UNIVERSIDAD PARA LA COOPERACION INTERNACIONAL
(UCI)

DEVELOPING A METHODOLOGY FOR MINI-GRID IMPLEMENTATION: A CASE STUDY OF THE 69.5KW PROJECT IN BELIZE

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DEDICATION

I dedicate this to my parents, who, against all odds, believed that I could achieve anything if I put in the effort, trusting that our Mighty God would fill in the gaps. They recognized the support I needed from a youthful age, and despite their demanding roles as the breadwinners, they were always available to provide it. I also dedicate this to my sister, who sharpened my speech. She was destined to be a teacher; one can reach anyone, whether typical or special. The mindset instilled in me was not about being the best, but about doing my best, and this was nurtured by the loving family with whom I grew up.

Lastly, I dedicate this to my wife. Throughout this stage of my life, she has been a constant source of support, encouraging me to complete this final work. Even in moments when we seemed distant, she never stopped supporting and encouraging me. I hope that if she ever chooses to further her studies, she will know that anything is possible with dedication and hard work.

ACKNOWLEDGMENTS

First, I want to thank the Almighty God for guiding me on this path to a higher education and for opening doors when I faced financial challenges. The God I serve, completes what he begins. Even in moments when I wanted to give up, God gave me the strength to continue.

I would like to express my gratitude to all my lecturers for sharing their knowledge with me throughout this program. A special thanks goes to my graduation seminar course facilitator and tutor, Ms. Paula Villalta, who guided me to the finish line of this program.

I cannot overlook the Energy Unit, under the Ministry of Public Utilities, Energy, Logistics & E-Governance, where I have served as an Energy Officer for over seven years. It was through my work at the Unit that I discovered my passion for project management. Although my undergraduate degree is in Electrical Engineering with a minor specialization in Power, I realized that the Energy Unit operates through diverse projects, each unique. More importantly, I had the privilege of working with various international and local stakeholders, such as Lait Up Belize, Latin American Energy Organization (OLADE), Belize Electricity Limited (BEL), Belize Telemedia Limited (BTL), and several line Ministries within the Government of Belize. These experiences confirmed that I am on the right path.

Lastly, I would like to acknowledge the University for International Cooperation (UCI) for equipping me with the knowledge and skills necessary for a successful career in project management. The University’s emphasis on green project management has set me apart from traditional project managers; I have no regrets in choosing to study at this esteemed institution.

ABSTRACT

This document presents the development of a methodology for the implementation of Solar PV mini-grid systems, focusing on a case study of the 69.5 kW project in Belize. The absence of standardized procedures in current project management has led to inefficiencies, delays, and satisfactory outcomes. To address these challenges, this project proposes a structured approach for executing, monitoring, and controlling mini-grid systems, with a particular emphasis on stakeholder engagement and resource efficiency.

The final product includes an assessment of the project management tools used by the Belize Energy Unit, informed by the experiences and feedback gathered from staff. This assessment identified existing gaps in practices, leading to the creation of a tailored project methodology that aligns current practices with the industry's best standards. While the primary approach utilized was a case study methodology, the project also benefited from analytical methodologies, complemented by guidance from the Project Management Institute.

The findings of this project conclude that there is a critical need for structured methodology, particularly given the pipeline of projects aimed at electrifying several rural communities with Solar PV mini-grid systems. The development of this methodology is essential to achieving these targets in the coming years.

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ABBREVIATIONS AND ACRONYMS

BEL	Belize Electricity Limited
BSIF	Belize Social Investment Fund
BTL	Belize Telemedia Limited
CDW	Cramer, Drews, and Willing (founders)
EU	European Union
FGP	Final Graduation Project
FPIC	Free Prior and informed consent
GOB	Government of Belize
GPM	Green Project Management
IEC	International Electrotechnical Commission
IPA	Indigenous People’s Affairs
IRENA	International Renewable Energy Agency
kW	Kilowatt
MiDH	Ministry of Infrastructure & Housing
MRT	Ministry of Rural Transformation
MS Project	Microsoft Project
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PV	Photovoltaic
RACI	Responsible, Accountable, Consulted, Informed
RBS	Risk Breakdown Structure
SDG	Sustainable Development Goal
SESB	Solar Energy Solutions Belize
SWOT	Strengths, Weaknesses, Opportunities, and Threats
UN	United Nations
WBS	Work Breakdown Structure

EXECUTIVE SUMMARY

Under the Ministry of Public Utilities, Energy, Logistics & E-Governance, the Belize Energy Unit has been working towards the United Nations (UN) 7th Sustainable Development Goal-affordable and clean energy for all. However, the Unit has faced significant challenges in achieving these objectives, primarily due to the lack of a structured methodology for managing Solar PV mini-grid projects. The problem identified was the inconsistency and inefficiency in current project implementation practices, which have led to delays and budget overruns, as seen in the Corazon Creek Village project. The project's justification lies in its potential to create a replicable framework that will enhance the efficiency of future mini-grid projects, ensuring they meet both environmental and social sustainability goals.

The general objective of this Final Graduation Project (FGP) was to develop a methodology that ensures consistent procedures and practices within the Belize Energy Unit for the implementing Solar PV mini-grid systems in remote areas, aiming to improve delivery time and ensure compliance with best practices and industry standards for reliable and sustainable electricity delivery. The specific objectives included the development of a template or checklist for project implementation, the creation of a stakeholder registry, the establishment of quality assurance procedures, the design of a detailed project schedule and milestones, and the implementation of risk management strategies.

The methodology involved a case study approach, using the ongoing 69.5kW Solar PV project to test and refine the proposed framework. enhance project management practices, reduce costs, and ensure successful project outcomes. This approach allowed for real-time validation and adjustments to ensure the methodology's effectiveness in addressing the identified challenges. While the primary methodology employed was a case study approach, an analytical methodology was also considered, along with guidance from the Project Management Institute.

The conclusions drawn from this study indicate that the proposed methodology can significantly improve project outcomes, reducing delays, and cost overruns while enhancing the reliability and sustainability of the energy systems. However, some non-favorable effects, such as potential resources overuse and stakeholder disengagement, were identified, and mitigation strategies were proposed.

Based on these findings, it is recommended that the Belize Energy Unit adopt this methodology for future projects, with ongoing monitoring and adjustments to address any emerging challenges. Additionally, further research is suggested to refine the methodology and expand its application to other renewable energy initiatives in Belize.

1 INTRODUCTION

1.1. Background

The implementation of renewable energy, Solar Photovoltaic (PV) mini-grid in rural areas has developed as a solution for addressing energy access challenges in regions where the conventional grid extension is not feasible. Thus, this Final Project (FGP) focuses on developing a methodology for implementing Solar PV mini-grids using a case study of a 69.5kW project in Belize.

The Belize Energy Unit, within the Ministry of Public Utilities, Energy, Logistics & E-Governance, was established to develop and implement energy policies that align with the country's sustainable development goals. Despite ongoing efforts, approximately 10% of Belize's population still lacks access to modern energy, particularly in the rural areas where extending the national grid is both economically and technically unfeasible. The government's 2023 National Energy Policy emphasizes the need to diversify energy sources and enhance rural electrification through innovative, sustainable solutions (Government of Belize, 2023).

Although the Belize Energy Unit has identified Solar PV mini grids as a strategic approach to providing reliable and clean energy to remote communities, there is currently no methodology for implementing these projects. Past projects in Belize have encountered challenges related to logistical complexities, lack of standardized procedures, and insufficient stakeholder engagement. These issues have often resulted in delays, budget overruns, and suboptimal performance of implemented systems. The nearly completed 69.5kW Solar PV mini-grid project will serve as a case study to analyze these issues and to develop a structured methodology that ensures the efficient execution and monitoring of similar projects. The methodology developed will be replicable across future projects, setting a precedent for effectively managing similar initiatives within the Belizean context. Therefore, this project represents a crucial step towards realizing the government's vision of universal energy access through sustainable means.

1.2. Statement of the problem

The Belize Energy Unit continues to face significant challenges in the implementation of Solar PV mini-grid systems in remote areas. A notable example is the Corazon Creek Village project in the Toledo District, a Mayan Communal Land, where any project requiring land must adhere to the principle of Free, Prior, and Informed Consent (FPIC). The FPIC process was completed in September 2023, allowing the project to proceed. However, a project initially expected to take seven months is still ongoing after more than 12 months. The delay primarily stems from the absence of a clear plan for initiating the project, such as a kick-start process.

The Corazon Creek Project highlights the broader issue faced by the Belize Energy Unit, which is the lack of a standardized methodology for planning, executing, and managing Solar PV mini-grid projects. The FPIC process, being new to the Belize Energy Unit, further complicated the project due to the absence of a structured approach. Continuing to deploy Solar PV mini grids without such a methodology, risks inefficiencies and potential project failures, which could undermine the government's efforts to enhance rural electrification and achieve its sustainable development goals.

There is an urgent need to develop a structured methodology to address these challenges by providing clear guidelines and standardized procedures for project implementation. The ongoing 69.5kW solar PV mini-grid project presents an opportunity to create such a methodology, improving project efficiency and effectiveness. Establishing this methodology while the project is still active, will set a precedent for future projects in Belize, enabling the Belize Energy Unit to better manage resources, engage stakeholders effectively, and contribute meaningfully to the goal of universal energy access.

1.3. Purpose

The Energy Unit is tasked with achieving the UN' 7th Sustainable Development Goal, which focuses on ensuring clean and affordable energy for all. Despite the global emphasis on renewable energy, Belize currently lacks a standardized methodology for managing mini-grid projects, leading to inconsistencies and difficulties in project execution. The purpose of this Final Graduation Project (FGP) is to develop a replicable methodology for the implementation of Solar PV mini-grid systems in Belize, using the 69.5kW project as a case study. This methodology will serve as a practical guide for the Belize Energy Unit and other stakeholders involved in rural electrification projects, addressing the existing challenges of inconsistency, inefficiency, and inadequate stakeholder engagement.

This project is driven by the critical need to enhance the effectiveness of renewable energy initiatives in Belize. By establishing a structured methodology, the study aims to ensure that Solar PV mini-grid projects are implemented in a way that maximizes their potential to provide reliable, sustainable, and cost-effective energy to remote communities. The expected benefits include improved project management practices within the Belize Energy Unit, reduced project delays, cost overruns, enhanced system performance and reliability, and increased stakeholder satisfaction through better engagement strategies. Ultimately, the successful implementation of this methodology will contribute to the national goal of achieving universal energy access and advancing sustainable development in Belize.

1.4. General objective

To develop a methodology that ensures consistent procedures and practices within the Belize Energy Unit for implementing Solar PV mini-grid systems in remote areas, aiming to improve delivery time and ensure compliance with best practices and industry standards for reliable and sustainable electricity delivery.

1.5. Specific objectives

1. Develop a template or checklist for mini-grid implementation projects to standardize processes and ensure project planning and execution.
2. Define the roles and responsibilities of stakeholders involved in the mini-grid implementation project to clarify accountability and enhance effective collaboration among project participants.
3. Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution.

4. Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines.
5. Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.

2 THEORETICAL FRAMEWORK

2.1 Company/Enterprise framework

2.1.1 Company/Enterprise background

The Belize Energy Unit, which operates under the Ministry of Public Utilities, Energy, Logistics & E-Governance, is structured around five key pillars: Energy Efficiency, Renewable Energy, Policy, Clean Energy, and Rural Electrification. This structure aligns with the 7th Sustainable Development Goal (SDG), “Affordable and Clean Energy.”

The Unit’s first pilot project for mini-grid was the La Gracia 24kW Smart Off-Grid System in the Cayo District, followed by the Indian Creek 400kW Hybrid Solar PV System in the Toledo District. While Solar PV technology has been established for some time, using it to power entire communities is a relatively new development in Belize. This approach has proven to be a viable solution for providing electricity to remote communities where extending the national grid is not economically feasible. In line with SDG 7 and the mandate to deliver renewable energy to all, Solar PV mini-grid systems have demonstrated their effectiveness and will be replicated in other rural communities. Currently, the Corazon Creek Village in the Toledo District is set to be energized with a 69.5kW capacity Solar PV system (Government of Belize, 2021).

2.1.2 Mission and vision statements

Energy Unit Mission: To plan, promote, and effectively manage the production, delivery, and use of energy through Energy Efficiency, Renewable Energy, and Cleaner Production interventions for the sustainable development of Belize (Government of Belize, 2023).

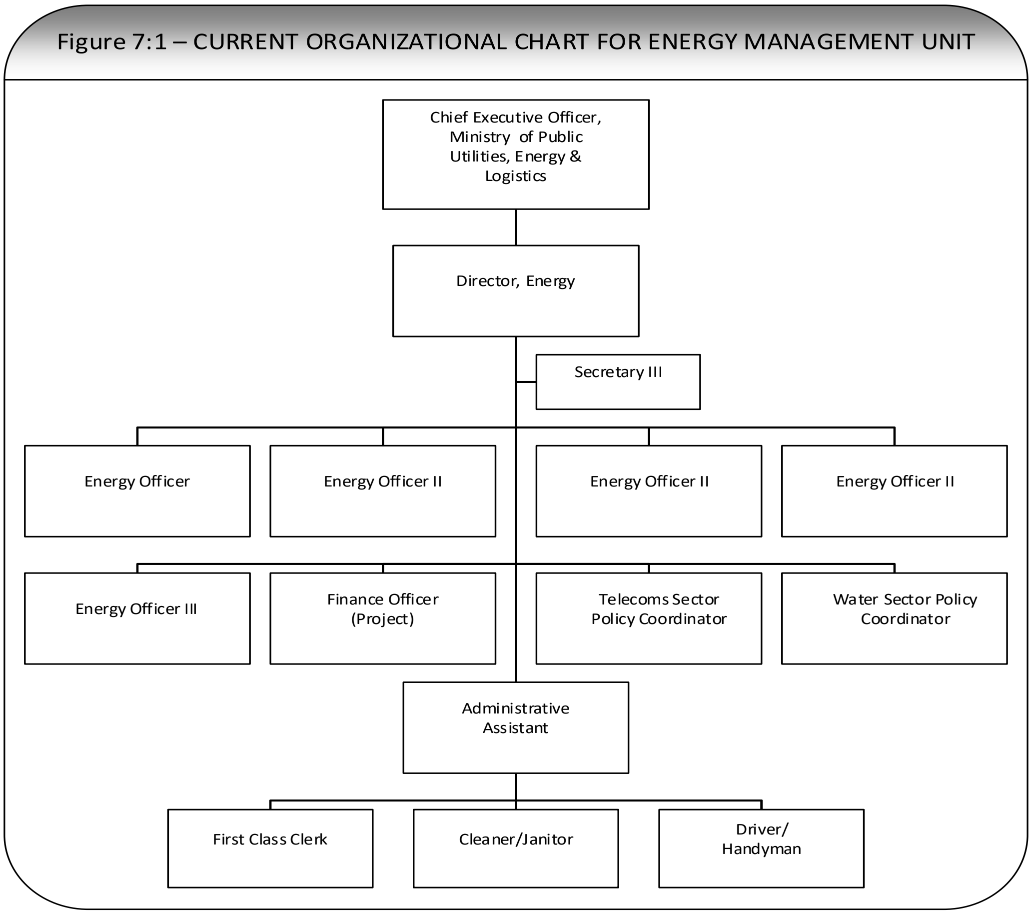
Energy Unit Vision: To improve the country's ability to effectively manage the energy sector, stimulate social and economic development through the energy sector and other cross-cutting sectors, and improve the sector's contribution to achieving Belize's Updated Nationally Determined Contributions (Government of Belize, 2023).

2.1.3 Organizational structure

The Energy Unit is relatively new within the Government of Belize, having been established under the 2011 Energy Policy. It is currently known as a Unit because of its initial formation, but ongoing work on the Energy Act aims to transform it into an Energy Department with an official government mandate. Consequently, the organizational structure is currently available only internally and not publicly, as not all positions are filled. Any work related to vacant positions is either left untouched or assigned to others within the existing structure.

At present, the energy Unit consists of 10 members, including the Chief Executive Officer. The current organizational structure, as shown in Figure 1 below, includes a total of 15 members. The Chief Executive Officer oversees the entire Ministry, including the Energy Unit. The Unit itself is led by the Energy Director (ED), who supervises all technical personnel including Energy Officers. The Energy Director is the immediate reporting supervisor for the technical personnel. If the Energy Director is unavailable, the most senior Energy Officer assumes responsibility. The structure is expected to evolve to improve organizational efficiency, with clearly defined roles and responsibilities.

Figure 1: Energy Unit Organizational Structure



Own Elaboration, Taken from Energy Unit Hierarchical Structure

2.1.4 Products Offered.

The Belize Energy Unit, as part of the Ministry of Public Utilities, Energy, Logistics & E-Governance, offers several key products aimed at enhancing energy access and sustainability in Belize. The main products offered by the Energy Unit include:

1. **Energy Efficiency Programs:** The Energy Unit develops and implements programs to improve energy efficiency across various sectors. These programs aim to reduce energy consumption and lower costs for consumers and businesses. The best practices from these programs will add to the support of the Final Graduation Project (FGP) to ensure that Solar PV mini grids are designed and operated efficiently.
2. **Renewable Energy Initiatives:** The Energy Unit promotes the adoption of renewable energy sources, mainly solar, as there is abundant sunlight in Belize. The FGP directly supports this initiative as it can help create a structured approach to deploying Solar PV mini grids, thereby expanding the use of renewable energy in remote areas.
3. **Policy Development and Advocacy:** The Energy Unit is involved in the formulation of energy policies that support sustainable development. This includes the creation of frameworks that facilitate the transition to clean energy. The FGP's objective of establishing a methodology for mini grids will provide a strategy to achieve the policy goals.
4. **Clean Energy Projects:** The Energy Unit undertakes various clean energy projects aimed at reducing greenhouse gas emissions and promoting sustainable energy practices. The FGP will contribute to these goals by providing a clean and reliable energy source to underserved communities.
5. **Rural Electrification:** One of the primary goals of the Energy Unit is to provide electricity to rural and remote areas that are not connected to the

national grid. The FGP’s focus on Solar PV mini-grids directly addresses this goal, offering a viable solution for rural electrification through sustainable means.

2.2 Project Management Concepts

This chapter lists the crucial project management concepts relevant to developing a methodology for implementing Solar PV mini-grid systems in remote areas. It includes project management principles, domains, project types, knowledge areas, the project life cycle, and their application to the Belize Energy Unit’s context.

According to the Project Management Institute’s (PMI) Guide to the Project Management Body of Knowledge (PMBOK Guide)-Seventh Edition, project management is a structured approach to managing and controlling projects to achieve specific objectives (PMI, 2021). The PMBOK Guide outlines the key principles and domains of project management, including stakeholder engagement, quality management, and risk management, which are important to ensuring the success of mini-grid projects.

In the context of the Belize Energy Unit, these principles can be adapted to manage the unique challenges of implementing Solar PV mini-grid systems in remote areas, for example, the project life cycle, as discussed by Kerner (2022) in Project Management: A systems Approach to Planning, Scheduling, and Controlling, provides a framework for planning, executing, and closing projects, which can be applied to the step-by-step development of mini-grid systems.

Moreover, Rose (2020) emphasizes the importance of quality management in project execution, especially in the context of renewable energy projects where maintaining high standards is critical. In his book, Project Quality Management: Why, What and How provides insights into establishing performance metrics and quality assurance procedures that align with international standards like those provided by the National Electrical Code Handbook, 14th edition by Mark W. Earley, P. E. (2017).

Lastly, sustainable project management practices, as stipulated by Carboni et al, (2018), are essential for the long-term success of Solar PV mini-grid systems. Their guide emphasizes the sustainability of project management by addressing socio-economic and environmental responsibility.

2.2.1 Project management principles

Project management principles provide the foundation for effectively managing projects. The following project management principles are essential for successful project execution. The Project Management Institute (PMI) listed 12 principles that can used to develop a methodology for implementing Solar PV mini-grid systems in remote areas within the Belize Energy Unit:

1. **Stewardship**: Be respectful and responsible.

   This can be applied by developing a code of ethics for the team to follow and highlighting the social responsibility and sustainability aspects in the execution of a project. Transparency and accountability are essential in any project activities.

2. **Team**: Create a collaborative project team environment.

This can be applied by creating communication channels and regular team meetings.

3. **Stakeholders:** To engage with stakeholders.

   To make this operational, the identification of all project stakeholders should be done in the early stage of the project and create a stakeholder engagement plan.

4. **Value**: It is essential in the delivery of value.

   The deliverables and project objectives should be defined to ensure alignment with the strategic goals of the Belize Energy Unit.

5. **Systems Thinking:** Recognize, elevate, and respect system interactions.

   One way to make this operational is by using complete project planning and execution.

6. **Leadership**: Demonstrate leadership behaviors.

   Promote leadership behaviors by providing training and resources for project leaders.

7. **Tailoring:** Tailor should be based on methodologies to the specific needs of a project.

   This can be done by modifying the project methodology to fit the specific aspects of Solar PV mini-grid projects.

8. **Quality:** To focus on quality management.

To create quality management that includes quality standards and metrics and conduct regular quality audits to ensure deliverables align with the required standards.

9. **Complexity**: Pilot complexity.

   Find sources of complexity in the project and develop action items to manage them.

10. **Risk:** Enhance risk responses.

    This can be done by implementing a risk management plan.

11. **Adaptability and Resilience**

    Foster a culture of continuous improvement.

12. **Change:** Enable change to achieve the envisioned future state

    The development of a change management plan is essential to manage project changes effectively.

2.2.2 Project management domains

The PMBOK Guide seventh edition (2021) describes several performance domains that are important for effective project management. They are interactive, interrelated, and interdependent areas of focus that work in unison to achieve project outcomes (PMI, 2021). There are eight domains, and each domain is relevant to the Final Graduation Project (FGP) as follows:

1. **Stakeholder Performance Domain:**

   This domain looks to interact with stakeholders, manage their expectations, and maintain their support throughout the project. For the

Solar PV mini-grid project, early identification, and continuous engagement of stakeholders, including community members, government officials, and suppliers will be important. A stakeholder management plan will be created to guarantee all stakeholder needs and concerns are addressed.

2. **Team Performance Domain:**

   This domain focuses on building and maintaining an effective project team and ensuring team performance. The methodology will include strategies for team formation, defining roles and responsibilities, and promoting effective communication within the team.

3. **Development Approach and Life Cycle Performance Domain:**

   This involves selecting and adapting the project life cycle and development approach that best fits the project context. The methodology will adopt a hybrid approach, combining predictive planning with adaptive execution to facilitate the unique challenges of remote Solar PV mini-grid projects. This will allow flexibility while maintaining control over scope, schedule, and quality.

4. **Planning Performance Domain:**

   This domain entails the requirements to develop a detailed plan that guides project execution and control.

5. **Project Work Performance Domain:**

This focuses on managing and performing the necessary work to reach project objectives, The methodology will highlight procedures for executing project tasks, monitoring progress, and adjustments, as necessary.

6. **Delivery Performance Domain:**

   To ensure that the project delivers the intended outcomes and benefits. The methodology will include measures to track and evaluate the performance of the Solar PV mini-grid systems, to ensure that they meet the defined objectives and deliver reliable and sustainable electricity to remote communities.

7. **Measurement Performance Domain:**

   This entails monitoring project performance and making necessary adjustments based on performance data, The key performance indicators (KPIs) and metrics will be established to monitor project progress and performance.

8. **Uncertainty Performance Domain**

   This looks at the uncertainties and risks that can affect the project and how to manage them. The risk management plan will be created to identify, assess, and mitigate risks associated with the Solar PV mini-grid projects.

2.2.3 Predictive, adaptative and hybrid projects

Depending on the nature and requirements of the projects, they can follow different approaches. In a predictive (Waterfall) life cycle, is considered suitable for a well-defined project with all requirements listed and clear. Several of the key features for predictive projects are as follows:

- Scope, time, and cost are well-defined at the start of a project.
- Changes are controlled and reduced.
- Follow a set of phases in a linear path which are typically initiation, planning, execution, monitoring and controlling, and closing.

Adaptive (Agile) lifecycle is perfect for projects with evolving requirements. In other words, the scope of work and requirements for a project are not clear or not well defined. Several of the key features of adaptive are as follows:

- Iterative and incremental approach to project execution
- Continuous stakeholder involvement and feedback
- Flexibility and responsiveness to changing requirements.

A hybrid life cycle is the combination of more than one project management approach, typically the combination of predictive and adaptive elements (PMI, 2021). Several of the key features of hybrid are as follows:

- Maintaining structure and control while being flexible
- Can be used for projects that require a balance between stability and flexibility.

The methodology for Solar PV mini-grid projects will adopt a hybrid approach, incorporating predictive elements for planning and scheduling and adaptive elements for accommodation of changes or modifications. By using a hybrid approach, the project can maintain control over well-defined aspects while remaining flexible to adapt to changes and uncertainties that can occur in the implementation of Solar PV systems in remote areas.

2.2.4 Project management

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. It encompasses a lifecycle such as initiating, planning, executing, monitoring, and closing projects (PMI, 2021). The project management concept will provide the skills, tools, and knowledge to assist in the development of the methodology for the implementation of Solar PV mini-grid projects.

2.2.5 Project management knowledge areas and processes

According to the Group Process Guide for PMI, there are 10 knowledge areas, and it is crucial to understand and manage the processes effectively. Each knowledge area comprises a set of processes applied throughout the five process groups: initiating, planning, executing, monitoring, controlling, and closing. Below are the ten knowledge areas relating to the processes within these groups:

1. Project Integration Management

   Integration management entails ensuring that all elements of the project are correctly coordinated. It utilizes all five processes as follows:

   - Initiating: To develop a project charter which is a formal short document that summarizes the project goals, objectives, resource requirements, preliminary schedule, cost, risk, and assumptions.
   - Planning: Develop a Project Management Plan for the entire project
   - Executing: Directing and managing project work

- Monitoring and controlling: To enable integrated change control if necessary.
- Closing: To close the project or phase; usually, the inauguration of a Solar PV mini grid is an indication of project closure.

2. Project Scope Management

   This knowledge of the area requires two processes which are planning, monitoring, and controlling. They are elaborated as follows:

   - Planning: Plan scope management, collect requirements, define scope, create WBS
   - Monitoring and Controlling: Validate Scope and control scope.

3. Project Schedule Management

   The schedule management looks at the timely completion of the project. Hence it focuses on two processes which are planning, monitoring, and controlling and they are elaborated as follows:

   - Planning: Plan schedule management, define activities, sequence activities, estimate activity durations, and develop schedules.
   - Monitoring and Controlling: Ensure that the schedule is on track.

4. Project Cost Management

   Cost management focuses on planning, estimating, and budgeting. financing, funding, managing, and controlling costs so the project can be finished within the approved budget. Two processes support the cost management knowledge of areas which are planning, monitoring, and controlling. They are explained as follows:

   - Planning: Plan Cost Management, Estimate Cost, and Determine Budget
   - Monitoring and Controlling: Ensuring Costs do not exceed the approved budget.

5. Project Quality Management

   Quality management confirms that the project will meet the needs for which it was undertaken. There are three processes needed to achieve this area, and they are as follows:

   - Planning: Plan quality management.
   - Executing: Manage quality
   - Monitoring and controlling: Ensuring quality.

6. Project Resource Management:

   This involves planning, estimating, and acquiring necessary resources. This also includes managing and developing team members related to the project and physical resources. There are three processes to accomplish this area, and they are as follows:

   - Planning: Plan Resource Management and estimating activity resources
   - Executing: Acquire Resources, develop team, Manage Team
   - Monitoring and Controlling: Ensuring availability of resources.

7. Project Communications Management

   Communications management looks at timely and accepted generation, collection, distribution, storage, retrieval, and ultimate disposition of project information. This area is prioritized in three processes, and they are explained as follows:

   - Planning: Plan Communications Management
   - Executing: Manage Communication
   - Monitoring and Controlling: Ensuring that communications are done according to best practices.

8. Project Risk Management

   Risk management entails identifying, analyzing, and responding to project risks. This, in short, maximizes the probability and consequences of positive events and minimizes the opposite or negative events. Thus, focuses on three processes which are as follows:

- Planning: Plan Risk Management, Identify Risk Perform Qualitative Risk Analysis, Perform Quantitative Analysis, and Plan Risk Responses
- Executing: Implement Risk Responses
- Monitoring and controlling: Monitoring Risk

9. Project Procurement

Procurement management focuses on acquiring goods and services from outside the project organization or externally. To achieve this area, three processes should be done, and they are as follows:

- Planning: Plan Procurement Management.
- Executing: Implement Procurements.
- Monitoring and Controlling: Control Procurements.

10. Project Stakeholder Management

Stakeholder management encompasses identifying all related persons related to the project or entity. This one includes 4 processes to accomplish this area, and they are as follows:

- Initiating: Identify stakeholders.
- Planning: Plan Stakeholder Engagement.
- Executing: Manage Stakeholder Engagement.
- Monitoring and Controlling: Oversee Stakeholder Engagement

The Final Graduation Project (FGP) methodology for implementing Solar PV Mini-Grid project may use at least 8 knowledge of areas to effectively develop, guide, and implement most of the phases of the methodology. In general, these mini-grid projects are funded by international stakeholders and the risk is high since the planning stage is not detailed.

2.2.6 Project life cycle

The project life cycle refers to the effort needed at different phases within the life of a project starting initiation to closure. As progress is made in a project, there a specific activities and deliverables that are expected to be completed and once completed, then the next phase commences. It is important to understand the different life cycles because it determines the appropriate approach for managing a project. The PMBOK Guide seventh edition (2021) lists the main types of project life cycles which are Predictive, Iterative, Incremental, Adaptive, and Hybrid.

Predictive Life Cycle.

The **predictive lifecycle,** also known as the waterfall approach, is described as a linear and sequential approach where the scope, time, and cost are established early in the project. This means that all the heavy planning is upfront and then continues to replan as progress has been made. There is a clear path from start to finish with minimal changes. The phases for the predictive life cycle are initiation, planning, execution, monitoring and controlling and closing. Detailed planning is usually done after the feasibility study is complete as noted in Figure 2 below:

Figure 2: Predictive Project Life Cycle

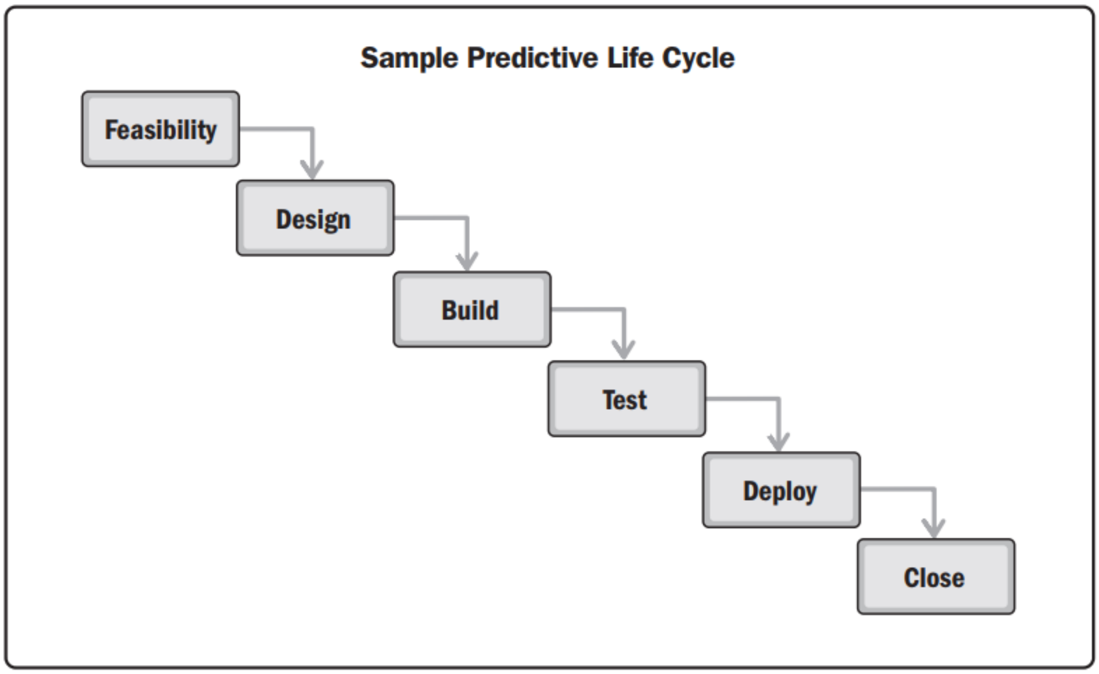


Figure 2-9. Sample Predictive Life Cycle

Source: Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK Guide) seventh edition, Project Management Institute, Inc. 2021, Figure 2-9, Page 43

The **iterative life cycle** is slightly different from the predictive life cycle where the scope is determined early but the time and cost estimated tend to extend as the project progresses to allow improvement based on feedback. The repeated cycles are iterations and can be done per phase which can start back at phase two for replanning. An iterative life cycle is suitable for projects where the requirements tend to increase based on feedback and may require replanning. The phases are initiation, planning, execution, review of feedback, and replanning if not satisfied.

The **incremental life cycle** is slightly different from the iterative approach as it incorporates feedback but delivers the project in a small usable segment. Unlike iteration where a product is usable at the last phase, the incremental life cycle implements working elements until the entire project is complete. This is ideal for a project where the set of requirements is known from the start and early delivery of parts of the project can be useful. The phases are initiation, increment planning, increment execution, increment delivery, and closing. This can be noted in Figure 3 below:

Figure 3: Iterative and Incremental Life Cycles

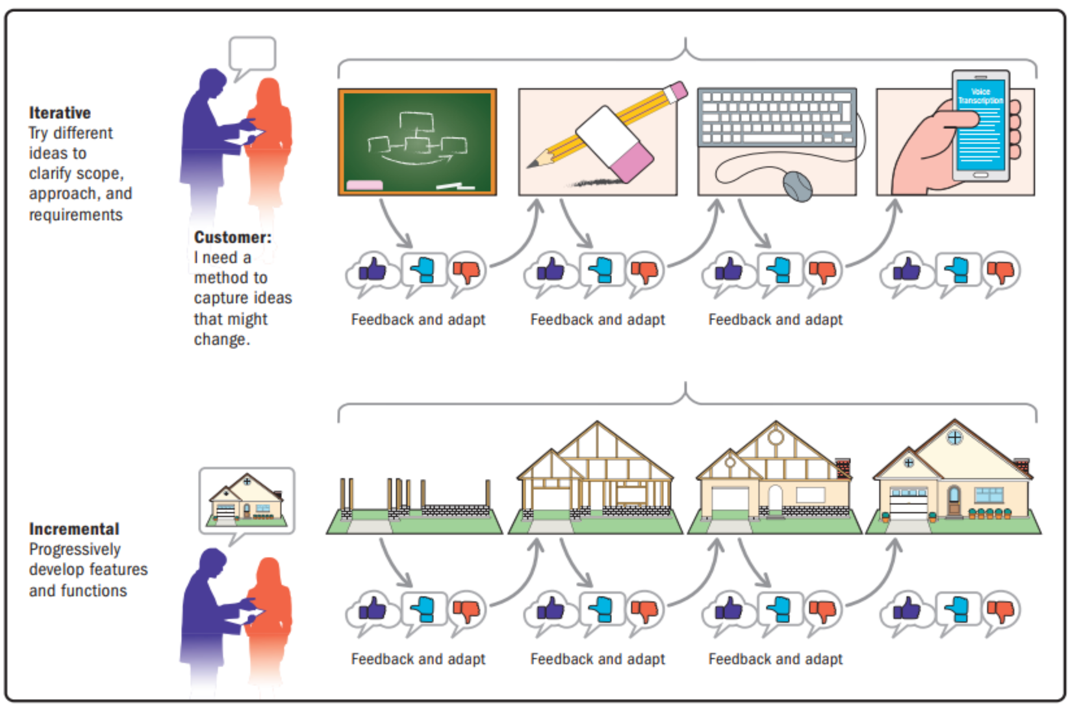


Figure 2-8. Iterative and Incremental Development

Source: Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK Guide) seventh edition, Project Management Institute, Inc. 2021, Figure 2-8, Page 37

Adaptive Life Cycle is also known as the agile approach, and it is best for projects with high levels of uncertainty, very fast-changing requirements, and high stakeholder involvement. This also incorporates an iterative concept to allow room for feedback but with prioritization and aim for rapid delivery through a short cycle or iteration. The phases are initiation, planning, iteration execution, iteration review and feedback, and adaptation.

Hybrid Life Cycle as defined in the PMBOK Guide seventh edition (2021), is "A combination of two or more agile and non-agile elements, having nonagile results. It usually uses a predictive approach for well-defined parts of the project and an adaptive approach for areas with higher uncertainty. The phases are initiation, planning, mixed execution (Predictive and Adaptive), monitoring and controlling, and closing.

In connection with the Project in Study, the methodology for implementing Solar PV mini grid in remote areas in Belize corresponds most closely to a Hybrid Life Cycle. This approach is because the methodology needs to establish well-defined procedures and practices for technical implementation, while also accommodating flexibility for community engagement and adaptation to local conditions.

Predictive Elements:

- Technical guidelines and standards for Solar PV mini-grid systems
- Define processes for project planning, design, and execution.

- Compliance with best practices and industry standards

Adaptive Elements:

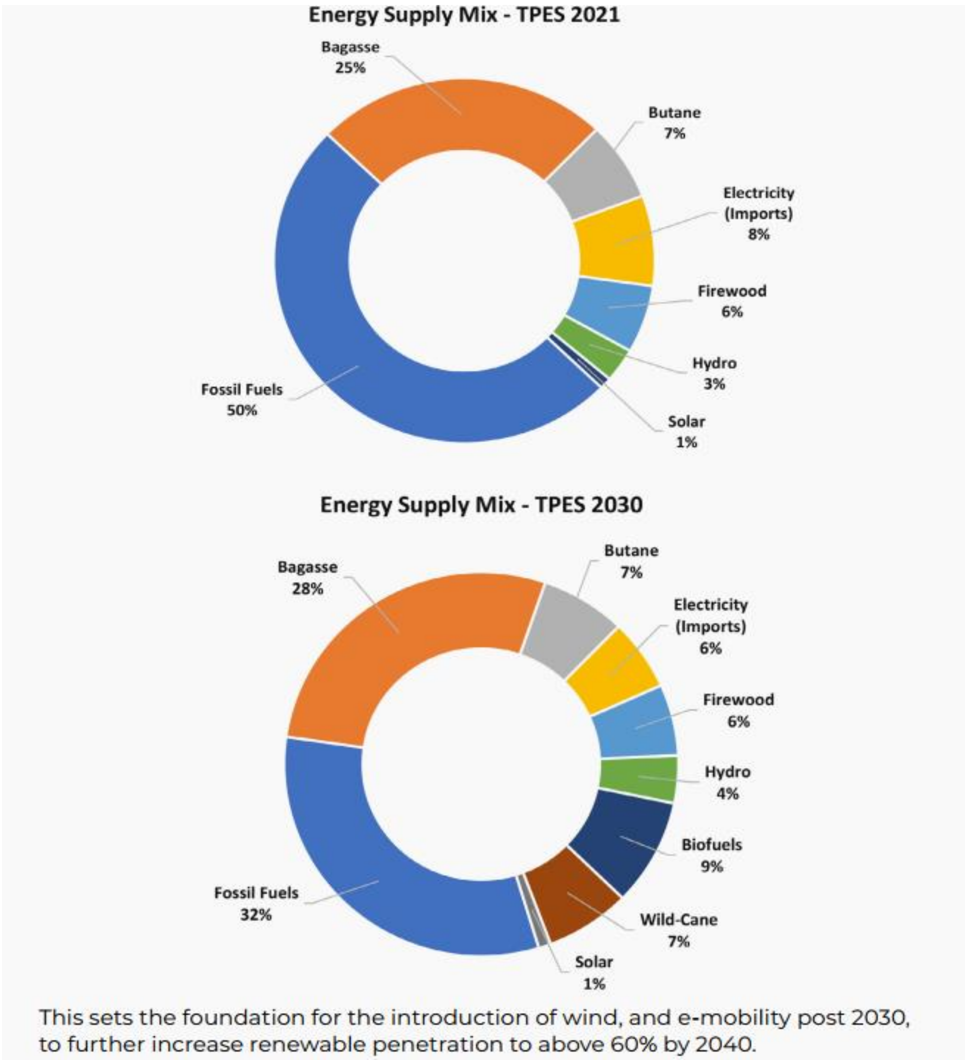
- Stakeholder engagement and community involvement require ongoing feedback and adjustments.
- Risk Management strategies need to be flexible to address unforeseen challenges.
- Continuous improvement of the methodology based on real-time data and feedback from existing pilot projects and implementation.

2.2.7 Company strategy, portfolios, programs, and projects

The Belize Energy Unit has an implementing strategy aligned with its goals of promoting energy efficiency, renewable energy, clean energy, policy development, and rural electrification. The strategy of the Belize Energy Unit focuses on achieving the 7th Sustainable Development Goal (SDG) of "Affordable and Clean Energy." Developing a methodology for implementing Solar PV mini-grid systems directly supports this strategic objective by providing a sustainable and reliable energy solution for remote areas. This will also indirectly improve the energy supply mix to include biofuels, as well as more solar, hydro, and biomass, and increase renewable energy penetration to 75% by 2030 and renewable energy electricity penetration of 75% by 2030 (Government of Belize, 2023)

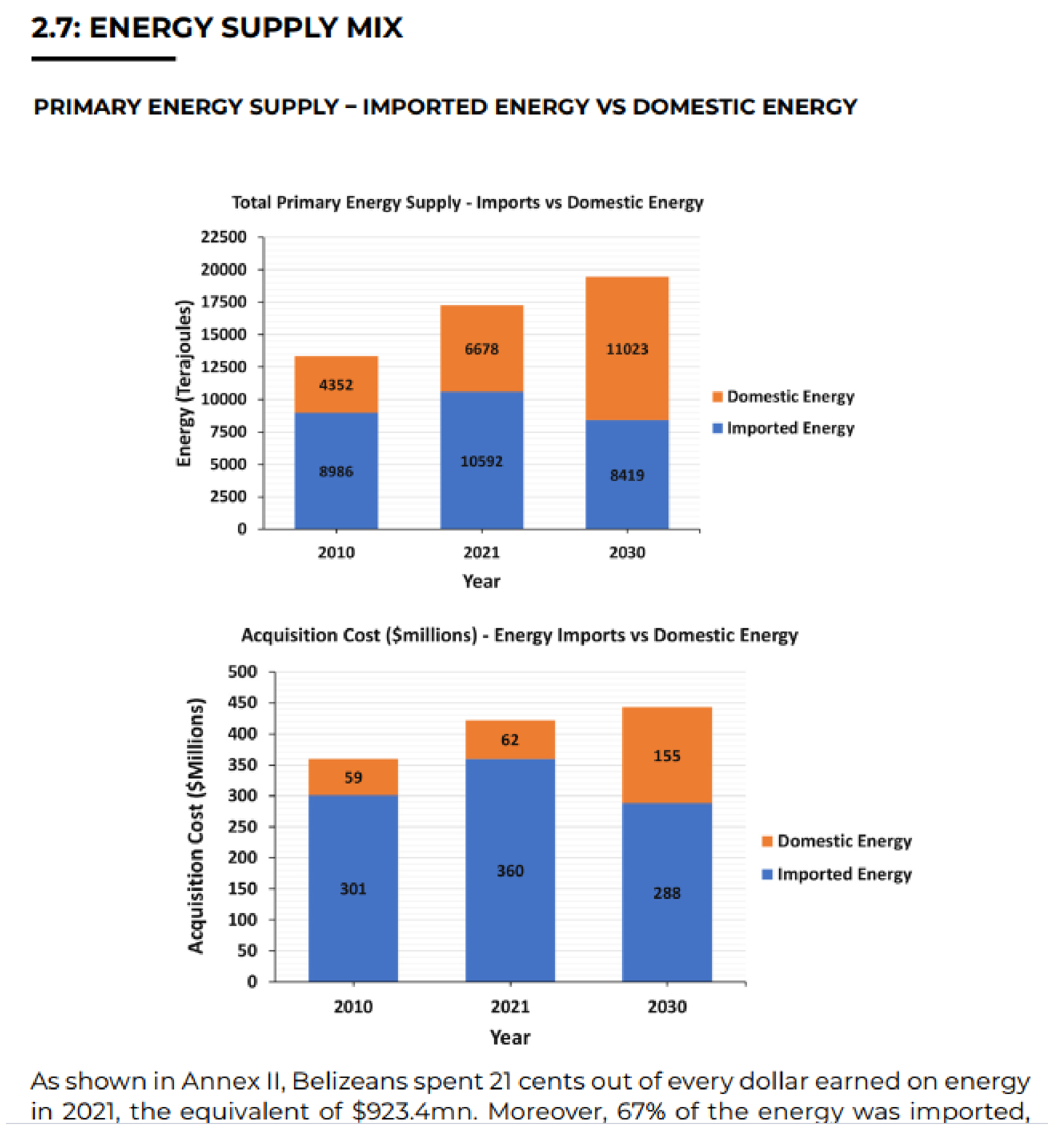
In Figure 5 below, note that there is a projection for domestic energy to increase from 39% of the total primary energy supply in 2023 to 57% in 2030. The project to develop a methodology for implementing Solar PV mini-grid systems is integral to the Belize Energy Unit's strategy of providing affordable and clean energy to remote areas. By creating a standardized approach, this methodology will enhance the efficiency and effectiveness of individual mini-grid projects supporting the objective of infrastructure or rural electrification. The performance metric for energy access is the increased percentage of households with reliable energy access.

Figure 4: Belize Energy Unit Energy Target



Source: Belize National Energy Policy 2023 (Government of Belize, 2023)

Figure 5: Energy Supply Mix



Source: Belize National Energy Policy 2023 (Government of Belize, 2023)

2.3 Other applicable theories/concepts related to the project topic and context.

2.3.1 Current situation of the problem or opportunity in study

The Belize Energy Unit, within the Ministry of Public Utilities, Energy, Logistics & E-Governance, has been tasked with advancing the country's energy sector through its five pillars: Energy Efficiency, Renewable Energy, Policy, Clean Energy, and Infrastructure. Despite significant progress, Belize faces challenges in providing reliable and sustainable electricity to remote areas. Extending the national grid to these regions is often economically unfeasible due to geographical barriers and low population density. Consequently, many remote communities remain without access to electricity, limiting their socio-economic development.

The first pilot project, the La Gracia 24kW Smart Off-Grid System in the Cayo District, and the Indian Creek 400kW Hybrid Solar PV System in the Toledo District have demonstrated the potential of Solar PV mini-grid systems as a practical solution for rural electrification. However, these projects have highlighted the need for a standardized methodology to ensure consistent and efficient implementation across various remote areas. What has been observed with the previous projects lacked a cohesive strategy. Some of the challenges these projects faced were inconsistent planning and execution, lack of standardization, and limited community involvement.

Currently, the Belize Energy Unit is in the process of addressing these issues through the development of an Energy Act, which will transform the Energy Unit into a formal Energy Department with an official government mandate. This transformation aims to improve organizational efficiency and ensure that all energy-related projects are aligned with national goals and standards. The Energy Unit has recognized the need for a standardized methodology for implementing Solar PV mini-grid systems as a critical step toward achieving its rural electrification goals.

The proposed methodology aims to:

- **Standardize Processes**: To develop a template or checklist for project implementation to ensure consistency and quality across all projects.
- **Define Roles and Responsibilities:** Clearly outline the roles and responsibilities of all stakeholders involved in the projects.
- **Develop Detailed Schedules:** Create detailed project schedules with clear milestones to track progress and ensure timely completion.

- **Implement Risk Management:** Identify and mitigate potential risks to minimize disruptions and ensure smooth project execution.

2.3.2 Previous research done for the topic in this study.

The Mini-Grids for Half a Billion People: Market outlook and handbook for Decision makers (World Bank, 2019)

This report focuses on the economic and technical feasibility of mini-grids in off-grid communities, highlighting the essentials of tailored policies and financial measures to achieve successful implementation. This can contribute to the development of methodology for implementing mini grid in Belize.

Sub-Saharan Africa: Policies for Renewable Energy Deployment (IRENA, 2024)

This highlights the strategic frameworks that have facilitated renewable energy deployment in Sub-Saharan Africa. There are lessons learned in terms of regulatory support and capacity building, which can be directly applied to the Belizean context to enhance the effectiveness of Solar PV mini grid projects.

Boosting Solar PV Markets: The Role of Quality Infrastructure (IRENA, 2017)

This research underscores the requirement of integrating quality assurance procedures within the methodology to ensure high performance and reliability of mini grid systems.

The GPM P5 Standard for Sustainability in Project Management (GPM Global, 2021) and Sustainable Project Management: The GPM Reference Guide (Carboni et al., 2018)

This guide demonstrates the frameworks for integrating sustainability into project management. This can add insights to the development of the methodology to ensure that the mini-grid projects contribute to long-term environmental and social goals.

Finally, the Government of Belize's updates and initiatives, such as the Progress in Corazon Creek Village's Energy Transformation Initiative (Government of Belize, 2024) and the Minister of Public Utilities and Logistics signs agreement for Corazon Creek Solar Hybrid Project (Government of Belize, 2021), provide practical examples of ongoing efforts to deploy solar PV mini-grid systems.

2.3.3 Other theory related to the topic in study.

Project Management Body of Knowledge (PMBOK) (PMI, 2021)

This book provides a comprehensive framework for project management, entailing ten knowledge areas and five process groups. This guide provides critical principles, processes, and best practices that are directly applicable to the implementation of solar PV mini-grid systems.

3 METHODOLOGICAL FRAMEWORK

3.1 Information sources

Information sources are the sites or data, whether physical or documentary, where digital information needed for the investigation is found. These sources are converted into working tools for researchers and members of the project team (Graduation Seminar, 2024). According to IGI Global, an information source is a person, thing, or place from which information comes, arises, or is obtained (IGI Global, n.d.). Information sources can be primary or secondary.

3.1.1 Primary sources

Primary sources of information are the first published records or accounts directly related to the topic of investigation and considered original. These are original documents produced by witnesses or recorders who experienced the events. They provide immediate unfiltered information and include raw data, original documents, and firsthand accounts (American Psychological Association, 2020).

The primary sources expected to be utilized for the development of methodology for Solar PV mini-grid in Belize are interviews with stakeholders, questionnaires, and direct observations. Interviews will be conducted with community leaders, experts involved in the Solar PV mini-grid project, and Energy Unit Staff. Questionnaires are to gather feedback from the community regarding their experience with the system. While in the community, observations can be done to collect data from the system and impact. Observation can provide evidence for effectiveness and highlight areas for improvement.

3.1.2 Secondary sources

Secondary sources of information are those which are either gathered from or summarize primary sources of information. This is considered secondhand information from other researchers. Secondary sources of information may include but are not limited to bibliography, reviews, manuals, journals, books, and articles. They are usually used to provide background information, context, and synthesis of existing research on a topic (American Psychological Association, 2020).

The secondary sources of information will be used to complete the development of the methodology of the FGP which are the World Bank reports that provide comprehensive insights into mini-grid implementation worldwide (World Bank, 2019), International Renewable Energy Agency (IRENA) publications that offer insights on renewable energy policies and practice and a journal article entitled Solar Photovoltaic Energy Progress in India by Sahoo, which provide context on case studies relevant to the project. Lastly, the International Electrotechnical Commissions will be utilized as standards and guidelines since Belize refers to this guideline for Solar PV Systems, and Project Management Institute (2021) PMBOK Guide.

Chart 1. Information sources

Objectives	**Information sources**	
	Primary	**Secondary**
Develop a template or checklist for mini-grid implementation projects to standardize processes and ensure project planning and execution.	Interview with Energy Unit personnel and external stakeholders	Word Bank (2019); IRENA (2024), IEC (2023), Rose's book (2020), PMBOK Guide (2021)
Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects	Questionnaires to residents and stakeholders	PMBOK Guide (2021); Scholarly article. Energy Policy (2023).
Establish quality assurance procedures and performance metrics for mini-grid systems	Direct observation and site visits	Rose's book (2020), IRENA (2017), and PMBOK Guide (2021)
Develop a detailed project schedule and milestones for mini-grid implementation projects	Meetings with technical experts and project leaders	PMBOK Guide (2021), Carboni et al. (2018), IRENA (2017)
Implement risk management strategies to identify and mitigate potential project risks	Surveys with stakeholders	GPM Global (2021); Risk Management for Project Driven Organizations (2021)

Note: The table above is elaborated by A. Matar, Author, 2024. Own work

3.2 Research methods

Research methods are the strategies, processes, or techniques utilized in the collection of data or evidence for analysis to uncover new information or create a better understanding of a topic (Research Guides, 2024). These strategies or methods can be qualitative, quantitative, or mixed, depending on the nature of the research question and required data. The analytic method may be employed to complete the final product, and descriptive may be used to develop the methodology.

3.2.1 Analytical method

The analytic method utilizes techniques to examine and clarify data. This includes identifying patterns, relationships, trends, and problems. This allows forecasting and drawing meaningful conclusions by understanding the data collected. There may not be time to run a pilot test on the methodology; hence, the analytical method conclusion will be drawn from the collected data.

3.2.2 Descriptive method

The Descriptive method entails observing and describing the features of the subject being studied without influencing it in any way. In other words, it provides a clear picture of current practices without altering any variables (Silverman, 2020). This type of method does not control or manipulate any of the variables but uses observation and measure them. This approach is essential in understanding the existing conditions in Belize’s Solar projects.

3.2.3 Case Study Method

The case study method is a full in-depth analysis of one case, person, event, or group. It permits a thorough examination of the context and processes involved, pr rich qualitative data (Yin, 2018)

Chart 2. Research methods.

Objectives	Research methods		
	Analytical Method	Descriptive Method	Case Study Method
Develop a template or checklist for mini-grid implementation projects to standardize processes and ensure project planning and execution.	Analysis of existing templates and checklists from similar projects to identify best practices and standardize processes.	Description of current processes and templates used in mini-grid implementation projects	In-depth analysis of a successful mini-grid implementation project to derive key elements for the templates.
Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects to clarify accountability and enhance effective collaboration among project participants.	Analysis of stakeholder roles and responsibilities in existing projects to identify gaps and improvement	Description of current stakeholder roles and responsibilities in similar projects	Case study of a mini-grid project with clear stakeholder roles to illustrate effective collaboration.

Objectives	Research methods		
	Analytical Method	Descriptive Method	Case Study Method
Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution.	Analysis of quality assurance procedures and performance metrics from existing mini-grid projects.	Description of current quality assurance procedures and performance metrics used.	Case study of a mini-grid project with successful quality assurance practices to derive best practices.
Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines	Analysis of project schedules and milestones from existing projects to identify key timelines and milestones	Description of current scheduling and milestone-setting practices in mini-grid projects.	Case study of a mini-grid project with a well-defined schedule and milestones to illustrate effective planning
Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.	Analysis of risk management strategies used in existing mini-grid projects to identify best practices.	Description of current risk management strategies and practices in similar projects	Case study of a mini-grid project with successful risk management practices to illustrate effective strategies,

Note: Table elaborated by A. Matar, Author, 2024. Own Work

3.3 Tools

Tools, being referenced to project management, are designed to assist in planning, executing, and managing projects effectively using techniques, software, or methodologies. Some of these tools can be used for scheduling, budgeting, resource allocation, risk management, and quality control (Project Management Institute, 2017). Moreover, tools based on the PMBOK Guide can also include templates, checklists, project management software, and communication platforms.

The selected tools for this project are in line with the specific objectives and are based on the recommendations from the PMBOK Guide as noted in the table below. These tools will provide the path in the development of a methodology for implementing Solar PV mini-grid systems in remote areas.

Chart 3. Tools.

Objectives	Tools
Develop a template or checklist for mini-grid implementation projects or standardize processes and ensure project planning and execution.	Project templates, checklists, Microsoft Project, or Excel for creating and standardizing project templates.
Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects to clarify accountability and enhance effective	RACI matrix, organizational charts, stakeholder analysis tools, and communication plans.

Objectives	Tools
collaboration among project participants.	
Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution.	Quality management tools, performance metrics dashboards, and checklists.
Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines.	Microsoft Project, scheduling software
Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.	Risk management software, risk registers, SWOT analysis, Monte Carlo simulation tool.

Note: Table elaborated by A. Matar, Author, 2024. Own Work.

3.4 Selected Tools for FGP Descriptions:

For the successful implementation of Solar PV mini-grid systems using the Corazon Creek mini-grid system as a case study, specific tools were selected from chart 3 and tailored to meet the unique requirements of the project. These tools were chosen based on their relevance to the specific objectives and their ability to facilitate effective project management, data collection, and analysis throughout the mini-grid implementation process. Below is a brief description of the key tools that were used:

I. **Microsoft Project**: This was used as a tool for creating project schedule and tracking milestones. This software can automatically calculate timelines and highlight critical paths, enabled effective management of project milestones. Moreover, Microsoft Project is useful for identifying overallocation of resources and proposing solutions such as task fast-tracking or crashing.

II. **Stakeholder Analysis Tools (Stakeholder Register and Collaboration Framework):** This was needed for the stakeholder roles and responsibilities, as well as the need for a structured framework for collaboration. These tools ensure effective stakeholder engagement by clearly defining the roles, responsibilities, and communication protocols of all parties involved. The stakeholder register listed key participants, while the collaboration framework established guidelines for resolving conflicts and fostering cooperation.

III. **Quality Management Tools (Checklists and Performance Metrics):** The FGP includes a deliverable for a quality assurance plan and a performance metric report, which implies the use of quality management tools. They provide a structured way to measure compliance with international standards, such as those outlined in the National Electrical Code (NEC) Handbook. The use of performance metrics also allowed for continuous monitoring and improvement of the system’s performance.

IV. **Risk Management Tools (Risk Register and Assessment Matrix)**: The risk management plan and risk assessment report are required tools to identify, prioritize and mitigate risks. The risk register listed potential risks, while the assessment matrix prioritized them based on probability and impact. This systematic approach enabled the project team to implement timely mitigation measures, reducing potential delay unforeseen issues.

V. **Excel Spreadsheets**: Utilized for various purposes, including maintaining the risk register, tracking performance metric, and documenting stakeholder information. This tool is ideal for creating templates and reports required for project monitoring and evaluation.

VI. **Communication Tools:** Communication was highlighted as a critical factor in the FGP, with tools like meeting schedules, progress reports, and stakeholder engagement strategies being key components. They ensure transparency and alignment among stakeholders.

3.5 Assumptions and constraints

Based on the information from Graduation Seminar 2024, an assumption is a fact assumed to be true for purposes of project planning without proof or demonstration at the time of project planning. An assumption is needed for the basis of project planning and decision-making. However, a constraint is a limiting factor that affects the execution of a project and performance, such as budget, time, resources, and scope (Project Management

Institute, 2021). These assumptions and constraints relating to the FGP are noted in Chart 4 below:

Chart 4. Assumptions and Constraints

Objectives	Assumptions	Constraints
Develop a template or checklist for mini-grid implementation projects to standardize processes and ensure project planning and execution.	Availability of standardized project management templates and checklists	Limited access to tools in remote areas
Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects to clarify accountability and enhance effective collaboration among project participants.	Stakeholders will collaborate to participate in the role-definition process.	Resistance to change and lack of protocol in stakeholder roles and responsibilities.
Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution.	Quality assurance process can be implemented from existing industry standards	There are limited quality materials at the Energy Unit Office or within the country.

Objectives	Assumptions	Constraints
Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines.	Availability and precise project scheduling tools are available	Probability of delays that may be caused by unforeseen events such as weather or disruption in business as usual.
Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.	All potential risks can be identified and reduced using risk management tools and techniques.	Expertise in risk management is limited in Belize and resources are in remote areas.

Note: Table elaborated by A. Matar, Author, 2024. Own Work

3.6 Deliverables

Based on the PMBOK Guide, seventh edition, a deliverable is any unique and verifiable product result or capability to perform a service required to complete a process, phase, or project. These can be reports, plans, designs, presentations, studies, or any other outputs that are developed throughout the lifecycle of the project.

The deliverables for the methodology to implement Solar PV mini-grid systems in remote areas are outlined in the specific objectives which add to the general objective. In this case, deliverables will be prioritized starting from the execution phase.

Chart 5. Deliverables

Objectives	**Deliverables**
Develop a template or checklist for mini-grid implementation projects to standardize processes and ensure project planning and execution.	1. Implementation Checklist: A comprehensive checklist covering all steps and procedures required for project and execution. 2. Standardized Template: Predefined templates for project documentation, planning, and reporting.
Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects to clarify accountability and enhance effective collaboration among project participants.	1. Stakeholder Role Definition: A document detailing the roles and responsibilities of each stakeholder. 2. Collaboration Framework: A framework outlining effective collaboration strategies among project participants.
Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution	1. Quality Assurance Plan: A detailed plan outlining the procedures and metrics for maintaining high-quality standards. 2. Performance Metric Report: A report specifying the key performance indicators and measurement methods.

Objectives	Deliverables
Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines	1. Project Schedule: A detailed timeline with milestones for tracking progress. 2. Milestone tracking Report: A report for monitoring and reporting milestone achievements.
Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.	1. Risk Management Plan: A comprehensive plan identifying potential risks and mitigation strategies. 2. Risk Assessment Report: A report detailing the risk analysis and assessment outcomes.

Note: Table elaborated by A. Matar, Author, 2024. Own work

4 RESULTS

Introduction

This chapter presents the project's results in alignment with its specific objectives whilst focusing on the structured methodology for implementing mini-grid systems in remote areas. This methodology prioritizes critical components to ensure that projects meet established standards for timeliness, reliability, and quality.

The first objective led to the creation of an implementation checklist and standardized templates, drawing on PMBOK Guide practices to streamline tasks and enforce quality standards across project phases. The second objective involved defining clear roles and responsibilities for stakeholders to promote effective communication and collaboration; tools like stakeholder role definitions and stakeholder engagement plans developed to facilitate these interactions. For the third objective, quality assurance procedures were formalized; incorporating performance metrics and compliance measures designed to align with recognized project management standards. The fourth objective addressed developing a comprehensive project schedule with specific milestones to aid in monitoring progress and maintaining project timelines. Lastly, robust risk management strategies were designed to identify potential project risks, accompanied by mitigation plans to minimize disruptions and enhance the stability of the mini-grid installation process.

Several aspects, however, will not be covered in this methodology due to their administrative, procedural, or external nature. Procurement and contracting, for example, involves specific administrative processes outside the immediate project management framework, while detailed budgeting and funding are governed by external financial arrangements. Human resource policies, post-implementation maintenance plans, and environmental impact assessments, although integral to project success, require specialized frameworks not included therein. These exclusions are noted to clarify the scope of this methodology, keeping the focus on practical project implementation aspects directly relevant to mini-grid installation in the community context.

4.1 Implementation Checklist

The following is the checklist and template that will help to ensure that key activities for the Solar PV mini-grid implementation is tracked and completed across the project phases: Initiating, Planning, Executing, Monitoring and Controlling, and Closing. Emphasis is from the third phase to the last phase. Although this methodology prioritizes phases 3 to 5, it also addresses phases 1 and 2, as any shortcomings in these initial phases will affect the success of the subsequent ones as noted in the checklist below.

Chart 6. Implementation Checklist

No.	Content	Details	Values/Notes	Status
		Phase 1: Initiating		
1	Conduct a feasibility study	Survey population, productive sectors, appliances, and load analysis using a sample to extrapolate the load		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
		profile of the entire community. Include verification of resident documentation such as social security card or passport.		
2	Perform a site assessment	Use drone imagery and land inspection. Conduct interviews with businesses, key institutions, the alcalde/chairman, and engage in participatory observation.		Good ☐ Poor ☐
3	Identify stakeholders	Record in a stakeholder register (internal team member, sponsor, residents, village leaders, government agencies, contractors). Develop a		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
		stakeholder engagement plan to involve them in the project		
4	Define the project charter	Required for larger projects, particularly when implementing multiple mini grids simultaneously		Good ☐ Poor ☐
5	Create preliminary project scope	Define access to power per household according to United Nations TIER levels		Good ☐ Poor ☐
6	Get initial approvals from Key stakeholders	Required for Mayan communities under the FPIC protocol. Attendance sheets and meeting minutes are necessary.		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
7	Perform preliminary risk identification	Evaluate land availability and community acceptance of the mini-grid project. Obtain permission for land use.		Good ☐ Poor ☐
		Phase 2: Planning		
No.	**Content**	**Details**	**Values/Notes**	**Status**
1	Develop the project management plan	Includes scope, schedule, cost, and quality baselines. Fixed budget often managed by external stakeholders		Good ☐ Poor ☐
2	Finalize the scope statement	Ensure that the scope aligns with the current budget.		Good ☐ Poor ☐
3	Create a Work Breakdown Structure (WBS)	Detail all tasks needed to achieve the project objectives.		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
4	Develop a detailed project schedule	Use a Gantt chart or timeline to list tasks and completion dates.		Good ☐ Poor ☐
5	Establish the project budget and funding plan	Develop a funding plan based on stakeholder input.		Good ☐ Poor ☐
6	Plan stakeholder communication	Create a communication matrix, especially for areas with limited connectivity.		Good ☐ Poor ☐
7	Define roles and responsibilities	Use a RACI matrix to ensure clarity on stakeholder roles		Good ☐ Poor ☐
8	Develop a quality management plan	Align standards with NEC minimum requirements		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
9	Establish risk management plan	List and prioritize up to five risks in a risk register		Good ☐ Poor ☐
10	Prepare procurement documents	Procure equipment and hire contractors as needed		Good ☐ Poor ☐
11	Define project governance and decision-making structure	Ensure management involvement for decision-making.		Good ☐ Poor ☐
Phase 3: Executing				
No.	**Content**	**Details**	**Values/Notes**	**Status**
1	Mobilize project team and contractors	Arrange transportation or include it in contractor services.		Good ☐ Poor ☐
2	Procure equipment and materials	Managed by implementing partners.		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
3	Perform site preparation	Contractors are responsible for civil works and foundations; the Ministry assists with access roads.		Good ☐ Poor ☐
4	Install solar panels and related electrical components	Ensure that contractors follow the installation plan.		Good ☐ Poor ☐
5	Coordinate electrical connections	Prioritize customer service after completing the mini-grid system.		Good ☐ Poor ☐
6	Implement training for community and technicians	Training provided by solar contractors.		Good ☐ Poor ☐
7	Document project activities	No specific report format: use photos and progress reports.		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
8	Monitor resource allocation	Ensure transportation and accommodation availability.		Good ☐ Poor ☐
9	Ensure compliance with quality standards and local regulations	Adhere to NEC 690 standards as recommended by the Public Utilities Commission (PUC).		Good ☐ Poor ☐
Phase 4: Monitoring and Controlling				
No.	**Content**	**Details**	**Values/Notes**	**Status**
1	Track project performance	Monitor schedule and budget adherence.		Good ☐ Poor ☐
2	Perform quality assurance checks	Test installation, and commissioning activities.		Good ☐ Poor ☐
3	Conduct inspections and safety audits	Ensure safter and quality compliance		Good ☐ Poor ☐

No.	Content	Details	Values/Notes	Status
4	Monitor stakeholder engagement	Address any concerns as they arise.		Good ☐ Poor ☐
5	Manage changes to the project plan	Update plans as needed.		Good ☐ Poor ☐
6	Monitor and mitigate risks	Regularly update the risk management plan		Good ☐ Poor ☐
7	Prepare for system commissioning	Conduct final testing and validation.		Good ☐ Poor ☐
8	Generate performance reports	Share with stakeholders		Good ☐ Poor ☐
Phase 5: Closing				
No.	**Content**	**Details**	**Values/Notes**	**Status**
1	Perform final system commissioning	Verify functionality and compliance		Good ☐ Issues detected ☐

No.	Content	Details	Values/Notes	Status
2	Conduct project closure meeting	Discuss lessons learned and complete final reports.		Complete ☐ Record status in notes
3	Handover project documentation	Transfer documents to the Ministry and operations teams.		Complete ☐ Record status in notes
4	Complete financial closure	Finalize payments and contracts.		Complete ☐ Record status in notes
5	Release project resources	Release staff, contractors, and equipment.		Complete ☐ Record status in notes
6	Archive project documentation	Ensure all documents are archived.		Complete ☐ Not found ☐
7	Document lessons learned	Capture insights for future mini-grid projects.		Complete ☐ Record status in notes

Note: Table elaborated with insights from Project Management Institute and by A. Matar, 2024.

4.1.2 Standardized Templates

These templates will help standardize documentation across mini-grid projects and ensure consistency in planning execution, and monitoring.

The table below is a typical project charter which is usable to formally authorize the project and list high-level objectives, stakeholders, and resources.

Chart 7. Project Charter Template

Project Title:

Project Charter

1. **Project Details**

Business Need/Project Objectives:

Project Requirements:

Product Description /Deliverables:

Project Does Not Include:

Pre-assigned Resources:

2. Stakeholder List

Name	Title	Role/Responsibility

3. Summary Milestone Schedule

High level timeline	
Milestone 1: Date:	
Milestone 2: Date:	
Milestone 3: Date:	
Milestone 4: Date:	

4. Project Considerations

High-Level Risks:

Acceptance Criteria:

Assumptions:

Constraints:

Source: Project Management Institute. Align People and Objective Kickoff Project Charter

In general, no one desires risks in projects, investments, or similar ventures. However, the reality is that risks are inevitable. The key is to identify and address them, which can significantly increase the likelihood of a project's success. The table below provides a basic framework for listing risks and their response plans. First, identify all potential risks, then prioritize them in the table accordingly.

Chart 8. Risk Register Template

Potential Consequences: High/Medium/Low
Risk Response: Accept, Transfer, Mitigate, Avoid

Risk	Probability/Impact	Risk Response	Risk Response Plan

Source: Project Management Institute. Planning Your Work with a few modifications.

This template is incredibly important. It must be noted that the methodology being applied here follows a hybrid approach, combining predictive planning with adaptive execution to address the unique challenges of implementing Solar PV Systems in remote areas. While thorough planning is essential, based on past experiences, changes are inevitable. There will be a demonstration of the original plan of what has been implemented. Changes are not inherently negative, as long as the outcomes remain positive. To manage these changes and prevent excessive modifications, the template below has been designed to track adjustments in project scope, schedule, and budget.

Chart 9. Change Control Log Template

Change NO.	Description of Change	Status	Impact (Scope/Cost/Time)	Action	Implementation Date
1	Power outage	Open	Scope	Troubleshooting	
2	A team member on sick leave	Late	Resources	Inform AO	
3	Request for spare parts	Closed	Time	Get quotations and Purchase orders	
4					

Note: Table elaborated with insights from Project Management Institute and by A. Matar, 2024.

One of the challenges is communication. It is easy to promise regular updates without having a clear plan for how or when they will happen. The template below has been designed to set clear communication expectations among stakeholders.

Chart 10. Communication Matrix Template

Information to be Shared	Purpose	Communication Type	Frequency	Audience
Kickoff meeting	Launch the project and review objectives and goals	Face-to-Face	Once	Project Team, Contractor, community members, Project Sponsor
Technical Meetings	Provide project updates	Virtual meeting	weekly	Project team and contractor.

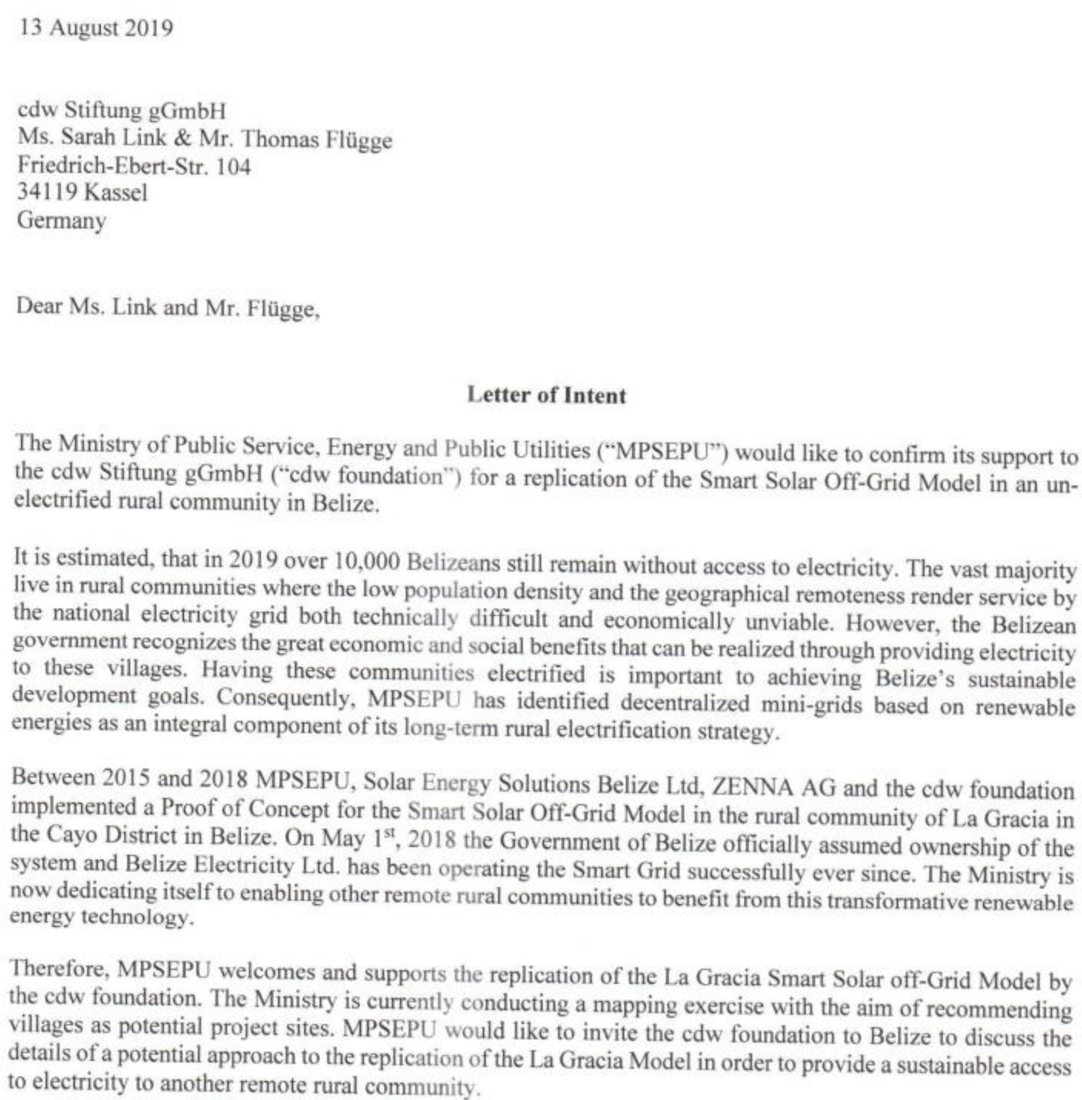
Information to be Shared	Purpose	Communication Type	Frequency	Audience
Management-Level Meeting	Address technical and non-technical concerns	Face-to-face or Email	As needed	CEO, Director, FO, AO, and Minister.
Customer Service and Energy Efficiency Awareness	Register customers and promote energy efficiency awareness for informed energy usage decision	Face-to Face	Once	Residents, village leaders, contractors, and project team.
Project Update	Keep community leaders informed and reassured during periods of stagnant progress	Face-to-Face	Quarterly or as needed	Project team, village leaders or project steering committees, and contractor

Note: Table elaborated with insights from Project Management Institute and by A. Matar, 2024.

After the successful electrification of the La Gracia Solar PV System in Cayo District in 2017, the goal was to replicate this model to further expand energy access in Belize. This effort gained momentum when a letter of intent was signed confirming the Ministry's support and welcoming the initiative by the CDW Stiftung, also known as the CDW Foundation. At that time, no village had been selected, so staff from the Energy Unit, along with CDW Foundation, toured two rural communities. Corazon Creek was chosen as the next village to be electrified using the improved model, largely because it hosts a high school that serves at least 12 surrounding communities. Subsequently, an agreement was established between the

Ministry, the CDW Foundation and Belize Electricity Limited (BEL), clearly outlining the roles of each stakeholder. Although Corazon Creek Village was selected in 2019 and the agreement was formalized in 2020, the project did not reach phase 4 (monitoring) until early 2024, and phase 5 (closing) was projected for November 2024. The significant delays could be mitigated had a proper checklist been in place.

Figure 6: Letter of Intent (2019)



13 August 2019

cdw Stiftung gGmbH
Ms. Sarah Link & Mr. Thomas Flügge
Friedrich-Ebert-Str. 104
34119 Kassel
Germany

Dear Ms. Link and Mr. Flügge,

Letter of Intent

The Ministry of Public Service, Energy and Public Utilities ("MPSEPU") would like to confirm its support to the cdw Stiftung gGmbH ("cdw foundation") for a replication of the Smart Solar Off-Grid Model in an un-electrified rural community in Belize.

It is estimated, that in 2019 over 10,000 Belizeans still remain without access to electricity. The vast majority live in rural communities where the low population density and the geographical remoteness render service by the national electricity grid both technically difficult and economically unviable. However, the Belizean government recognizes the great economic and social benefits that can be realized through providing electricity to these villages. Having these communities electrified is important to achieving Belize's sustainable development goals. Consequently, MPSEPU has identified decentralized mini-grids based on renewable energies as an integral component of its long-term rural electrification strategy.

Between 2015 and 2018 MPSEPU, Solar Energy Solutions Belize Ltd, ZENNA AG and the cdw foundation implemented a Proof of Concept for the Smart Solar Off-Grid Model in the rural community of La Gracia in the Cayo District in Belize. On May 1st, 2018 the Government of Belize officially assumed ownership of the system and Belize Electricity Ltd. has been operating the Smart Grid successfully ever since. The Ministry is now dedicating itself to enabling other remote rural communities to benefit from this transformative renewable energy technology.

Therefore, MPSEPU welcomes and supports the replication of the La Gracia Smart Solar off-Grid Model by the cdw foundation. The Ministry is currently conducting a mapping exercise with the aim of recommending villages as potential project sites. MPSEPU would like to invite the cdw foundation to Belize to discuss the details of a potential approach to the replication of the La Gracia Model in order to provide a sustainable access to electricity to another remote rural community.

Figure 7: Letter of Agreement (2021)

Agreement

Project "Solar Off-Grid Electrification of Corazon Creek"

The agreement is made by and between:

Ministry of Public Utilities and Logistics

Sir Edney Cain Building
Belmopan, Belize
(hereafter referred to as "Ministry")

and

Belize Electricity Limited

2 ½ Miles Philip Goldson Highway
P.O. Box 327
Belize City, Belize
(hereinafter referred to as „BEL")

and

cdw Stiftung gGmbH

Friedrich-Ebert-Straße 104
34119 Kassel, Germany
(hereinafter referred to as „cdw")

1. Description of the Project

The Government of Belize has committed itself to achieving universal access to affordable modern energy by 2030 (Belize Sustainable Energy Roadmap) as well as to transition to 100% Renewable Energy (85% by 2030). It is estimated, that in 2019 over 10.000 Belizeans living in rural communities remain without access to electricity. The Government of Belize recognizes the great economic and social benefits that can be realized through providing electricity to these villages.

In order to contribute to achieving the goals set in the Belize Sustainable Energy Roadmap as well as in the Horizon 2030: the National Development Framework for Belize, the parties aim to electrify the remote rural community of Corazon Creek in the Toledo District in Belize via a decentralized hybrid electrification model based on solar energy.

2. Project Partners

Ministry of Public Utilities and Logistics

The Ministry of Public Utilities and Logistics is responsible for the governance of the energy sector in Belize. The Ministry's mission is to "plan, promote and effectively manage the production, delivery and use of energy through Energy Efficiency, Renewable Energy and Cleaner Production interventions for the sustainable development of Belize." In line with the National Development Framework for Belize, the Ministry has adapted a strategy based on decentralized renewable energy mini grids to electrify remote rural communities.

Belize Electricity Limited

BEL is the only licensed distributor of electricity service in Belize. It is majority government-owned and pursues a mission to deliver safe, reliable and sustainable energy solutions to enhance the quality of life and the productivity of enterprise and to support national development as well as to achieve universal access to energy by 2030. As part of its strategy to expand electricity services to all Belizeans BEL is striving to electrify remote rural communities via renewable energy mini grids.

cdw Stiftung gGmbH

cdw is a non-profit organization that develops and finances rural electrification projects based on solar off-grid technology in order to promote the development of remote rural regions. It was created in 2012 by the founders of SMA Solar Technology AG, a leading global specialist in photovoltaic system technology. The organization's objective is inter alia development cooperation with a focus on establishing sustainable and economically viable local operator and ownership models. It works closely with all local stakeholders dedicated to increasing rural access to electricity. cdw is independent, charitable and does not pursue any economic interests.

3. Responsibilities

Ministry of Public Utilities and Logistics

The Ministry agrees to assume ownership of the power generation unit in Corazon Creek. cdw will hand over the power generation unit to the Ministry after the installation of the infrastructure has been completed and before it is put into operation.

The Ministry further commits to assuming the following responsibilities:

- Installing Belize Electricity Limited as the operator of the power generation unit
- Ensuring the conformity of the project with the Belizean Development Framework
- Assuming the role as primary contact person for the village council and population of Corazon Creek
- Ensuring land use rights for the power generation unit and providing the corresponding legal documentation of those rights
- Ensuring any necessary communication and legal understanding with the Public Utilities Commission surrounding the project "Solar Off-Grid Electrification of Corazon Creek"
- Providing cdw with access to all data gathered regarding the development of the electricity consumption in Corazon Creek and the system performance of the power generation unit for a period of at least 5 years after the system is put into operation.

- Ensuring any necessary communication and legal understanding with the Public Utilities Commission surrounding the project "Solar Off-Grid Electrification of Corazon Creek"
- Providing cdw with access to all data gathered regarding the development of the electricity consumption in Corazon Creek and the system performance of the power generation unit for a period of at least 5 years after the system is put into operation.

Belize Electricity Limited

BEL agrees to assume the responsibility for the operation of the power generation unit in Corazon Creek for the time the system is put into operation.

BEL further commits to assuming the following responsibilities:

- Installing and financing of the distribution network for Corazon Creek
- Acquiring all relevant skills for the operation of the power generation unit

cdw Stiftung gGmbH

- Coordination of all project partners and relevant steps
- Financing and installation of the solar power generation unit as described in the following documentation:
  - 2020-08-11 cdw_Corazon Creek_Meeting MPSEPU-BEL-cdw-SESB; presentation shared with all parties during the virtual meeting on August 11, 2020
  - 2020-09-06 cdw_Corazon Creek_Technical Fact Sheet; shared with all parties on September 06th, 2020
- Financing of technical support and training units during the first 12 months of the operation of the system in Corazon Creek.

4. Time schedule

The partners strive to complete the installation of the electricity supply in Corazon Creek within the 12 months upon the signing of the cooperation agreement.

The partners commit to notifying each other in case of delays in the project development caused by the consequences of the Corona Pandemic in order to discuss how best to adapt the common implementation strategy.

5. Duration

The cooperation begins with the signing of the contract and ends after the completion of the first 12 months of operation of the power generation unit.

3

The cooperation agreement may be terminated at any time by giving 3 months' notice to the end of each month. The right of a party to terminate the cooperation agreement for good cause remains unaffected.

Annex

1) Letter of Intent signed by the Ministry of Public Service, Energy and Public Utilities, dating August 13th, 2019.
2) Declaration of Intent signed by Belize Electricity Limited and cdw Stiftung gGmbH, dating August 3rd, 2020.
3) Presentation shared by cdw with all partners during the virtual meeting on August 11, 2020 ("2020-08-11 cdw_Corazon Creek_Meeting MPSEPU-BEL-cdw-SESB"
4) Technical Fact Sheet shared with all partners on September 6th, 2020 (2020-09-06 cdw_Corazon Creek_Technical Fact Sheet)

Corazon Creek Mini-Grid Solar System plan:

Figure 8 to 10 depict the original design for the Corazon Creek Solar PV System. Initially, the plan called for a land area of approximately 62m (203ft) by 32m (104ft) to accommodate 188 solar panels, each with a capacity of 370W. This brought the total system size to 69.5kW in terms of the solar array. The land size was intentionally increased to allow for future expansions as energy demand grew. This plan was agreed upon in September 2020.

However, by June 2021, when confirmation on the land size was required as part of the consent agreement between the GOB and the community for land use, the land area had been reduced to 40m (131ft) by 23m (77ft). This change, though significant, went unnoticed or unaddressed because there was no formal template in place to capture such changes and assess their impacts. While smaller areas may have reduced fencing costs, it also limited the space for future solar panel expansion. On a positive note, an adjustment led to an increase in the total number of solar panels purchased to 192, although only 188 panels were installed, keeping the system size at 69.5kW. The remaining four panels have been stored as spares in the control room for future maintenance needs.

The generation unit arrived and was tested in 2021 but delays in securing the signed consent agreement meant that the pre-training only occurred in May 2022, with the agreement itself finalized in September 2023. The project kickoff meeting was held in November 2023. Although the government recognized the main risk in securing the community's contribution of land for the generation unit, there was no structured plan to mitigate this risk, apart from ongoing communication with the community.

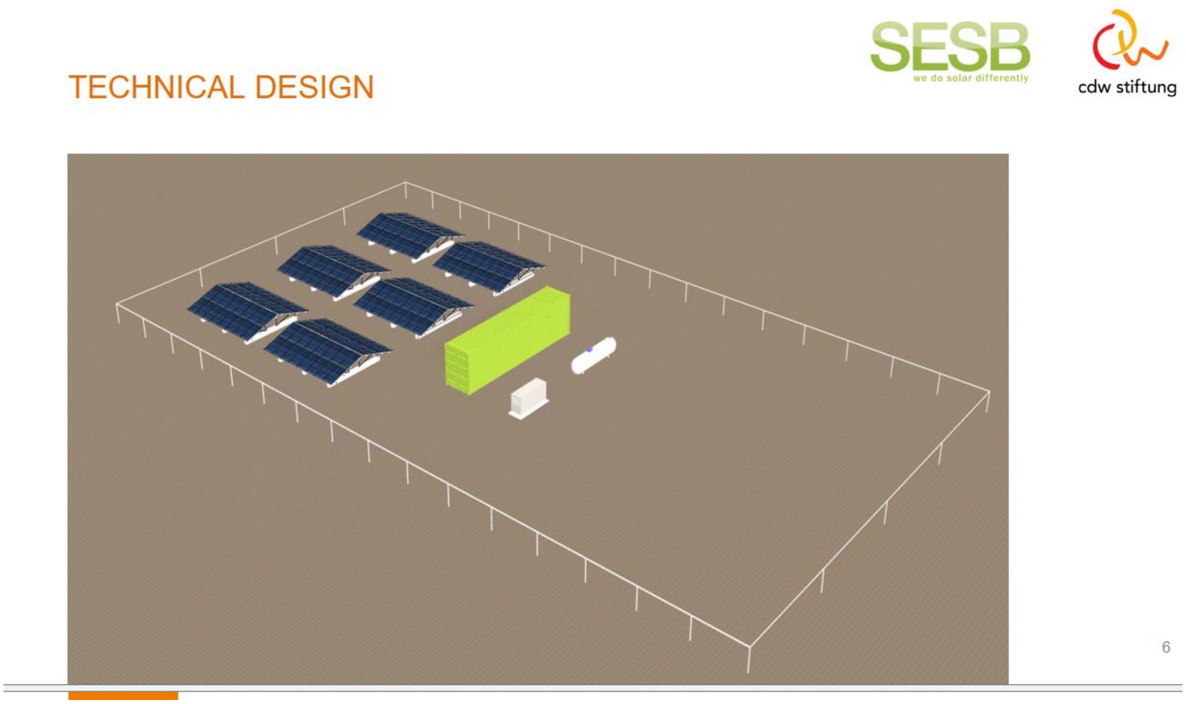
The two major weaknesses in the project were the absence of a formal risk management plan and the lack of clearly defined roles, responsibilities, governance, and decision-making processes. Additionally, there was no standardized format for documenting meetings or when the plan was presented to the Ministry, other than their activities being outlined in the letter of agreement and in presentation.

One positive aspect was the active involvement of the project sponsor, CDW Foundation. They not only managed the financing, coordination, and installation of the power generation unit, but also offered to construct service entrances and wire homes with three lights and two outlets each. However, this increased the CDW Foundation's budget, a change that was not formally recorded, aside from the consent agreement.

Flexibility from the contractor and project sponsor was crucial, as a project that could have been completed by 2022 is now nearing completion in the final quarter of 2024.

Figure 8 below illustrates the initial design, where only half the land would be utilized, allowing the GOB to install additional panels in the future as the community's energy demand increased.

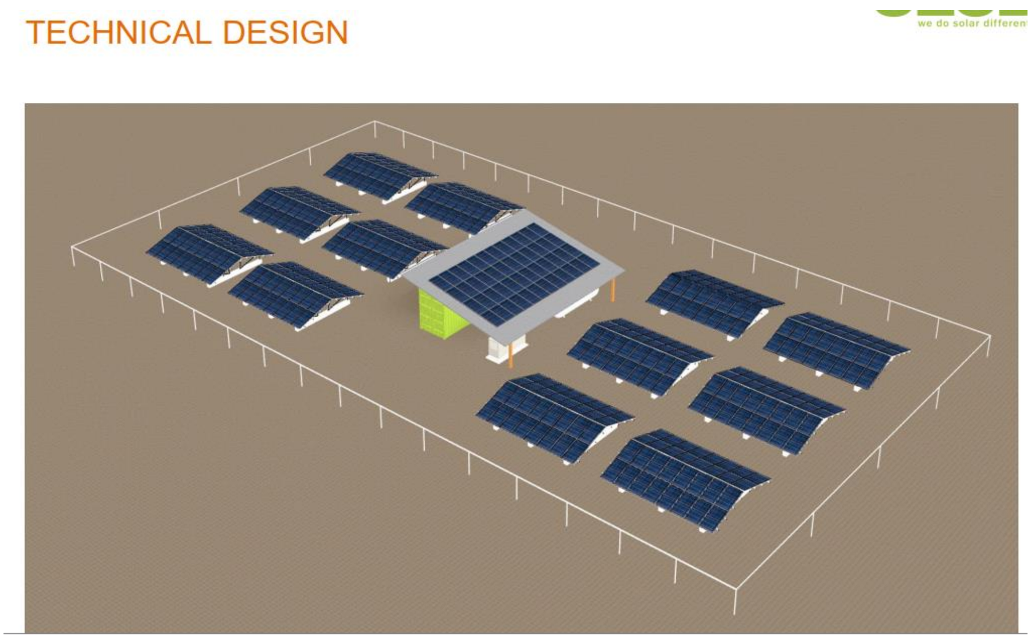
Figure 8: Initial 3D Technical Design 2020



Source: Corazon Creek Solar PV Project, System plan design, SESB, Contractor. 2020

Figure 9 depicts the proposed future technical design to accommodate energy growth, incorporating a smart solution by installing solar panels over the control room. This approach helps to reduce heat load on the room, thereby minimizing the energy required by the air conditioner to maintain a cool environment.

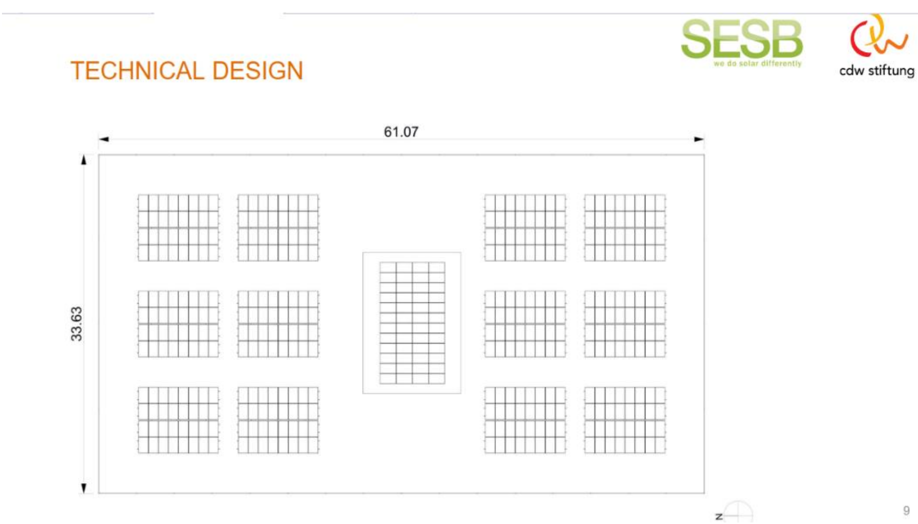
Figure 9: Initial Future Technical Design Project for energy Expansion.



Source: Corazon Creek Solar PV Project, System plan design, SESB, Contractor. 2020

The figure below presents a 2D drawing of the land area required for the generation site.

Figure 10: Initial 2D technical design overview.



Source: Corazon Creek Solar PV Project, System plan design, SESB, Contractor. 2020

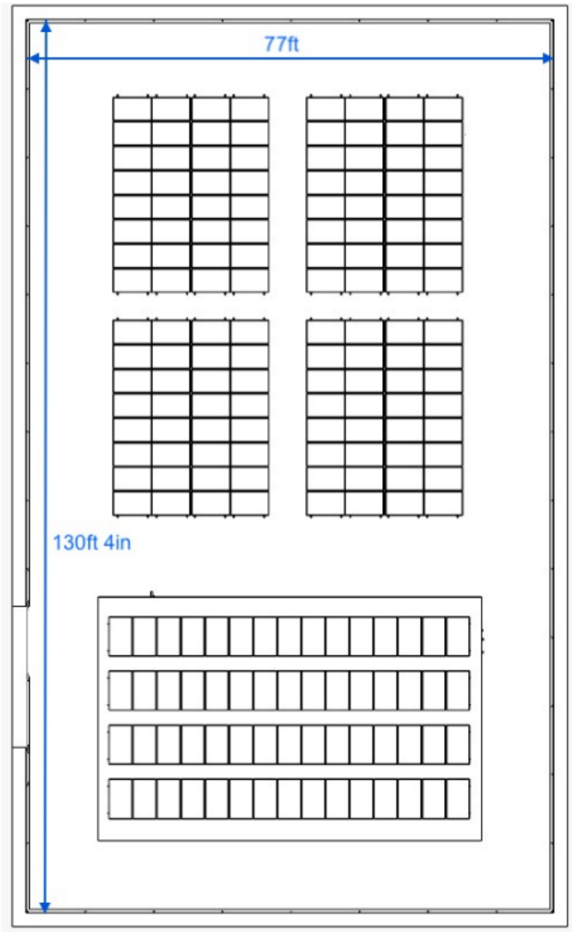
Figure 11 to 14 show the final designs submitted by the contractor, Solar Energy Solutions Belize (SESB). While there is limited space for future panel installations, there is still capacity to increase the inverter size beyond the current 36kW and expand the battery system from its current 172kWh. The system also includes a robust 60kW backup generator.

The figure below presents the final technical design in a 3D format.

Figure 11: Final 3D Technical Design 2021

Source: Corazon Creek Solar PV Project, System plan design, SESB, Contractor. 2021

Figure 12: Final 2D Technical Design Overview



Source: Corazon Creek Solar PV Project, System plan design, SESB, Contractor. 2021

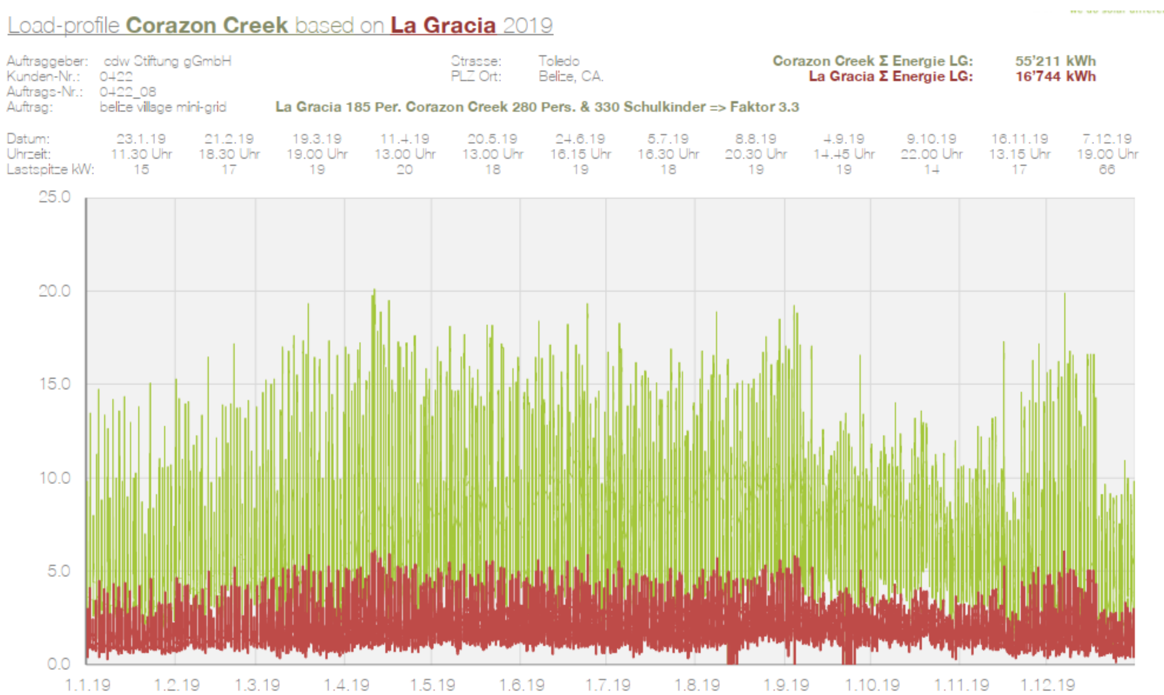
The figures 13 and 14 below present the load profile for Corazon Creek Community, which was compared with the La Gracia load profile from 2019. La Gracia has approximately 40 households and a primary school, while Corazon Creek has 50 households, a primary school, and a high school. It was determined that the high school would be the largest energy consumer. The La Gracia system was found insufficient, as load growth occurred almost immediately after its installation. It remains unclear what methodology SESB used to calculate the load profile for Corazon Creek. However, through another project funded by the European Union, the Government of Belize (GOB) and Belize Electricity Limited (BEL) obtained a load calculation methodology for mini grids. This methodology accounts for energy growth over a 10-year period, with significant growth expected in the first three years, followed by a gradual plateau.

The methodology for the European Development Fund (EDF-11) project was provided by Trama Techno Ambiental (TTA), a larger, more experienced company in the solar field. TTA's approach included collecting community data using specialized equipment like drones and utilizing software to design the system and provide realistic budgeting. Although the Corazon Creek system design did account for future growth by allowing space for more solar panels, inverters, and a battery bank, the original analysis was done in 2019, while installation began in 2024. Initially, the consent agreement was expected to be signed in September 2021, with installation starting soon after, but delays meant the actual installation did not commence until 2024.

In the meantime, Corazon Creek's high school constructed four additional classrooms, with eight more currently under construction. This highlights an important lesson: when there's a significant gap between the load profile analysis and system installation, the scope of the project needs to be revisited to assess the level of energy service required. Decisions must be made about whether to provide power only to households or to all customers, and whether to offer 24-hour service. If reliable power for all is the goal, another load profile analysis would be necessary. If energy demand exceeds supply, power outages will occur, or the generator will need to run more frequently, undermining the goal of sustainability.

Figure 13 below shows a load profile conducted by SESB, where the high school's energy consumption was lower at the time. The chart appears to be in area format.

Figure 13: Load profile Corazon Creek based on La Gracia 2019

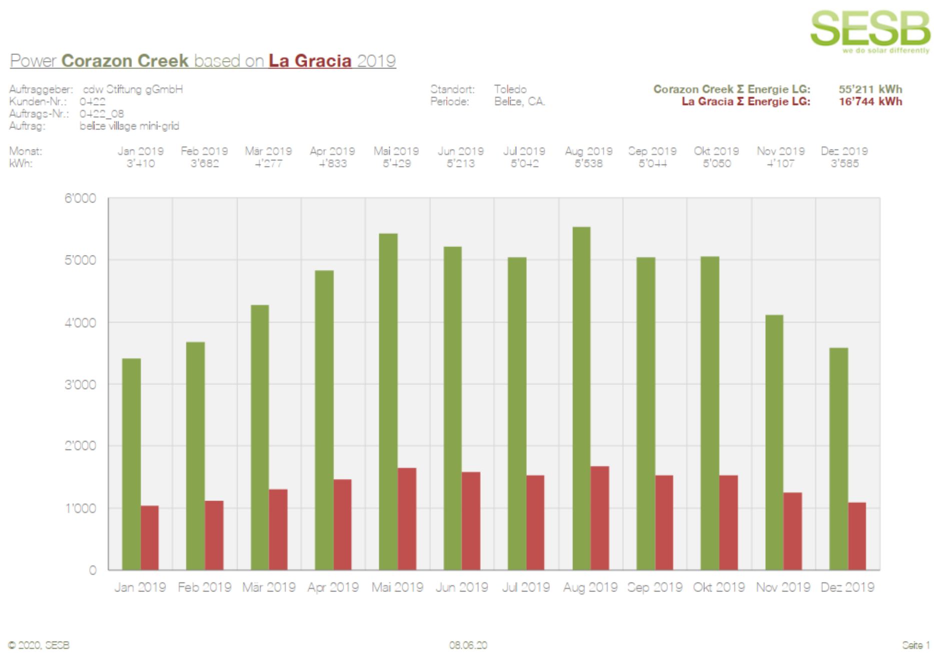


Source: Corazon Creek Solar PV Project, Load profile analysis, SESB, Contractor. 2019

Figure 14 below presents a bar graph comparing the La Gracia 24kW system with the Corazon Creek 36kW system. Although the solar array for Corazon Creek has a capacity of 69.5kWP, the inverter is currently sized at 36kW. In comparison, La Gracia has 96 solar panels, each rated at 255kW, resulting in a 24kW solar capacity. However, this does not mean the system will produce exactly 24kW, just as Corazon Creek's array will not generate exactly 69.5kWp. While theoretically possible, actual output will always be lower. The

Corazon Creek system is designed to generate 36kW, supplemented by a 60kW backup generator whereas la Gracia has a smaller 22kW backup generator.

Figure 14: Power Corazon Creek based on La Gracia 2019



Source: Corazon Creek Solar PV Project, Load profile analysis, SESB, Contractor. 2019

The image below was taken by TTA during their visit to Belize. The objective was to assess existing and ongoing mini-grids in the country, identifying successful practices and avoiding pitfalls to improve the EDF-11 project and future mini grid initiatives in Belize.

Figure 15: Drone Imagery of the Generation Unit

Source: Corazon Creek Solar PV Project, PV array mounting image, TTA, Contractor. 2024

Figure 15 above, the final artifact, closely resembles Figure 11 from the planning stage. Despite the limited planning details, significant delays in the signing of the consent agreement and increased material costs, the project was successfully executed thanks to the flexibility of the project sponsor and contractor with budget and time. This level of flexibility, however, is not the case for other ongoing projects.

The image below, also captured by TTA, shows a side elevation view.

Figure 16: Side Elevation of the control room.

Source: Corazon Creek Solar PV Project, PV array mounting image, TTA, Contractor. 2024

Figure 17 below, captured by TTA, shows a front elevation view.

Figure 17: Front Elevation of the entire power generation unit.

Source: Corazon Creek Solar PV Project, PV array mounting image, TTA, Contractor. 2024

4.2. Deliverable 1: Stakeholder Role Definitions

In figure 7 above, the letter agreement only listed key stakeholders which is the Ministry, BEL and CDW Foundation and highlighted the roles. While that may be okay in the initiating phase, it is very crucial to identify other stakeholders, not only those that can contribute to the success of the project but those that will be benefitted from the project.

Therefore, the document below defines the roles, responsibilities, and accountability measures of each stakeholder involved in the mini grid implementation project. In the end, all the parties understand their duties and are authorized to contribute effectively toward project success.

Chart 11. Stakeholder Role Definitions

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
Energy Unit	Project Coordinator	Manages day-to-day project activities, ensuring adherence to timelines, quality standards, and stakeholder	High	Responsible for overall project execution and maintaining effective stakeholder engagement.

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
		engagement. Facilitates communication with local communities.		
Indigenous People's Affairs (IPA)	FPIC advisor	Oversees the consultation and consent process (FPIC) for projects impacting the lands or wellbeing of the Maya people of Southern Belize	High	Responsible for submitting request letters, assisting with translation, and arranging logistics for meetings, ensuring adherence to FPIC protocols.
Ministry of Rural	Liaison officer	Ensure alignment with the Ministry's	Medium	Supports in addressing project obstacles, informs

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
Transformation (MRT)		mission to improve lives through access to essential services like energy.		community leaders of meetings, and mediates conflicts.
CDW Stiftung (CDW Foundation)	Financial Sponsor	Provides funding and coordinates the design and installation of the Power Generation Unit, along with wiring homes with lights, outlets, and service entrances.	Medium	Responsible for financing the project and overseeing the project execution.
Contractor (SESB)	Technical Lead (Mini-Grid,	Manages the design and installation of the	High	Accountable for timely delivery of technical

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
	Wiring, and Connections)	Power Generation Unit and provides technical support during testing phases. Ensures compliance with PUC regulations for home wiring.		components, including system installation and home connections.
BEL	Joint Technical Lead (Distribution Network)	Responsible for designing, installing, and financing the distribution network. Manages the energization of homes and businesses.	High	Accountable for the timely installation and operation of the distribution network, ensuring homes and businesses are energized.

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
		Operates the power generation Unit at Corazon Creek.		
Community Leaders	Local Representatives	Engages with the community to ensure alignment and support for the project. Facilitates communication between the project team and residents	High	Accountable for representing the community's interests and ensuring active participation in the project.
Corazon Creek High School	Energy User/ Stakeholder	Represents the largest energy consumer in the community.	Low	Responsible for communicating energy needs and ensuring the

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
		Provides data for load profiling and feedback on energy needs.		school's connection to the system is considered.
Lait Up Belize funded by the European Union	External Funder/Advisor	Provides additional funding for complementary aspects of the project. Advises on best practices for sustainable energy projects	Medium	Accountable for funding monitoring and policy recommendations.
Belize Social Investment Fund (BSIF)	Stakeholder for the High School	Oversees the construction of eight additional classrooms and	Low	Ensure efficiency in energy systems by avoiding the installation of

Stakeholder	Role/Title	Responsibilities	Authority Level	Accountability
		ensures the building is powered efficiently. Manages the budget for energy expenses.		additional solar solutions where a solar power plant is already in place, and guarantee the building, along with existing structures, is properly energized.

Note: Table elaborated with insights from Project Management Institute and by A. Matar, 2024.

Chart 11 above derived from the letter of agreement, which outlines the parties involved and their roles. This chart expands on that by providing more detailed information to facilitate the work. In several cases, a RACI chart, representing Responsibility, Accountability, Consulted, and Informed, can also be used. It is also known as responsibility assignment matrix. This differs from the stakeholder role definitions shown in Chart 11. In the RACI chart, the first column lists all activities, while the top row identifies stakeholders, with R, A, C, and I assigned to each stakeholder accordingly. However, listing all activities can be challenging and impractical, especially for a ministry that oversees various documents. The RACI matrix is more commonly used in the private sector, for instance, when implementing a solar mini grid, the contractor might list all tasks and assign roles to staff, while for a Ministry, simply outlining the overall tasks is typically sufficient.

4.2.1 Collaboration Framework

To create a structured framework for collaboration, communication, and decision-making among stakeholders in the mini-grid among in the mini-grid implementation project. This framework will bring forth coordination and resolution of potential conflicts.

Chart 12. Collaboration Framework

Communication Channels

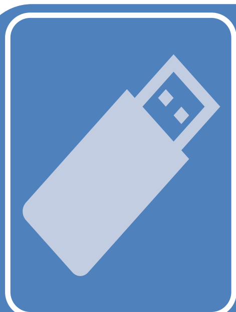
- Primary Mode of Communication:
  - Email: Formal communication
  - WhatsApp: Informal for quick update
  - Vitual meetings: Weekly or bi-weekly video conference calls.
- Reporting:
  - Progress Reports-Submitted to Ministry monthly.
  - Meeting minutes: Weekly or bi-weekly

Decision-Making Progress

- Strategic Decisions: Major decisions (scope changes, budget increases) require approval from Ministry and the Project Sponsor
- Operational Decisions: Day-to-day decision such as schedule adjustments, minor technical modifications are made by the Project Coordinator in consultation with the contractor and joint technical implementer (BEL)
- Escalation Procedure: In the case of disputes, the Project Coordinator will escalate issues to a steering committee composed of respresntatives from the Ministry, Project Sponsor, village leaders, and contractor for final resolution.

Conflict Resoltion Protocol

- Step 1: Attempt resolution at the lowest possible level (e.g. between the Project Coordinator, Joint technical team, and village leaders).
- Step 2: If unresolved, escalate the issue to the Ministry for mediation
- Step 3: If necessary, request cabinet to facilitate negotiations.



Information- Sharing Platform

- Share Project Drive (Teams , SharePoint, or Onedrive)
  - All project docments, designs, progress reports, and meeting minutes will be stored in a centralized location for easy access.
  - Permissions will be managed by the Project Coordinator to ensure that stakeholders have access to the necessary information.

Collaboration Effectiveness Tracking

- Quaterly Stakeholder Surveys:
  - If the project extends beyond a year, a bi-annual survey can be conducted. Stakeholders will provide feedback on communitation effectiveness and decision-making processes to identify gaps and areas for improvement.
- Collaboration Perfomance Metrics
  - Timelineess of communication- reponses within 24 hours for urgent matters.
  - Engagement Levels- attendance at meetings, timely submission of reports.
  - Conflict Resolution Time-Time taken to resolve disputes.

4.3. Quality Assurance Plan

The purpose of the quality assurance plan is to establish procedures and performance metrics for mini- grid systems to maintain high standards of system performance. This includes international standards and best practices in solar PV quality assurance, including references like the NEC handbook. In the context of mini-grids, the Ministry, through its Energy Policy 2023, is committed to achieving universal access to Tier 4 level service as a minimum standard, in line with the United Nations Tiers of Electrification.

For mini-grid implementation, it is ideal to standardize aspects such as design modeling methodology, software tools (e.g., Helioscope, HOMER Pro), load profiling, future demand projections, simulation processes, assumptions, and budget determination. One energy expert noted that if Tier 4 level service is required for future mini-grid projects, it should be clear what modeling methodology will be used. Standardizing mini-grid implementation allows for better comparison between systems.

However, this is not always the case. Often, a budget is set first, and then the system size and future demand are adjusted to fit within that budget, leading to unclear project scopes. This can make it difficult to maintain quality and ensure end-user satisfaction. The Quality Assurance Plan aims to incorporate lessons learned, avoid repeating past mistakes, and ensure that the final product aligns with the needs and expectations of the end-users, rather than simply reflecting the priorities of the project sponsor or the Ministry.

The Quality Assurance Plan is noted below:

Project Quality Plan

1. Quality Objectives (what and why)

What:

- To ensure system's design, installation, and operation comply with the required standards such as the Public Utilities Commission (PUC) Belize and the National Electrical Code (NEC)

Why:

- To guarantee the reliability and longevity of the system components such as solar panels, inverters, and battery storage.
- To maintain safe and efficient operations that meet the projected energy demands of Corazon Creek Village.

2. Key Responsibilities

Stakeholder	Role	Quality Responsibility
Energy Unit	Project Coordinator	Ensure compliance with national energy regulations and oversee system quality control.
Contractor (SESB)	Technical Lead	Conduct quality checks before shipping to site on

Stakeholder	Role	Quality Responsibility
		equipment and during installation and test system performance before commissioning
BEL	Distribution Lead	Ensure that the distribution network meets their standards, and integrates effectively with the system
CDW Stiftung (Sponsor)	Financial Sponsor	Monitor resource allocation for quality implementation.

3. Quality Assurance Measures

   - **Design Review**: Ensure to review the design before construction to verify that the system meets the technical requirements and Level of Service as noted in figure 18.

The table below, chart 13, shows the following information to review to complete Design Review step.

Chart 13. Design Information Table

General	
Project name	
Project Site	
Location (Longitude and Latitude of Site)	
PV Generator	
Total nominal capacity at STC (kWp)	
Total number of PV modules	
PV module manufacturer and model	
PV structure type	
Battery	
Battery type	
Total nominal capacity (kWh)	
Battery nominal voltage (Vdc)	
Manufacturer and model	
Power Electronics	
Battery Inverter total capacity (kVA continuous)	

Battery Inverter manufacturer and model	
Battery inverter total number	
Hybrid Inverter total capacity (kVA)	
Hybrid Inverter manufacturer and model	
Hybrid inverter total number	
PV charge controller total capacity (kWdc)	
PV charger controller manufacturer and model	
PV charge controller total number	
PV Inverter total capacity (kWac)	
PV Inverter manufacturer and model	
PV inverter total number	
Back-Up Generator	
Prime power (kVA)	
Manufacturer and model	
Fuel type	
Step-Up Transformer	
Nominal power (kVA)	

Type	
Step-up voltage (V)	
Manufacturer and model	
Powerhouse	
Type	Concretes, Containerized solution, structural insulated panels…
Number and type of rooms	E.g., 1x storage, 1x office, 1x toilet, 1x guard, etc.

Note: Table elaborate by TTA and technical stakeholders, 2024. Share work.

The Figure below is a multi-tier framework developed by the World Bank and Energy Sector Management Assistance Program (ESMAP). TIER 4 is the aim.

Figure 18: Level of Service (Multi-tier framework)

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3[b]	TIER 4	TIER 5
Capacity	Power capacity ratings (W or daily Wh)	Less than 3 W	At least 3 W	At least 50 W	At least 200 W	At least 800 W	At least 2 kW
		Less than 12 Wh	At least 12 Wh	At least 200 Wh	At least 1 kWh	At least 3.4 kWh	At least 8.2 kWh
	Services		Lighting of 1,000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability[a]	Daily Availability	Less than 4 hours	At least 4 hours		At least 8 hours	At least 16 hours	At least 23 hours
	Evening Availability	Less than 1 hour	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability		More than 14 disruptions per week			At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours"	(> 3 to 14 disruptions / week) or ≤ 3 disruptions / week with > 2 hours of outage	At most 3 disruptions per week with total duration of less than 2 hours
Quality		Household experiences voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability		Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		No bill payments made for the use of electricity				Bill is paid to the utility, prepaid card seller, or authorized representative	
Health and Safety		Serious or fatal accidents due to electricity connection				Absence of past accidents	

Source: https://mtfenergyaccess.esmap.org/methodology/electricity

- **Material Verification:** Check that all materials (solar panels, inverters, batteries) meet industry quality standards before installation.

  Quality Assurance System that complies with ISO 9001 or an equivalent or higher standard. All systems and equipment must adhere to recognized international and regional standards, demonstrating reliability and proven performance in commercial-scale deployments. All equipment shall be new and in perfect working condition.

All containers and packaging for components shipped separately must be constructed to withstand land or sea transport conditions.

The engineering, construction, and commissioning of the mini-grid systems shall adhere to the following standards, or their Belizean or regional adaptations:

- IEC 60364, specifically IEC 60364-7-712 (Electrical installations of buildings)
- IEC TS 62257 (Recommendations for renewable energy and hybrid for rural electrification)
- IEC 62548 (Design requirements for PV arrays)
- IEC 61936-1 (Power installations exceeding 1 kV AC)
- IEC 60287 (Electric Cables-Calculation of the current rating)
- IEC62305 (Protection against lightning)
- NEC 2020 (National Electrical Code) (applicable to electrical installations in Belize, aligned with U.S. standards)
- Belize National Building Code (for structural and civil works, ensuring local compliance)

➢ **Installation Inspection:** Perform Visual Inspection during key stages of installation process (foundation, PV module, battery system, generator, Hybrid Inverter, battery Inverter, PV Inverter, and powerhouse)

Chart 14. Installation Inspection Activities

PV Module	
1. The PV modules are clean	Yes ☐ No ☐
2. The PV modules do not show any kind of damage (Scratches, impacts, cell cracks or snail tracks, delamination, etc.)	Yes ☐ No ☐
3. There is no shading on the PV modules (vegetation, obstacles, fences, etc.)	Yes ☐ No ☐
4. Correct distance between PV arrays and fencing (front and both sides)	Yes ☐ No ☐
5. The PV modules are securely fastened to the structure via middle and end clamps, without any sign or defect nor gaps between the clamps and the modules.	Yes ☐ No ☐
6. Each module must be grounded through the designated earth hole and securely connected to the structure	Yes ☐ No ☐
PV Structure	
7. PV structure is correctly fixed and stable.	Yes ☐ No ☐

8. PV structure does not show any sign of damage (cracking, etc.) or corrosion	Yes ☐ No ☐
9. PV structure foundations base plate and anchor bolts are firmly attached, without any gap between base plate and foundation, and correctly centered at the foundations' middle point.	Yes ☐ No ☐
10. The PV structure foundations do not show any sign of damage (cracking and crumbling due to bad concrete mixing, porosity due to excessive water, etc.)	Yes ☐ No ☐
11. There is no electrolytic couple between metals of different nature.	Yes ☐ No ☐
12. Correct depth if driven piles or screws.	Yes ☐ No ☐
Outdoor DC Cabling	
13. The cable routing is as per approved design	Yes ☐ No ☐
14. All PV connectors are plug-in MC4 connectors from the same manufacturer and with the correct IP rating.	Yes ☐ No ☐
15. PV connections are tight (perform a pull test on a sample of connections).	Yes ☐ No ☐

16. The PV cables are correctly fixed below the PV modules and to the structures, without being in contact with sharp edges that could pose a risk of insulation damage.	Yes ☐ No ☐
PV COMBINER BOXES	
17. The PV combiner box is installed below the PV modules avoiding direct sun exposure.	Yes ☐ No ☐
18. The PV combiner box is firmly mounted using suitable fasteners.	Yes ☐ No ☐
19. The PV combiner box material is as per approved design.	Yes ☐ No ☐
20. The PV combiner box cables are securely tightened (check the tightness of the crimping by slightly pulling it.)	Yes ☐ No ☐
21. The PV combiner box material is as per approved design.	Yes ☐ No ☐
22. The PV combiner box IP rating is as per approved design.	Yes ☐ No ☐
Powerhouse/Container	
23. Powerhouse/container and its foundations is built as per approved design.	Yes ☐ No ☐

24. Powerhouse/ container and its foundation do not show any type of defect (cracks, corrosion, painting defects, openings, etc.)	Yes ☐ No ☐
25. Cable entries are properly installed using conduits without gaps nor openings.	Yes ☐ No ☐
26. Interior spaces are clean and tidy	Yes ☐ No ☐
27. The floor is regular with correct finishing layer.	Yes ☐ No ☐
28. The office room contains all materials as per project requirements (number of chairs, desks, laptops, etc.)	Yes ☐ No ☐
29. Water runs through toilet and sink in the toilet room.	Yes ☐ No ☐
30. The doors open towards the exit way.	Yes ☐ No ☐
31. Door includes push bars as applicable	Yes ☐ No ☐
32. Ventilation and/ or air conditioning system is installed as per approved design and does not show any type of defects.	Yes ☐ No ☐

33. All documentation is in place in the correct language: • As-built report, including all technical notes and drawings. • O&M manual • Component documentation (datasheets, manuals, warranties) • Commissioning documentation signed by all relevant stakeholders (at the end of commissioning)	Yes ☐ No ☐
Battery	
34. The area around the batteries is kept clear and free of combustible materials, gasoline and/or other flammable fumes, vapors, and liquids.	Yes ☐ No ☐
35. The installation of components is as per approved designed.	Yes ☐ No ☐
36. The separation distances (front, side, and rear access) are as per manufacturer instructions.	Yes ☐ No ☐
37. Racks and battery modules are correctly installed without any kind of defect (cracks, corrosion, chemical leakage, etc.,)	Yes ☐ No ☐
38. Each batter module and BMS is correctly labelled.	Yes ☐ No ☐

39. The battery terminals and terminal connectors are properly protected with insulator material to avoid accidental short-circuits.	Yes ☐ No ☐
40. The battery terminals are labeled with voltage hazard sign	Yes ☐ No ☐
41. The cables are neatly installed and the connections to the terminals are tight.	Yes ☐ No ☐
42. Metallic mass (structures, BMS rack, etc.) are earthed as per approved designed.	Yes ☐ No ☐
PV charge controllers	
43. The controllers do not show any sign of defect.	Yes ☐ No ☐
44. The controllers are installed as per approved design.	Yes ☐ No ☐
45. The manufacturer's minimum separation distances are respected to allow efficient heat dissipation.	Yes ☐ No ☐
46. The controllers are properly fixed onto the wall or supporting structure.	Yes ☐ No ☐
47. The controllers are properly labelled.	Yes ☐

	No ☐
48. Positive cables have red insulation and negative cables have black insulation.	Yes ☐ No ☐
49. Communication network terminator is installed correctly	Yes ☐ No ☐
50. The controllers are earthed as per approved design with green/yellow cable.	Yes ☐ No ☐
Hybrid Inverter	
51. The inverters do not show any sign of defect	Yes ☐ No ☐
52. The inverters are installed as per approved design	Yes ☐ No ☐
53. The manufacturer's minimum separation distances are respected to allow efficient heat dissipation.	Yes ☐ No ☐
54. The inverters are properly fixed onto the wall or supporting structure.	Yes ☐ No ☐
55. The inverters are properly labelled.	Yes ☐ No ☐
56. All cables are properly labelled.	Yes ☐

	No ☐
57. Positives cables have red insulation and negative cables have black insulation.	Yes ☐ No ☐
58. Communication network terminator is installed correctly	Yes ☐ No ☐
59. The inverters are earthed as per approved design with green/yellow cable.	Yes ☐ No ☐
Battery Inverters	
60. The inverters do not show any sign of defect	Yes ☐ No ☐
61. The inverters are installed as per approved design	Yes ☐ No ☐
62. The manufacturer's minimum separation distances are respected to allow efficient heat dissipation.	Yes ☐ No ☐
63. The inverters are properly fixed onto the wall or supporting structure.	Yes ☐ No ☐
64. The inverters are properly labelled, indicating master and slaves.	Yes ☐ No ☐
65. All cables are properly labelled.	Yes ☐

	No ☐
66. Positives cables have red insulation and negative cables have black insulation.	Yes ☐ No ☐
67. Communication network terminator is installed correctly	Yes ☐ No ☐
68. The inverters are earthed as per approved design with green/yellow cable.	Yes ☐ No ☐
PV Inverters	
69. The inverters do not show any sign of defect	Yes ☐ No ☐
70. The inverters are installed as per approved design	Yes ☐ No ☐
71. The manufacturer’s minimum separation distances are respected to allow efficient heat dissipation.	Yes ☐ No ☐
72. The inverters are properly fixed onto the wall or supporting structure.	Yes ☐ No ☐
73. The inverters are properly labelled.	Yes ☐ No ☐
74. All cables are properly labelled.	Yes ☐

	No ☐
75. Positives cables have red insulation and negative cables have black insulation.	Yes ☐ No ☐
76. Communication network terminator is installed correctly	Yes ☐ No ☐
77. The inverters are earthed as per approved design with green/yellow cable.	Yes ☐ No ☐
Generator	
78. The area around the generator is kept clear and free of combustible materials, gasoline and/ or other flammable fumes, vapors, and liquid.	Yes ☐ No ☐
79. The generator is installed as per approved design (location, inside powerhouse or not, power ratings, fenced, etc.)	Yes ☐ No ☐
80. Ensure there are no leakages (Coolant, fuel, oil, battery electrolyte, etc.)	Yes ☐ No ☐
81. Storage tank is available and properly installed with the capacity specified in the project requirements.	Yes ☐ No ☐
82. Ensure proper ventilation if generator is inside a powerhouse room (air intakes, outlets, fans, and air ducts)	Yes ☐ No ☐

83. Ensure that electrical cables to the generator are properly terminated, tight and secure.	Yes ☐ No ☐
84. Ensure that the communications cables between generator's controller and the controller from some other component such as batteries, PV inverters, are completed and terminated at both ends, and run through dedicated PVC conduits.	Yes ☐ No ☐
85. Warning signs and alarms are present and functional.	Yes ☐ No ☐

Note: Table elaborate by TTA and technical stakeholders, 2024. Share work.

4. Quality Control Measures

   - **Step 1: Verification of the results-** Conduct regular inspections to ensure that all materials, wiring, and components conform to quality standards. Comparing results with the specifications and by conducting systematic audits at each phase.
   - **Step 2: Conduct data analysis-** Test solar panels, inverters, battery systems, and wiring before final installation.
   - **Step 3: Documentation**- Ensure detailed records of each phase are maintained, including test results and certifications.
   - **Compliance Reviews-** Conduct checks to ensure compliance with PUC standards for wiring and connections of homes, health, and safety regulations.

5. Key Deliverables

   a. Regular Inspection Reports (weekly during critical phases)

   b. Test certificates for panels, inverters, and batteries.

   c. Quality checklists after each major installation step.

6. Performance Monitoring

   a. **Performance Testing**: After installation, performance tests will be conducted to ensure that the system delivers power to design.

   b. **Post-installation Monitoring:** System performance will be monitored for 30 days to ensure reliable operation and identify any defects. If non-conformance is identified, the contractor will issue a corrective action request that outlines the problem and resolution timeline.

4.3.1 Performance Metric Report

The performance of the metric report is to track and measure and it is constructed to measure efficiency, reliability, and effectiveness of the mini-grid system. This report will use pre-determined performance indicators to evaluate system operations and ensure it meets the energy demands of future underserved communities.

The table below presents the list of tools available at the Ministry, including details on their brand, model, and relevant units of measurement. While possessing these tools is important, the ability to effectively use them is equally important for obtaining accurate results. By utilizing these KPIs and corresponding instruments, the Ministry will be able to monitor and optimize the performance of the mini-grid system, ensuring its efficiency, reliability, and longevity. It is important to note that Chart 15 does not include KPIs for transformer load factor and cost per kWh delivered, as these fall under BEL's area of expertise, given their responsibility for transmission and distribution of electricity.

Chart 15. Key Performance Indicators

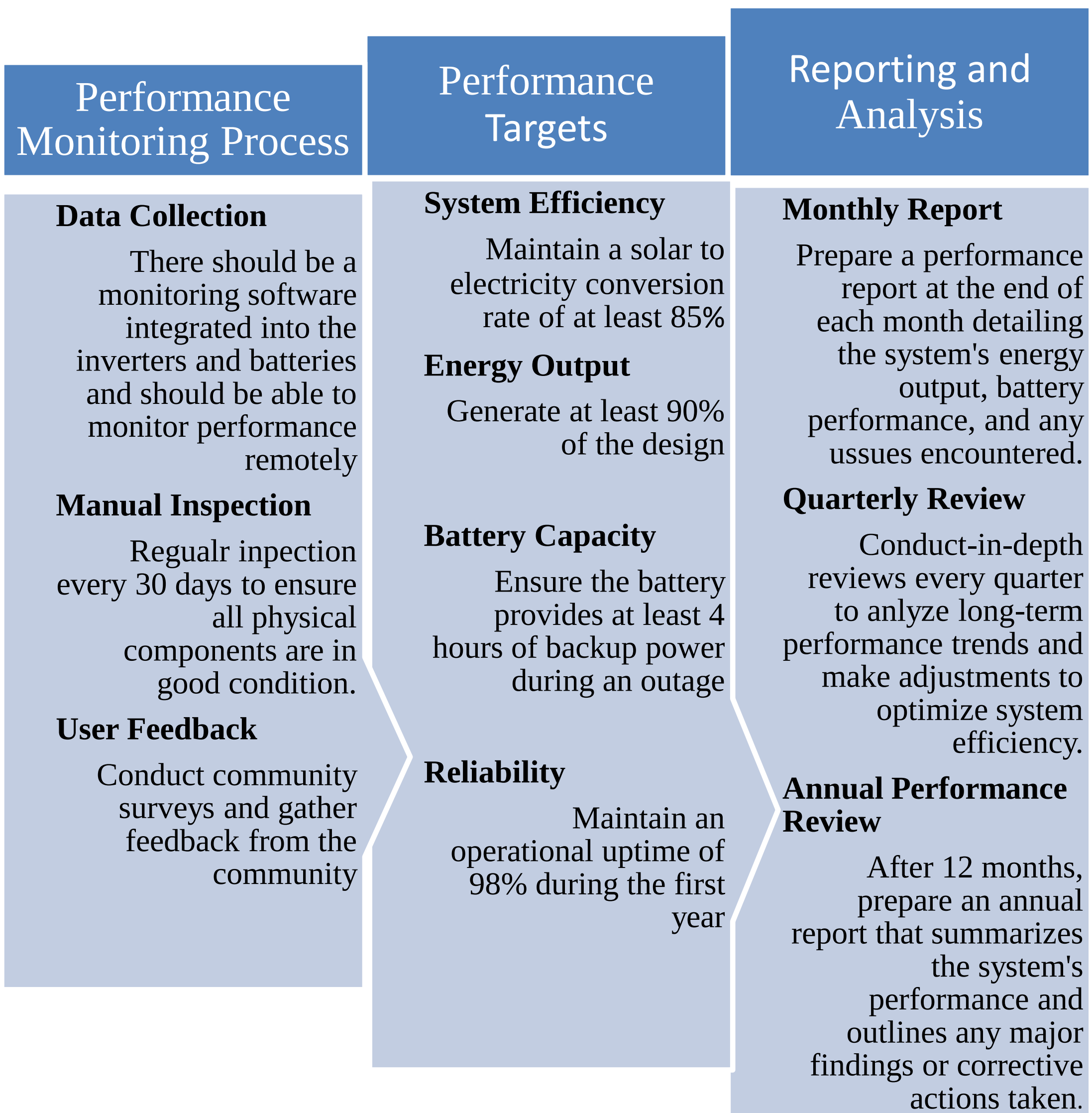
Num	KPI	Instrument Description	Brand and Model	Magnitude	Unit
1	System Efficiency	Solar System Analyzer	HT Solar 300N	System Performance	kW
2	Energy Output	Power Logger/Power Analyzer	Fluke 1738	Power, Energy	kW, kWh
3	Reliability (Uptime)	Power Logger/Power Analyzer	Fluke 1738	Uptime/Downtime	
4	Battery Performance	Solar System Analyzer	HT Solar 300N	Storage Capacity	kWh
5	Maintenance Requirements	Multifunction Installation Tester, 1500V PV insulation Test	HT PV-ISOTEST	Insulation Resistance	V

Num	KPI	Instrument Description	Brand and Model	Magnitude	Unit
6	Solar Irradiance	Solar Radiation Meter	Fluke	Irradiance	W/m2
7	Panel Hotspot Detection	Infrared Thermal Imaging Camera	Fluke Ti Series	Surface Temperature	°C or °F
8	CO_2 Emissions Reduction	Emission Analyzer	Testo 300	Oxygen, CO, CO_2 of back-generator	%

Note: Table elaborated by A. Matar, Author, 2024. Own work

Once the measurements have been completed to assess whether the system is performing as expected, the next steps are outlined in Chart 16. These steps include the following: Performance Monitoring Process, Performance Targets, and Reporting and Analysis. Once these are conducted, it will be possible to determine if performance metrics are within the established targets or if they fall below expectations. If the performance falls short, the project team will develop an improvement plan to address any deficiencies. Specific actions to optimize system performance could include replacing faulty components, adjusting the panel tilt, or recalibrating the battery system. Chart 16 provides further details on these components.

Chart 16. Key Performance Process



Note: Chart elaborated by A. Matar, Author, 2024. Own work

4.4. Project Schedule

Creating a project schedule is a fundamental aspect of any project. When the consent agreement for Corazon Creek was signed, a kick-off meeting was required to initiate the project. During this meeting, management requested a project timeline. One of the joint project leaders provided a written list of deliverables with estimated time limits for each, while the other gave a verbal overview of their deliverables.

Although many project managers use Microsoft Project to develop schedules, this software, though available at the Ministry, is underutilized. The reasons include lack of staff training, inexperience with the software, and limited information regarding the project's specific activities. A project schedule provides crucial insights into the project's progress and helps the project manager determine when to conduct various phases such as the implementation checklist, installation inspections, and performance metric reporting, as previously discussed.

Building a project timeline requires careful planning, including identifying key tasks, their duration, dependencies, and responsible stakeholders. The project schedule outlined in this FGP will highlight the essential components needed to create a comprehensive schedule that management will find valuable.

In the Corazon Creek mini-grid project, two joint project leaders are responsible: one oversees the solar plant, wiring, lights, outlets, PUC connection approval, and service entrance construction for homes, while the other manages the distribution network and home connections. Although future projects may involve additional third or even fourth parties, following this methodology increases the likelihood of successful implementation while ensuring that quality and standards are upheld.

Below are the key components necessary for creating an effective project schedule.

Key Components

- Task Breakdown: List all major tasks required for project completion, from planning and design to installation, testing, and final commissioning.
  - The task breakdown should focus solely on the implementation phase and not include planning activities. Tasks such as creating civil engineering drawings like PV power plant designs, technical building structural plans, diesel generator shelter layouts, water management system drawing, security fencing entry gate designs, and access road drawings should be completed during the planning stage and not after the kick-off meeting. Additionally, the signing of the consent agreement should also be finalized before the kick-off to avoid any delays during implementation.
  - While the planning phase should ideally include a detailed project schedule, it often only outlines the project's start and end dates without these specifics.
  - Therefore, the task breakdown for the implementation phase will begin from survey mapping for distribution network, detailed community load profile, supply and transportation of equipment and materials, followed by installation, commissioning, operational acceptance,

training and finally, project closure, which includes the system's inauguration.

Chart 17. Task Breakdown Table

Deliverable	Estimated Timeline	Details
Mapping survey for distribution network	1 week	Ensure data is gathered for both current load and future demand growth
Community Survey to create a Load Profile	1 week	Engage with local community members to assess typical usage patterns, future demand, and special cases like the high school.
Permitting and Regulatory Approvals	4 weeks	Any required environmental clearance or Ministry permits should be obtained during this

Deliverable	Estimated Timeline	Details
		stage to avoid delays later.
Procurement of materials and equipment for solar mini grid and distribution network	4 months	Includes sourcing from approved vendors, tender process, and material lead times. Consider potential delays in shipping.
Land Preparation and Foundation Work	6-8 weeks	Clear the land, prepare foundation for equipment such as inverters, batteries, and solar panels. Any groundwork that needs specialized equipment should be completed.
Delivery of Container and installation of Roof Structure	2 weeks	Includes both transport logistics and the setting up of temporary or

Deliverable	Estimated Timeline	Details
		permanent structures for storage and installation.
Delivery of Poles and step-up transformer	4 weeks	Ensure materials for the grid installation arrive in parrel with the equipment needed for solar power generation to avoid delays.
Installation of batteries and Inverters	2 weeks	Batteries and invers are installed and tested. Ensure proper safety checks and operational test runs.
Installation of Poles	3 weeks	Install distribution poles for electrical network. Ensure all poles are in line with

Deliverable	Estimated Timeline	Details
		approved distribution layout.
Installation of transformers and network	3 weeks	Includes both installing transformers and wiring the distribution network. BEL should ensure that electrical codes and standards are followed.
System Commissioning	1 week	Perform initial tests of the entire mini grid, ensuring all components communicate and operate as expected.
PUC approval for connection of households	2 weeks	Coordinate with the PUC for any necessary site inspections and approvals for

Deliverable	Estimated Timeline	Details
		connections. Make sure paperwork is submitted early to avoid delays.
Service Entry for households	10 weeks	Installation of service entry boxes and meters at households. Ensure compliance with local electrical regulations.
Wiring of households	7 weeks	Homes should be wired with appropriate lighting and power outlets. Conduct inspections to ensure compliance with electrical standards.
Connection of homes	7 weeks	Once wiring is complete, connect homes to the grid and energize. Perform

Deliverable	Estimated Timeline	Details
		system checks on the performance of each household connection.
Inspection and Certification of Electrical Systems	1 week	After installation and wiring, obtain certifications to ensure compliance with safety and performance standards.
Planning for inauguration of project	7 weeks	Include community involvement, Government Press Office, and the coordination of a formal handover ceremony.

Table elaborate by technical stakeholders, 2024. Share work.

The installation time frame in table 17 above may vary depending on the availability of financial and human resources. Microsoft Project can help account for this by identifying potential resource allocation or conflicts. Additionally, it is important to closely monitor permitting and approvals, as delays in government approvals can become a bottleneck. To mitigate this, permitting processes should run in parallel with procurement activities. Finally, planning for the project inauguration can be challenging due to budget constraints and management approvals. To ensure a smooth transition, it is crucial to keep all stakeholders informed and have the necessary documentation ready for a successful handover in the project's final stages.

- Task Dependencies: Establish the sequence of activities, indicating which tasks depend on the completion of others.
    - Based on the information in chart 17 above, the task dependency breakdown is structured in a table format, showing the Task Name, its Predecessor (the task that needs to be completed before it), and its Successor (the task that follows next) and it is noted below:

Chart 18. Task Dependency Table

Task Name	Predecessor	Successor
Execution Phase		
Mapping Survey for Distribution Network	None	Community Survey to Create Load Profile
Community Survey to Create Load Profile	Mapping Survey for Distribution Network	Permitting and Regulatory Approvals

Task Name	Predecessor	Successor
Permitting and Regulatory Approvals	Community Survey to Create Load Profile	Procurement of Materials and Equipment
Procurement of Materials and Equipment	Permitting and Regulatory Approvals	Delivery of Container and Installation of Roof Structure, Delivery of Poles, and Step-Up Transformer
Land Preparation and Foundation Work	Permitting and Regulatory Approvals	Delivery of Container and Installation of Roof Structure, Installation of Batteries, and Inverters
Delivery of Container and Installation of Roof Structure	Procurement of Materials and Equipment, Land Preparation and Foundation Work	Installation of Batteries and Inverters
Delivery of Poles and Step-Up Transformer	Procurement of Materials and Equipment	Installation of Poles

Task Name	Predecessor	Successor
Installation of Batteries and Inverters	Land Preparation and Foundation Work, Delivery of Container, and Installation of Roof Structure	System Commissioning
Installation of Poles	Delivery of Poles and Step-Up Transformer	Installation of Transformer and Network
Installation of Transformer and Network	Installation of Poles	Service Entry Installation for Households
Service Entry Installation for Households	Installation of Transformer and Network	Household Wiring
Household Wiring	Service Entry Installation for Households	System Commissioning
Monitoring and Controlling Phase		

Task Name	Predecessor	Successor
PUC Approval for Connection of Households	Household wiring and Service Entry Installation for Households	Inspection and Certification of Electrical System
Inspection and Certification of Electrical System	PUC Approval for Connection of Households	Household Connections to Grid
Household Connections to Grid	Inspection and Certification of Electrical System	System Commissioning
System Commissioning	Installation of Batteries and Inverters, Installation of Transformers and Network.	Conduct a comprehensive test with all connected loads
Conduct a comprehensive test with all connected loads	Connections to the grids and system commissioning	Planning for Inauguration of Project

Task Name	Predecessor	Successor
Closure Phase		
Planning for Inauguration of Project	Installation of Inverters and Batteries (Runs parallel to other tasks)	None (Final project)
Executing the Inauguration Ceremony	Planning for the Inauguration and Conduct a comprehensive test with all connected loads	

Table elaborated by technical stakeholders, 2024. Share work.

- Timeline: Define the start and end dates for each task, ensuring the overall schedule aligns with the project's deadline.
    - The ideal approach to creating the project timeline is to begin with the kick-off meeting and estimate the duration for each task. Microsoft Project will automatically calculate the total project duration. Based on the scheduled date of the kick-off meeting, the project completion date can be determined.

- Milestones: Highlight key project milestones.
  - Milestones will be detailed in the milestone tracking report, but the project manager should highlight key points in the project timeline that mark the completion of major tasks or phases.
  - One approach is to identify critical phases by dividing the project into distinct segments, such as procurement, installation, and commission. Milestones should also align with task dependencies, as transitions between tasks often serve as natural milestones. For example, the completion of solar panel installation would occur after the delivery and setup of equipment.

- Resource Allocation: Assign project team members or contractors responsible for each task to ensure accountability.
  - The Ministry will need to continuously monitor resource use, particularly in human resources, to ensure there is no overallocation or underutilization. For example, if one task finishes early, resources could be shifted to support a delayed task, or additional resources can be allocated to address bottlenecks. Currently, the Ministry has two staff members overseeing energy access projects, one managing on-the-ground tasks, while the other attends update meetings. Although sending one staff member to manage fieldwork may not significantly

impact adherence to the methodology, effective human resource management is crucial for project success.

If resource allocation is addressed, the following table can be applied to the Ministry:

Chart 19. Resource Allocation Table

Resource Type	**Key Tasks**	**Allocated Personnel**	**Estimated Timeframe**
Project Manager	Overall project oversight, coordination	1 Project Manager	Full project duration
Electrical Engineer	Supervise installation of solar system	2 Electrical Engineers	Installation and Commissioning
Site Engineer	Supervise construction, foundation, poles, wiring	1 Site Engineer	Site preparation, installation phases

Resource Type	Key Tasks	Allocated Personnel	Estimated Timeframe
Procurement or Finance Officers	Manage materials and equipment procurement	1 Procurement or Finance Officer	Procurement phase (4 months)
Support Staff	Documentation, scheduling, logistics	1 support staff	Ongoing support

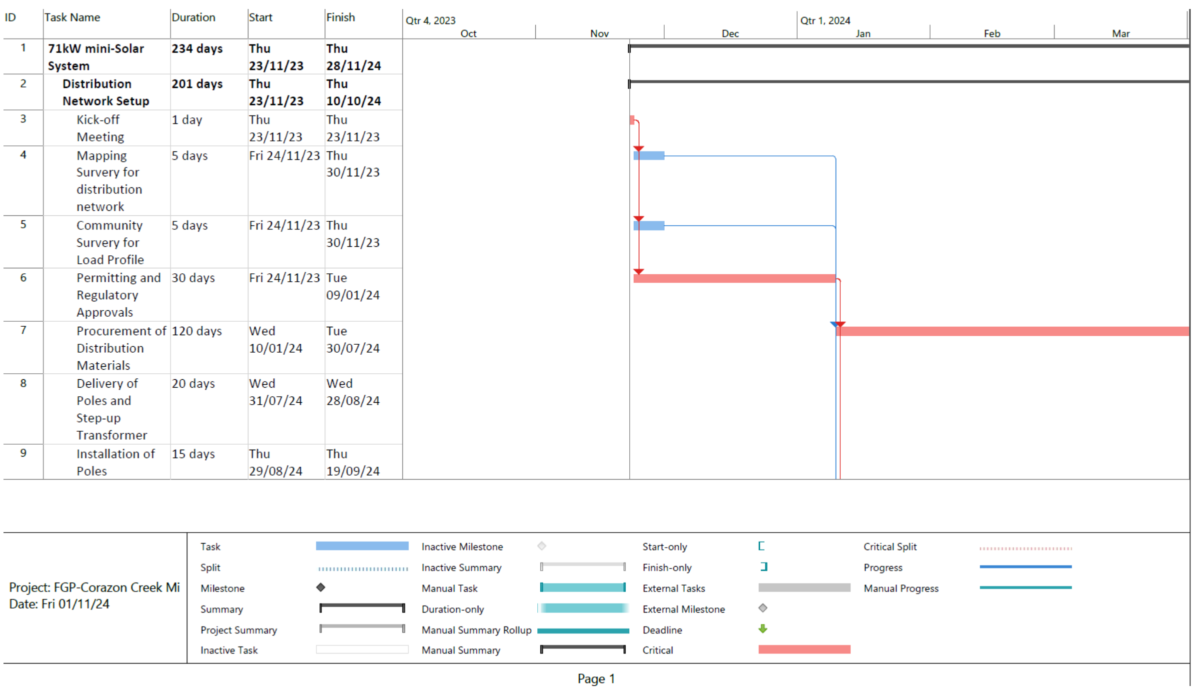
Note: Chart elaborated by A. Matar, Author, 2024. Own work

The table above outlines key personnel ideally needed for this type of work. However, this may not always be the case. Typically, project sponsors or third parties manage the funds, reducing the need for a procurement or finance officer. In the case of Corazon Creek, two electrical engineers, one with a project management background, and a support staff were essential. Occasionally, the foundation or framework for solar panels may raise concerns. The Ministry could seek assistance from the Ministry of Infrastructure, Development & Housing (MiDH) for site engineering support or invest in training its current staff.

Using the Corazon Creek Solar PV Mini Grid Project as a case study, a detailed schedule was developed as outlined below. Given the interdependence of deliverables and the need for extensive coordination across phases, the activities are organized into functional segments: Distribution Network Setup, Solar System Installation, Household Connection Preparation, Household Connection to Grid, System Testing and Commissioning and Community

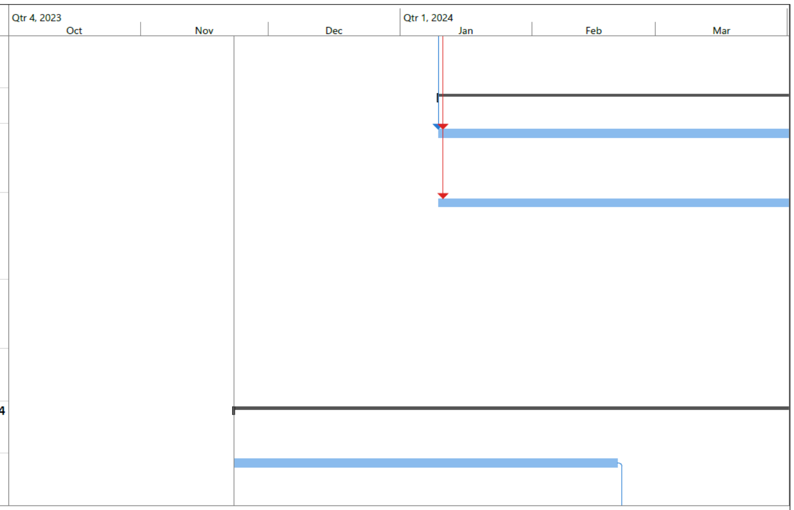
Engagement and Inauguration. Microsoft Project was used to create this schedule, enabling automated milestone tracking upon task completion. This software not only facilitates scheduling but also supports effective execution management by identifying resource overallocation and offering solutions, such as fast-tracking or crashing, for critical path tasks that encounter delays.

Figure 19: Project Schedule based on Corazon Creek Case Study



ID	Task Name	Duration	Start	Finish
1	**71kW mini-Solar System**	**234 days**	**Thu 23/11/23**	**Thu 28/11/24**
2	**Distribution Network Setup**	**201 days**	**Thu 23/11/23**	**Thu 10/10/24**
3	Kick-off Meeting	1 day	Thu 23/11/23	Thu 23/11/23
4	Mapping Survery for distribution network	5 days	Fri 24/11/23	Thu 30/11/23
5	Community Survey for Load Profile	5 days	Fri 24/11/23	Thu 30/11/23
6	Permitting and Regulatory Approvals	30 days	Fri 24/11/23	Tue 09/01/24
7	Procurement of Distribution Materials	120 days	Wed 10/01/24	Tue 30/07/24
8	Delivery of Poles and Step-up Transformer	20 days	Wed 31/07/24	Wed 28/08/24
9	Installation of Poles	15 days	Thu 29/08/24	Thu 19/09/24

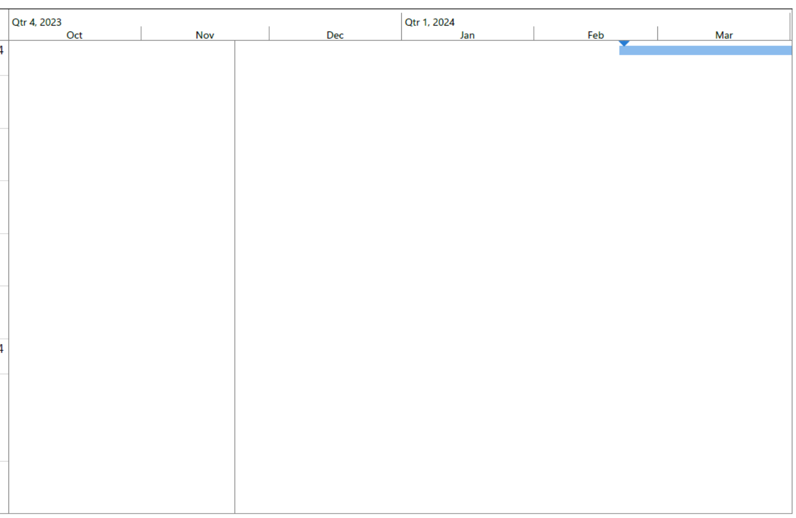
ID	Task Name	Duration	Start	Finish
10	Installation of Tranformers and Network	15 days	Fri 20/09/24	Thu 10/10/24
11	**Solar System Installation**	**140 days**	**Wed 10/01/24**	**Wed 28/08/24**
12	Procurenment of Solar Materials and Equipment	120 days	Wed 10/01/24	Tue 30/07/24
13	Land Preparation and Foundation Work	40 days	Wed 10/01/24	Mon 08/04/24
14	Delivery of Container and installation of Roof Structure	10 days	Wed 31/07/24	Wed 14/08/24
15	Installation of Batteries and Inverters	10 days	Thu 15/08/24	Wed 28/08/24
16	**Household Connection Preparation**	**85 days**	**Thu 23/11/23**	**Fri 26/04/24**
17	Service Entry Installation for Households	50 days	Thu 23/11/23	Tue 20/02/24



Project: FGP-Corazon Creek Mi
Date: Fri 01/11/24

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Critical | Critical Split | Progress | Manual Progress

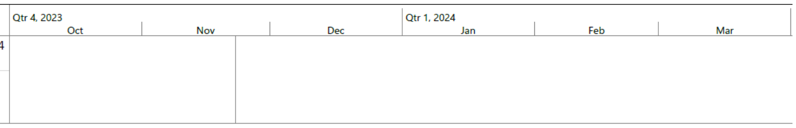
ID	Task Name	Duration	Start	Finish
18	Household Wiring	35 days	Wed 21/02/24	Fri 26/04/24
19	**Household Connection to Grid**	**146 days**	**Tue 30/04/24**	**Mon 25/11/24**
20	PUC Approval for Household Connection	10 days	Tue 30/04/24	Mon 13/05/24
21	Inspection and Certification of Electrical	1 day	Tue 14/05/24	Tue 14/05/24
22	Connection of Homes to the Grid	30 days	Fri 11/10/24	Mon 25/11/24
23	**System Testing and Commissioning**	**32 days**	**Fri 11/10/24**	**Wed 27/11/24**
24	System Commissioning	5 days	Fri 11/10/24	Fri 18/10/24
25	Conduct a Complete Test with all Connected Loads	2 days	Tue 26/11/24	Wed 27/11/24
26	**Community Engagement and Inauguration**	**63 days**	**Thu 29/08/24**	**Thu 28/11/24**



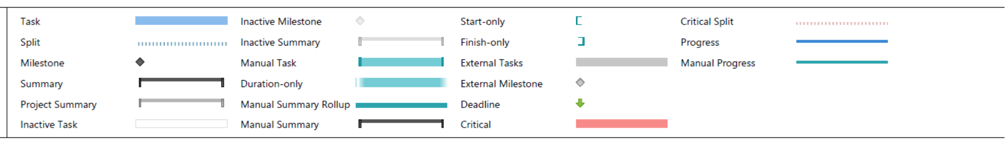
Project: FGP-Corazon Creek Mi
Date: Fri 01/11/24

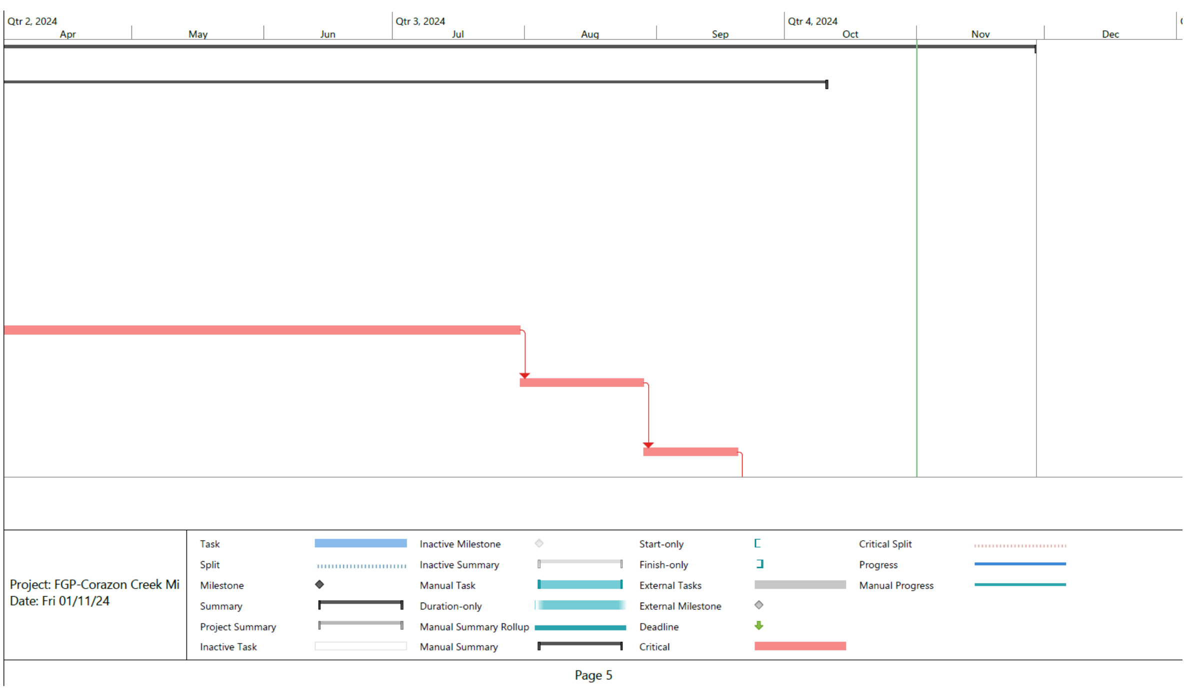
Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Critical | Critical Split | Progress | Manual Progress

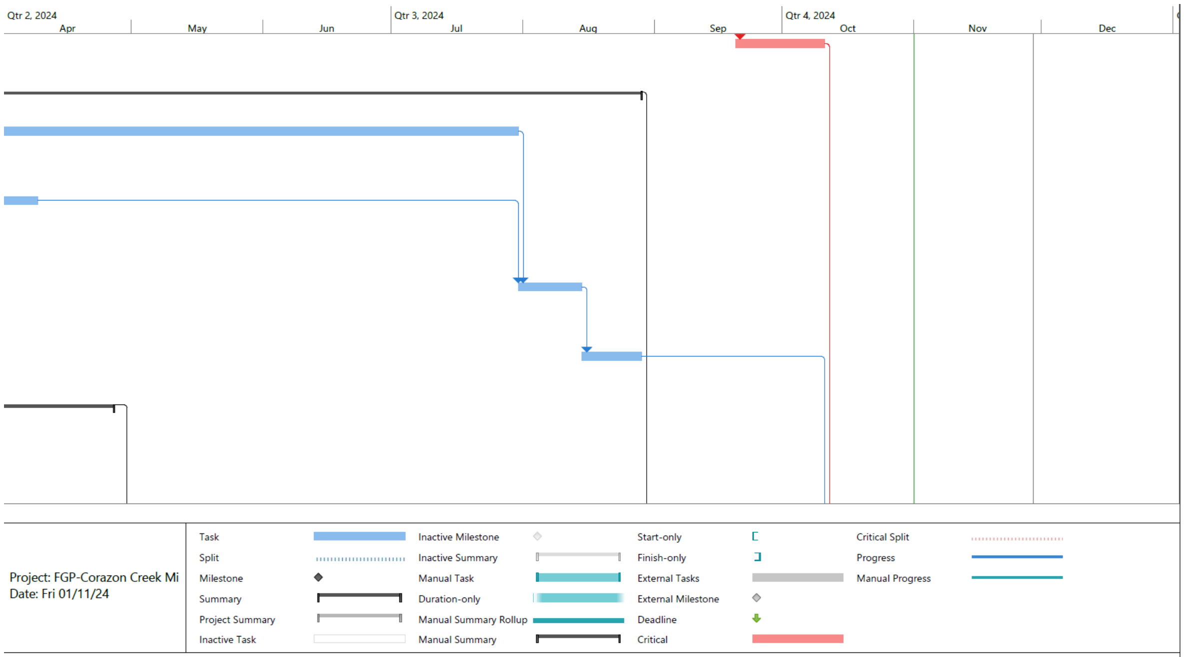
ID	Task Name	Duration	Start	Finish
27	Planning for Project	35 days	Thu 29/08/24	Fri 18/10/24
28	Executing the Inauguration Ceremony	1 day	Thu 28/11/24	Thu 28/11/24



Project: FGP-Corazon Creek Mi
Date: Fri 01/11/24






Qtr 2, 2024
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Qtr 4, 2024
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Project: FGP-Corazon Creek Mi
Date: Fri 01/11/24
Task
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Summary
Project Summary
Inactive Task
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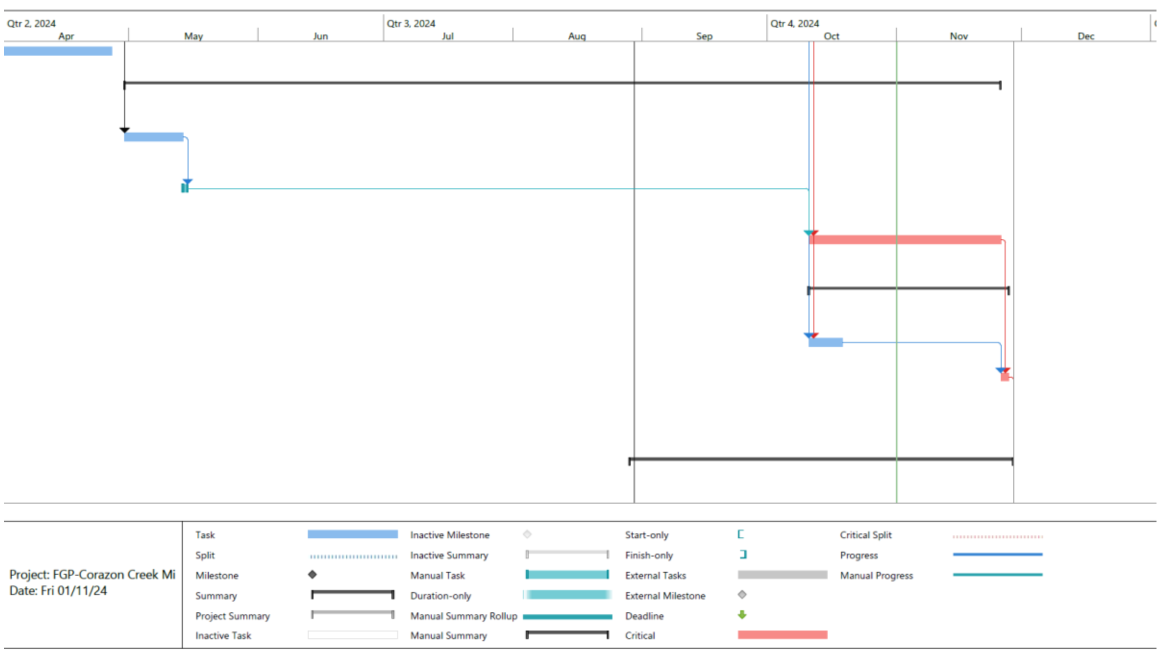
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Project: FGP-Corazon Creek Mi
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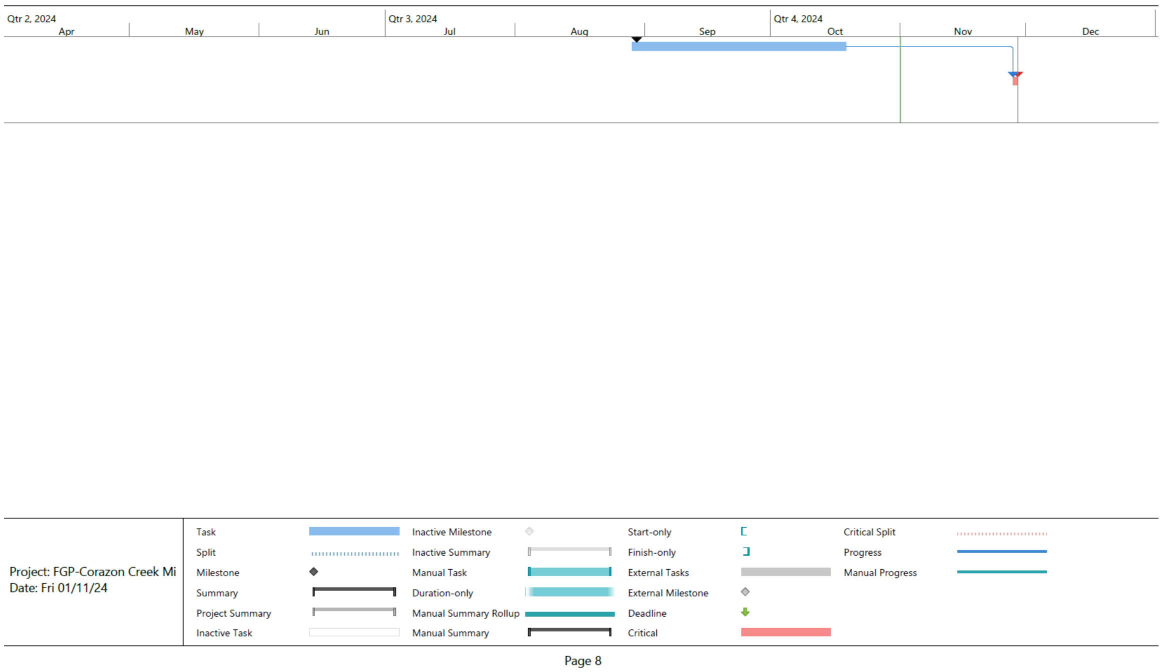


Note: Chart elaborated by A. Matar, Author, 2024. Own work

Figure 19 above displays the project schedule created using information from charts 17 and 18, which outline the task breakdown and task dependencies, respectively. While a work breakdown structure (WBS) could have been employed, these tables serve as practical tools to capture information efficiently, especially during meetings were drawing a WBS is impractical. This project schedule was based on Corazon Creek case study, with a start date on November 23, 2023, following the kickoff meeting. The calculated timeline estimates completion by November 28, 2024, ending with the inauguration as the final milestone, achieving an impressive 234-day duration.

Currently, the inaugurations are set for November 11, 2024, but as of November 1, 2024, note that several homes connections remain pending, with finalization expected by November 8, 2024. These delays highlight the absence of a written timeline to track pending deliverables. Additionally, the generation unit, which arrived in Belize in 2021, was initially projected for completion by 2022. This approach overlooked the necessity of securing a signed consent agreement as the first step. Due to this, procurement for the distribution network, requiring overseas sourcing, was also delayed. In an optimized schedule, the kickoff meeting would have followed the signing of the consent agreement, initiating procurement of both solar generation and distribution materials.

Stakeholder input suggested a four-month timeline for equipment delivery after procurement. However, while the generation unit arrived early in 2021, it could not be installed until February 2024 due to pending agreements. Distribution system equipment, ordered in 2024, arrived by June but faced significant transport delays from widespread wildfires. Originally, the inauguration was estimated for September 2024, but the schedule confirmed that November would have been the earliest realistic date. A detailed schedule from the outset would have revealed these timing conflicts. Although completion by November 11 is close, remaining homes should have been connected in October 2024, and commissioning completed prior to the inauguration. Invitations have already been sent to stakeholders, so the event will proceed as planned. Ideally, a project like this should span no more than 8 months.

4.4.1 Milestone Tracking Report

It is essential not to confuse deliverables with milestones. A milestone marks the completion of a significant event, often a point of recognition or achievement, and can include a deliverable. However, a deliverable is not a milestone; it is a tangible output expected to be accomplished during the project. For example, signing a consent agreement is a milestone, not a deliverable. The milestone tracking report serves to monitor project progress, highlighting if the project is on schedule and flagging any delays or issues that could affect the timeline.

The following table below provides an overview of the significant project milestones in the implementation of a solar mini-grid based on the case of Corazon Creek.

Chart 20. Milestones Overview Table

Milestone	Task/Phase	Estimated Completion Date	Actual Completion Date	Status	Comments
1. Consent Agreement signed	Completion of the initial agreement			Completed	Kick-off preparation initiated immediately after signing

Milestone	Task/Phase	Estimated Completion Date	Actual Completion Date	Status	Comments
2. Kick-Off Meeting	Formal project launch			Completed	Key stakeholders aligned on objectives and timeline.
3. Distribution Network Mapping Survey	Mapping of grid layout			In Progress	Survey team on-site for data collection,
4. Community Load Profile Survey	Gathering data on energy demand			Scheduled	To be conducted after distribution network mapping
5. Procurement of Equipment	Securing solar			Scheduled	Parallel activities to ensure

Milestone	Task/Phase	Estimated Completion Date	Actual Completion Date	Status	Comments
	panels, batteries				timely delivery
6. Land Preparation and Foundation Work	Clearing and preparing the site for installation			Scheduled	Land clearing underway, foundation layout to follow
7. Delivery of Equipment (Solar System	Equipment delivered to the site			Scheduled	Coordinate with procurement and transport teams.
8. Solar Panel Installation Completed	Installation of solar panels			Scheduled	Panel delivery and setup dependent

Milestone	Task/Phase	Estimated Completion Date	Actual Completion Date	Status	Comments
					on prior activities.
9. Battery and Inverter Installation	Installation of energy storage and inverters			Schedules	Final system checks to follow installation
10. Pole and Transformer Installation	Erecting poles and installing transformer			Scheduled	Coordinate with distribution network team.
11. Service Entrance & Household Wiring completed	Household wiring for energy connection			Scheduled	Households wired for final connection approval
12. PUC Approval Submitted	Submission for			Scheduled	Parallel with wiring

Milestone	Task/Phase	Estimated Completion Date	Actual Completion Date	Status	Comments
	approval to PUC				completion; necessary for certification.
13. System Commissioning	System operation tests			Scheduled	Testing procedures scheduled with system engineers.
14. Connection of Homes Completed	Homes fully connected and energized			Scheduled	Connection scheduled PUC approval
15. Inauguration planning and even	Official handover and			Scheduled	Preparation underway for project closure and

Milestone	Task/Phase	Estimated Completion Date	Actual Completion Date	Status	Comments
	community event				event execution.

Note: Chart elaborated by A. Matar, Author, 2024. Own work

Next, it is important to define certain milestones. Therefore, the following are key milestone descriptions:

- **Consent Agreement Signed-** This initial milestone is crucial as it marks the formal start of the project. Once the agreement was signed, the project kick-off can be scheduled, and all stakeholders are aligned.
- **Kick-Off Meeting-** This milestone sets the stage for project execution. All key personnel and stakeholders were briefed on the project schedule, roles, and objectives.
- **Procurement of Equipment-** Timely procurement ensures that equipment, such as solar panels, batteries, and inverters, arrives on time. Delay in procurement could result in cascading delays across subsequent milestones.
- **System Commissioning-** Testing the system to ensure it operates within the desired parameters before PUC approval and final connection to households. This milestone is key identifying any system faults before full operation.

- **Inauguration Planning and Event-** This milestone represents the official conclusion of the project, marking the transition to the operational phase and handover to the community.

Lastly, there are few recommendations for monitoring which include but not limited to:

- **Weekly Status Updates:** Conduct weekly project meetings to review progress against milestones.
- **Documentation:** Ensure all reports, test results, and approval are documented and accessible for project audits.
- **Stakeholder Involvement:** Keep key stakeholders informed at every milestone to ensure transparency and quick decision-making.
- **Adjustments**: If any milestone is delayed, make necessary adjustments to avoid further delays in subsequent tasks.

4.5. Risk Management Plan

The purpose of this risk management plan is to outline how risks will be identified, assessed, and mitigated throughout the mini-grid implementation project. In his book, Project Risk Management, Roland Wanner emphasizes that every project is inherently exposed to risks. To clarify, one should understand what risk management is. According to Wanner, there is often a misunderstanding about what it truly entails. People manage capital, physical assets, people, information, and time. However, unlike these other resources, time management is impossible because time is intangible, constantly passing, cannot be controlled, or retrieved. Risk management is similar in this regard.

A risk is an uncertainty that may or may not occur in the future. Once this uncertainty materializes, it becomes a certainty which is a problem. Because risk is invisible, it cannot be fully controlled or grasped. Although risk cannot be managed directly, actions can be taken to influence the likelihood or impact of the risk. These actions can be managed, which is the focus of this risk management plan.

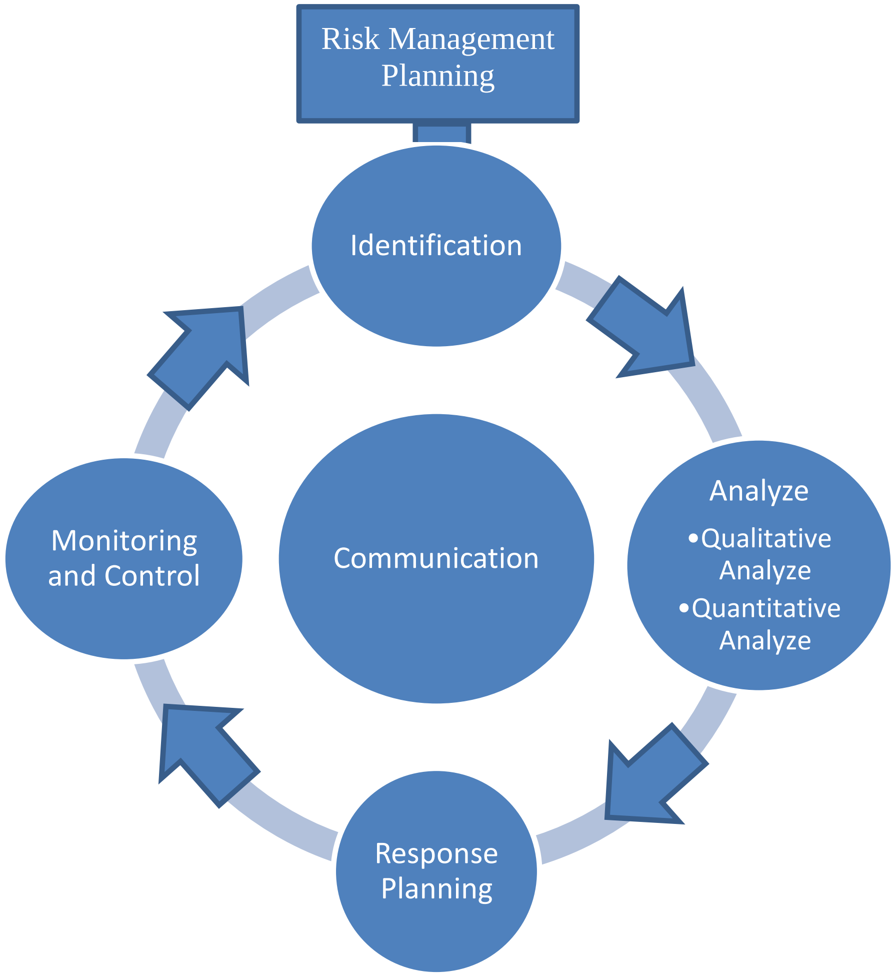
Risk management is often overlooked at the Ministry. This plan is specifically tailored to address this, as Wanner points out that 74% of all projects exceed their budget, timeline or fail to deliver on their original scope, for example, the Corazon Creek project was selected because it houses a high school that serves 12 neighboring communities. Due to significant delays, however, there is a risk that the project may be inaugurated without the high school being connected to the grid, primarily because the cost of connecting the school was not considered and communication gaps arose. This risk management plan aims to prevent such issues from recurring.

Objectives:

- To proactively identify potential risks and issues.
- To implement mitigation strategies to minimize impact on project objectives.
- To ensure continuous monitoring and effective communication of risks.
- To establish clear roles and responsibilities for risk management.

Risk Management Approach:

Figure 20: Risk Management Approach Cycle



Source: Procorus. Project Risk Management, Roland Wanner, 2013, Figure 2, Page 21.

This plan follows six key steps:

- **Risk Management Planning:** Establish how risk management will be executed within the project. This includes defining responsibilities, identifying key stakeholders, outlining the processes to be followed, and detailing the specific activities involved in managing risks.

- **Risk Identification:** Identify potential risks and opportunities that could impact the project or individual task. This involves creating a comprehensive list of all identified risks.
- **Risk Analysis (qualitative/quantitative):** Evaluate the identified risks to determine which should be tracked further. Assess the probability and impact (positive or negative) of each risk qualitatively. Depending on the project's size or internal company policies, risks may also undergo quantitative analysis before prioritizing them. Currently, there are no defined scales at the Ministry for rating probability and impact. The following tables provide a suggested framework to guide the rating process. For impact, values related to schedule, cost, and quality/performance can help make subjective ratings more consistent. Converting percentage values to approximate days or dollars amounts can provide greater clarity on the scope of "low" to "high" risk levels.

The table below provides a guide for rating probability.

Chart 21. Rating the Probability

Rating	Interpretation
5-very high	80% -100%
4- high	50%-80%
4- moderate	30%-50%
2-low	10%-30%
1-very low	Rather unlikely (0%-10%)

Source: Procorus. Project Risk Management, Roland Wanner, 2013, Page 64

If a risk was rated at 5 for probability, it indicates a high likelihood that the risk will occur.

The table below provides a guide for rating the impact.

Chart 22. Rating the Impact

Rating	Schedule	Cost	Quality
5-very high	Delay in delivery >20% (…. Days)	Exceedance >20% (…$)	The result of the project is unusable
4- high	Delay in delivery 10 to 20% (…Days)	Exceedance 10 to 20% (…$)	A lower quality is not acceptable
3- moderate	Delays in delivery 5 to 10% (…Days)	Exceedance 5 to 10% (…$)	Important areas are affected

Rating	Schedule	Cost	Quality
2- low	Delays in delivery <5% (…Days)	Exceedance <5% (…$)	Only a minor reduction of quality
1-very low	Delay in delivery is insignificant	Exceedance is insignificant	Barely noticeable differences

Source: Procorus. Project Risk Management, Roland Wanner, 2013, Page 64

The rate scales for probability and impact use values were categorized as Low, Moderate, or High, with a suggested numerical range from 1 to 10.

Chart 23. Rating Scale with 10 Steps

Scale	1	2	3	4	5	6	7	8	9	10
Rating	← Low →			← Moderate →			← High →			

Source: Procorus. Project Risk Management, Roland Wanner, 2013, Page 65.

- **Risk Response Planning**: Develop actions to mitigate the probability and/or impact of each risk or to enhance opportunities. These planned actions are then implemented accordingly.
- **Monitoring and Control**: Put the risk response plans into action, regularly monitor and assess the effectiveness of the measure, and adjust or define new actions as needed. Conduct periodic risk reviews.

- **Communication**: Ensure continuous communication, both internally and externally, about existing risks, newly identified risks, and all risk management activities throughout the project.

The Roles and Responsibilities table below shows the relationship between planning and execution, broken down into staff, means, motives, and strategies:

Chart 24. Roles and Responsibilities Table

Staff	Means	Motives	Strategies
Project Manager	Microsoft Project, Risk Register, Task, Scheduling Software	Ensure timely delivery of the project, manage resources, and avoid delays	Use detailed scheduling and monitoring tools to identify risks early and adjust task dependencies accordingly.
Procurement/Finance Officer	Procurement Software, Supplier Contracts, Financial Approvals	Securing necessary material and equipment on time and within budget	Parallelize procurement with other tasks (e.g., permitting) and mitigate delays through alternative suppliers
Engineering Team	Design Software (Helioscope, Homer Pro), Technical Drawings	Ensure that the technical components are accurately designed and installed	Use standardized design methodologies and regular site inspections to mitigate risks of design flaws or delays.
Support Officer	Regulatory Compliance	Ensure all permits and approval (e.g., consent agreement,	Oversees that permit (PUC approvals) are

Staff	Means	Motives	Strategies
	Guideline, Legal approvals	environmental clearance, PUC certificates) are in place	obtained in parallel with procurement to avoid bottlenecks.
Public Relation Officer	Communication Tools, Public Meetings	Ensure community engagement and communication throughout the project	Regular updates to village leaders, hold meetings, and use surveys to monitor satisfaction and feedback.
Quality Assurance Officer	QA Tools, Checklists for Mini-Grid Standards	Ensure the mini-grid system meets established performance metric and quality standards	Regular performance monitoring post-installation to identify system inefficiencies early and take corrective actions.

Note: Chart elaborated by A. Matar, Author, 2024. Own work

The Ministry may not have the ability to hire the necessary staff, so the roles of Project Manager, Quality Assurance Office and Public Relations Officer could be shared among the engineering team.

The tools and techniques are crucial and the center of the risk management plan. The following tools and techniques are noted below:

- Risk Assessment Matrix: A table used to assess the likelihood and impact of each risk.

Figure 21: Risk Matrix Template

No of Risk Identification	WBS Element	Risk Type	Risk		
			Cause	Description	Efect
Risk ID	Element number in the WBS. It can be component, product, deliverable or work package	Risk categorization or taxonomy (Technical, schedule, experience, scope…)	*Identifying the cause. Example: If the equipment is not available*	*Risk Description*	*Specify what the effect would be if the risk occurs. Example: then the project will be delayed.*

Symtom	Impact (A/M/B)	Probability (A/M/B)	Evaluation		Response	Responsible
			Value (1 al 9)	Level (A/M/B)		
Identify an alarm or warning sign that the risk may occur. Example: the supplier does not provide a specific answer, it only delays the delivery of the equipment. Remember that not all risks have symptoms.	*Evaluate the probability that the risk will occur. (High, Medium and Low)*	*Evaluate the impact on the project if the risk occurs. (High, Medium and Low)*	*According to the probability and impact matrix shown below*	*Based on the value in the previous column, the risk level is established: high, medium, low*	*Specify the action that the project team will take to eliminate, transfer, or mitigate the threat or to exploit, enhance, or share an opportunity.*	*Name of the person responsible for the project team that will carry out the risk response action.*

Expected monetary value

Impact $	%	EMV

Source: Risk Assessment Matrix, University for International Cooperation, 2024

Table 20 above was originally extracted from an Excel file and could not fit on this page, so it has been divided into sections for better readability. Please note, if quantitative analysis is not conducted, typically reserved for large-scale projects or those with significant investment, then the analysis should include determining the impact, probability percentage, and expected monetary value. It is recommended to use Excel for managing the Risk Assessment or Risk Register, which be further detailed in the Risk Assessment Report.

- Monthly Risk Review Meetings: Regular meetings to review risk status and adjust strategies if necessary.

4.5.1 Risk Assessment Report

This Risk Assessment Report highlights the potential risks identified for mini-grid implementation, including an evaluation of their likelihood and impact. It also outlines proposed mitigation strategies to minimize the negative effects on the project.

The table below is a risk register which shows a detailed document that records all identified risks, their severity, mitigation plans, and status updates.

Chart 25. Risk Register

RBS	Category	Cause	Risk	Consequence	Probability	Impact	Total Risk Score	Owner	Strategy	Mitigation
2.2	Environment	Weather-related	Delay in project implementation	Can delay the project completion	3 (medium)	4 (moderate)	12 (moderate)	Project manager	Implement a contingency plan	Accept
1.2	Technical	Technical Issues with equipment	Equipment malfunction	Project delay and increase cost for repairs	3 (medium)	8 (significant)	24 (High)	Lead Engineer	Testing and maintenance	Mitigate
5.1	Social	Community resistance	Opposition from the local community	Project delay and increasing budget	2 (Low)	2 (minor)	4 (Low)	Project manager	Actively engage community	Accept

Source: Risk Register, University for International Cooperation, 2024

It is important to avoid redundancy when managing risks. While a Risk Assessment Matrix and a Risk Register are similar, the Risk Register should be highlighting the top 8 risks or less, whereas the Risk Assessment Matrix is used to identify all potential risks. Managers generally prefer receiving the Risk Register as a report, and it is best to manage this in an Excel file rather than a Word document. One technique that project managers often use to identify risks is the Risk Breakdown Structure (RBS), which is typically done after completing the Work Breakdown Structure (WBS). For this reason, each risk should be labelled with the RBS code. The Risk Register should be continuously updated as the project progresses, with new risks potentially emerging along the way. Additionally, it is crucial to include a mitigation plan for identified risks, particularly those that are rated as extremely high.

5 CONCLUSIONS

The results of the project underscore the importance of a structured and phased methodology in implementing mini-grid systems within remote communities, specifically as applied in the Corazon Creek Solar PV Mini Grid Project. This case study highlights the need for a standardized process, stakeholder alignment, quality assurance procedures, project scheduling guidelines, and risk management in achieving sustainable and effective energy solutions. These specific objectives collectively support the overarching goal of providing effective energy access. If the Government of Belize, through the Ministry of Public Utilities, Energy, Logistics & E-Governance, is committed to achieving universal access to affordable modern energy by 2030 (per the Belize Energy Roadmap) and transitioning to 100% renewable energy, with an interim target of 85% by 2030, this methodology should be strongly considered. The Ministry is well positioned to fulfill its mandate, though potentially beyond the initially set time limit. Below reflects the five different specific objectives crafted to achieve the general objective of this FGP at its inception.

1. **Standardized Project Implementation Framework:**

   Developing a comprehensive checklist and process standardization for mini-grid implementation was crucial for creating a reliable framework. This checklist ensured a structured approach for project activities, helping to streamline coordination among project teams and avoid ambiguities. The standardization of tasks not only facilitated efficient execution but also set a precedent for future mini-grid projects in Belize.

2. **Clear Stakeholder Role Definitions and Accountability:**

Establishing clear definitions of stakeholder roles, as shown in the stakeholder role definitions chart, was essential for delineating each party's responsibilities and authority levels. This approach enables effective collaboration among project participants, ensuring that each stakeholder's contributions were aligned with the project's success. The structured collaboration framework helped manage expectations and reduce misunderstandings, fostering a more cohesive working environment.

3. **Quality Assurance and Performance Metrics:**

   The quality assurance protocols, and performance metric developed for this project were instrumental in maintaining high standards of project execution. By implementing performance measures for the solar PV mini-grid system, the project team could closely monitor system reliability and effectiveness, which are essential for ensuring long-term sustainability.

4. **Efficient Project Scheduling and Milestones:**

   The detailed project schedule, built from task dependency tables, played a pivotal role in tracking milestones and meeting deadlines. The initial kickoff date, task durations, and completion timeline were essential for maintaining a realistic and achievable timeline. By managing critical path tasks, the project could be executed within the planned time limit, demonstrating that comprehensive scheduling can significantly enhance project outcomes.

5. **Risk Management Strategies:**

Risk management strategies helped anticipate potential challenges, allowing the team to implement preemptive measures. This approach minimized disruptions and ensured smooth project progress, illustrating the value of risk mitigation in maintaining project integrity. Risk assessments for logistics and resource allocation proved especially relevant, given the supply delays and land reallocation encountered in the project.

6 RECOMMENDATIONS

Despite being currently understaffed, the Ministry's team demonstrates dedication and flexibility by often going beyond their roles, as observed in the Corazon Creek Case Study. However, this often leads to improvised approaches in handling project activities. It is essential for management to adopt a structured framework to ensure consistency and efficiency. When hiring new staff, these structured processes should be readily available and clearly communicated. Management, as key overseers of these improvements, is encouraged to consider the following recommendations:

1. **Establish Standardized Project Planning Templates and Procedures**

   Directed to: The CEO, with implementation by the Head of the Energy Unit.

   To ensure consistency, a recommendation was that standardized templates for project planning be developed and piloted with the EDF-11 Energy Access Project or upcoming initiatives. These templates should guide staff through the various phases of project implementation, fostering a more organized and replicable approach.

2. **Create a Stakeholder Collaboration Framework**

   Directed to: The Ministry, in collaboration with line Ministries, statutory bodies, NGOs, and funding partners.

   Developing a structured framework for stakeholder engagement will provide clear guidelines on roles, responsibilities, and communication channels. This is particularly important in projects involving remote and Indigenous communities. The Stakeholder Role Definitions table from the FGP should be used as a reference to prevent misunderstandings and ensure cohesive participation.

3. **Develop and Implement Quality Assurance Protocols**

   Directed to: Project Manager or appointed Energy Officer

   To ensure high standards, quality assurance protocols need to be developed. Currently, there is no designated project manager for quality assurance within the Energy Unit, and a recommendation is that an officer with project management expertise oversee this aspect. This will enhance the consistency and reliability of energy access programs.

4. **Define Clear Project Timelines and Tracking Mechanisms**

   Directed to: Management, specifically Energy Officers within the Ministry.

   Implementing a detailed project schedule with milestone tracking is essential for maintaining accountability and meeting project deadlines. The Energy Unit should not only equip each officer with desktop access and relevant project management software but provide training to use these tools effectively.

5. **Integrate Risk Management Strategies in Early Planning**

   Directed to: Energy Director

   A risk management approach should be introduced from the project's conceptual stage, with the Energy Director taking the lead. Implementing a risk assessment matrix to identify, rank, and mitigate potential risks will address logistical, environmental, and community-related challenges in vulnerable areas, enhancing project resilience.

6. **Advocate for Organizational Policy Adjustments to Support Project Flexibility.**

   Directed to: Government of Belize, in consultation with the Ministry.

To support smoother project implementation, particularly in remote regions, a recommendation was that organizational policies or a dedicated energy act be adapted to increase flexibility in procurement and project timeline. These adjustments could expedite permissions and prioritize procurement processes, streamlining essential steps and better accommodating local needs.

7 VALIDATION OF THE FGP IN THE FIELD OF REGENERATIVE AND SUSTAINABLE DEVELOPMENT

Understanding the difference between regenerative and sustainable development is fundamental to evaluating the impact of this Final Graduation Project (FGP). Sustainable development focuses on minimizing negative environmental impacts by reducing harmful substances and CO_2 emissions. Conversely, regenerative development aims to enhance positive environmental impacts and restore natural systems. This FGP, which develops a methodology for implementing Solar PV mini-grid systems in Belize, aligns with both these principles. The project strives to ensure that renewable energy initiatives not only function effectively but also contribute significantly to broader environmental and social goals.

The design of the FGP impacts three critical aspects of regenerative and sustainable development: environmental sustainability, resource efficiency, and community empowerment. By deploying Solar PV mini-grids, the project directly reduces reliance on fossil fuels and decreases greenhouse gas emissions, thereby supporting environmental sustainability. The methodology was designed to optimize resource use during project implementation, minimizing waste and fostering a circular economy which is key to regenerative development. Furthermore, the FGP emphasizes involving all stakeholders, including local communities, in the project process. This engagement promotes social sustainability by enhancing community support and participation.

The primary deliverable of the FGP is a structured and replicable methodology for Solar PV mini-grid projects. This methodology is intended to improve project management practices, leading to fewer delays and cost overruns, and ensuring that the project is completed on time and within budget. Additionally, it incorporates strategies for effective stakeholder engagement, which can lead to more successful project outcomes and greater community support.

However, the project acknowledges potential challenges, such as resource overuse, technical difficulties, and stakeholder disengagement. To address these issues, the methodology includes guidelines for minimizing resource use and implementing sustainable practices. It also incorporates thorough quality assurance procedures and ongoing monitoring to ensure system performance. For stakeholder engagement, the methodology emphasizes continuous interaction and robust feedback mechanisms to address concerns and enhance community involvement.

The FGP's alignment with sustainable development objectives can be assessed using the P5 standard, which evaluates the project based on Purpose, Process, Product, People, and Planet. The project's purpose is to develop a methodology that supports sustainability and regeneration through effective Solar PV mini-grid implementation. The Process involves enhancing efficiency, quality, and stakeholder engagement. The product is a detailed methodology that improves Solar PV system performance and reliability. The project also focuses on involving stakeholders, including the community, and reducing fossil fuel use, contributing to environmental sustainability.

In terms of regenerative development, the FGP addresses three dimensions ecological regeneration, social regeneration, and economic regeneration. It aims to reduce environmental impacts through renewable energy, emphasizes community involvement and resilience, and improves economic sustainability by reducing costs and enhancing efficiency.

Overall, the FGP's methodology supports both regenerative and sustainable development by addressing these critical aspects and providing strategies to overcome potential challenges.

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APPENDICES

Appendix 1: FGP Charter

CHARTER OF THE PROPOSED
FINAL GRADUATION PROJECT (FGP)
21dx

1. Student name

Amin Ali Matar

2. FGP name

Developing a Methodology for Mini-Grid Implementation: A Case Study of the 69.5kW Project in Belize

3. Application Area (Sector or activity)

Rural Electrification

4. Student signature

5. Name of the Graduation Seminar facilitator

Ms. Paula Villalta

6. Signature of the facilitator

7. Date of charter approval

August 31st, 2024

8. Project start and finish date

July 8, 2024	January 17, 2024

9. Research question

How can a standardized methodology improve the implementation and management of mini-grid projects, as demonstrated by the 69.5kW project in Belize?

10. Research hypothesis

A standardized methodology for implementing mini-grid projects will significantly enhance project execution, quality control, and adherence to timeline

11. General objective

To develop a methodology that ensures consistent procedures and practices within the Belize Energy Unit for implementing Solar PV mini-grid systems in remote areas, aiming to improve delivery time and ensure compliance with best practices and industry standards for reliable and sustainable electricity delivery.

12. Specific objectives

1. Develop a template or checklist for mini-grid implementation projects to standardize processes and ensure project planning and execution.
2. Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects to clarify accountability and enhance effective collaboration among project participants.
3. Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution.
4. Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines.
5. Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.

13. FGP purpose or justification

The Belize Energy Unit, along with various stakeholders, has implemented Solar PV mini-grid systems in remote areas such as the La Gracia 24kW, Indian Creek 400kW and Corazon Creek 69.5kW projects. These systems are crucial for providing reliable and sustainable electricity to underserved communities where extending the national grid is economically unfeasible. Despite the global focus on renewable energy, Belize lacks a standardized methodology for managing mini-grid projects, leading to inefficiencies and inconsistencies. Developing a

comprehensive methodology will address these gaps, ensuring timely completion of projects in compliance with best practices and industry standards. This project is vital for transforming the energy landscape of communities in Belize by enhancing the efficiency and effectiveness of mini-grid implementations. Current projects have faced significant delays and issues, such as the La Gracia project's battery system upgrade and the Indian Creek project's oversized transformer causing VAR issues. The Corazon Creek project lacks a structured progress measurement system. With starting costs of $500,000 USD and larger systems incurring higher costs, delays have led to budget overruns due to global inflation. By standardizing processes, clarifying stakeholder roles, and optimizing resource allocation, the Belize Energy Unit can maintain initial budgets, increase project completion rates within scheduled time limit, and enhance community satisfaction by providing reliable and sustainable electricity.

14. Work Breakdown Structure (WBS). In table form, describing the main deliverable as well as secondary, products or services to be created by the FGP.

1 FGP

1.1 Graduation Seminar

1.1.1 FGP Profile Deliverables

1.1.1.1 FGP Charter

1.1.1.2 Annexes: FGB Work Break down Structure, FGP Schedule, & Preliminary Bibliography

1.1.1.3 Chapter I. Introduction

1.1.1.4 Chapter II. Theoretical Framework

1.1.1.5 Chapter III. Methodological Framework

1.1.1.6 Chapter VII Validation of Regenerative and Sustainable Development

1.1.1.7 Completion of Executive Summary Abstract Chapter 1-3 FGP Document and Charter

1.2 Tutoring Process

1.2.1 Assigned Tutor

1.2.1.1. Tutor Assignment

1.2.1.2. Appointment and communication with Tutor

1.2.2 Adjustment of Previous chapters (if Necessary)
1.2.3 FGP Solar PV Mini Grid Development Process
1.2.3.1 Integration Management to ensure coordination of all project components, stakeholder, and processes.
1.2.3.2 Develop a scope management plan.
1.2.3.3 Develop a schedule management plan which outlines all project activities to be completed.
1.2.3.4 Propose the necessary tools (Software) which complements the proposed method.
1.2.3.5 Develop a Quality Management Plan to manage and control the project and quality requirement for the project.
1.2.3.6 Develop a Communication Management Plan to exchange ideas or keep stakeholders informed.
1.2.3.7 Develop a Risk Management Plan that lists and prioritizes risks that could delay project progress or lead to failure.
1.2.3.8 Develop a Stakeholder Management Plan that identifies the persons and groups in the project and strategies for engagement.
1.2.3.9 Develop a Human Resource management plan to manage the resources required for implementation.
1.2.3.10 Develop a Regenerative/sustainable procurement management plan that identifies and assigns contracts to suppliers.
1.2.4 Chapter V. Conclusions
1.2.5 Chapter VI. Recommendations

1.3 Reading by viewers
1.3.1 Reviewers’ assignment request
1.3.1.1 Assignment of 2 Reviewers
1.3.1.2 Communication with Reviewers
1.3.1.3 FGP submission reviewers
1.3.2 Reviewers works.
1.3.2.1 Reviewer 1
1.3.2.1.1 Reviewer 1 FGP Reading
1.3.2.1.2 Reviewer 1 Report
1.3.2.2 Reviewer 2
1.3.2.2.1 Reviewer 2 FGP Reading
1.3.2.2.2 Reviewer 2 Report

1.4 Adjustment
- 1.4.1 Report for Reviewers.
- 1.4.2 FGP Document update based on Reviewers report.
- 1.4.3 Second Review by Reviewers.

1.5 Presentation to Board
- 1.5.1 Final Review by board
- 1.5.2 Presentation to Board
- 1.5.3 Board Examination Evaluation and Grade Report

15. FGP budget

Item	Description	Cost (USD)
Software License Acquisition	Project Management Software and Work Break Down Structure (WBS) Pro	$500
Hardware	Laptop or Computer Upgrade	$700
Work Tour	Transportation for site visit and meetings	$500
Reviewing drafted FGP by certified English Professor	To review grammar and technical accuracy	$150
Printing and Binding	Hard copy to print FGP and mail to the University	$100
	Total	**$1,950**

16. FGP planning and development assumptions.

- **Access to information**: Complete access to information regarding the Corazon Creek Solar PV Mini-grid Project will be provided, with stakeholders willing to share additional details as needed.
- **Project Management Software:** The Belize Energy Unit will recognize the advantage of project management software beyond Microsoft Project, such as WBS Schedule Pro, Trello, and Asana.
- **Research Commitment**: A commitment of 20 hours per week will be allocated for research throughout the development of the FGP.
- **Support from the Energy Unit:** The Energy Unit will facilitate my FGP development by permitting time off from work for project-related activities

17. FGP constraints

- The FGP must be completed within a fixed time limit of 12 weeks or 3 months, which includes all phases from research to final documentation.
- The budget estimated is limited to approximately $2,000 USD and it should cover all necessary expenses such as software, hardware, and traveling.
- The FGP will focus only on the implementation methodology for Mini-Grid using Corazon Creek 69.5kW Solar PV System as a case study.
- Due to the time and budget constraints, there may be limitations to extend the quality assurance procedures and performance metrics that can be developed.

18. FGP development risks

1. **Risk of Insufficient Stakeholder Engagement:**
    - **Root Cause:** Limited availability of project stakeholders to provide detailed information or feedback.
    - **Risk Event:** Challenging in obtaining data and insights from stakeholders involved in the Corazon Creek Solar PV Mini-Grid Project
    - **Impact**: Incomplete information could hinder the development of a practical methodology, potentially affecting the project's quality
2. **Risk of Software or Hardware Failures:**
    - **Root Cause:** Technical issues or malfunctions with project management software or hardware used for data analysis and documentation.
    - **Risk Event:** Unexpected software crashes or hardware breakdowns during critical phases of the FGP development.
    - **Impact:** Delays in data processing and document preparation, which could affect the project timeline and completion.
3. **Risk of unforeseen Changes in Project Scope:**
    - **Root Cause**: Evolving requirements or changes in the Corazon Creek Project that were not initially accounted for.
    - **Risk Event:** New information or changes in project scope that require significant adjustments to the FGP methodology.
    - **Impact**: Additional work to incorporate changes, potentially leading to delays and increased complexity in the project
4. **Risk of Limited Access to Relevant Data:**
    - **Root Cause:** Inaccessibility or restriction of critical data related to Solar PV mini-grid system's performance or implementation.
    - **Risk Event:** In ability to gather essential data for analysis and methodology development.
    - **Impact:** Compromised quality of the FGP due to incomplete analysis,

19. FGP main milestones

Milestones are related to deliverables on the second level (deliverables) and third level (control accounts) of the WBS of section 14 of this Charter. At the same time the deliverables are related to the specific objectives (in the case of the FGP please include the times for the tutorship reviews as well as for the readership).

Deliverable	**Finish estimated date**
1.1 FGP Graduation Seminar	August 27th 2024

1.1.1. FGP Profile Deliverable	August 27th, 2024
1.1.1.1 FGP Charter (1-22)	August 27th, 2024
1.1.1.2 Annexes: FGP Work Break down Structure, FGP Schedule, & Preliminary Bibliography	July 29, 2024
1.1.1.3 Chapter I Introduction	August 19th 2024
1.1.1.4 Chapter II Theological Framework	July 29th, 2024
1.1.1.5 Chapter III Methodological Framework	August 5, 2024
1.1.1.6 Chapter VII Validation of Regenerative and Sustainable Development	August 26th, 2024
1.2 Tutoring Process	November 25th, 2024
1.2.1 Assigned Tutor	November 25th, 2024
1.2.1.1 Tutor Assignment	September 2nd, 2024
1.2.1.2 Appointment and communication with Tutor	September 2nd, 2024
1.2.2Adjustment to Previous Chapter (if necessary)	September 9th, 2024
1.2.3 FGP Solar PV Mini Grid Development Process	November 25, 2024
1.2.3.1 Integration Management to ensure coordination of all project components, stakeholder, and processes	September 16, 2024
1.2.3.2 Develop a scope management plan	September 23, 2024
1.2.3.3 Develop a schedule management plan which to outline all project activities to be completed	September 30, 2024
1.2.3.4 Propose the necessary tools (software) which complements the proposed method	October 14th, 2024
1.2.3.5 Develop a Quality Management Plan to manage and control the project and quality requirement for the project	October 7th, 2024
1.2.3.6 Develop a communication Plan	October 7th, 2024
1.2.3.7 Develop a risk management plan	October 14th, 2024
1.2.3.8 Develop a Stakeholder Management Plan	October 21st, 2024

1.2.3.9 Develop a Human Resource Management Plan	October 28th, 2024
1.2.3.10 Develop a Regenerative and Sustainable Procurement Management Plan	November 4th, 2024
1.2.4 Chapter V. Conclusion	November 11th, 2024
1.2.5 Chapter VI. Recommendations	November 11th, 2024
1.3 Reading by Review	January 13th, 2024
1.3.1 Reviewer Assignment Request	November 18th, 2024
1.3.1.1 Assignment of 2 Reviewers	November 18th, 2024
1.3.1.2 Communication with Reviewers	November 18th, 2024
1.3.1.3 FGP submission reviewers	November 25th, 2024
1.3.2 Reviewer works	December 9th, 2024
1.3.2.1 Reviewer 1 FGP Reading	December 2nd, 2024
1.3.2.2 Reviewer 1 report	December 2nd, 2024
1.3.2.2 Reviewer 2	January 6th, 2024
1.3.2.2.1 Reviewer 2 FGP Reading	January 6th, 2024
1.3.2.2.2 Reviewer 2 Report	January 13th, 2025
1.4 **Adjustment**	January 17th, 2025
1.5 **Presentation to Board**	January 20th, 2025

20. Theoretical framework

20.1 Estate of the "matter"

The Belize Energy Unit, established within the Ministry of Public Utilities, Energy, Logistics & E-Governance, is tasked with addressing the country 's energy needs in line with the 2011 energy policy. A significant challenge facing the Energy Unit is providing reliable and sustainable energy to remote areas where extending the

national grid is not economically feasible. This challenge is created by the need to achieve the seventh Sustainable Development Goal (SDG 7), which is Affordable and Clean Energy.

To address this, The Energy Unit has embarked on several pilot projects to implement solar PV mini-grid systems. These projects include the La Gracia 24kW Smart Off-grid System in Cayo District and the Indian Creek 400kW Hybrid Solar PV system in Toledo District. Thes initiatives are aimed at demonstrating the practical use of solar energy to power remote communities. The upcoming project in Corazon Creek Village, featuring a 69.5kW capacity solar PV system, further emphasizes the commitment to this solution (Government of Belize, 2021).

The primary improvement proposed to address these challenges is the development of a standardized methodology for implementing solar PV mini-grid systems. This methodology aims to ensure consistency in procedures and practices within the Belize Energy Unit, improving project delivery times and compliance with best practices and industry standards. Previous research done on this study was sourced from the World Bank, IRENA, Sahoo and GPM.

20.2 Basic conceptual framework

Project Management, Solar PV Mini-Grid Systems, Renewable Energy, Sustainable Development Goals (SDGs), Energy Policy and Regulation, Quality Assurance and Standards, and Risk Management.

21. Methodological framework

Objective	Name of deliverable	Information sources	Research method	Tools	Restrictions
Develop a template or checklist for mini-grid implementation projects to standardize processes and	Implementation checklist	Primary: Interview with Energy unit Personnel Secondary: Existing project templates,	Analytical method	PMBOK Guide, MS Excel	Availability of industry standards and best practices

Objective	**Name of deliverable**	**Information sources**	**Research method**	**Tools**	**Restrictions**
ensure project planning and execution		industry standards, PMBOK Guide			
	Standardized Templates	Primary: Observation, Interview Secondary: Project documentation	Analytical	Excel	Accessibility to existing project documents
Define the roles and responsibilities of stakeholders involved in mini-grid implementation projects to clarify accountability and enhance effective collaboration among project participants	Stakeholder Role Definitions	Primary: Questionnaires for Stakeholders Secondary: Organizational policies	Analytical	MS. Word	Stakeholder availability for interviews
	Collaboration Framework	Primary: Focus Group Secondary: Case studies	Analytical Method	MS Word	Participation and feedback from stakeholders

Objective	**Name of deliverable**	**Information sources**	**Research method**	**Tools**	**Restrictions**
Establish quality assurance procedures and performance metrics for mini-grid systems to maintain high standards of system performance and reliability through project execution	Quality Assurance Plan	Primary: Expert Consultation Secondary: Quality Standards (ISO), PMBOK Guide	Analytical Method	Quality Management Tools, MS Word	Access to quality standards and expert availability
	Performance Metric Report	Primary: Performance data Secondary: technical literature	Case Study Method	MS Excel, Data Analysis Tools	Availability performance data
Develop a detailed project schedule and milestones for mini-grid implementation projects to ensure clear timelines and milestones for tracking progress and meeting project deadlines	Project Schedule	Primary: Project timelines from previous projects Secondary: PMBOK Guide	Analytical Method	MS Project, Scheduling Software	Accessibility to historical project data and expert consultation

Objective	Name of deliverable	Information sources	Research method	Tools	Restrictions
	Milestone Tracking Report	Primary: Field reports Secondary: Project Management Literature, case studies	Analytical Method	MS Excel, Tracking Software	Consistent progress reporting and data logging
Implement risk management strategies to identify and mitigate potential project risks to minimize disruptions and ensure smooth progress toward project completion.	Risk Management Plan	Primary: Risk assessments Secondary: Risk Management framework, PMBOK Guide	Analytical Method	Risk Management Software, MS Word	Accessibility to risk data and expert availability
	Risk Assessment Report	Primary: Risk Analysis data, observation Secondary: Risk assessment literature	Case Study Method	Risk Analysis Tools, MS Excel	Availability of risk analysis data and access to relevant literature

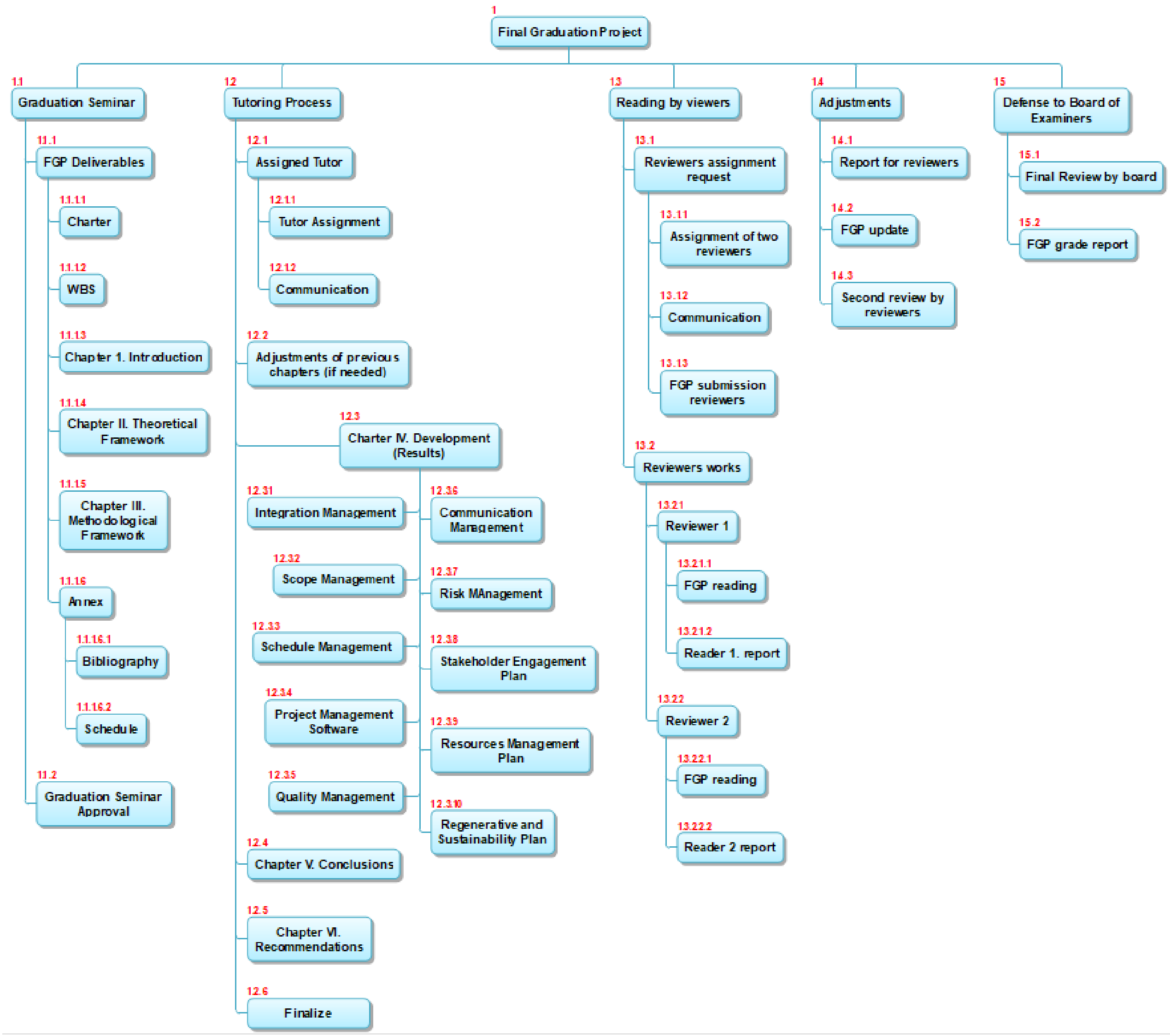
22. Validation of the work in the field of regenerative and sustainable development.

The FGP focuses on validating the project's alignment with regenerative and sustainable development principles. It explores how the project complies with these concepts and enhances positive environmental and social impacts. The FGP contributes to environmental sustainability by developing a methodology for the implementation of Solar PV mini-grid systems, which reduce reliance on fossil fuels and lower greenhouse gas emissions. This approach supports sustainable development goals by promoting cleaner energy sources. Additionally, the project ensures resource efficiency by employing a methodology that minimizes waste, supports recycling, and adheres to circular economy principles.

The FGP also advances community empowerment by involving local stakeholders in the planning and execution phases, which fosters social sustainability and addresses local needs. The project adds to regenerative development by creating a replicable methodology for Solar PV mini-grid projects, setting a standard for future initiatives in Belize. It improves project management by tackling issues like resource overuse, technical challenges, and stakeholder disengagement, leading to more effective and sustainable project outcomes. Site visits might be reduced by ensuring that each visit is purposeful and impactful.

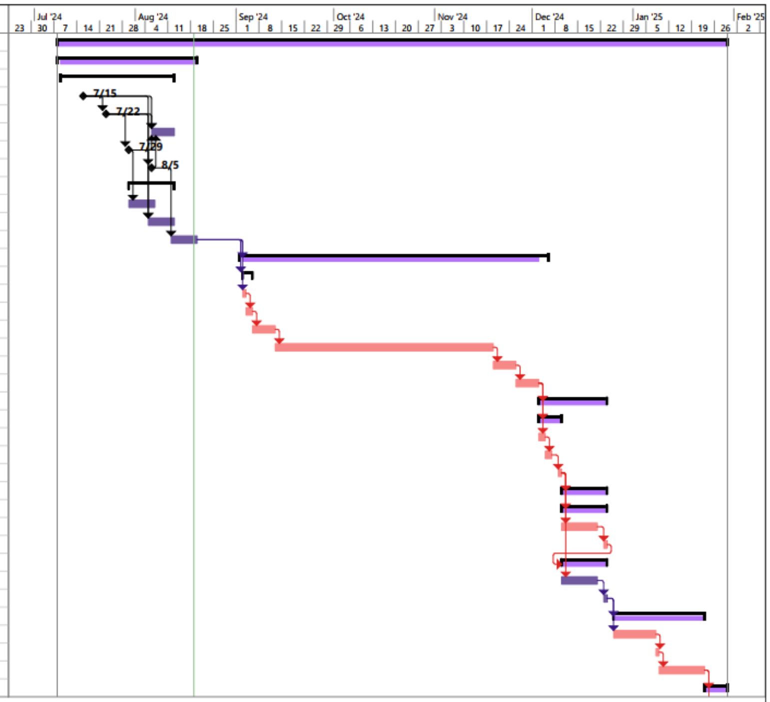
The indicators that will be to measure the project's impacts are reduction in greenhouse gas emissions, using emission calculators and comparisons if possible, and for resource efficiency metrics, comparing energy before and energy after using volume to energy output. Additionally, project management efficiency will be measured by monitoring adherence to timelines and budgets, with key performance indicators focusing on delays, cost overruns, and schedule compliance.

Appendix 2: FGP WBS



Appendix 3: FGP Schedule

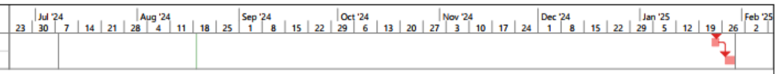
ID	Task Name	Duration	Start	Finish
1	**Final Graduation Project**	**148 days**	**Mon 7/8/24**	**Wed 1/29/25**
2	**Graduation Seminar**	**31 days**	**Mon 7/8/24**	**Mon 8/19/24**
3	**FGP Deliverables**	**25 days**	**Tue 7/9/24**	**Mon 8/12/24**
4	Charter	5 days	Tue 7/9/24	Mon 7/15/24
5	WBS	5 days	Tue 7/16/24	Mon 7/22/24
6	Chapter 1. Introduction	5 days	Tue 8/6/24	Mon 8/12/24
7	Chapter II. Theoretical Framework	5 days	Tue 7/23/24	Mon 7/29/24
8	Chapter III. Methodological Framework	5 days	Tue 7/30/24	Mon 8/5/24
9	**Annex**	**10 days**	**Tue 7/30/24**	**Mon 8/12/24**
10	Bibliography	6 days	Tue 7/30/24	Tue 8/6/24
11	Schedule	6 days	Mon 8/5/24	Mon 8/12/24
12	Graduation Seminar Approval	6 days	Mon 8/12/24	Mon 8/19/24
13	**Tutoring Process**	**69 days**	**Mon 9/2/24**	**Thu 12/5/24**
14	**Assigned Tutor**	**3 days**	**Tue 9/3/24**	**Thu 9/5/24**
15	Tutor Assignment	1 day	Tue 9/3/24	Tue 9/3/24
16	Communication	2 days	Wed 9/4/24	Thu 9/5/24
17	Adjustments of previous chapters (if needed)	5 days	Fri 9/6/24	Thu 9/12/24
18	Charter IV. Development	47 days	Fri 9/13/24	Mon 11/18/24
19	Chapter V. Conclusios	5 days	Tue 11/19/24	Mon 11/25/24
20	Chapter VI. Recommendations	5 days	Tue 11/26/24	Mon 12/2/24
21	**Reading by viewers**	**15 days**	**Tue 12/3/24**	**Mon 12/23/24**
22	**Reviewers assignment request**	**5 days**	**Tue 12/3/24**	**Mon 12/9/24**
23	Assignment of two reviewers	2 days	Tue 12/3/24	Wed 12/4/24
24	Communication	2 days	Thu 12/5/24	Fri 12/6/24
25	FGP submission reviewers	1 day	Mon 12/9/24	Mon 12/9/24
26	**Reviewers works**	**10 days**	**Tue 12/10/2**	**Mon 12/23/24**
27	**Reviewer 1**	**10 days**	**Tue 12/10/2**	**Mon 12/23/24**
28	FGP reading	9 days	Tue 12/10/24	Fri 12/20/24
29	Reader 1. report	1 day	Mon 12/23/2	Mon 12/23/24
30	**Reviewer 2**	**10 days**	**Tue 12/10/2**	**Mon 12/23/24**
31	FGP reading	9 days	Tue 12/10/24	Fri 12/20/24
32	Reader 2 report	1 day	Mon 12/23/2	Mon 12/23/24
33	**Adjustments**	**20 days**	**Thu 12/26/2**	**Wed 1/22/25**
34	Report for reviewers	9 days	Thu 12/26/24	Tue 1/7/25
35	FGP update	1 day	Wed 1/8/25	Wed 1/8/25
36	Second review by reviewers	10 days	Thu 1/9/25	Wed 1/22/25
37	**Defense to Board of Examiners**	**5 days**	**Thu 1/23/25**	**Wed 1/29/25**



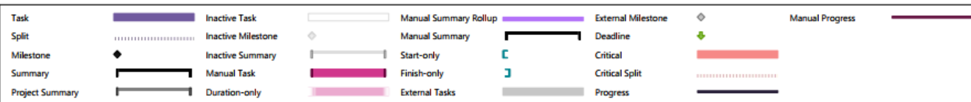
Project: FGP WBS
Date: Mon 8/19/24

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Critical · Critical Split · Progress · Manual Progress

ID	Task Name	Duration	Start	Finish
38	Final Review by board	2 days	Thu 1/23/25	Fri 1/24/25
39	FGP grade report	3 days	Mon 1/27/25	Wed 1/29/25



Project: FGP WBS
Date: Mon 8/19/24



Appendix 4: Philological Dictum

Cecile Maxine Ramirez
1 Valencia Street
City of Belmopan
Cayo District
Belize

27th November, 2024

Academic Advisor
Universidad para la Cooperacion Internacional (UCI)
Avenida 15, Calle 35
San Jose 10101
Costa Rica

Dear Academic Advisor,

Re: Philosophical Review of Final Graduation submitted by Amin Ali Matar in partial fulfillment of the requirements for the Master's in Project Management Degree.

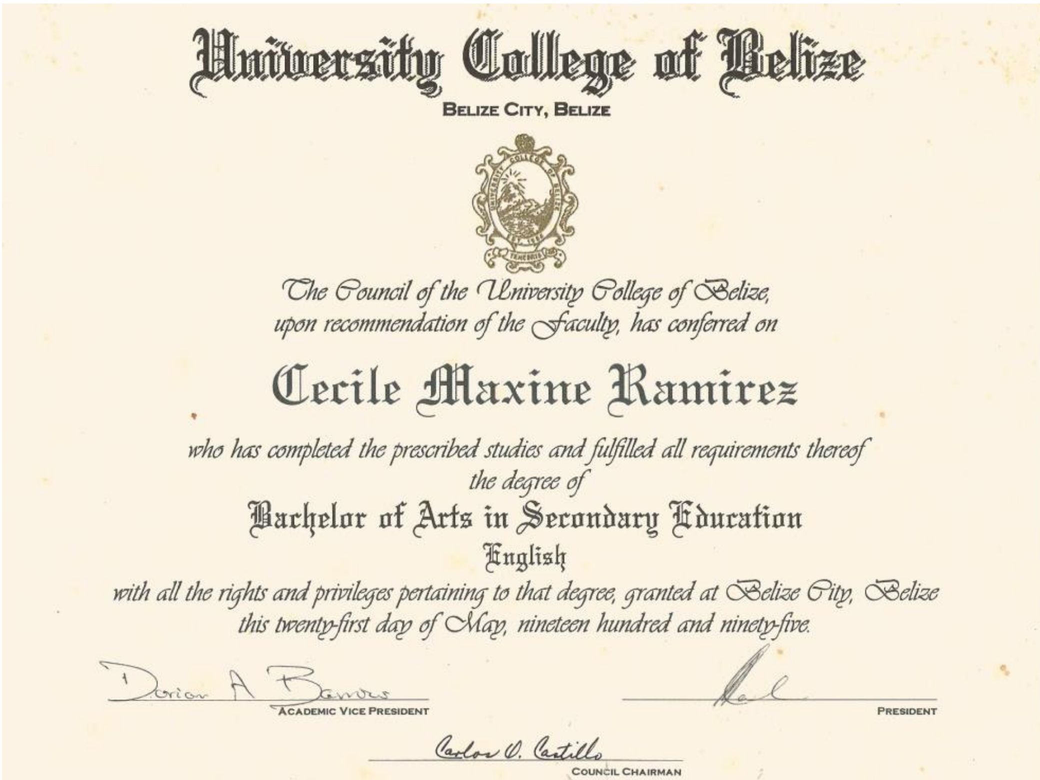
I hereby confirm that Amin Ali Matar has made all required corrections and improvements suggested to the project entitled "Developing a Methodology for Mini-grid Implementation: A Case Study of the 69.5kW Project in Belize" document as I have recommended.

In my judgement, the document meets the literary and linguistic standards required of a student studying for a degree at the Master's level.

Yours sincerely,

Miss Cecile Ramirez M. Ed.

Appendix 4.1: Academic Qualifications of Philologist



University College of Belize

BELIZE CITY, BELIZE

The Council of the University College of Belize,
upon recommendation of the Faculty, has conferred on

Cecile Maxine Ramirez

who has completed the prescribed studies and fulfilled all requirements thereof
the degree of

Bachelor of Arts in Secondary Education

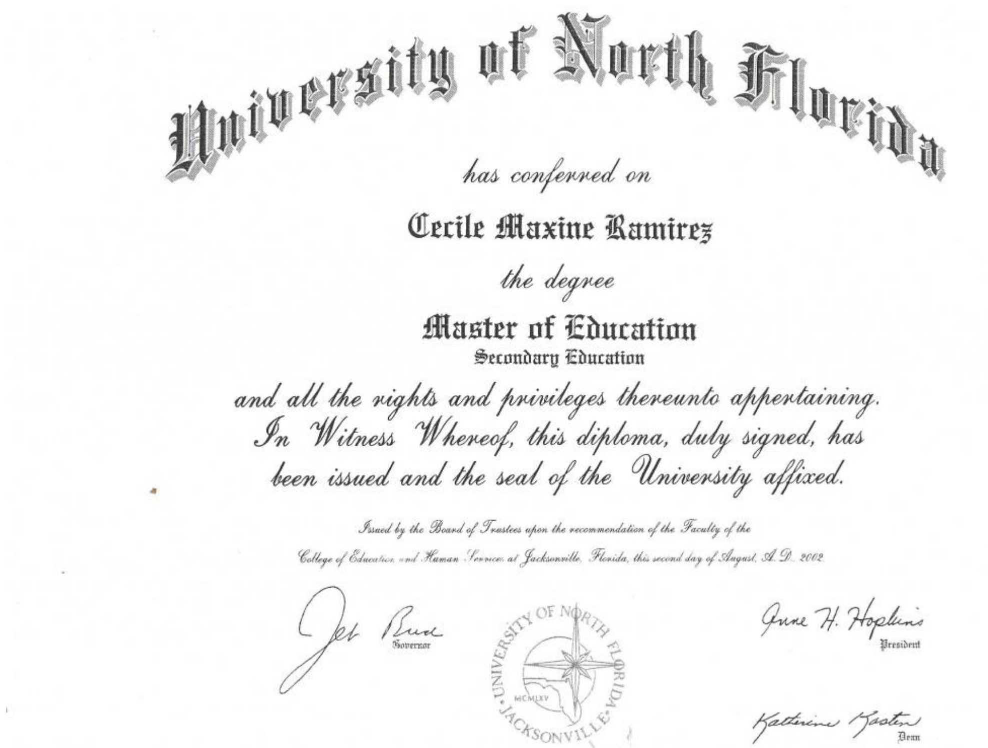
English

with all the rights and privileges pertaining to that degree, granted at Belize City, Belize
this twenty-first day of May, nineteen hundred and ninety-five.

Dorian A Barrow
ACADEMIC VICE PRESIDENT

PRESIDENT

Carlos O. Castillo
COUNCIL CHAIRMAN



University of North Florida

has conferred on

Cecile Maxine Ramirez

the degree

Master of Education

Secondary Education

and all the rights and privileges thereunto appertaining. In Witness Whereof, this diploma, duly signed, has been issued and the seal of the University affixed.

Issued by the Board of Trustees upon the recommendation of the Faculty of the College of Education and Human Services at Jacksonville, Florida, this second day of August, A.D. 2002

Governor

President

Dean

University of North Florida

College of Education and Human Services

Certificate of Award

May it be known that this Certificate has been presented to

Cecile Maxine Ramirez

For the satisfactory completion of 12 semester hours of intensive course work in Teaching English as a Second Language (TESOL)

On this 2nd day of August, 2002

Program Sponsor

Dean of the College of Education

Appendix 5: Ministry's Letter of Consent

MINISTRY OF PUBLIC UTILITIES, ENERGY, LOGISTICS &
E-GOVERNANCE
7299 George Price Boulevard - Second Floor, Toucan Plaza Building,
Phone: 822-0810/822-0401 Fax: 822-2394

My Ref: **P/ENG/01/2024(56)**

Mr. Amin Matar
Energy Officer III
Energy Unit

July 10th, 2024

Dear Sir:

Reference is made to your letter dated July 9th, 2024 in relation to request for No Objection to submit and publicise "Developing a Methodology for Mini-Grid Implementation: A Case Study of the 66kW Project of Belize'.

Please note that the Chief Executive Officer has granted permission for you to proceed.

The Ministry wishes you all the best in the remainder of your studies.

Sincerely,

Valerie Middleton (Ms.)
For: Chief Executive Officer