our device facilitates the efficient allocation of limited resources, contributing to economic growth and industrial development in developing countries. It promotes the development of robust infrastructures by providing better energy management solutions that expand energy access to a greater share of the population. Additionally, our device plays a crucial role in integrating renewable energy sources into the existing grid, ensuring a sustainable and clean energy supply. The smart energy solution management enabled by our device leads to inclusivity in various aspects of life, as access to energy has the potential to transform economies and societies in the underserved regions. Not only does it grant the right to access electricity, but it also enables access to transportation, economic activities, and education, driving significant social advancements. In this way, our device's impact extends beyond energy management, supporting the overall development and well-being of communities in developing countries.

Research

3.1 Preliminary research

The global energy landscape is characterized by significant disparities in access and consumption, with profound implications for sustainable development. According to data from Our World in Data, approximately 940 million people, constituting 13% of the world's population, still lack access to electricity (Hannah Ritchie, 2022). Moreover, per capita electricity and energy consumption exhibit substantial variations, exceeding 100-fold and 10-fold differences across different regions, respectively (Hannah Ritchie, 2022), energy access is closely intertwined with income levels, as poorer households are more likely to lack access to reliable and affordable energy sources (Our World in Data, n.d.). Over time, the geographical distribution of energy poverty has undergone a significant shift, with Sub-Saharan Africa now being home to nearly two-thirds of the global population without electricity access, compared to South Asia's previous predominance (Hannah Ritchie, 2022). These statistics underscore the urgent need to address energy inequality and work towards achieving universal access to sustainable and modern energy sources.

3.2 Liberia Case

A few years ago, Liberia was considered a country with little to no access to electricity. Nowadays, this started to change for good, but the country still has energy problems because due to a variety of different factors.

After sunset, Liberia's rural areas go dark. Life in Liberia is mainly from sunrise to sunset as a large part of the population has no access to the power grid provided by the government. As a consequence of its history among others, where once there were development and structures to help the country, now only shells remain. For Liberians, power outages are part of their daily lives if they have access to power, otherwise, the most common thing for people, especially in rural areas far from the big cities, is to carry out daily tasks by hand. What is nowadays considered obvious to do with a machine, they have to resort to other means.

Figure 1 - Impact of lack of access to electricity

According to the International Energy Agency, only about 12% of the population has access to electricity. This is due to a variety of factors, including the lack of energy infrastructure and the lack of financial and technical resources to build and maintain the existing infrastructure.

Some of the main drawbacks experienced in Liberia when accessing energy include:

- **Lack of access to electricity**
  Most of the population in Liberia does not have access to electricity. This makes it difficult to carry out day-to-day activities such as charging mobile phones, using electrical appliances and performing tasks after dark. Most of the people live their life from sunrise to sunset. They need to use manual processes to do the exact same things that other people do with machines, for example laundry.
- **Dependence on fossil fuel energy**
  In Liberia, most electricity is generated from fossil fuels, such as oil and diesel. This dependence on fossil fuels can result in high costs and greenhouse gas emissions.

- **Lack of energy infrastructure**

  The lack of energy infrastructure in Liberia is a major obstacle to energy access. Many rural areas of the country lack power lines, and the lack of roads and bridges can make transportation and installation of equipment difficult.

- **High energy costs**

  Energy in Liberia is expensive, especially for those who have access to electricity. This can be a challenge for people living in poverty who rely on energy to carry out their daily activities.

- **Frequent power outages**

  These are common in Liberia. This can make it difficult to plan and carry out activities, both at home and in business.

In summary, energy access is a major challenge in Liberia due to a variety of factors, including lack of energy infrastructure, dependence on fossil fuels and high energy costs.

Most of the country's energy, is from fossils, but it is of common knowledge that they have a huge potential for renewable energies, especially on hydroelectrical and solar energy. The goal of the country is to have a better access to this source in 2050, and according to WorldData.info *"Liberia can completely be self-sufficient with domestically produced energy."*

The information given continually is for having an idea of how much energy of the country comes from each source.

Energy source	total in Liberia	Percentage in Liberia	Percentage USA	per capita in Liberia	per capita USA
Fossil fuels	695.37 m kWh	40,5 %	59,9 %	133.89 kWh	2.06 kWh
Nuclear power	0.00 kWh	0,0 %	19,5 %	0.00 kWh	0.67 kWh
Solar energy	8.58 m kWh	0,5 %	3,2 %	1.65 kWh	0.11 kWh
Wind power	0.00 kWh	0,0 %	8,3 %	0.00 kWh	0.29 kWh
Water power	1.01 bn kWh	59,1 %	7,0 %	195.39 kWh	0.24 kWh
Tidal Power Plants	0.00 kWh	0,0 %	0,0 %	0.00 kWh	0.00 kWh
Geothermics	0.00 kWh	0,0 %	0,4 %	0.00 kWh	0.01 kWh
Biomass	0.00 kWh	0,0 %	1,7 %	0.00 kWh	0.06 kWh

Note: The sum of each data in this table adds up to 100.10 percent and may not be accurate. Worlddata.info receives this data from the US Office of Public Affairs (CIA) and will not make any presumptuous changes to it.

The given production capacities for electric energy have a theoretical value, which can only be obtained under ideal conditions. They are measuring the generatable amount of energy, that would be reached under permanent and full use of all capacities of all power plants.

After looking at the information, the most used by people are, fossil fuels but there are also people with access to solar and hydroelectrical. There are different NGOs like Lib.Solar[1] that help Liberians to access energy through transportable solar panels.

Figure 2 - Energy sources in use in Liberia

Figure 3 - Living conditions in the absence of electricity

Considering the difficulty of accessing the energy given by the government, these tools can help Liberians to keep up with some activities after sunset, for example, studying.

The problem with these tools is, what happened after the battery runs out? The rest of the population that does not have access to the public power grid relies on unreliable and inefficient energy sources, such as small petrol and diesel generators, firewood, charcoal, candles, paraffin, battery-powered LED lamps and lanterns, and palm oil. The solution needs to be improved for having a better life quality.

[1] https://www.lib.solar/

Figure 4 - Living conditions in the absence of electricity

Although they have a lot of potential for renewable energies, the energy generation and infrastructure inside the country is an issue that still needs to be cared for.

Since 2004, Liberia has been in a transitional phase, slowly rebuilding after a series of violent civil wars that, among other things, destroyed most of the country's power infrastructure. Before the conflict, they relied mainly on the Monrovia distribution network, which at 180 megawatts (MW) accounted for 98% of all electricity and included three radial lines to neighbouring counties. In addition, 11 mini-grids (totalling 13 MW) supplied other county capitals.

The World Bank is one of several international partners working with the Government of Liberia and the national power company to restore electricity supply, with an emphasis on rural electrification that will help balance development beyond the capital of Monrovia.

The two main factors delaying energy access and the improvement of renewables inside the country are, infrastructure as we already mention, and energy management. For resuming the causes of it, the factors are:

- **Outdated electricity infrastructure**

  Much of Liberia's energy infrastructure is old and in disrepair due to years of civil war and lack of investment in infrastructure.

- **Lack of transmission and distribution of infrastructure**

  Liberia's power transmission and distribution network is limited and does not reach all areas of the country, leaving many communities without access to electricity.

- **Low level of electrification**

  According to the International Energy Agency, only 9% of Liberia's population had access to energy in 2019, limiting the country's economic development.

- **Power sector management problems**

  Power sector management is weak due to lack of regulation and corruption, which has hindered investment in the sector and the improvement of electricity infrastructure.

- **Dependence on fossil fuels**

  They rely heavily on imported fossil fuels to generate electricity, so electricity is expensive and unsustainable in the long term.

Even though there are many things to improve and to take care of, there are organizations that are involved to make a difference. In these moments there is a project going on that will give energy access to more people across the country. The name of the project is, West Africa Power Pool Project, better known as **WAPP**[2], a big scale project of infrastructure that will connect the countries of west Africa.

Led by the Economic Community of West African States (ECOWAS) the World Bank as an investor, help to improve power generation and distribution in the West African region. The project aims to increase power generation capacity, build and upgrade power transmission and distribution infrastructure and improve power sector management in ECOWAS member countries.

[2] https://www.ecowapp.org/

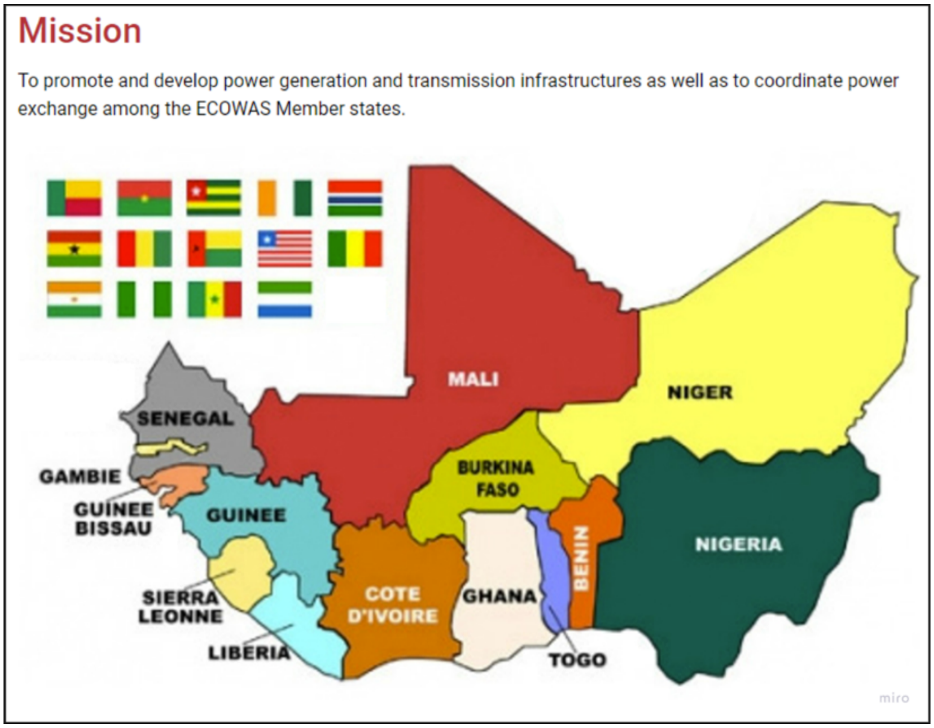


Figure 5 - ECOWAS Counties Map

ECOWASS has many members, but the project being developed in Liberia, is only with neighboring countries.

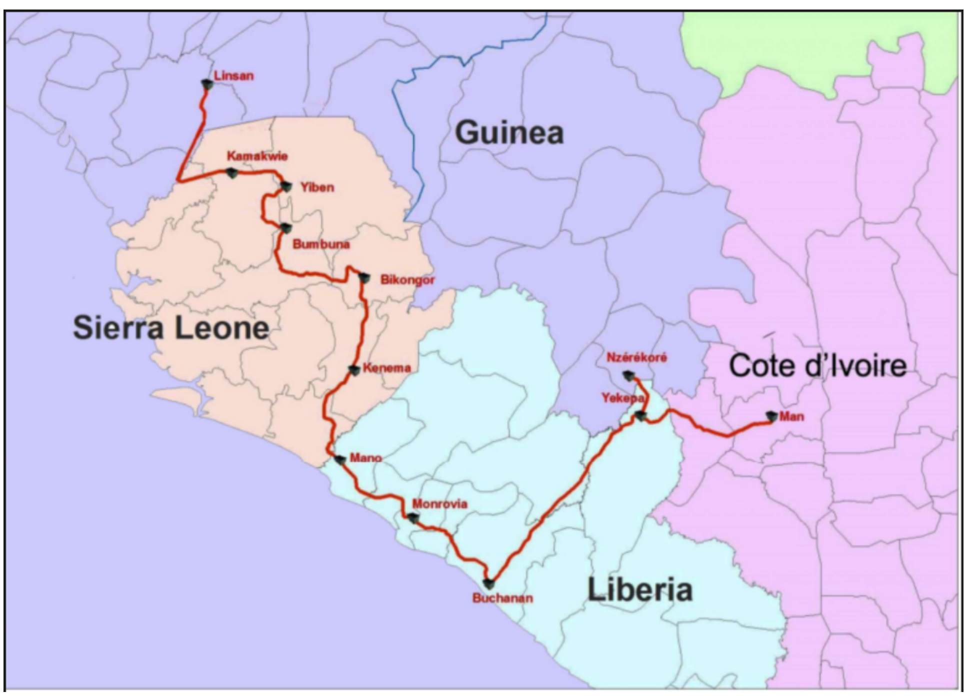


Figure 6 - WAPP Project's Infrastructure Plan

The goal of this project is to provide modern and reliable energy infrastructure through the creation of a high-voltage transmission network across the West African region, thereby improving access to electricity and supporting economic development in the region. The power transmission network will connect power plants and substations throughout the West African region, including Liberia. From the substations, power will be distributed to urban and rural areas through distribution lines.

It is divided in three phases:

1. The construction of high-voltage transmission lines and substations in the member countries.
2. The construction of additional transmission lines and the improvement of electricity sector management.
3. The construction of new power plants and the promotion of the use of renewable energy sources in the region.

The first phase inside Liberia had already started, and the high voltage transition crosses important parts of the country as the capital but also it is strategically located to continue the connection to other countries.

Figure 7 - Infrastructure distribution based on population density

From one side, in urban areas, power will be distributed mainly through the existing distribution network, which is already in operation in many Liberian cities. In these areas, power is expected to reach homes and businesses through the existing distribution network and the future improves the project will make on.

On the other side, in rural areas, the distribution of electricity can be more challenging due to the lack of existing infrastructure. To overcome this challenge, additional distribution lines will be constructed to reach rural areas. These distribution lines can be more costly to construct due to geographical conditions and lack of existing infrastructure, so innovative solutions are being explored, such as the use of renewable energy technologies, such as solar and mini-hydro, which can be more economical and easier to implement in rural areas considering the potential of the country for renewable energies.

"This post-conflict environment provides an opportunity for a fresh start and an opportunity for Liberia to lead in the development of rural renewable energy in West Africa," said Augustus Goanue, head of Liberia's Rural and Renewable Energy Agency (RREA).

In summary, the distribution of electricity to urban and rural areas of Liberia will be carried out through the transmission and distribution network to be constructed as part of the WAPP project and is expected to reach homes and businesses through the existing distribution network in urban areas and through additional distribution lines in rural areas.

3.3 Global Energy Crisis

The global energy crisis is a complex and multifaceted challenge that poses significant obstacles to achieving universal access to sustainable and modern energy. Despite notable progress in expanding energy access, an estimated 660 million people are projected to still lack access to electricity by 2030, with the majority concentrated in Sub-Saharan Africa (Bank, Report: Universal Access to Sustainable Energy Will Remain Elusive Without Addressing Inequalities., 2021)This highlights the urgent need to address the disparities in energy access and ensure affordable, reliable, sustainable, and modern energy for all, as outlined in Goal 7 of the Sustainable Development Goals (Nations, n.d.)

A report by the World Bank emphasizes that universal access to sustainable energy will remain elusive unless inequalities are addressed (World Bank, 2021). It highlights the persisting challenges faced by Sub-Saharan Africa, where a significant portion of the population lacks access to electricity. In fact, as of 2020, the top 20 least-electrified countries in the world were all located in Africa (Statista, 2020). While the global number of people without electricity has decreased substantially in the past two decades, progress in Sub-Saharan Africa has been relatively stagnant, accounting for approximately eight out of every ten people without electricity in 2021 (Statista, 2020).

The World Energy Transitions Outlook 2022, published by the International Renewable Energy Agency (IRENA), sheds light on several factors contributing to the global energy crisis (IRENA, 2022). The current centralized energy system heavily dependent on fossil fuels not only imposes a high economic cost but also exacerbates the impacts of human-caused climate change. The report estimates that approximately 3.3 to 3.6 billion people are already living in highly vulnerable settings due to climate change (IRENA, 2022). To mitigate these challenges, a comprehensive energy transition is necessary.

Moreover, the global energy crisis has been exacerbated by the aftermath of the COVID-19 pandemic. The rapid post-pandemic economic rebound outpaced the energy supply, leading to shortages and increased prices in oil, gas, and electricity markets worldwide (IEA, n.d.). This crisis was further intensified by the 2022 Russian invasion of Ukraine, which disrupted energy supplies and added strain to global energy markets (IEA, n.d.). These events highlight the vulnerabilities of the global energy system and the need for robust and resilient energy infrastructure.

Addressing the global energy crisis requires concerted efforts and transformative actions. Overhauling policies, fiscal regimes, and energy sector structures that impede progress is crucial to driving the necessary energy transition (IRENA, 2022). The report highlights the untapped potential for renewable energy sources to reduce dependence on fossil fuels and mitigate climate change risks (IRENA, 2022). Renewable energy, particularly solar and wind technologies, has become the cheapest option in most regions and dominates current investments in the power sector (IRENA, 2022).

Furthermore, the global energy crisis presents an opportunity to prioritize sustainable development and bridge the energy access gap. Investing in renewable energy infrastructure can help alleviate energy import dependence for many countries, stimulate economic growth, and create employment opportunities (IRENA, 2022). It is crucial to ensure that the energy transition is inclusive and benefits all segments of society, including marginalized communities and regions that have historically faced energy poverty and lack of access.

In the context of Africa's energy transition, it is important to highlight the significant potential for renewable energy sources across the continent. North Africa, in particular, has been leading the way in renewable energy developments, with countries like Egypt making substantial investments in this sector. Sub-Saharan Africa, on the other hand, boasts immense potential for solar, wind, hydropower, and geothermal energy sources (World Energy Council, 2022). However, the continent faces the challenge of balancing energy security, environmental sustainability, and energy affordability, as highlighted by The World Energy Trilemma Index 2022 released by the World Energy Council. The index ranks several African countries, including Zimbabwe, Mozambique, Malawi, Chad, and the Democratic Republic of the Congo, in the bottom 10 nations in terms of their ability to address these aspects of the energy transition. In contrast, countries like Sweden, Denmark, and Switzerland lead the ranking with their strong energy policies focused on decarbonization, access, affordability, environmental sustainability, and diverse energy sources (World Energy Council, 2022).

While some progress has been made in Africa's energy transition, there is still a significant gap in energy equity. According to the Africa Energy Outlook 2022 report by the International Energy Agency (IEA), 43% of the continent's population still lacks access to electricity, compared to only 13% globally (IEA, 2022). Sub-Saharan Africa accounts for the majority of people without electricity access, with the percentage rising from 74% to 77% after the pandemic (IEA, 2022). Although countries like Kenya, Ethiopia, Nigeria, and Tanzania have shown improvement in recent years, addressing the energy access gap remains a pressing challenge.

3.4 Importance of AI in Addressing the Problem

In the context of addressing the challenges in energy generation and transmission, the role of artificial intelligence (AI) cannot be overstated. AI presents a promising avenue for developing innovative solutions that can optimize energy distribution, improve efficiency, and ensure sustainable development. By leveraging AI technologies, we can gain valuable insights from data, enable predictive analysis, and enhance decision-making processes.

3.4.1. Data-Driven Insights

AI enables the collection and analysis of vast amounts of data related to energy consumption, infrastructure, and environmental factors. Through advanced data analytics techniques, AI can identify patterns, trends, and anomalies that may not be apparent through traditional methods. This data-driven approach provides valuable insights into energy usage patterns, identifies inefficiencies, and helps in understanding the complex dynamics of energy generation and transmission.

3.4.2. Predictive Analysis and Planning

One of the significant advantages of AI is its ability to perform predictive analysis based on historical data and real-time inputs. By applying machine learning algorithms to energy consumption data, AI systems can forecast future energy demands and identify potential challenges or bottlenecks in the energy supply chain. This predictive capability allows for proactive planning, efficient resource allocation, and effective management of energy generation and distribution networks.

3.4.3. Optimization and Efficiency

AI algorithms can optimize energy distribution by dynamically adjusting energy flows based on real-time demand and supply conditions. By continuously monitoring energy consumption patterns, AI systems can identify opportunities for optimizing energy usage, reducing wastage, and improving overall efficiency. This includes optimizing power transmission lines, prioritizing essential services during shortages, and integrating renewable energy sources to maximize their utilization.

3.4.4. Intelligent Decision Support

The complexity of energy generation and transmission requires sophisticated decision-making processes. AI systems can provide intelligent decision support by analyzing multiple factors, considering diverse variables, and simulating different scenarios. This helps in making informed decisions regarding energy allocation, infrastructure investments, and policy interventions. AI-powered decision support systems can also consider social, economic, and environmental factors to ensure equitable and sustainable energy distribution.

3.4.5. Continuous Learning and Adaptation

AI systems have the ability to continuously learn and adapt based on new data and changing conditions. This allows for ongoing optimization and improvement of energy generation and transmission processes. As the system collects more data and learns from real-world feedback, it can refine its algorithms, enhance predictive capabilities, and adapt to emerging trends and challenges in the energy sector.

Design Process

4.1 Methodology

The design process followed a collaborative approach involving research, brainstorming sessions, idea voting, and in-depth problem analysis. Research on SDG 9 and related terms was conducted, followed by a brainstorming session to generate ideas for different subsections of SDG 9. The ideas were voted upon, and the most promising ones were selected for further exploration. The selected problems were then analyzed in detail to identify key issues and propose AI-based solutions.

4.2 Previous steps

4.2.1 Research on SDG 9

To gain a comprehensive understanding of SDG 9, extensive online research was conducted. The research focused on the objectives, targets, and indicators of SDG 9, as well as the associated challenges and opportunities. This research formed the foundation for the subsequent design process.

4.2.2 Defining Important Terms

To ensure clarity and a shared understanding, important terms related to infrastructure, industries, innovation, and information technology were defined. This step helped establish a common vocabulary for the design process and facilitated effective communication among team members.

4.3 Brainstorming Session

The brainstorming session was conducted to generate ideas that aligned with the different subsections of SDG 9, specifically targeting **9.1** (Infrastructure Enhancement), **9.4** (Sustainable Industrialization), and **9.C** (Innovation and Infrastructure).

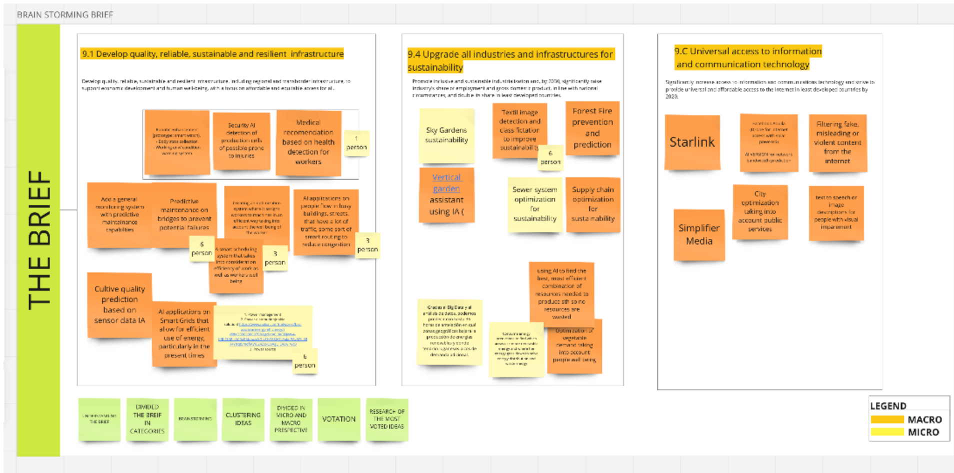


Figure 8. The first Brainstorm session board

4.3.1 Ideas for SDG 9.1- Infrastructure Enhancement

During the brainstorming session, several ideas were proposed to enhance infrastructure. These ideas included robotic enhancement, medical recommendations, bridge failure prediction, traffic/people flow optimization, and the implementation of smart grids.

4.3.2 Ideas for SDG 9.4- Sustainable Industrialization

Ideas related to sustainable industrialization were discussed, focusing on vertical gardens, advanced sewer systems, prevention of forest fires, optimized supply chains, efficient waste management, and sustainable farming practices.

4.3.3 Ideas for SDG 9.C- Innovation and Infrastructure

In the context of innovation and infrastructure, ideas such as deep fakes detection, Starlink satellite network, enhanced public services through AI, and content moderation solutions were proposed during the brainstorming session.

4.3.4 Voting and Selection Process

After the brainstorming session, the ideas were evaluated, and a voting process was conducted to select the most promising ones. Following the vote, the main ideas that emerged were bridge failure prediction (utilizing predictive AI), power generation and distribution optimization, sustainability issues in the fashion industry, and predictive maintenance for various sectors.

4.3.5 Problem 1: Energy Generation and Transmission

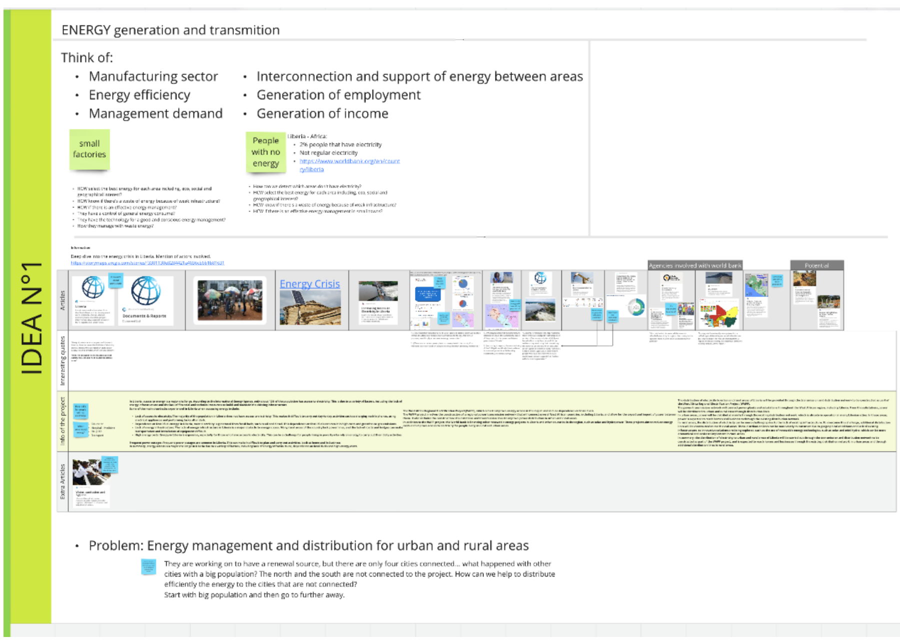


Figure 9. Initial research board

Key Issues

The selected problem of energy generation and transmission highlighted several key issues. These included energy inefficiency in the manufacturing sector, the challenge of managing energy demand, the lack of knowledge regarding optimal energy sources based on ecological, social, and geographical factors, inefficient energy management resulting from weak infrastructure, and the presence of waste energy.

AI-Based Solutions

To address these key issues, AI-based solutions were proposed. These solutions involved advanced analytics for energy efficiency, demand forecasting and optimization, intelligent energy source selection, predictive maintenance for infrastructure, and real-time monitoring of energy consumption. These AI-based solutions aim to improve energy management, reduce waste, and enhance the overall efficiency and sustainability of energy generation and transmission systems.

Relevance to SDG 9

The proposed AI-based solutions for energy generation and transmission align with SDG 9's objective of building resilient infrastructure and promoting sustainable industrialization. By optimizing energy efficiency, reducing waste, and enabling effective energy management, these solutions contribute to the development of sustainable and resilient energy systems. Additionally, the implementation of these solutions can lead to improved interconnection between areas, generate employment opportunities, and stimulate economic growth.

4.3.6 Problem 2: Textile Image Detection and Classification for Sustainability

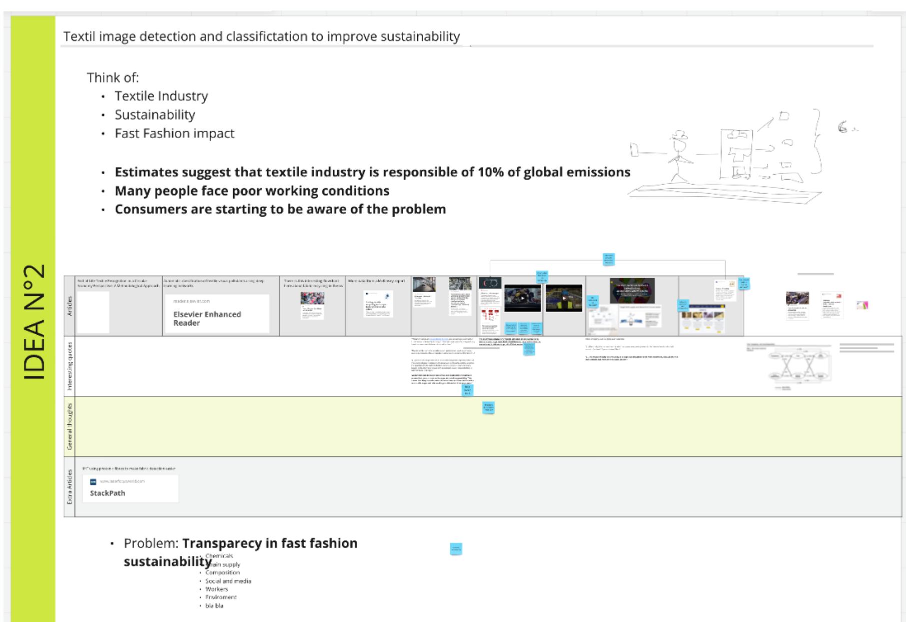


Figure 10 - Textile Imagine Detection Idea Board

Key Issues

The problem of sustainability in the fashion industry was identified as an important challenge within SDG 9. Key issues included the lack of transparency in fast fashion supply chains, concerns regarding chemical usage, the social and environmental impact of textile production, and the need for improved working conditions for industry workers.

AI-Based Solutions

AI-based solutions were proposed to address these challenges. These solutions focused on textile image detection and classification to enhance sustainability. By utilizing computer vision and machine learning algorithms, these solutions aim to identify and assess various aspects of textile production, such as chemical composition, supply chain transparency, worker conditions, and environmental impact. This technology can enable consumers to make informed choices and encourage sustainable practices within the fashion industry.

Relevance to SDG 9

The proposed AI-based solutions for textile sustainability align with SDG 9's objective of promoting sustainable industrialization. By improving transparency, reducing chemical usage, and ensuring better working conditions, these solutions contribute to the development of a more sustainable and ethical fashion industry. They also support the goal of fostering innovation in the textile sector to create more sustainable production and consumption patterns.

4.3.7 Problem 3: Predictive Maintenance for Efficiency and Security

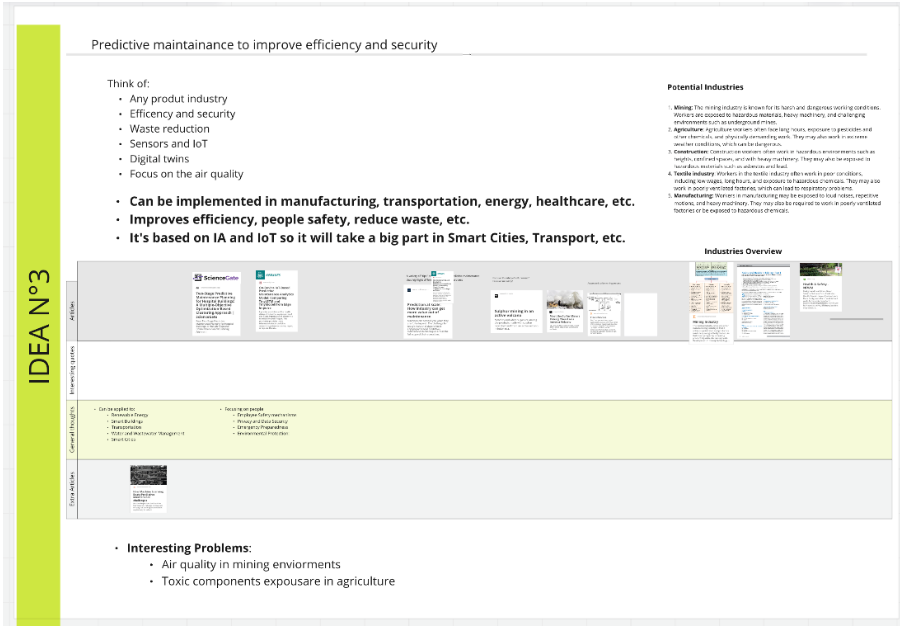


Figure 11 - Predictive Maintenance Idea Board

Key Issues

The problem of predictive maintenance was identified as a crucial issue for various industries, including manufacturing, transportation, energy, healthcare, and more. Key issues included efficiency and security concerns, waste reduction, the need for real-time monitoring, and the impact of equipment failure on productivity and safety.

AI-Based Solutions

AI-based solutions were proposed to address these challenges through predictive maintenance. By leveraging AI algorithms, sensor data, and Internet of Things (IoT) technology, these solutions enable the early detection of equipment failures, facilitate proactive maintenance scheduling, optimize resource allocation, and enhance operational efficiency. This approach reduces downtime, improves safety, and minimizes waste in diverse industrial settings.

Relevance to SDG 9

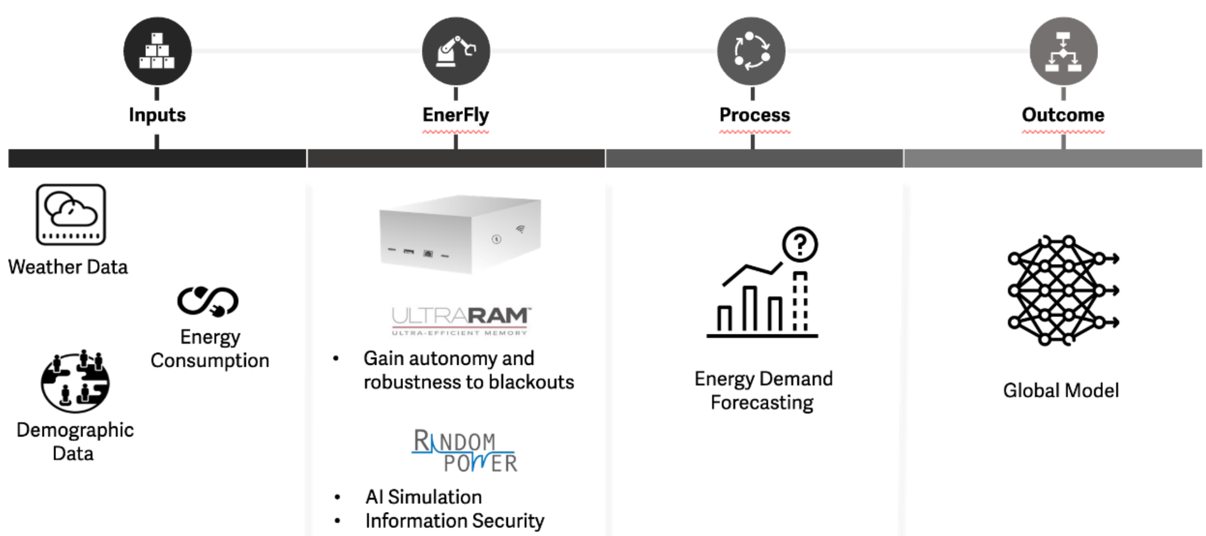
The proposed AI-based solutions for predictive maintenance align with SDG 9's objective of building resilient infrastructure and fostering innovation. By implementing predictive maintenance strategies, industries can improve operational efficiency, reduce waste, ensure worker safety, and extend the lifespan of critical infrastructure. This contributes to the overall resilience and sustainability of industries, aligning with the goals of SDG 9.

The Solution

5.1 Conceptual Solution

To address the challenges of energy generation and transmission, a conceptual solution based on a tree-like network of connected IoT devices with federated learning capabilities is proposed. This solution aims to make energy distribution more efficient by leveraging advanced data collection, learning, and optimization techniques.

5.1.1 Idea explanation



Each device within the network uses data on energy consumption, weather and demographic indicators to learn and understand the energy consumption patterns at its specific location. By continuously monitoring consumption and learning from it, the devices are able to compute local models that forecast energy demand. This real-time local model based on actual consumption patterns leads to more efficient utilization of the available energy in each local station.

Each local station has available a local model that is eventually shared to the energy providers and they are able to get insights about each station and also merge all local models into a global one which could be able to represent better the overall situation leading to a more effective energy management through federated learning.

This solution is particularly enhanced with the help of the ATTRACT technologies UltraRAM and Random Power:

- UltraRAM technology improves energy autonomy and minimizes the loss of information in the event of blackouts, ensuring data integrity and system resilience.
- RandomPower technology could help to improve AI simulations and help to secure models with robust encryption.

The solution not only supports for a better energy distribution but also enables them to perform predictive analysis and anticipate potential energy shortages or excesses in advance. By having this foresight, the system can optimize energy distribution accordingly and take proactive measures to balance supply and demand.

5.1.2 Liberia framework

Liberia is particularly a good fit for our solution since presents resource and infrastructure limitations. This include having a fragmented power grid, poor/none network connectivity, distributed population in small towns and poor energy supply with a large number of blackouts.

The key on why the solution could help Liberia is that first each substation/town could have our device and take advantage of it having a forecast of the consumption. Moreover, the energy distributers could have at some point the information of the situation in each substation by getting the local model.

It is main important to highlight that obtaining the local model of each substation could be done at any time without any need of network connection. For example: A person could go with a USB to each substation, get the local model through a USB and go to the capital (Monrovia) to share the model with the energy providers so they can get insights on energy demand and also do the model aggregation process. The person could return to his town with the global model to also update the local one to include global information.

This example on Liberia is a working example of our solution that works without network infrastructure. However, this solution could be also implemented in any country and the models could be shared through the network unlocking many opportunities:

Equitable Energy Distribution

The conceptual solution prioritizes fair and efficient energy distribution to end users based on their consumption levels. By considering the consumption data from each device, the system can allocate energy resources proportionally. In cases where there is insufficient energy production, the system dynamically adjusts the distribution, giving priority to essential services such as hospitals while maintaining a balanced distribution among other users. This equitable approach ensures that energy resources are utilized efficiently and in a manner that meets the needs of all users.

Optimization of Power Transmission

Addressing the issue of power loss during transmission is crucial for energy efficiency. The conceptual solution incorporates optimization techniques inspired by the Traveling Salesman Problem (TSP) to minimize energy losses in power transmission lines. By optimizing the routes and configurations of the transmission lines, the system maximizes the efficiency of energy transmission from the source to the destination. This optimization process reduces wastage and ensures that the maximum amount of energy reaches its intended recipients.

Integration of Renewable Energy

Recognizing the importance of renewable energy sources, the proposed solution supports the integration of technologies such as solar panels. In areas where renewable energy production exceeds local consumption, the system intelligently distributes the surplus energy to nearby towns using the connected devices and learned models. This capability facilitates the efficient utilization of renewable energy resources and minimizes wastage.

Fair Energy trading

Perhaps, one of the most interesting applications can be found in the energy market. As more sources of energy enter the market, more data is generated and there are more players involved. If data is not properly protected, then different players in the market could use it to manipulate the system in their favour. The most prominent example in this case is the Energy Crisis in California, from 2000 to 2001. During this period, California transitioned from a monopolistic energy market to a more liberal one allowing free trade of energy between various participants. It was an effort well praised, yet shortly after the energy prices skyrocketed, and the state started experiencing rolling blackouts. Enron, one of the biggest energy companies, used their knowledge of the newly designed system to submit fraudulent information about energy demand and supply, as well as entered undisclosed partnerships that gave them access to energy scheduling and physical infrastructure. All this allowed them to inflate or deflate energy prices to their advantage. (Nix et al., 2021) Enron's market manipulation remains one of the biggest scandals in the energy industry.

Looking at Liberia's fractured infrastructure, developing economy, and developing regulations and legislations in infrastructure such information security that ensure fair trading is essential. As Liberia looks to invest in its renewable energy sources, it will be more important than ever that the energy consumption data are properly encrypted in order to prevent individual or institutional players in the market to benefit from information asymmetry.

Polices and Research

Well-protected data could also help research in the field of energy and set the foundation for better policies and regulations. By using random numbers to better protect energy consumption data we are increasing the amount of data available for research, but not only, as information is well protected and it complies with regulations in place. Enerfly could allow for a higher volume of data, with a greater granularity that could enable more in-depth research into energy consumption patterns, grid management, or efficient distribution of energy. Deeper research into the field could aid in the detection of energy gaps, integration of renewable energy resources, and improvement of current energy management processes solutions. Policymakers can also draw insights from concrete data to draft more evidence-based policies that support a more sustainable and efficient use of energy.

5.2 Prototype

5.2.1 Physical prototype

Figure 12 - Enerfly Prototype

Product Specification

Material	Aluminium
Size	200mm x 125mm x 75mm
Ports	1x USB 3.0 | 1x USB Type-C | 1x Ethernet
Components	UltraRAM | Computational Unit | RandomPower | TF card slot | Bluetooth

Our prototype, EnerflyNode, will be a universal solution for not only the sub-developed country but also the well-developed country.

Connectivity

The connectivity is a key aspect of our prototype, we include a built-in Wi-Fi or module and also an Ethernet port to provide reliable network connectivity. With seamless integration into existing Wi-Fi networks, this device enables effortless communication and data transfer. This allows us to communicate and update our local within nodes and also to communicate with the main model located at the central.

As not all the country has availability of internet, specifically for the undeveloped country, we will provide the option to update via tf card, usb port, and also Bluetooth to provide a wireless connection, in that way, we can download and upload the model to the EnerflyNode to update the model following the Federated learning methodology, so they can manually update this information.

Running code seamlessly is another important requirement for the device. We include a Raspberry Pi-like computation unit, it provides a versatile and flexible platform for executing scripts such as Python scripts and applications.

Privacy (Data integrity)

Data integrity is crucial, and our prototype is designed to withstand power blackouts without compromising your valuable information. Its resilient architecture and power backup mechanism ensure uninterrupted operation during unexpected power disruptions. So, we include the RandomPower for enhancing our model and for privacy, so that we can secure the integrity of the consumption information, that only the authorized authority has access to it. We also include UltraRAM as this technology provides Non-Volatile memory storage and low power consumption, which is perfect for our device.

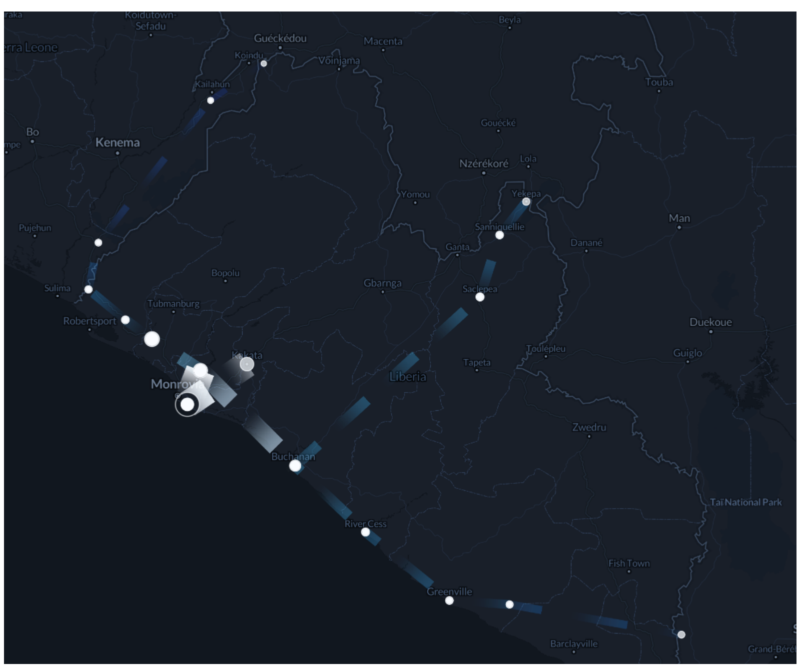
Durability

Finally, to ensure durability and longevity, our prototype is built with corrosion-resistant materials. The use of high-quality aluminium enhances the device's resilience against corrosive elements, making it suitable for various environments, including industrial and outdoor settings. Additionally, aluminium construction offers excellent thermal conductivity, efficiently dissipating heat generated during operation, thereby enhancing performance and maintaining optimal temperature conditions.

5.2.2 Simulation

To better illustrate the capabilities of our solution, we have developed a simulation featuring three predefined scenes, using Liberia as an example. Liberia has an ongoing optimization plan, and we have utilized real data to design this simulation, aligning it with the country's specific context. In the simulation, each dot represents a city, including the location where our device will be installed: inside the nearest control system of the substation to the city. This strategic placement allows us to access consumption data effectively. In the case of Liberia, the main model will be installed in Monrovia, where the energy is produced.

First Scene



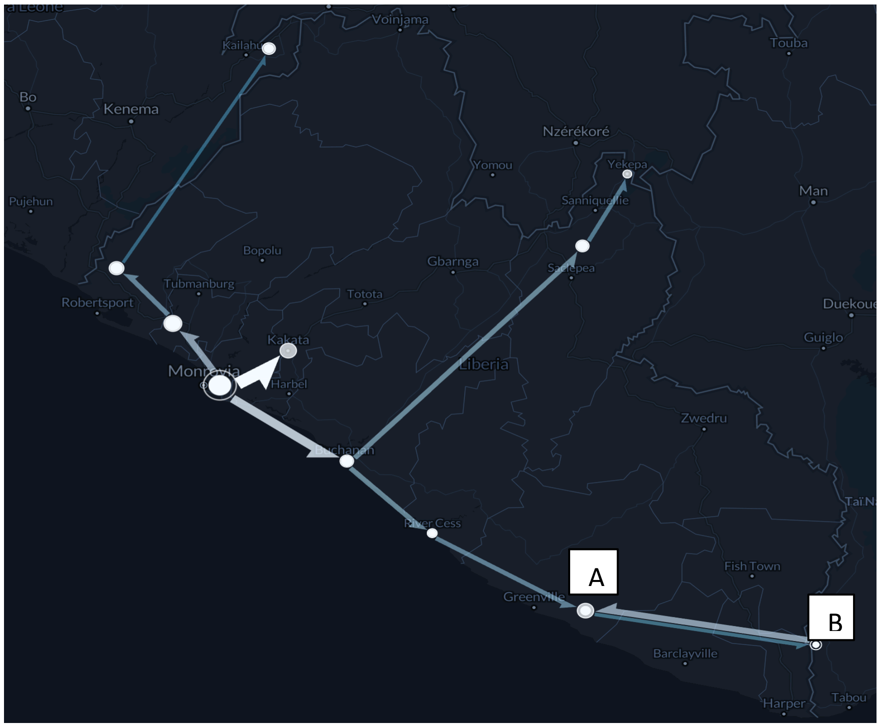
In the first scene of the simulation, when an adequate power supply is available from Monrovia, the generated electricity is distributed to other cities. As each city consumes a portion of the energy, our devices measure and record this consumption data. Utilizing this information, the devices update their local models and establish communication with other nodes, including the central node in Monrovia, to update the global model.

Second Scene

In the second scene of the simulation, our solution goes beyond data collection. Leveraging the collected data and local models, our system utilizes predictive analytics to forecast periods of power shortage and peak power consumption. This predictive capability allows for proactive measures to be taken to balance supply and demand effectively. In cases where there is insufficient energy production to meet the demand, the system dynamically adjusts the distribution of available energy resources.

By utilizing both the local models and the global model, our system optimizes energy distribution accordingly. It prioritizes essential services, such as hospitals, ensuring they receive adequate power supply even during periods of shortage. Simultaneously, the system strives to maintain a balanced distribution of energy among other users, taking into account their specific needs and requirements.

Third Scene



In the final scene of the simulation, we showcase another capability of our system. As mentioned earlier, while our system measures, predicts, and prevents power shortages, it also has the potential to optimize power distribution. Although Liberia has not yet implemented renewable energy sources in the current phase, future plans include the installation of renewable energy infrastructure.

In this scene, we simulate the scenario where renewable energy generation is introduced in City B. Our predictive models forecast that City B will produce more energy than it consumes within a 24-hour period. Leveraging this information, our system dynamically adjusts the energy distribution strategy. Instead of routing energy from City A to City B, our system identifies the optimized route to distribute the surplus energy generated in City B to the nearest cities.

This optimization challenge can be framed as a Traveling Salesman Problem (TSP), where the objective is to find the most efficient route to minimize energy distribution costs while ensuring energy reaches the intended destinations. By effectively solving this TSP problem, our system optimizes the energy distribution process, maximizing the utilization of renewable energy resources and minimizing energy losses during transmission.

5.3 Challenges and Limitations

The potential of the project and its scalability are intriguing. One of the main challenges that EnerFly will face is integrating with the available technology and infrastructure in the country. The ideal approach is to utilize WIFI, but the reality is that this system may not be applicable in countries like Liberia due to their current infrastructure. This implies that alternative solutions need to be explored, which may potentially hinder the optimal effectiveness of the proposed solution.

As a result, in such cases, it was decided to work with a Lora module or alternatively have an operator handle the data collection. In the event that the latter is implemented, it will be necessary to extensively train artificial intelligence to learn how to anticipate possible future issues in electricity distribution. It is always crucial to consider that the initial objective is to provide energy to key locations in the country that truly need it, such as hospitals.

A Lora module is a wireless communication device that uses Lora WAN (Long Range Wide Area Network) technology. It allows data transmission over long distances with low power consumption. Lora modules are used for various applications like remote monitoring, asset tracking, and environmental sensing. They offer the benefits of long-range communication, energy efficiency, and the ability to operate in areas with limited infrastructure. In summary, Lora modules enable long-distance wireless communication with low power consumption, making them suitable for the project application.

Another point to consider is the prevalence of energy theft in certain regions. For this reason, in the future, it could be considered as part of an improvement to the project itself. While the device will be protected against data theft through RandomPower technology, the same ease of protection does not apply to energy. A question for the future would be: What can be done with artificial intelligence to prevent energy theft? Determining the feasibility of this would require further research involving specialists in the field. However, it is important to take into account that energy theft could also impact consumption management.

Furthermore, it is crucial to consider how people will be notified about changes in their energy usage. If individuals do not have effective means of communication, it could pose a problem for household users. As the project will prioritize locations with urgent energy needs, such as hospitals or schools, communication methods can be implemented to facilitate timely and efficient personnel deployment if necessary. For domestic use, the most effective way to keep the population informed is by organizing consumption schedules. Here, artificial intelligence will play a significant role in processing real-time and spatial data on consumption peaks.

By keeping key consumption points informed and implementing specific consumption schedules that may vary by city or population level, energy can be managed more efficiently and equitably. Countries like Liberia could utilize consumption time slots to improve the economies of both rural and urban areas. However, it is important to acknowledge that while the ideal scenario is achieving sustainable and equitable energy consumption for the entire population, which helps redistribute energy waste, this is not the current reality in these countries. Therefore, as these countries develop, the most important priority up to now is to assist in prioritizing energy in key locations for the country and its inhabitants.

5.4 Conclusion and Recommendations

When confronted with the project's challenges and considering potential technologies for data collection, it became evident that EnerFly's range is determined by the chosen technology. Contributing to the country's development through projects like **WAPP** is crucial to fully capitalize on the proposal's potential.

This technological discrepancy raises the question: What if the proposal is implemented in other countries? After extensive deliberation with team members, the response is that it depends, but the project scalability is substantial. The potential exists, yet the scope hinges on the implementing country, its infrastructure, and the available technology.

Energy management, consumption, and waste are global concerns affecting various nations. Regulating them to improve efficiency is a worldwide interest. If we consider countries with comparable conditions to Liberia, others with similar characteristics can be found, particularly within the same continent.

Today, it is imperative to ensure equal opportunities and conditions for all. However, this does not imply that the proposal is exclusively applicable to such scenarios. EnerFly aims to enhance energy efficiency, and management, and potentially facilitate resource redistribution through cross-border connections. As a versatile tool, it can be employed in developed countries as well, offering even greater potential due to its advanced infrastructure. This would aid in improving energy consumption for those who view energy as an essential right. Notably, EnerFly can adapt to the regulations and network requirements of each specific country or system, promoting responsible consumption and distribution. Furthermore, it continuously learns from collected data to enhance its efficacy.

Reflection

These days, access to energy is considered obvious and normal. Thousands of people around the world use energy to go about their daily lives, and dependence on it is arguably self-evident. Even at this very moment, you, reading this report, are using various devices. But what if this is not the case for everyone, and are there places on the planet that do not have this same privilege? Unfortunately, the answer is yes, there are plenty of countries in the world that do not have this access. There are even countries that do not have the infrastructure and distribution of electricity and do not have the energy management that would allow them to solve consumption problems.

The continent with the biggest energy infrastructure problems is Africa. Due to different factors that vary from country to country, access to electricity is not available to all or is difficult to maintain.

However, the countries of this continent are not the only ones with this problem. There are other regions of the world that, despite being more developed, still have problems with energy distribution and infrastructure.

The question is, can anything be done to help improve their electricity management? We are aware that in order to be able to carry out energy management, you have to invest in infrastructure. That is why the search for investors is necessary. This can make the process of improving a territory take longer, but it does not mean that it should not be done. What would it be like to look back and see all that has been achieved?

In carrying out the project, we focused on helping to create a level playing field, starting with the people who needed it most, which is why the research started with a specific country in need of change.

Recent events, such as the war in Ukraine, have heightened the world's interest in the energy crisis. However, this is a long-standing problem for some regions. The only thing that has changed is that the people who use it on a daily basis realized that it was not a right, but a privilege.

Wouldn't it be amazing if we could all use this tool to improve our lives in a sustainable way that enables global collaboration? Could we, in an ideal future, contribute to sustainable and collaborative management through our technology?

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