Support to improve sustainability of the electricity service in the Upper Suriname region

Preliminary Comparison of Intervention Alternatives

Final Report

Ref: 18M3_85

Prepared for:

EBS
EnergieBedrijven Suriname

Version 1 December 2018

Version 2 January 2019

Project:	Support to improve sustainability of the electricity service in the Upper Suriname region
Client:	Inter-American Development Bank (IDB)
Beneficiary:	EnergieBedrijven Suriname (EBS)
Consultant:	Trama TecnoAmbiental (TTA)
Contract/Project Code:	BID: CCB/CSU0010-2018 TTA: CI-18-0018

Final Report

Deliverable #3: Preliminary Comparison of Intervention Alternatives

Related Documents	**Type**	**Draft/Final**	**Date of Delivery**
D1. Inception report	Word		18/9/2018
D2. Summary document of assumptions	Word		31/10/2018
D3. Final report	Word		20/12/2018

Financed by:	Inter-American Development Bank (IDB)

PRESENTATION

This is the "Preliminary Comparison of Intervention Alternatives", gathering the content as required in the Terms of Reference

Table of Contents

Tables

Figures

Table of Acronyms

Abbreviations	Explanation
ATP	Ability to Pay
CAPEX	Capital Expenditure
EBS	N.V. Energie Bedrijven Suriname
ESIA	Environmental and Social Impact Assessment
GHG	Greenhouse Gas
IDB	Interamerican Development Bank
LCOE	Levelized Cost of Energy
MV	Medium Voltage
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photovoltaic
RE	Renewable Energy
SF	Solar Fraction
TTA	Trama TecnoAmbiental
WTP	Willingness to Pay

Executive Summary

The "Preliminary Comparison of Intervention Alternatives" document aims to provide information to decision makers in Suriname to decide upon an alternative for the electrification of the Upper Suriname river. It is a high-level description of four scenarios providing 24/7 electrification for 12 communities in the Upper Suriname Region, with a total of 4,200 inhabitants: Gingeston, Pambooko, Abenaston, Amakakonde, Kajapaati, Jawjaw, Lespaansie, Adawai, Gunsi, Ladoani, Tjalikondë and Nieuw Aurora. The consultants have not visited the region and thus this is a desk study based on information gathered mainly from EBS, IDB and other sources. The different scenarios compared are:

1. **Scenario 1: 100% diesel**: conventional off-grid electrification in each community based on diesel fueled mini-grids.
2. **Scenario 2: Solar mini-grids**: off-grid electrification of the 12 communities using PV-hybrid mini-grids with battery storage in each community.
3. **Scenario 3: Grid extension** (based on EBS plans of extension)
    a. **Scenario 3A: Grid extension EBS**: grid extension from Atjoni/Pokigron to Nieuw Aurora with the existing PV-hybrid plant in Atjoni/Pokigron including additional solar generation capacity of 250 kWp (for a total of 750 kWp), combined with diesel.
    b. **Scenario 3B: Grid extension with additional PV as required**: grid extension from Atjoni/Pokigron to Nieuw Aurora with the optimum generation capacity of the existing PV-hybrid plant in Atjoni/Pokigron.
4. **Scenario 4: Mixed grid extension and solar mini-grids**: high solar fraction grid extension from Atjoni/Pokigron limited by the capacity of the PV-hybrid plant in Atjoni/Pokigron (extended to 750 kWp), combined with PV-hybrid mini-grids implemented in each of the remaining communities.

Furthermore, an additional **100% solar scenario** has been defined and simulated, with autonomous solar mini-grids for each village, without any diesel backup and is evaluated only compared against Scenario 2, not in the multi-criteria comparison.

Chapter 1 provides the introduction of the study, the motivation and objectives behind it and some context for understanding the challenges. **Chapter 2** describes the methodology followed by the consultants.

In **Chapter 3**, electricity demand for each community is estimated. This is a critical step towards ensuring sustainable electrification projects, due to the impact of demand on component sizing, budget and financial feasibility of projects. Without the possibility of a field trip to carry out questionnaires, visit the communities and get acquainted with the local context, the consultants have reviewed demand estimations, existing data from the operating off-grid PV-hybrid plant in Atjoni/Pokigron and have built demand models for the different types of users, in order to estimate the aggregated potential electricity demand of each of the 12 communities. Such estimates have been reviewed by EBS and IDB based on their knowledge of the region. Thus, a series of validated demand profiles provides a common ground for comparisons among the different scenarios of electrification. Demand estimates range from 0.67 kWh/day to 6.41 kWh/day for household tiers, 1.46 kWh/day to 5 kWh/day for commercial and 1 kWh/day to 2.6 kWh/day for health and education institutions. The demand per community ranges between 50 kWh/day in Adawai to 1237 kWh/day in the cluster of Nieuw Aurora, Tjalikondë and Ladoani.

Chapter 4 presents the information collected about the technical and cost assumptions of each intervention alternative. Firstly, for the generation based on solar technologies, the solar radiation is considered as 5.4 kWh/m^2-day on average over a year. The basis for the intervention costs is the recently implemented PV-hybrid microgrid project in Atjoni/Pokigron, which is relevant due to the solar technologies used and the location. Secondly, for hydropower, consultants have reviewed existing studies, however, these do not provide estimates of energy generation due to lack of information on seasonality, which is not assessed in detail (further studies should be developed). Thus, hydropower has not been considered in the comparative study. Furthermore, in this chapter, the cost of diesel used for electricity generation is determined. This is between 0.82 USD/L in Atjoni and 1.05 USD/L in Nieuw Aurora depending on the distance from Atjoni, which is also a key aspect as a baseline case of conventional electrification strategy and backup for either of the solar PV-based scenarios. Finally, the information related to the grid extension option is presented in this chapter, which is based on information gathered directly from EBS.

Chapter 5 presents the results of scenario simulations. The simulation tool determines the optimal capacities of components (e.g. solar PV capacity), based on the aforementioned estimations of demand, technical aspects and costs. Optimal capacities are considered those that result in a low levelized cost of energy (LCOE) and have a high solar fraction. The results show that autonomous mini-grids with high solar fraction (over 90%) have the lowest LCOE, while the grid extension scenarios are more expensive solutions, but still cheaper than the only-diesel scenario. This is due to the high costs for the construction and operation of the medium voltage line which is necessary for the grid extension from Atjoni towards the rest of the Upper Suriname communities, as well as the cost of diesel transported on site.

Chapter 6 analyses the results of the quantitative and qualitative assessment, using several comparison and evaluation criteria. The quantitative assessment results have been obtained using an analytical method based on weighted scores. Stakeholders should agree on the relative weights allocated. The results are summarized in the following spider-chart, with the Subtotals for Financial, Technical and Environmental criteria. It is to note that the higher the score, the further the point in the chart, thus, overall, the "winning" scenario is the one with the broadest area covered. The quantitative criteria for comparison are:

- FINANCIAL: F1. CAPEX; F2. OPEX; F3. LCOE
- TECHNICAL: T1. SOLAR FRACTION; T2. SECURITY OF FUEL SUPPLY; T3. TRANSMISSION LINE LOSSES
- ENVIRONMENTAL: E1. CO_2 EMISSIONS GENERATED; E2a and E2b. NOISE; E3 LAND USE

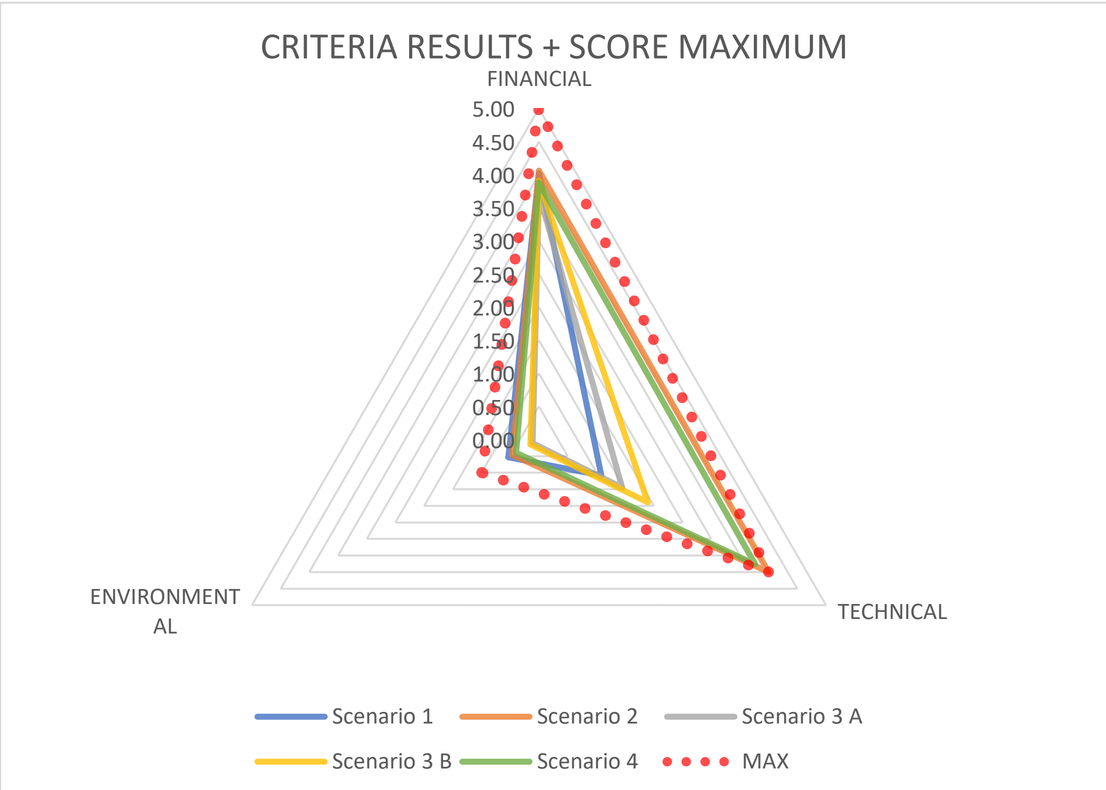


Figure 1: Spider chart comparison graph for all scenarios, per criteria

- The scenarios with high "solar fraction" rate high in technical aspects due to the low dependence on diesel. Besides, this implies a low LCOE as a result of the combination between CAPEX and OPEX. Besides, for example, "grid extension" Scenario 3B has higher LCOE and especially higher land use, 22 times Scenario 2. Under Scenario 2.

- Overall, in the spider chart, the “broadest area” covered is by the Scenario 2. It must be recalled that this graph does not include the qualitative criteria.
- The grid extension scenarios 3A and 3B have higher CAPEX and LCOE than Scenario 2, given the cost of grid extension and its operation. Scenario 4 combines the advantages of single mini-grids with the extension of the Atjoni grid since the excess capacity of Atjoni plant can electrify the three first towns from there (Gingeston, Pambooko, Abenastor). It must be noted that grid extension and use of transformers adds losses to the system, which should be considered as “additional demand”, thus increasing the size and capacity of infrastructure. From a PV-based generation perspective, any additional demand, especially losses, are to be avoided since it requires oversizing the plants to account for such losses. This study has not calculated detailed losses and thus this qualitatively hampers grid-extension scenarios.
- Greenhouse gas (GHG) emissions are also related to diesel use; thus, high solar-fraction scenarios score high. More specifically, Scenario 2 has the lowest GHG from operation followed by Scenario 4, while Scenarios 3B and 3A have approximately five times and seven times higher GHG than Scenario 2.
- Land use has been considered as the area taken by the permanent infrastructure such as PV plants, technical buildings and right-of-way of grid extension. Thus, the diesel scenario tops this rank due to its minimal permanent infrastructure. Then, the solar PV mini-grids scenario has approximately 20 times lower land use than the grid extension scenarios 3A and 3B. The mini-grid footprint can decrease even more by introducing the concept of a multi-use building and installing the PV generator on a “pergola”, providing shade to the technical house and creating a shaded are for the community.

Chapter 7 presents a 100% solar scenario, with autonomous solar mini-grids for each village without any diesel backup, which has not been included in the multi-criteria analysis. This scenario shows that it is feasible to supply the demand of the villages purely with solar power, by applying demand side management measures and increasing the storage capacity of the mini-grids. Even though the LCOE remains unchangeable, it has other direct and indirect benefits:

- The absence of diesel generators results to zero CO2 emissions and noise
- Lower operational needs
- Elimination of the need for fuel, and also elimination of the associated logistics costs and dependency.

In **Chapter 8** a benchmark of management models for mini-grids and tariffs is presented to provide alternatives for further discussion among stakeholders. Both have strong implications in the sustained service in remote areas. Besides, Energy Efficiency must be at the forefront of remote electricity service deployment and should be part of the business model of the operating entity.

This study helps to frame the discussion of the Upper Suriname river electrification alternatives and provides a common ground for comparison among them. Stakeholders should agree on the relative weights allocated. An important next step prior to the intervention will be to develop a detailed study of the demand at the communities, based on field trips and also the field evaluation of the existing infrastructure, a grid study (if applicable depending on the selected scenario) or a detailed ESIA study following local NIMOS regulations.

1. Introduction

Suriname counts a population of approximately 541,700 people within an area of 163,820 km^2. More than half of Suriname's population lives in the capital Paramaribo, on the coast near the mouth of the Suriname River. The interior of Suriname, which is extended towards the Amazon rainforest, is composed of about 217 villages.

Approximately 60% of the interior villages have small isolated electrical power systems generated by diesel generator sets with a limited supply that can go up to 6 hours a day. The owner and operator of all micro power systems is the Ministry of Natural Resources and the service to users is free of charge. To provide a 24/7 hours electricity to the interior of the country is one of the main objectives of the government through the national strategies.

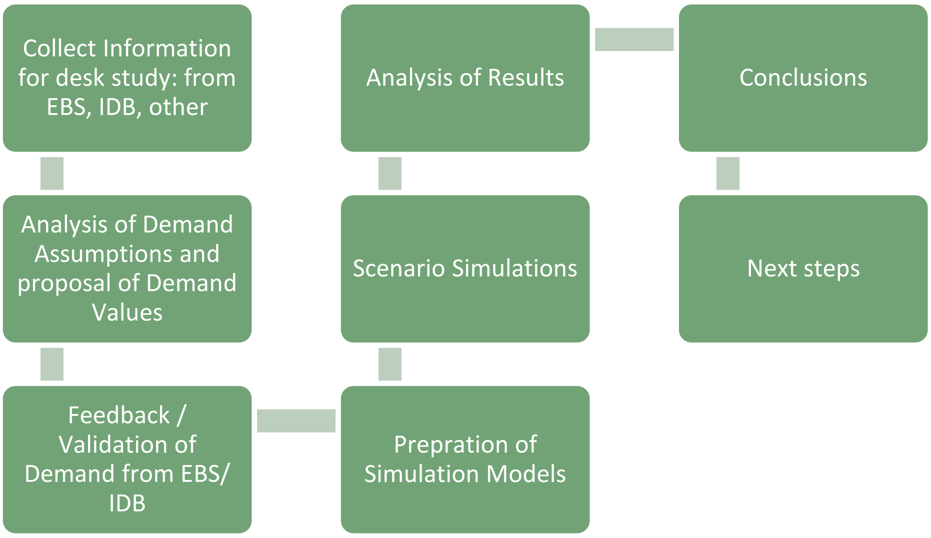
In this context, the program SU-L1009 "Support to Improve Sustainability of the Electricity Service Program" is financed by IDB with the Government of Suriname and executed by EBS. One of the main projects executed in this program has been the commissioning, in February 2018, of a 500 kWp off-grid solar PV plant with battery energy storage and diesel backup, providing 24 hours electricity to Pokigron and Atjoni in the upper Suriname Region.

The European Commission has approved funds to co-finance activities within this program, mainly to provide 24/7 electricity access based on renewable energies to 12 communities in the Upper Suriname Region, with a total of 4,200 inhabitants, namely Gingeston, Pambooko, Abenaston, Amakakonde, Kajapaati, Jawjaw, Lespaansie, Adawai, Gunsi, Ladoani, Tjalikondë and Nieuw Aurora.

TTA has been hired for in order to prepare technical studies to support the decision makers to select the optimum scenario for the electrification of the 12 targeted communities, having in mind the future electrification of the southern communities in Upper Suriname region. Moreover, this document presents management challenges and recommendations to operate the mini-grid plants in a sustainable way. Finally, TTA recommends the next steps up to execution and operation of the plant(s).

2. Methodology

This chapter describes the methods carried out during the consultancy.



2.1. Information Analysis

The analysis of the information has been carried out with a critical review of available literature based on TTA's experience and on references provided by EBS and IDB. A field trip has not been included in this consultancy and thus this is a desk study. A summary document of assumptions has been shared with EBS and IDB during this phase (the "Summary Document of Assumptions") and validated. This analysis aimed to set and validate the basis for comparison among the different scenarios. The analysis of information has been focused in the following aspects:

- Context and location of the area of intervention
- Existing and available information about solar and hydro power potential
- Number of users per community
- Different types of user profiles (electrical equipment assumed to be used)
- Estimated electricity demand per user
- Costs of technical components
- O&M costs
- Costs of distribution/transmission lines

2.2. Scenario Description

The different scenarios, providing an uninterruptible electricity service, are described below:

Table 1: Description of the scenarios

Scenario	Name	Description
1	100% diesel mini-grids	Conventional off-grid electrification in each community based on generation with diesel fuel
2	Solar Mini-grids	Off-grid electrification of the 12 communities using autonomous PV-hybrid mini-grids with battery storage in each community
3A	Grid extension with 250 kWp additional PV	Grid extension from Atjoni/Pokigron to Nieuw Aurora utilizing the existing PV-hybrid plant in Atjoni/Pokigron including additional solar capacity of 250 kWp (for a total of 750 kWp) and supply of the remaining demand with diesel generators
3B	Grid extension with optimum PV	Grid extension from Atjoni/Pokigron to Nieuw Aurora considering optimum PV capacity of the existing PV-hybrid plant in Atjoni/Pokigron, according to optimization simulations
4	Mixed grid extension with solar mini-grids	Grid extension from Atjoni/Pokigron, only up to where the capacity of the expanded (a total of 750 kWp) PV-hybrid plant in Atjoni/Pokigron allows and then the remaining villages are electrified through mini-grids

It should be noted that, in order to have a common basis for comparison through all scenarios, methodologically, the study considers the total number of connections and demand, including the one from Atjoni/Pokigron mini-grid. The Atjoni/Pokigron mini-grid has not been optimized but, instead, the existing (installed) components and real costs have been used.

2.3. Simulations of RE Plant Performance

The scenarios are simulated with the HOMER Pro® mini-grid software. The different simulation models provide various results, including:

- Installed capacity of PV generator, inverters, batteries and diesel generators (if not defined);
- Technical indicators: solar fraction, excess energy, battery autonomy, annual fuel consumption;
- Economic indicators: CAPEX, OPEX, LCOE;
- Environmental indicators: CO_2 emissions.

Renewable resources:

- Solar: HOMER counts with a built-in database for radiation and this is not considered critical for the level of detail required in the study;
- Hydro: The TOR mention mini-hydro as an option, however, as stressed by the Consultants and as explained in the inception report, a preliminary analysis of the level of detail of already identified mini-hydro sites is low in order to produce concrete results.

Inputs for the different communities will differ in:

- Total electricity demand per community and peak power;
- Costs, mostly due to different distances from Atjoni/Pokigron. The cost of components on each site follows the same increase as the diesel on site to compensate for logistics' costs. Cost estimates are based on the Atjoni/Pokigron mini-grid and discussed between the consultants and EBS/IDB.

In the case of PV-hybrid energy plants, these can be classified according to the solar fraction and the ratio between solar capacity and nominal load of consumption, as follows.

Table 2: Summary of possible hybrid plants based on the solar fraction and the ratio between solar capacity and nominal load of consumptions

Category	Indicative solar fraction	Ratio between solar capacity (kW_{STC}) and demand nominal load	Photovoltaic generation features
Low	< 20%	< 50%	• The generator set always running • No restrictions on photovoltaic production • No need for control • Low fuel consumption reduction • Low investment costs and a high return on investment • Little impact: low environmental benefits and low savings in absolute terms
Medium	20% - 50%	> 50%	• The generator set always running • Simple PV production controller or small energy storage capacity for voltage and frequency regulation • Important to have a spinning reserve • Substantial benefits
High	> 50%	>150%	• The generator set is not always working • Requires sophisticated control for network regulation and control of electronic components • Requires a battery to ensure service stability and supply the demand during periods of production transition where there is no photovoltaic production • It has high investment costs, and low operating costs • High environmental benefits
	Autonomous > 80%		• The generator set as emergency or backup • Requires sophisticated control for network regulation and control of electronic components • It requires a battery to make a shift of use of photovoltaic energy • It has high investment costs, and low operating costs • High environmental benefits

2.4. Methodology for Scenario Comparison

After the preliminary analysis of literature and the information shared by EBS and IDB, as well as assumptions' validation, the consultants have evaluated and compared the different scenarios. Various quantitative and qualitative criteria have been chosen in order to compare the scenarios, under a technical, financial, social and environmental point of view.

The aim of the analysis is to support the decision-makers to choose the better electrification scenario to execute in the area of intervention and this is done by comparing quantitatively and qualitatively different criteria selected by TTA, EBS and IDB.

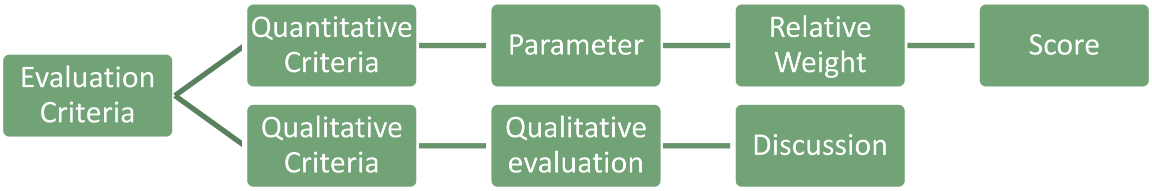


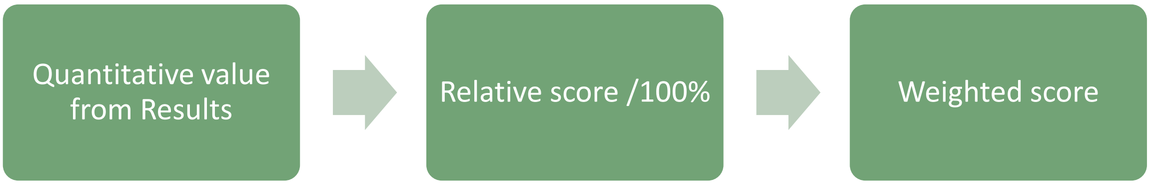
Figure 2: Classification for analysis and comparison of scenarios

The qualitative criteria are described in their respective part showing advantages and disadvantages to open the discussion.

The quantitative criteria are calculated based on their respective parameter (obtained from the simulation tool) and relative weight presented below. The parameter values are compared following the methodology explained beforehand.

2.4.1. Quantitative vs. Qualitative

2.4.1.1. Quantitative Comparison



Every quantitative criterion has a certain parameter (result) value for each scenario. The parameter value is calculated as a score in percentage following a logical formula comparing each parameter with the best one (lowest or highest):

Calculation when the winner ("*best*") is the **lowest**

IF LOWEST PARAMETER VALUE: $\rightarrow Score\ \%\ Assigned = 100\ \%$

OTHERS: $\rightarrow Score\ \%\ Assigned = 100 \times \frac{Lowest\ Parameter\ Value}{Parameter\ Value}$

Calculation when the winner ("*best*") is the **highest**

IF HIGHEST PARAMETER VALUE: $\rightarrow Score\ \%\ Assigned = 100\ \%$

IF NOT: $\rightarrow Score\ \%\ Assigned = 100 \times \frac{Parameter\ Value}{Highest\ Parameter\ Value}$

Then the percentage score is converted into a score over 10. Finally, each criterion has a relative weight to get a weighted score.

$$Weighted\ Score = Relative\ Weight\ (\%) \times Base\ 10\ Score$$

The weighted scores of the evaluation criteria are aggregated per part (Financial, Technical, Environmental) and in total.

2.4.1.2. Qualitative Comparison

Every qualitative criterion is discussed for the different scenarios in each analysis part.

2.4.2. Selected Criteria

The following table summarizes the criteria used for comparison. For the quantitative criteria, weights have been allocated but can be modified by the project stakeholders.

An overall score is calculated by weighting the individual parameter score with the relative weight. For each scenario, a "spider-web" type of graph provides a visual representation of the relative score in the different criteria.

Table 3: Summary of quantitative criteria with respective description, parameter and relative weight

EVALUATION CRITERIA	DESCRIPTION	PARAMETER (unit)	RELATIVE WEIGHT
FINANCIAL			**50,0%**
CAPEX	Capital Expenditure is the total investment expenditure, considering all investments in a scenario	USD, from simulations and assumptions	10,0%
OPEX	Operational Expenditures to exploit and maintain the energy infrastructure	USD/year from simulations and assumptions	10,0%
LCOE	The LCOE is the total cost of energy over the life of equipment that generates it	USD/kWh from simulations and assumptions	30,0%
TECHNICAL			**40,0%**
SOLAR FRACTION	Share of solar energy in total supply	% solar supply	15,0%
SECURITY OF FUEL SUPPLY	Risk of non-fuel supply because of limitations of access. Will be linked to the liters used/year	$L_{Diesel\ Consumed}$ / year	15,0%
ELECTRICAL TRANSMISSION LINE	Electrical losses in LV lines and MV lines	% Energy losses / Demand	10,0%
ENVIRONMENTAL			**10,0%**
GHG EMISSIONS	GHG Emissions by the diesel generators, operation per year	GHG Emissions $kgCO_{2\text{-}eq}$ / year	4,0%
NOISE	Noise from the operation of diesel gensets	$L_{Diesel\ Consumed}$ / year	0,5%
		Number of gensets	0,5%
LAND USE	Needs of land-use for electrical infrastructures: land clearing, right of way etc.	m^2 of land-use	5,0%

Table 4: Summary of qualitative criteria

EVALUATION CRITERIA	DESCRIPTION	Potential Impacts / Parameters
TECHNICAL		
MV TRANSFORMER LOSSES	Electrical load losses and no-load losses from the transformers	High losses imply higher generation requirements as an additional demand
INTRINSIC SAFETY	Defined as safety of electrical infrastructures	Risk to safety operators or others, due to voltage level of lines (electrocution, falling cables, fire)
CONTINUITY OF SERVICE	Resiliency from events that may occur within the area	Interruptions of service
EXTENDING SERVICE BEYOND current analysis area	Advantages/inconveniences of each alternative with regards to extending the service beyond in the Upper Suriname region	Assessing whether each of the scenarios has an impact on the further efforts to provide electricity service in the region or in replicable areas
OPERATIONAL CHALLENGES – Managing scattered generation projects	Management of one central versus several autonomous plants, community involvement and salaries, strongly depending on selected management model	Several autonomous generation plants may need more personnel permanently on each site, increased complexity instead of managing one centralized generation infrastructure
OPERATIONAL CHALLENGES – Managing MV lines in the forest	Management, maintenance and operation of MV lines	Need of qualified technicians for medium/high voltage grid maintenance and associated costs
CONSTRUCTION DURATION	Duration to construct the plants, including associated studies, logistics and construction of the generation part and distribution lines (LV and MV)	Autonomous mini-grids can be constructed simultaneously by different teams (shorter option) or same team constructing them one after the other. Centralized solutions can be constructed faster. MV lines need complex ESIA comparing to autonomous mini-grids with LV distribution, and additional road construction
SOCIAL		
LAND RIGHTS	Organization and management of ownership of lands	Potential Issues related to ownership of lands and crossing communities
EMPLOYMENT OPPORTUNITIES	Job creations linked to the installation and O&M of the energy infrastructure	Transmission lines, PV-hybrid plant, battery management, and some O&M tasks can be done by local, trained technicians, depending on the existing knowledge and abilities
SATISFACTION OF COMMUNITY WITH INFRASTRUCTURE	Defined as degree of people involvement in the energy infrastructures management. (e.g., Community based management, public institution management, proximity with the energy infrastructures)	No significant differences among scenarios
KNOWLEDGE REQUIRED FOR O&M	Technical knowledge needed to maintain and operate the	More complex and higher voltage infrastructure will require higher degree technicians

	energy infrastructures, possible involvement of locals	

2.4.3. Technical Criteria

2.4.3.1. Quantitative Criteria

T1. Solar Fraction

The Solar Fraction is the percentage of solar supply respected to total supply as a result of the simulations.

T2. Security of fuel supply

The security of fuel supply is related to the liters of diesel consumed by the generators per year. This parameter is a result of the simulations. The main factors affecting the security of fuel supply is the accessibility (e.g. road, river and variability) and financial limitations.

T3. Transmission line losses

The study has entered into the detail of simulating the flows of energy in each scenario. The electrical transmission losses are calculated as losses in kWh per day and are then convert in a share of the total energy demand. They are limited to two factors: losses in low voltage lines (for all scenarios) and medium voltage lines (Scenarios 3A, 3B and 4). The losses from mast mounted MV transformers is discussed qualitatively in chapter 6.1.2 due to lack of information concerning the type of transformers used.

TTA uses an upper limit of 3% for the voltage drop of LV lines in its rural electrification designs, from the general distribution board to the furthest user, to assure a high quality of service to all users. This same percentage is considered for the calculation of electrical losses in LV lines for this study.

The medium voltage 12 kV power line losses are calculated in function of the distance, the maximum power admissible, the conductor's conductivity (at 70ºC) and the section chosen for each of the transmission section. The section has been selected in function of the market availability and with the limitation of a voltage drop upper limit of 3 % from Atjoni/Pokigron to Niew Aurora. It is considered an aluminum conductor with a conductivity of $28 m/\Omega mm^2$.

2.4.3.2. Qualitative criteria

The qualitative criteria chosen for the technical analysis are:

- The MV mast-mounted transformer losses
- The intrinsic safety for each scenario from the energy infrastructures, mainly related to the proximity of the infrastructure to users and the voltage level
- Continuity of service, measured as the resilience of the service to blackouts in the lines or other
- Expanding the service beyond: the benefit for the future electrification in Upper Suriname region
- Operational challenges due to management of scattered generation projects
- Operational challenges due to management, maintenance and operation of MV lines in a forest area
- Construction duration

2.4.4. Financial Criteria

The CAPEX (F1), OPEX (F2) and LCOE (F3) are the quantitative indicators used in the Financial Analysis topic.

The CAPEX of the alternative will be the upfront costs to build the required infrastructure; the OPEX include operation of components and replacement of equipment of the generation plant and distribution line; finally, the LCOE is the total cost of energy, an indicator of the balance between the costs and energy generated over the project cycle.

2.4.5. Social and Environmental Criteria

This part aims to describe the social and environmental impacts of the different scenarios in the area of intervention.

The criteria chosen for comparing the scenarios are the GHG emissions, the noise from the generation plant, the land-use needed for energy infrastructures, the land-rights, the employment opportunities and the feeling of satisfaction of community with infrastructure. Some criteria are quantitative and can directly be used to make the comparison, some others are qualitative and are discussed.

2.4.5.1. Quantitative criteria

E1. GHG Emissions from the diesel generators

GHG emissions are measured in CO_2-equivalent emissions generated by the diesel generations per unit of power per year ($kgCO_{2\text{-}eq}$/kWh/year).

E2. Noise from diesel generators

The noise from the generation of diesel generators is represented by two variables which are the number of gensets (E2a) and the liters of fuel consumed per year (E2b) in each scenario. The direct impact of this criterion is the discomfort and hearing fatigue of the noise for the inhabitants and fauna nearby the gensets.

E3. Land-use

Energy infrastructure has an impact on the use of land. The study considers for land use all permanent infrastructure, such as the PV Generator, the technical building for electric equipment ("power house"), the MV Transmission lines, and the diesel generator building.

The land-use for each scenario is calculated based on the following considerations:

- Scenario 1:
  - Diesel generator building: 15 m^2
- Scenario 2, 3A, 3B, 4:
  - PV Generator area: 8 m^2 / kWp
  - Power house for < 50 kWac output: 60 m^2
  - Power house for > 50 kWac output: 70 m^2
- Scenario 3A, 3B, 4:
  - MV transmission lines land clearing: 14,000 m^2 / km

The MV transmission lines need to have 4 meters of projected road and 5 meters on each side of the road, which make an area of 14 m^2 per meter. To calculate the PV generation area consideration, a 300 Wp PV panel area of 1.7 m^2 has been assumed and that there is 30% additional space than the area of the PV panels (due to the inclination of panels and walking spaces).

According to a document published in January 2018 by the National Institute for Environment and Development in Suriname (NIMOS) [1] "the country wishes to maintain its status as one of the world's most forested countries" by reducing emissions from deforestation and forest degradation. The REDD+ Strategy is explained as follows:

[1] "Forest Reference Emission Level for Suriname's REDD+ Programme"

Suriname's tropical forest continues and improves its contribution to the national and community growth, welfare and wellbeing of current and future generations through planning, research, effective protected areas management and sustainable forest management, resulting in an efficient use of the forest and natural resources, ecosystem services and the preservation of biodiversity, while continuing to offer a substantial contribution to the global environment, enabling the conditions for an adequate compensation for this global service.

Figure 3: REDD+ Programme's strategy

Thus, despite the fact that this study does not assess the relative impact of the interventions' land use compared to other economic activities (such as agriculture, mining etc.), it is considered as an important criterion to compare each scenario's contribution to this aspect.

2.4.5.2. Qualitative Criteria

Land Rights

Energy infrastructure, whatever the alternative, will probably require organizing for and managing land rights. The larger the area required for "land use", the higher the potential issues with ownership of land. This may also be an added issue if conflicts exist among communities, e.g. if a line has to cross along several communities.

Employment opportunities

During the construction of infrastructure, it is expected that local workforce will participate and thus part of the works will be done by local inhabitants. Besides, mini-grids can employ local staff for basic maintenance tasks and operation of the plant alternative.

Satisfaction of community with infrastructure

Based on consultants' experience, the mini-grid projects which have been successfully implemented in the past have had a strong component of community participation. It is important to implement this since early project design, for example by interviewing local population and community capacity building. This will also have an additional technical advantage, since component sizing can adapt to the needs that will be served.

Although this criterion has no obvious winning scenario, the applicable (if existent) methodologies of social impact should be used during project detailed design.

Knowledge required for O&M

In this criterion, the scenario with the minimum knowledge needed to perform O&M tasks has more positive impact. For example, MV certified electricians will be needed where MV is present, whereas LV lines can be operated by less skilled staff.

3. Electricity Demand Estimations

The assessment includes a review of the existing literature and information provided by IDB and EBS regarding rural electrification in Suriname and Upper Suriname region, renewable energy resources in Upper Suriname, existing initiatives and executed projects for rural electrification in the country focusing on investment and O&M costs, as well as energy demand estimations from the communities in the area of intervention. TTA wrote a summary assumptions report including the above, which was validated by EBS and IDB.

This part presents the main findings and conclusions from the literature review, including context, demand and costs for the analysis and simulations.

3.1. Location and distance from Atjoni/Pokigron

The 12 targeted communities are located along the Suriname river, south from Atjoni/Pokigron as shown in Figure 4. The study considers the communities of Ladoani (#10), Tjalikondë (#11) and Nieuw Aurora (#12) as a single cluster (hereafter called cluster A) because of their proximity and the existing electric distribution.

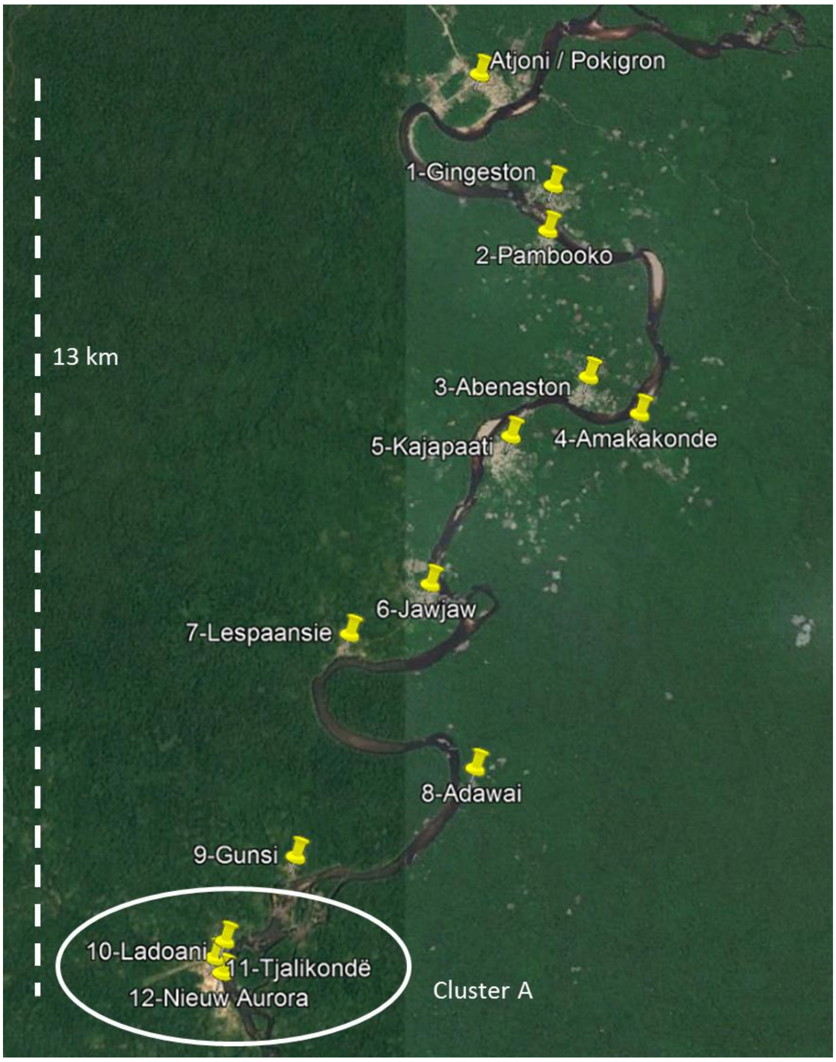


Figure 4: Location of communities

The distance from Atjoni/Pokigron to each community is presented in Table 5.

Table 5: Location and distance from Atjoni to each targeted community (Source: April 2018 "Field Visit Upper Suriname Region")

	Name	Coordinates	Distance from Atjoni (km) of the expected grid extension	Cluster considered
1	Gingeston	4º28'34.10''N 55º21'28.59''W	4.2	N/A
2	Pambooko	4º28'12.87''N 55º21'31.19''W	4.5	N/A
3	Abenaston	4º27'4.23''N 55º21'12.17''W	6.7	N/A
4	Amakakonde	4º26'46.86''N 55º20'48.24''W	7	N/A
5	Kajapaati	4º26'36.39''N 55º21'48.59''W	8.5	N/A
6	Jawjaw	4º25'27.14''N 55º22'26.43''W	11	N/A
7	Lespaansie	4º25'3.77''N 55º23'4.11''W	12.4	N/A
8	Adawai	4º24'1.26''N 55º22'5.36''W	16.2	N/A
9	Gunsi	4º23'20.19''N 55º23'29.22''W	18.7	N/A
10	Ladoani	4º22'40.98''N 55º24'2.22''W	21	Cluster A
11	Tjalikondë	4º22'33.15''N 55º24'7.14''W		
12	Nieuw Aurora	4º22'26.14''N 55º24'3.51''W		

3.2. Population and potential connections

The number of potential connections is calculated based on data from EBS in Atjoni/Pokigron which categorizes the connections in households, small commercials and schools/churches (88%, 11% and 1% respectively of total number of connections). This same ratio is used for the other communities since there is no further information on non-residential users.

Table 6: Tariffs and number of connections in Pokigron/Atjoni (Excel "kWh usage Atjoni August 2018")

Tariffs	Connection type	Number	% Connections
Tariff 11	Households	311	88%
Tariff 21	Small commercial	37	11%
Tariff 25	Schools and Churches	4	1%

Thus, based on CBB-2017 population, an estimation of 3 inhabitants per household on average and the distribution of categories, the following table is the basis for the demand estimation that will follow.

Table 7: Demography and potential connections of each community (Calculations based on CBB-2017, revised by EBS)

Ref	Name	Population (CBB-2017)	Nº Inhabitants /household	Nº Households	Nº Commercials	Nº Schools and Churches	Total Nº Connections
1	**Gingeston**	322	3	107	4	1	112
2	**Pambooko**	240	3	80	3	1	84
3	**Abenaston**	473	3	158	7	2	167
4	**Amakakonde**	287	3	96	4	0	100
5	**Kajapaati**	873	3	291	10	2	303
6	**Jawjaw**	385	3	128	7	2	137
7	**Lespaansie**	173	3	58	2	0	60
8	**Adawai**	49	3	16	1	0	17
9	**Gunsi**	100	3	33	4	0	37
A	**Cluster**	1330	3	443	30	4	477

3.3. Electricity Demand Estimation

3.3.1. Demand Tiers

The following tables show the different demand tiers per connection type and category, as well as the average demand of the connections within each tier using the demand data from Pokigron and Atjoni. The following shares for each tier are adapted accordingly in order to extract the demand of the project villages.

HOUSEHOLDS

Table 8: Estimated tiers for Households category based on Atjoni/Pokigron data

Tier	Range (kWh/month)	Share of connections within tier range (%)	Average demand per tier	
			Monthly demand (kWh/month)	Daily Demand (kWh/day)
T1-H	(0,50]	41%	20.46	0.67
T2-H	(50,100]	24%	72.42	2.38
T3-H	(100,150]	20%	119.69	3.94
T4-H	(150,250]	10%	194.95	6.41
T5-H	(250,4500]	4%	919.08	30.23
Average demand of households			**109.35**	**3.60**
Average demand of households without Tier T5-H			**70.18**	**2.31**

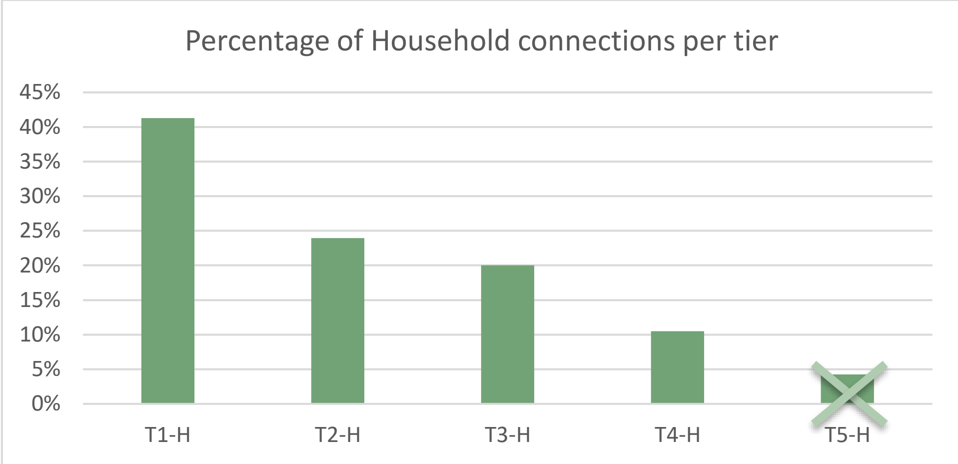


Figure 5: Estimated percentage of household connections per tier based on data from Atjoni/Pokigron

The analysis on the households shows special loads (or anchor loads) which are high consuming loads from 250 to 4500 kWh/month. These loads should be excluded from the statistic study in a prefeasibility stage, but they should be investigated in following stages.

COMMERCIALS

Table 9: Estimated tiers for Commercials category based on Pokigron and Atjoni data

Tier	Range (kWh/month)	Share of connections within tier range	Average demand per tier	
			Monthly demand (kWh/month)	Daily Demand (kWh/day)
T1-C	(0,100]	31%	44.43	1.46
T2-C	(100,200]	26%	151.60	4.99
T3-C	(200,500]	20%	274.21	9.02
T4-C	(500,4500]	23%	1810.35	59.55
		Average demand of commercials	**521.58**	**17.16**

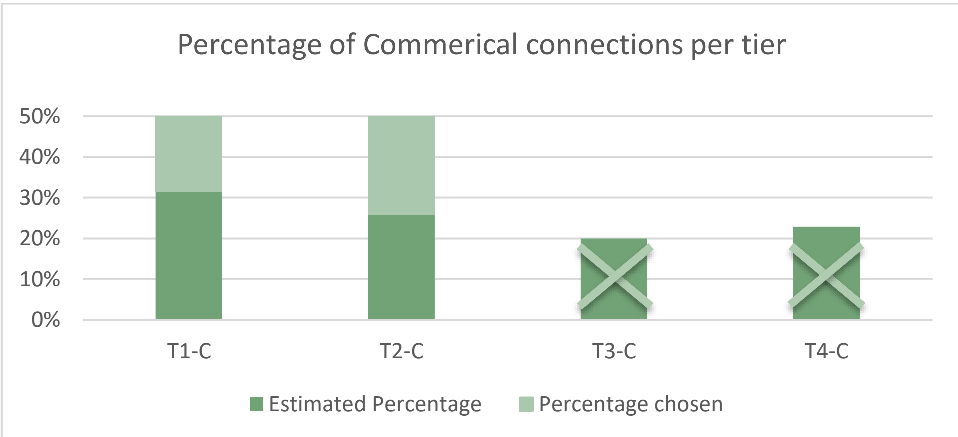


Figure 6: Estimated percentage of commercial connections per tier based on data from Atjoni/Pokigron

In the commercials' category, there are 8 connections (23%) with a consumption distributed between 500 and 4500 kWh/month. From TTA's experience, those are anchor loads that could be industrial users or telecommunication towers for example. According to EBS, to extrapolate the demand to the 10 villages, it is assumed that 50% are in the tier T1-C and 50% are in the tier T2-C.

SCHOOLS AND CHURCHES

Table 10: Estimated tiers for Schools and Churches category based on Pokigron and Atjoni data

Tier	Range (kWh/month)	Share of connections within tier range (%)	Average demand per tier	
			Monthly demand (kWh/month)	Daily Demand (kWh/day)
T1-SC	(0,51]	50%	33.67	1.11
T2-SC	(51,71]	25%	60.93	2.00
T3-SC	(71,91]	25%	79.78	2.62
Average demand of schools and churches			**58.12**	**1.71**

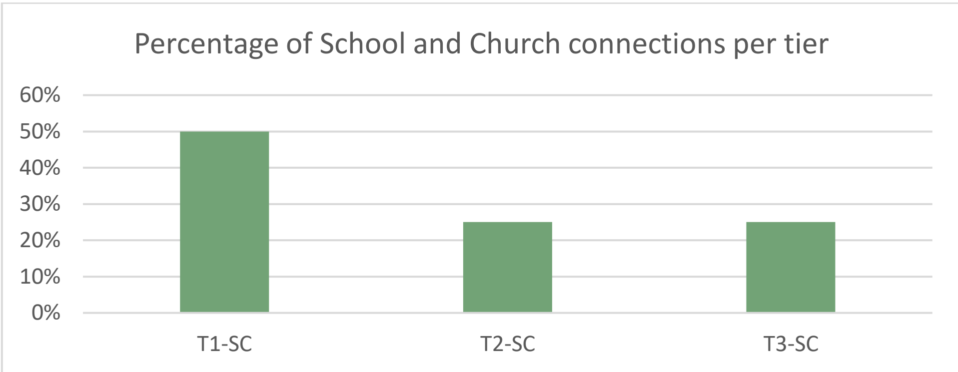


Figure 7: Estimated percentage of school and church connections per tier based on data from Atjoni/Pokigron

This demand categorization will be used for the extrapolation of the demand of the 10 service areas.

The following table presents the estimated demand in each of the targeted villages. The design demand assumes a 10% increase of the resulted demand calculated through the current population and the Atjoni/Pokigron data, according to EBS feedback.

Table 11: Demand per community per tier (kWh/day)

Name	Gingeston	Pambooko	Abenaston	Amakakonde	Kajapaati	Jawjaw	Lespaansie	Adawai	Gunsi	Cluster
REF	1	2	3	4	5	6	7	8	9	A
	kWh/day									
T1-H	30	22	44	27	81	36	16	5	9	123
T2-H	62	45	91	55	167	74	33	10	19	253
T3-H	83	63	126	75	228	102	47	12	28	350
T4-H	71	51	109	64	199	83	38	13	19	295
T1-C	3	3	6	3	7	6	1	1	3	22
T2-C	10	10	20	10	25	20	5	5	10	75
T1-SC	1	1	1	0	1	1	0	0	0	2
T2-SC	0	0	2	0	2	2	0	0	0	2
T3-SC	0	0	3	0	3	3	0	0	0	3
TOTAL	259	196	401	234	713	327	142	45	88	1.125
TOTAL +10%	285	215	441	257	784	359	156	50	97	1.237
TOTAL/ connection	**2.66**	**2.66**	**2.70**	**2.67**	**2.68**	**2.68**	**2.68**	**2.77**	**2.69**	**2.70**

3.3.2. Estimated Demand of communities

The table below presents the estimated daily electricity demand and the peak power of the communities. Moreover, the daily load profiles of Atjoni/Pokigron and Cluster A are also illustrated, in order to explain the different profiles estimated of the targeted communities. All daily load profiles are presented in Annex 11.2.

Table 12: Summary table of daily electricity demand and peak power for each community

Name	REF	Design electricity demand (kWh/day)	Peak power (kW)
Gingeston	1	285	42
Pambooko	2	215	31
Abenaston	3	441	63
Amakakonde	4	257	38

Kajapaati	5	784	115
Jawjaw	6	359	51
Lespaansie	7	156	23
Adawai	8	50	7
Gunsi	9	97	13
Cluster	A	1237	177
Atjoni/Pokigron		1345	121
TOTAL without Atjoni/Pokigron		3881	560
TOTAL with Atjoni/Pokigron		5225	668

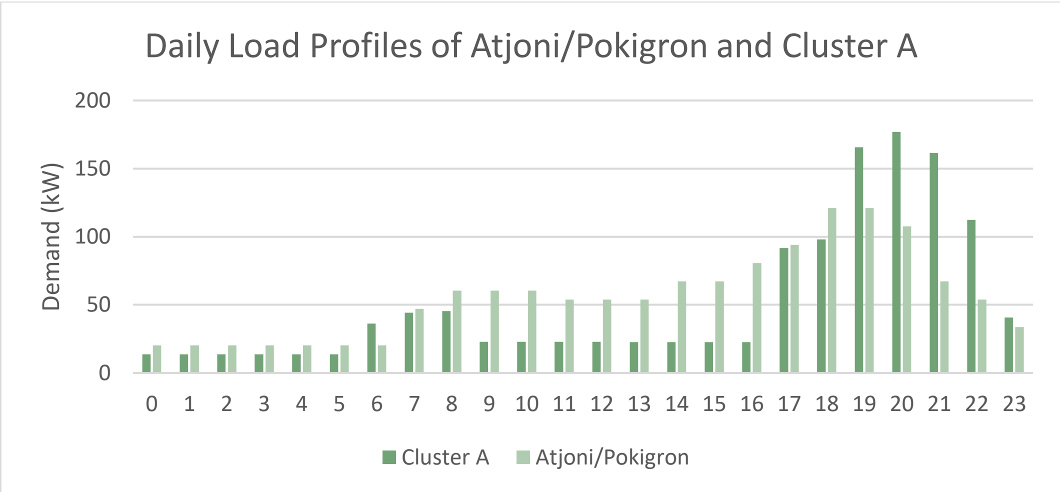


Figure 8: Normalized Daily Load profiles of Atjoni/Pokigron and Cluster A

The estimated daily electricity demand profile of Atjoni/Pokigron is more distributed throughout the day than the one of Cluster A, which shows a relatively higher peak at night, even though the daily demand is lower than in Atjoni/Pokigron. This observation is explained by the fact that less commercial loads have been considered in Cluster A than in Atjoni/Pokigron, as well as the other smaller communities (1 to 9). As discussed with EBS, the clients under tiers T3-C and T4-C, estimated from the Atjoni/Pokigron mini-grid have not been considered for the demand estimation of the rest of the communities. This assumption is based on the fact that Atjoni is a hub of services (secondary school, supermarkets, restaurants…) for all the villages located in the Upper Suriname, as Atjoni is the last village accessible by road.

4. Technical and Cost aspects

4.1.1. Solar

4.1.1.1. Solar Resource

The solar resource has been taken from the online database PVGIS-SARAH (for each of the villages, the solar resource is considered the same for this stage of the study). The average radiation is 5.4 kWh/m^2/day and the monthly distribution is shown below. There are no real data measurements available.

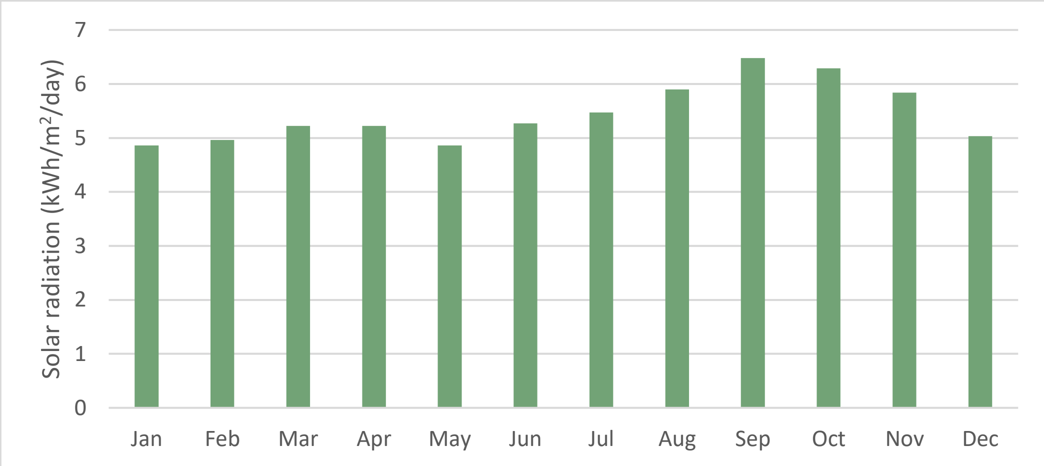


Figure 9: Radiation data in Upper Suriname villages

4.1.1.2. Solar Technology

In January 2018 a new PV-hybrid plant with storage and diesel generators in Atjoni/Pokigron was inaugurated, consisting of 500 kWp solar peak power and 5,000 kWh battery nominal capacity. The electricity distribution network in the community has been upgraded to minimize losses. Moreover, smart meters with pre-payment options will be installed in the households, commercial buildings, schools and churches to facilitate billing to customers. The objectives of the plant are to minimize the operation costs of the diesel gensets and to maximize a secure uninterruptible supply to the customers.

The technical specifications of the Atjoni PV- Hybrid Plant are shown below.

Table 13: Technical Specifications Atjoni PV-hybrid plant (source: EBS)

Atjoni PV-hybrid Plant - Technical Specifications	
Photovoltaic Generator	
Type PV Module	300 Wp / polycrystalline
Brand and Model	ChinaLand Solar Energy CHN300-72P
Number Total PV Modules	1,680
Total Installed Capacity @STC (kWp)	504
Inclination Angle	5º
Facing Azimuth	0º (PV panels face South)
Battery Inverter-charger	
Number Total Inverters	18
Brand and Model	ABB ESI-S 120A Single Phase
Inverter Output Nominal Power (kW)	27.6
System Output Nominal Power (kW)	496.8
Solar Inverter	
Number Total Inverters	14

Brand and Model	ABB TRIO-27.6-TL
Inverter Output Nominal Power (kW)	27.6
System Output Nominal Power (kW)	386.4
Battery	
Battery Type	Valve Regulated Sealed Lead Acid with Gel electrolyte - OPzV
Brand and Model	Sacred Sun GFMJ-1000H
Capacity @C10 @25ºC	1000 Ah
Number of Batteries / Bank	311
Number of Battery Banks	8
Depth of Discharge (%SOC Nominal)	70%
System Nominal Voltage	622 Vdc
System Nominal Capacity @10 @25ºC	4976 kWh
Diesel Backup Genset	
Brand and Model	CaterPillar 350
Number	2
Rated Power Standby	437 kVA / 349.6 kW
Power Factor cos phi	0.8
Rated Voltage	240 Vac / 139 Vac
Rated Frequency	60 Hz

4.1.2. Hydropower

Due to the actual lack of information concerning the micro-hydro power technologies, unless a more mature study is available, the mini-hydro-based microgrid is not deemed a valid alternative to the study. However, TTA keeps a chapter in the assignment about the mini-hydro alternative to discuss the topic and indicate the limitations.

The 2012 report "Mini-micro hydropower – a solution to sustainable development in the interior of Suriname" highlights three potential sites, Afobasu Sula, Aprisina Sula and Felusie-Mindrihati. However, the two sites Aprisina Sula and Felusie-Mindrihati are not recommended for further elaboration of studies. The report identifies the following information for Afobasu Sula, which is identified as a recommended site to provide electricity in the villages within the project range Nieuw Aurora, Tjalikondë, Gunsi:

Table 14: Potential micro-hydro Afobasu Sula (Source: "Mini-micro hydropower" June 2012)

Afobasu Sula	
Distance to Nieuw Aurora (km)	1.2 km
Villages to be electrified	Nieuw Aurora, Tjalikondë, Gunsi
Head (m)	1.6
Flow (m^3/s)	5
Suggested Turbine	Screw-Type
Number of Units	2
Output per Unit (kW/Unit)	60
Total Budget Estimated in 2012 (USD)	697,188

The report presents the following budget specifications of the micro-hydro potential site Afobasu Sula:

Table 15: Budget specifications of potential micro-hydro Afobasu Sula (Source: "Mini-micro hydropower" June 2012)

Item	Percentage	Total (US$)
Preparations		10,000
Supporting material		15,000
Local material (wood, sand, gravel)		15,000
Materials out of Paramaribo, e.g. Cement, steel and other		15,000
Transportation		15,000
Construction of the powerhouse as a shelter for the generator and the electronic parts		25,000
Complete turbine (two)		100,000
Electrical Component, including the transformer and installation and transmission line		275,000
Training, Monitoring, Evaluation and Supervision		15,000
Sub-total		***485,000***
Local labour	15%	75,750
Sub-total		557,750
Unforeseen	10%	55,775
Profit and risks	15%	83,663
Final total		**697,188**

This potential site can be part of the electrification of the cluster Nieuw Aurora/Tjalikondë/Ladoani. However, the study does not provide a detailed demand assessment. The potential site Afobasu Sula has a low head, which implies that the seasonality has a strong impact on the variation of the potential. The site is therefore kept as an example but the lack of information concerning the head in function of the season does not allow TTA to provide an estimation of the potential energy production at the level that other proposed scenarios will be analyzed. An additional study is to be done on the seasonal variation of the site's head to get a power factor as accurate as possible.

4.1.3. Diesel mini-grids

4.1.3.1. Existing generators with diesel fuel

The information of the existing installed diesel genset capacity is available and presented in the following table:

Table 16: Existing diesel genset capacity installed in the targeted villages (source: EBS)

REF	Name	Installed Diesel Genset (kW)
1	Gingeston	40
2	Pambooko	30
3	Abenaston	68
4	Amakakonde	40
5	Kajapaati	55
6	Jawjaw	68
7	Lespaansie	30
8	Adawai	12
9	Gunsi	30
A	Nieuw Aurora/Tjalikondë/Ladoani	115

Due to the lack of information about the state of the actual diesel generators, those are not considered in the scenario comparison.

4.1.3.2. Diesel Cost

The cost of diesel at the various locations is given in the table below. In Atjoni, the diesel price is 0.82 USD/L and then, the cost is increase depending on the distance of each community to Atjoni to compensate for transportation costs.

Table 17: Diesel cost on-site (source: EBS)

REF	Name	Diesel cost on site (USD/L)
1	Gingeston	0.90
2	Pambooko	0.90
3	Abenaston	0.90
4	Amakakonde	0.90
5	Kajapaati	0.90
6	Jawjaw	0.90
7	Lespaansie	1.05
8	Adawai	1.05
9	Gunsi	1.05
A	Nieuw Aurora/Tjalikondë/Ladoani	1.05

4.1.3.3. Maintenance Costs for diesel generators

Based on the experience of EBS, the maintenance costs for diesel generators are the following:

Table 18: Maintenance costs for diesel generators in Atjoni and Upper Suriname Region

	Approximated cost (USD/kW)	Service Frequency
Regular Service	12.2	In Atjoni, every 300 hours in average
Major Revision	50.81	Every 10,000 Running hours

4.1.4. Grid Extension

The grid extension characteristics considered are the ones from the rural electrification proposal from Pokigron to Nieuw Aurora, of a total of USD 7.25M. The grid extension scenario considers providing service to all clients, connected to 12 kV line. It is to note that, in those scenarios, EBS is looking into the option to expand the line in the future for the other Upper Suriname river villages. Therefore, it is to note that the line will be ready to be increased to 33 kV. The components such as insulators, potential transformers, current transformers will be rated for 33 kV but initially the grid will be operated at 12 kV. Moreover, all villages in the right side of the river will be connected by overhead 12 kV lines through river crossings. EBS plans an additional increase of the existing plant in Atjoni by 250 kWp additional PV capacity.

The distribution line rows for 12 kV distribution lines require 4 meters projected road and 5 meters land clearing on both sides along the projected road. Hence, every meter of distribution line path requires a space of 14 m^2 land clearing. Existing jungle paths connecting the villages can be reused.

4.1.5. Inputs for analysis/simulations

The table of inputs for the analysis and simulations is presented in Annex 11.3. This includes cost on investment and O&M of components under each scenario, their expected lifetime before replacement, as well as the discount rate, the inflation rate, the accepted annual capacity shortage, the level of service and the project lifetime.

All component costs have been based on the information from Atjoni mini-grid, increased by the same factor as of the diesel cost to reflect incremented logistics costs (10% up to Kajapaati and 28% up to Nieuw Aurora). Simulations have been done considering installed costs and taking into account all relevant soft costs such as logistics, detailed design, commissioning, etc.

5. Scenario Simulations

This part presents the preliminary sizing of components of the different electrification scenarios in the area of intervention. The different electrification scenarios have been simulated to get the optimized solution. As aforementioned, in order to make all scenarios and indicators comparable, different assumptions have been taken into account:

- Atjoni/Pokigron mini-grid is considered as an additional mini-grid for the comparison, including its real installed capacities, costs and demand as of the real 2018 performance data. Hence, the CAPEX of all scenarios presented below include the costs of the existing mini-grid in Atjoni/Pokigron
- The total number of connections and demand, including Atjoni/Pokigron, are 1787 connections and 5225 kWh/day respectively.
- Transmission line amongst the villages is done in MV, while the distribution line within each village is done in low voltage (AMKA lines), with all associated costs.
- For the Scenario 3 and 4, PV capacity extensions are located in Atjoni

In all scenarios, the simulator performs a sensitivity analysis for different component sizes and those are optimized in terms of lower LCOE. From the results with the lowest LCOE, the option selected is the one with the highest solar fraction.

5.1. Scenario 1: 100% DIESEL

The scenario 1 is a conventional off-grid electrification based on generation with diesel fuel to cover the total demand, each village with its own source of generation.

Table 19: Simulation results of Scenario 1

Village	Genset (kW)	CAPEX (USD)	LCOE (USD/kWh)	OPEX (USD/year)	Fuel (L/year)	CO_2 emissions (kg/year)
Atjoni	700	43,7778	0.643	278,826	178,710	469,026
Gingeston	51	81,456	0.734	69,765	49,489	129,542
Pambooko	38	58,177	0.736	52,975	37,154	97,256
Abenaston	76	136,823	0.714	103,376	66,042	172,873
Amakakonde	46	69,337	0.737	63,245	44,649	116,875
Kajapaati	140	210,935	0.7	182,553	105,777	276,883
Jawjaw	62	99,970	0.79	95,207	56,276	147,308
Lespaansie	28	43,815	0.839	44,055	27,132	71,022
Adawai	8	13,416	0.841	14,175	8,358	21,879
Gunsi	17	27,018	0.844	27,018	16,678	43,656
Cluster A	220	313,469	0.758	313,062	154,656	404,829
TOTAL	**1,386**	**1,492,94**	**0.720**	**1,244,257**	**744,921**	**1,951,149**

5.2. Scenario 2: PV-HYBRID MINI GRIDS

The scenario 2 consists of electrifying all the communities using an off-grid electrification based on PV-hybrid mini-grids in each community. The optimization results to high solar fraction mini-grids with battery storage and a diesel genset used as a backup in case there is not enough solar generation in low radiation days.

Table 20: Simulation results of Scenario 2

Village	PV (kWp)	Genset (kW)	Converter (kW)	Battery (kWh)	SF	Excess energy	Autonomy (hours)	CAPEX (USD)	LCOE (USD/kWh)	OPEX (USD/year)	Fuel (L/year)	CO_2 emissions (kg/year)
Atjoni	500	700	500	5000	100%	16%	63	2,423,688	0.727	152,647	446	1,170
Gingeston	120	51	51	452	94%	27%	27	416,695	0.594	26,660	3,352	8,775
Pambooko	85	38	38	360	93%	22%	28	306,309	0.588	20,406	2,722	7,125
Abenaston	190	76	76	680	94%	28%	26	630,082	0.582	40,564	4,436	11,612
Amakakonde	100	46	46	428	93%	21%	28	360,336	0.585	24,486	3,391	8,876
Kajapaati	300	140	140	1300	93%	20%	28	1,072,474	0.574	74,016	8,174	21,397
Jawjaw	140	62	62	600	93%	21%	28	560,568	0.645	37,443	4,189	10,965
Lespaansie	60	28	28	268	93%	20%	29	250,587	0.664	16,647	2,025	5,301
Adawai	20	8	8	80	93%	24%	27	90,056	0.704	5,218	616	1,614
Gunsi	40	17	17	152	93%	25%	26	163,059	0.675	10,156	1,208	3,161
Cluster A	480	220	220	2000	93%	21%	27	1,886,092	0.638	129,022	12,043	31,523
TOTAL	**2,035**	**1,386**	**1,186**	**11,320**	**94%**	**22%**	**31**	**8,159,946**	**0.642**	**537,265**	**42,602**	**111,519**

The simulations result to PV-hybrid mini-grids with high solar fraction for all villages, with an average of 94%. Storage also offers an autonomy of more than a day. All PV plants have an excess of more than 20%, which is not generated due to curtailment (when batteries are full or demand is low). This amount of energy can meet a possible increase of demand in the future.

The largest mini-grid is proposed for the cluster of Nieuw Aurora, Tjalikondë and Ladoani (480 kWp), while the smallest mini-grid results for Adawai (20 kWp).

5.3. Scenario 3: GRID EXTENSION

The scenario 3A considers a grid extension from Atjoni/Pokigron to Nieuw Aurora with an additional solar capacity of 250 kWp in the existing PV-hybrid plant in Atjoni/Pokigron, which makes a total of 750 kWp solar.

The scenario 3B considers a grid extension from Atjoni/Pokigron to Nieuw Aurora with an upgrade of the existing PV-hybrid plant in Atjoni/Pokigron.

The demand of all villages is aggregated, including the one of Atjoni/Pokigron. No additional genset is required for those scenarios. The results of the Scenarios 3A and 3B are shown below.

Table 21: Simulation results of Scenario 3A and 3B

Scenario	PV (kWp)	Genset (kW)	Converter (kW)	Battery (kWh)	SF	Excess energy	Autonomy (hours)	CAPEX (USD)	LCOE (USD/kWh)	OPEX (USD/year)	Fuel (L/year)	CO_2 emissions (kg/year)
3A	750	700	500	5,000	47%	0%	16	9,314,884	0.702	555,137	312,758	820,839
3B	1200	700	500	5,000	67%	9%	16	10,017,528	0.690	472,173	192,922	506,329

Scenario 3A simulates the EBS plans to increase the PV generator to 750 kWp, while keeping the battery inverter and storage capacity of Atjoni fixed and extending the transmission line down to Nieuw Aurora. This scenario has a solar fraction of 47% and no excess energy is available. The CAPEX of USD 9.3M includes the costs of the existing plant in Atjoni and all extension costs.

For the Scenario 3B, the simulator optimizes the PV generator for the existing inverter, genset and battery capacity in Atjoni. The optimum capacity is 1,200 kWp, 450 kWp higher than the option proposed in Scenario 3A. This results to a medium solar fraction grid of 67% and a need of less than

200,000 L of diesel per year for the operation of the gensets. Scenarios 3B has a slightly lower LCOE than Scenario 3A (0.690 USD/kWh compared to 0.702 USD/kWh).

5.4. Scenario 4: MIXED

The Scenario 4 is a mixed scenario consisting of a grid extension from Atjoni/Pokigron limited by the planned capacity of 750 kWp and combined with PV-hybrid mini-grids for each of the remaining communities.

The analysis showed that a grid extension from Atjoni's power plant of 750 kWp can cover the demand of the villages with a high solar fraction down to Abenaston, the third village after Atjoni. From Amakakonde downwards, the communities are electrified through autonomous mini-grids (same as Scenario 2).

Table 22: Simulation results of Scenario 4

Village	PV (kWp)	Genset (kW)	Converter (kW)	Battery (kWh)	SF	Excess energy	Autonomy (hours)	CAPEX (USD)	LCOE (USD/kWh)	OPEX (USD/year)	Fuel (L/year)	CO_2 emissions (kg/year)
From Atjoni to Abenaston	750	700	500	5000	94%	9%	37	5,430,304	0.776	189,600	17,585	46,151
Amakakonde	100	46	46	428	93%	21%	28	360,336	0.585	24,486	3,391	8,876
Kajapaati	300	140	140	1,300	93%	20%	28	1,072,474	0.574	74,016	8,174	21,397
Jawjaw	140	62	62	600	93%	21%	28	560,568	0.645	37,443	4,189	10,965
Lespaansie	60	28	28	268	93%	20%	29	250,587	0.664	16,647	2,025	5,301
Adawai	20	8	8	80	93%	24%	27	90,056	0.704	5,218	616	1,614
Gunsi	40	17	17	152	93%	25%	26	163,059	0.675	10,156	1,208	3,161
Cluster A	480	220	220	2000	93%	21%	27	1,886,092	0.638	129,022	12,043	31,523
TOTAL	**1,890**	**1,221**	**1,021**	**9,828**	**93%**		**29**	**9,813,476**	**0.689**	**486,588**	**49,231**	**128,988**

6. Results

This chapter shows the results and the analysis of the information obtained during data collection and the simulations, including quantitative and qualitative criteria discussed beforehand and covering technical, financial, social, environmental and operational aspects.

6.1. Technical Analysis

The technical analysis compares quantitatively the scenarios using indicators such as the solar fraction, risk of non-supply of diesel fuel, electrical transmission line losses. Furthermore, it discusses qualitatively the respective intrinsic safety, transformer losses, continuity of service and the future electrification beyond the intervention area under each scenario.

6.1.1. Quantitative criteria

The following table presents the values of the three criteria for each scenario:

Table 23: Summary table of technical quantitative analysis

CRITERIA	PARAMETER	Scenario 1	Scenario 2	Scenario 3A	Scenario 3B	Scenario 4
Solar fraction	% solar supply	0	94%	47%	67%	93%
Security of fuel supply	L of diesel consumed per year	744,921	42,602	312,758	192,922	49,231
Transmission losses	% Energy Losses / Demand	3.00	3.00	6.08	6.08	3.06

6.1.2. Qualitative Criteria

The qualitative discussion for the technical analysis is based on the intrinsic safety in the different energy infrastructures and the ease to extend the electrification to southern villages in Upper Suriname region.

MV mast-mounted transformer losses

The losses from transformers have a high impact on the necessary energy to follow the demand of the villages. Transformers have two types of losses: load losses and no-load losses. The following table presents the requirements for mast-mounted transformers from 25 to 315 kVA according to the European Commission Ecodesign Directive.

Table 24: Requirements for mast-mounted transformers from 25 to 315 kVA. Source: No. 548/2014 Commission for implementing the Ecodesign Guideline 2009/125/EG

Rated Power (kVA)	Max load losses P_K (W)	Max no-load losses P_0 (W)
25	C_K (900)	A_0 (70)
50	C_K (1,100)	A_0 (90)
100	C_K (1,750)	A_0 (145)
160	C_K + 32% (3,102)	C_0 (300)
200	C_K (2,750)	C_0 (356)
250	C_K (3,250)	C_0 (425)
315	C_K (3,900)	C_0 (520)

Due to lack of information concerning the MV transformers' norms and the rated power of transformers used in Suriname, it is proposed to present an example of losses from transformers in Abenaston to show the impact of using transformers on the energy losses in villages with low demand.

In the EBS study for electrification of the targeted communities, it is considered to put four transformers for the community of Abenaston. In the study, it is considered that the transformers have a rated power of 25 kVA to be able to accept the estimated peak power demand of the village (63.39 kW).

Table 25: MV Transformer losses estimation in Abenaston

	Value
Peak power (W)	63.4
Daily energy demand (kWh/day)	440.9
Number of transformers 25 kVA	4
Total max no-load losses P_0 (W)	280
Daily energy max no-load losses (kWh/day)	6.7
Estimated daily energy load losses (kWh/day)*	2.2
Transformer losses/Daily energy demand	2%

* Considering 25% load losses on the total transformer losses.

The total transformer losses for Abenaston from the assumptions represent 2% of the total energy demand.

<u>Intrinsic Safety</u>

Energy infrastructures can provoke electrocution and fire due to poor operation and maintenance of equipment and/or weather events (such as strong wind and rain). Extreme weather conditions can cause falling of cables and, hence, risk of electrocution. This implies the necessity to design and implement monitoring and maintenance mechanisms, preventive or corrective, to lower the risks. Moreover, awareness campaigns to the communities could prevent theft and contact with live cables.

The criteria used here have been related to the existence of MV lines vs. LV lines and the distances of transmission lines.

Table 26: Intrinsic Safety qualitative analysis results

	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Intrinsic safety	☑☑☑	☑☑☑	☑	☑	☑☑

(where "☑" is a relative favorable score)

<u>Continuity of service</u>

This criterion related to the existence of distributed generation or not; that is, in the case of MV transmission with a centralized generation plant, the service will depend on the quality and status of such line. In the event of an interruption of service (blackout) at some point of the line, all downstream communities will remain unserved. Thus, the resiliency is higher for distributed generation than for centralized generation. The economic value of such resiliency could be assessed by considering the value of economic losses due to blackouts and the expected frequency of blackouts. The highest resiliency is thus allocated to Scenarios 1 and 2 for being based on distributed generation, however, it is higher for the solar-based mini-grids due to the use of an endogenous resource. Then, it has been assigned lower resiliency for Scenario 4, due to its mixed nature, and finally, Scenario 3 because it relies on the MV transmission line.

Table 27: Continuity of service qualitative analysis results

	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Resilience	☑☑	☑☑☑	☑	☑	☑☑

(where "☑" is a relative favorable score)

Extending the service beyond

The comparison study considers only the 12 targeted communities, nonetheless, this study also addresses the potential benefit of taking one path or the other in the process of providing service to communities which lay upstream of the Suriname river, or even, taking the results of this study for other regions of the country. The discussion on advantages and disadvantages of the different scenarios on the potential continuity of service is presented below.

If analyzed from the perspective of proving a valid strategy that can be replicable, some additional questions should be answered about the new target regions:

- Demand: in terms of demand level, are the remaining/other communities similar, higher or lower?
- Ability and willingness to pay: will the differences in ATP (Ability to Pay)/WTP (Willingness to pay) affect in the approach to be taken in the remaining communities?
- Costs: in further communities, costs can be expected to be higher due to increased transportation costs
- Management model: depending on the selected approach, if existent, community organizations can be useful to facilitate the implementation of the management model

Table 28: Extending the service beyond qualitative analysis results

	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Value or Advantage	It has the fastest upfront deployment and lowest fixed land use	The deployment of mini-grids is independent of the progress of works in other communities, although economies of scale would provide benefits A proven and functioning technical, financial and management model could be replicated, and trained O&M staff could be available for a wide service-area covering several communities	If this scenario is selected the marginal extension will be technically more feasible, especially if wires are ready for upgrade	If this scenario is selected the marginal extension will be technically more feasible, especially if wires are ready for upgrade	As a mix of scenarios, compensates lack of one with benefits of other. The maximum available capacity of Atjoni/Pokigron will be used to serve the nearby communities and then the further down communities will be served by microgrids. A similar strategy of building a big plant at a selected upstream community and then extend the line and do microgrids could be applied
Inconvenient	An increasing number of diesel generators would mean an increasing O&M budget for the operators, and an increasing supply of fuel to upstream communities, increasing cargo needs	Depending on the management model established, it implies to operate a number of mini-grids per region (however tools exist to manage such infrastructure)	If a centralized generator is considered, the furthest connections will have to face increasing issues with power quality	If a centralized generator is considered, the further connections will have to face increasing issues with power quality. An alternative would be to split the needed generation into fewer, high capacity PV generators	The decision of where to perform grid extension and where to deploy mini-grids may depend on each case, may not be standardized

Operational challenges

Autonomous mini-grids need more staff for operation and maintenance of the plants but with less technical skills. It will be more complex to manage a number of scattered generation plants rather than one single centralized plant. This is why less “positive” points are allocated to Scenarios 1 and 2. Also, MV lines imply the need of specialized technicians, but also more challenging tasks for construction and O&M of the lines such as road opening and maintenance of the right of way in the forest. This is why less “positive” points are allocated to Scenarios 3 and 4.

Scenario	Scenario 1	Scenario 2	Scenario 3 A	Scenario 3 B	Scenario 4
Scattered generation management	☑	☑	☑☑☑	☑☑☑	☑☑
MV lines management in forest	☑☑☑	☑☑☑	☑	☑	☑☑

Construction duration

Options implying grid extension and transmission line will need a more detailed and demanding environmental and social impact assessment study, although the construction may be fast. Several autonomous mini-grids can be longer to construct (unless construction of the different sites is done in parallel). Installing diesel generators will be fastest option.

Scenario	Scenario 1	Scenario 2	Scenario 3 A	Scenario 3 B	Scenario 4
Implementation duration	☑☑☑	☑☑	☑☑	☑☑	☑☑

6.2. Financial Analysis

This chapter presents the financial analysis of the different scenarios, assessing the CAPEX, OPEX and LCOE costs for the different technologies in the area of intervention. As explained in chapter 2.2, the Atjoni/Pokigron infrastructure has been included in the scenarios in order to account for the expected oversized capacity in the Scenarios 3 and 4. Thus, for a more accurate result of the CAPEX only of the project to service the 12 additional communities, it is here presented as "CAPEX without Atjoni".

The costs result from the simulations and assumptions of each scenario. Those criteria are quantitative and are compared with the calculation method presented in part 2.4.

Table 29: Financial Analysis Results

Indicators	Unit	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
CAPEX total	USD	1,492,194,00	8,159,946,00	9,314,884,00	10,017,528,00	9,813,476,00
CAPEX without Atjoni	USD	1,099,877	5,736,258	6,956,946	7,543,590	7,397,787
OPEX	USD/year	1,244,257,00	537,265,00	555,137,00	472,173,00	486,588,00
LCOE	USD/kWh	0.72	0.63	0.70	0.69	0.689
CAPEX/ Connection	USD/connection	1,034	5,655	6,455	6,942	6,801

The Scenario 1 requires the lower capital expenditures among scenarios. However, it has the highest LCOE (0.72 USD/kWh) due to high operational costs in fuel consumption and maintenance of diesel generators.

The Scenario 2 present the lowest LCOE (0.63 USD/kWh). The specific cost of Scenario 2 is 4,010 USD/kWp (this indicator is not relevant for the other scenarios). Also, it shows lower capital expenditures compared to the scenarios 3A, 3B and 4, due to the absence of the transmission line.

The Scenario 3B has the lowest operational expenditures mainly since the generation plant is located in Atjoni, where the cost of diesel is considered lower (0.82 USD/L) than in the other villages, but also because less diesel is needed comparing to the other grid extension scenario.

The scenario 3A and 3B results to a very similar LCOE (0.69-0.70 USD/kWh). The scenario 3A has a lower CAPEX than 3B and vice versa for OPEX due to the higher solar fraction of scenario 3B.

6.3. Social and Environmental Analysis

This part aims to describe the advantages and disadvantages of the different scenarios in the area of intervention for social and environmental impacts.

Some criteria are quantitative and can directly be used to make the comparison, some others are qualitative and can open the discussion through the decision-makers.

6.3.1. Quantitative Criteria

1. <u>GHG Emissions from the generation of diesel generators</u>

GHG emissions from diesel generators have been calculated based on assumptions and simulations. The table below shows the parameter value for each scenario:

Table: Summary table of the GHG emission criterion parameter values

Scenarios	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
GHG Emissions (kgCO2eq/year)	1,951,149	111,519	820,839	506,329	128,988
Factor x / best	17.50	1.00	7.36	4.54	1.16

2. Land-use

The Scenario 1 needs 10 diesel generator buildings of 15 m^2.

The Scenario 2 needs 10 PV-hybrid technical buildings of 60 m^2 and the necessary land for the 1535 kWp solar plants. Nonetheless, it should be noted that the footprint of PV mini-grids can be even less by introducing the concept of the multiuse building and installing the PV generators on a pergola over the technical building. The pergola concept has several benefits, including providing shade to the technical building an dropping the interior temperature that has direct effects to the performance and lifetime of the batteries. Such a solution can be seen in the following figure, where the shaded space can be used from the community, while the building can host customer care offices or serve other purposes.

Figure 10: Technical building with a pergola (Source: TTA)

The Scenario 3A needs space for adding 250 kWp solar to the existing plant in Atjoni/Pokigron and for Medium Voltage distribution lines.

The Scenario 3B needs space for adding 700 kWp solar to the existing plant in Atjoni/Pokigron and for Medium Voltage distribution lines.

The Scenario 4 needs space for adding 250 kWp solar to the existing plant in Atjoni/Pokigron, for Medium Voltage distribution lines from Atjoni to Gingeston and for PV-hybrid power stations and 1140 kWp solar plants in the villages from Amakakonde to Nieuw Aurora.

Table 30: Summary Table of land-use criterion parameter values

Scenarios	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Number of diesel generator buildings	10				
Number of PV-diesel technical building (<50kW)		6			4
Number of PV-diesel technical building (>50kW)		4	1	1	4
Total PV Capacity to be installed (kWp)		1,535	250	700	1,390
Distance of MV lines (km)			21	21	6.7
Total Land-use (m^2)	150	12,990	296,000	299,600	105,370

Scenarios	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Factor x / lowest	1.0	86.6	1,973.3	1,997.3	702.5
Factor x / Scenario 2	-	1	22.8	23.1	8.1

3. Noise from diesel generators

Table 31: Summary of the parameter values for diesel generation noise

Scenarios	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Number of Diesel Gensets	12	12	2	2	9
Diesel Consumed (L/year)	744,921	42,602	312,758	192,922	49,231

6.3.2. Qualitative Criteria

Land Rights

Land rights are linked to the land use of each Scenario and the implication that the footprint of the generation and distribution and transmission lines. Land rights are country-specific and linked to the regulations but also traditions of the communities. Since no related information has been available, land rights in the area of intervention should be investigated in the following activities by social and legal specialists.

Table 32: Qualitative comparison issues with land rights

Scenario	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Potential issues with land rights	☑☑☑	☑☑☑	☑	☑	☑☑

(where "☑" is a relative favorable score)

Employment opportunities

Consultants do not count with sufficient information in order to assess in detail the differences from case to case, but a general-level assessment can be as follows: from consultants' operational experience with mini-grid projects, autonomous solar mini-grids can employ local members of the communities in order to perform basic, non-specialized O&M tasks that do not require technical knowledge. Such personnel can be caretakers, local operators and guards that can clean the PV modules, add distilled water to the batteries and collect the service fees in case of prepaid meters. Diesel generator maintenance would also need a special local caretaker, but it is not foreseen that local staff will be involved in the maintenance of the MV lines.

Scenario	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Local jobs	☑	☑☑☑	☑☑	☑☑	☑☑☑

(where "☑" is a relative favorable score)

Satisfaction of community with infrastructure

Based on consultants' experience, the microgrid projects which have been successful in the past have had a strong component of community participation. This step is important since early project design phase, for example considering interviews with the locals and potential end-users and community capacity building can result to important benefits for the operation of the mini-grids, such as satisfaction with the service, non-failure of payments and limit theft.

Although the winning alternative is not obvious in this criterion, the applicable (if existent) methodologies of community consultation and best practices should be applied.

Knowledge required for O&M

As aforementioned, it can be expected that participation of local, less trained staff can be applied in the cases of LV microgrids, thus, these scenarios score higher, rather than in the case of MV scenarios.

Scenario	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Ability of locals to participate in O&M	☑☑☑	☑☑☑	☑	☑	☑

Need of Environmental and Social Impact Assessment

This criterion will depend on local guidelines/regulations (such as NIMOS), it is estimated that Scenarios 3 and 4 will require a higher depth and higher complexity assessment. For instance, the path for the right-of-way of MV lines may imply the construction of a road and impact to the way of life of these communities, it remains to be defined with the application of local ESIA guidelines/regulations.

Scenario	Sc. 1	Sc. 2	Sc. 3A	Sc. 3B	Sc. 4
Need of ESIA	☑☑☑	☑☑☑	☑	☑	☑

6.4. Summary of Results

The summary of results is presented in the two following tables. Table 33 presents the normalized scores of each quantitative criterion whereas Table 34 presents the weighted scores. The higher score the better.

Table 33: Results summary of quantitative analysis normalized scores

			Scenario 1	Scenario 2	Scenario 3A	Scenario 3B	Scenario 4
	EVALUATION CRITERIA	UNIT	NORMALIZED SCORE (1 FOR BEST)				
	FINANCIAL						
F1	CAPEX	USD	1.00	0.18	0.16	0.15	0.15
F2	OPEX	USD / year	0.38	0.88	0.85	1.00	0.97
F3	LCOE	USD / kWh	0.88	1	0.90	0.92	0.92
	TECHNICAL						
T1	SOLAR FRACTION	% Solar Supply	0.00	1.00	0.50	0.71	0.99
T2	SECURITY OF FUEL SUPPLY	$L_{Diesel\ Consumed}$ / year	0.06	1.00	0.14	0.22	0.87
T3	TRANSMISSION LINE LOSSES	% Total Demand	1.00	1.00	0.49	0.49	0.98
	ENVIRONMENTAL						
E1	CO2 EMISSIONS GENERATED	$kgCO_2$ / year	0.06	1.00	0.14	0.22	0.86
E2a	NOISE	Nº Gensets	0.17	0.17	1.00	1.00	0.18
E2b		$L_{Diesel\ Consumed}$ / year	0.06	1.00	0.14	0.22	0.87
E3	LAND USE	m^2 land-use	1.00	0.01	0.00	0.00	0.00

Table 34: Results summary of quantitative analysis weighted scores

				Scenario 1	Scenario 2	Scenario 3A	Scenario 3B	Scenario 4
	EVALUATION CRITERIA	UNIT	RELATIVE WEIGHT	WEIGHTED SCORE				
	FINANCIAL		**/5**	**4.02**	**4.06**	**3.72**	**3.91**	**3.88**
F1	CAPEX	USD	1	1.00	0.18	0.16	0.15	0.15
F2	OPEX	USD / year	1	0.38	0.88	0.85	1.00	0.97
F3	LCOE	USD / kWh	3	2.64	3.00	2.71	2.76	2.76
	TECHNICAL		**/4**	**1.09**	**4.00**	**1.45**	**1.90**	**3.77**
T1	SOLAR FRACTION	% Solar Supply	1.5	0.00	1.50	0.75	1.07	1.49
T2	SECURITY OF FUEL SUPPLY	$L_{Diesel\ Consumed}$ / year	1.5	0.09	1.50	0.20	0.33	1.30
T3	TRANSMISSION LINE LOSSES	% Total Demand	1	1.00	1.00	0.49	0.49	0.98
	ENVIRONMENTAL		**/1**	**0.53**	**0.46**	**0.11**	**0.15**	**0.40**
E1	CO2 EMISSIONS GENERATED	$kgCO_2$ / year	0.4	0.02	0.40	0.05	0.09	0.35
E2a	NOISE	Nº Gensets	0.05	0.01	0.01	0.05	0.05	0.01
E2b		$L_{Diesel\ Consumed}$ / year	0.05	0.00	0.05	0.01	0.01	0.04
E3	LANDUSE	m^2 land-use	0.5	0.50	0.01	0.00	0.00	0.00
	TOTAL		**/10**	**5.64**	**8.53**	**5.28**	**5.95**	**8.05**

As an overall comment on scenarios, the following take-outs can be highlighted:

Table 35: Summary of results

Scenario	Scenario 1	Scenario 2	Scenario 3 A	Scenario 3 B	Scenario 4
Technical	Highest diesel use Fastest upfront deployment Being isolated LV mini-grids, grade high in intrinsic safety, are resilient but very dependent on diesel supply	Very low diesel use Being isolated LV mini-grids, grade high in intrinsic safety, are the most resilient If a valid mini-grid model is proven it can be deployed elsewhere if certain conditions are met, without depending on grid extension	Intermediate diesel use Highest transmission losses Line failure affects downstream villages Further down villages will need to wait for grid extension End-of-line voltage/frequency issues may arise	Very low diesel use Highest transmission losses Line failure affects downstream villages Further down villages will need to wait for grid extension End-of-line voltage/frequency issues may be solved with distributed PV generation	Low diesel use Line failure affects downstream villages Expanding the grid from “central” towns combined with mini-grids would be the most flexible approach Does not show high excess energy available in Atjoni
Financial	Lowest CAPEX Highest OPEX and LCOE	CAPEX comparable to Sc 2-4, Lowest LCOE	CAPEX comparable to Sc 2-4, Intermediate LCOE	CAPEX comparable to Sc 2-4, Intermediate LCOE	CAPEX comparable to Sc 2-4, Lowest LCOE
Social and Environmental	Highest GHG emissions Lowest land use Lowest potential land rights issues Low complexity/knowledge required for O&M. Higher complexity of managing scattered generators	Lowest GHG emission Low land use Lowest potential land rights issues Low complexity/knowledge required for O&M. Higher complexity of managing scattered generators	High GHG Highest land use Highest potential land rights issues, social impact due to road between communities Higher complexity of O&M tasks Need of complex ESIA	Intermediate GHG Highest land use Highest potential land rights issues, , social impact due to road between communities Higher complexity of O&M tasks Need of complex ESIA	Intermediate GHG High land use High potential land rights issues, , social impact due to road between communities High complexity of O&M tasks Need of complex ESIA

This first graph shows the results, visually, for all the quantitative criteria.

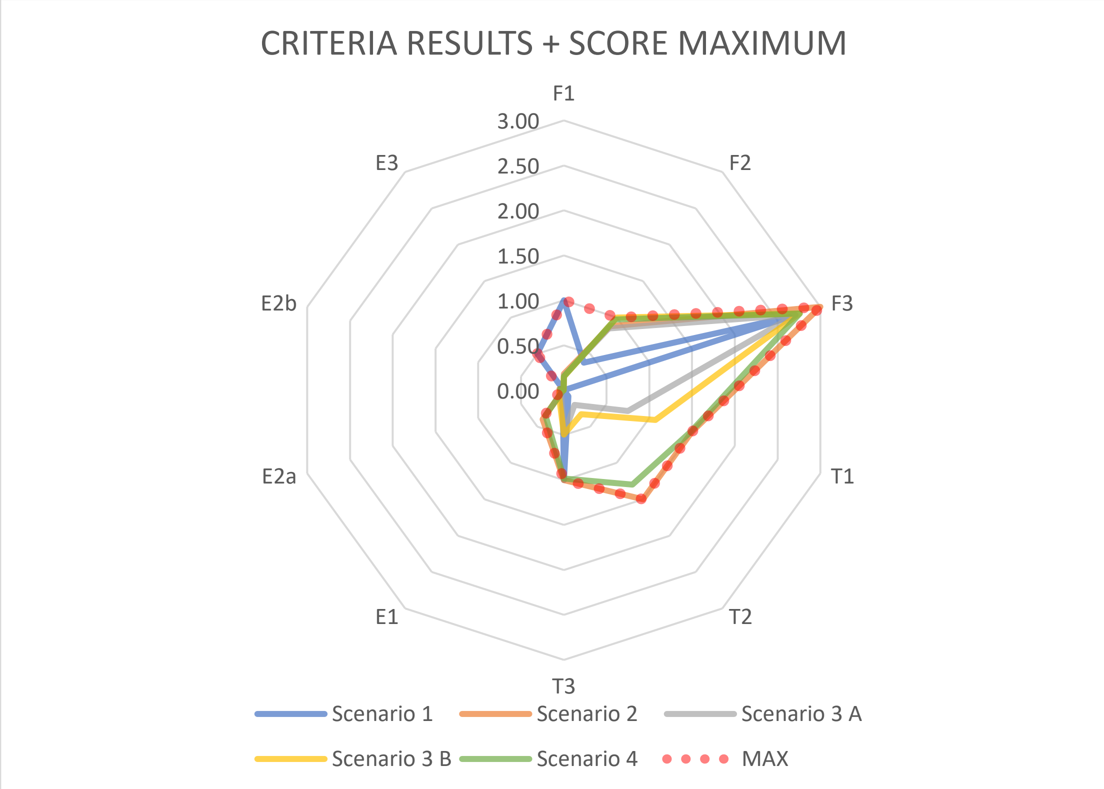


Figure 11: Detailed spider weighted comparison graph for all scenarios

This other graph shows the results, as a summary of the 3 groups of criteria (Financial, Technical and Environmental).

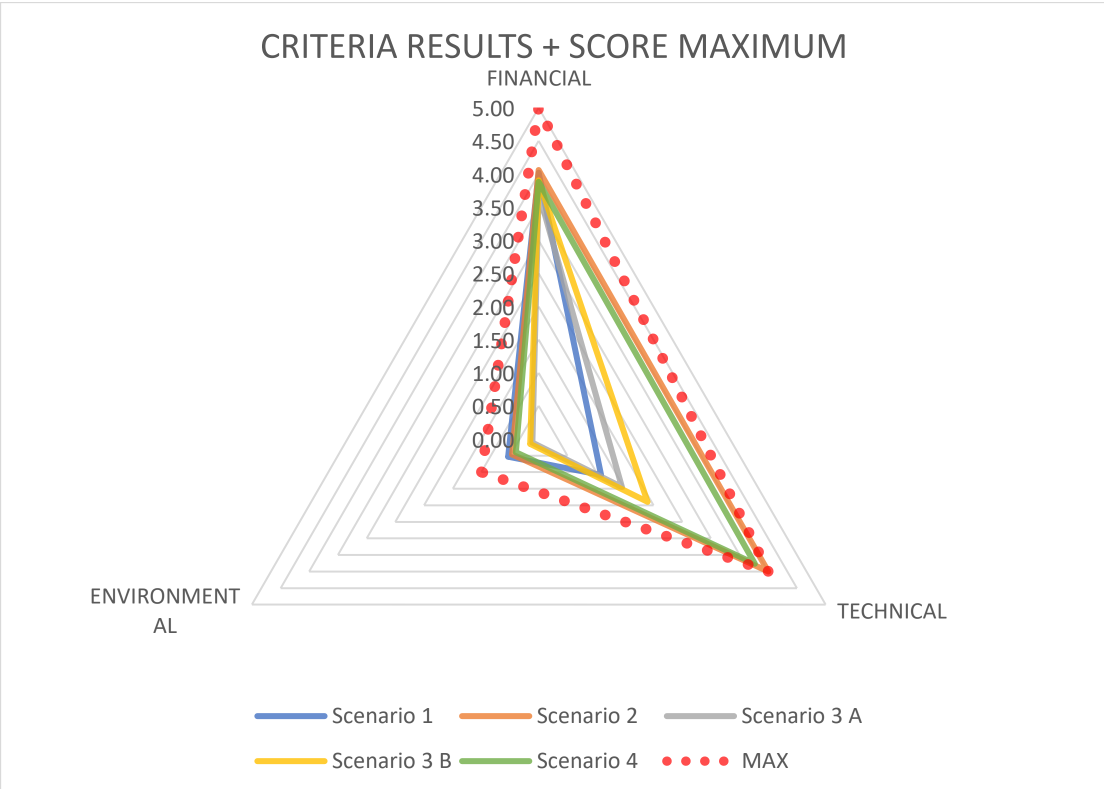


Figure 12: Summarized weighted comparison graph for all scenarios

7. A Step Forward to 100% Solar Mini-grids

Additionally to the scenarios for rural electrification analyzed and presented in the previous chapters, the Consultants have simulated a 100% solar scenario: autonomous solar mini-grids for each village without any diesel backup. The results of this analysis are compared to the ones obtained for Scenario 2, where in average, the solar fraction of the villages under the study resulted to 93%.

In conventional systems offering uninterruptible supply, not having a backup source of electricity based on fossil fuels may subsequently result to oversizing the plant components, in order to supply the loads during instances of continuous low radiation and night hours. Off-grid electrification, based completely on renewable energy sources, require managing the end-user demand, also known as demand side management. This can be automatized through intelligent metering technologies or can be realized by offering capacity building to the end-users towards a rational and efficient use of energy.

In order to simulate the all-solar scenario without oversizing the mini-plant components, it has been allowed a 5% of capacity shortage on the demand estimated for each village and used in the previous simulations. This 5% of shortage is not electricity that the mini-grid fails to supply; instead, it is an amount of energy managed, manually or automatically, in order not to be demanded during times not favorable for solar generation. For instance, this amount of energy can be either shifted in time and used during daytime instead of night hours (deferrable or interruptible loads), or not demanded through energy efficiency measures.

The simulation results are presented below and compared with the results obtained for Scenario 2.

Village	Scenario 2 (Without Atjoni)						100% solar Scenario (Without Atjoni)					
	PV (kWp)	Battery (kWh)	Autonomy (hours)	CAPEX (USD)	LCOE (USD/kWh)	OPEX (USD/year)	PV (kWp)	Battery (kWh)	Autonomy (hours)	CAPEX (USD)	LCOE (USD/kWh)	OPEX (USD/year)
Gingeston	120	452	27	416,695	0.594	26,660	120	580	34	418,789	0.590	23,595
Pambooko	85	360	28	306,309	0.588	20,406	90	444	35	325,050	0.605	18,330
Abenaston	190	680	26	630,082	0.582	40,564	180	932	36	628,010	0.576	36,165
Amakakonde	100	428	28	360,336	0.585	24,486	100	592	39	370,785	0.585	21,407
Kajapaati	300	1300	28	1,072,474	0.574	74,016	300	1864	40	1,115,714	0.58	65,332
Jawjaw	140	600	28	560,568	0.645	37,443	150	732	34	576,643	0.643	32,461
Lespaansie	60	268	29	250,587	0.664	16,647	60	368	40	258,024	0.661	14,368
Adawai	20	80	27	90,056	0.704	5,218	22	96	32	93,053	0.703	4,467
Gunsi	40	152	26	163,059	0.675	10,156	40	200	35	164,965	0.666	8,743
Cluster A	480	2000	27	1,886,092	0.638	129,022	500	2648	36	1,952,183	0.639	112,648
TOTAL	**1,535**	**6,320**	**27**	**5,736,258**	**0.613**	**384,850**	**1,562**	**8.456**	**36**	**5,903,216**	**0.614**	**337,516**

Comparing the results of the two scenarios, it can be concluded that opting for an all-solar solution would result in the need of a slightly higher CAPEX of 3%, due to the need of additional storage to offer additional autonomy to the mini-grids (in average, 36 hours instead of 27). However, in the 100% solar Scenario, OPEX is approximately 14% lower than Scenario 2 due to the lack of diesel consumption. The average LCOE remains, in practical terms, the same.

Nonetheless, the 100% solar scenario has other technical, economic, social and environmental advantages, direct and indirect, compared to Scenario 2:

- The absence of diesel generators results to zero CO_2 emissions and noise
- Lower operational needs
- Elimination of the need for fuel, and also elimination of the associated logistics costs and dependency
- Furthermore, in the case of a particular event or of an unforeseen increase of the demand, a diesel- or other fuel generator can be added to the generation plant.

8. Management challenges and recommendations

8.1. Management Models for micro-grids

Management models and service fee schemes/values are a crucial part in the success of rural electrification projects, together with other success factors. Hence, some of the challenges and adopted solutions are hereby presented (in other case-studies, in other countries), to be considered by decision makers and to be addressed in detail in the following steps.

The Consultants have experience in projects related to the development of operators of rural, off-grid energy services (for example, DOSBE project Development of electrical operators for the poverty reduction in Ecuador and Peru). The following recommendations and comments are not necessarily directly applicable in Suriname, as a regulatory and legal framework assessment has not been performed, however, these may be important.

There is no standard, internationally agreed optimum management model for rural electrification and its selection depends on multiple factors. The consumer´s ability and willingness to pay and the type of consumers, the traditional and administrative structure of the community, the experience in other similar collective projects, the local technical capacity, the investor returns expectations of the project (if applicable) and the available funds are amongst the factors that will determine the optimum model in each case. In the case of Upper Suriname, without a doubt, the lessons learned from the experience in Atjoni/Pokigron solar PV plant and EBS' experience must be considered.

Thus, the Consultants hereby want to introduce different possibilities, Consultants are aware of the limitations that the existing management structures may impose, however, these can feed ongoing discussions and a more detailed proposal.

8.2. Review of available management models

As explained, these are related to other parameters such as the project financing and the type of service fees applied. The decision process and four main management model alternatives are illustrated in Figure 13 (see "Operator Models").

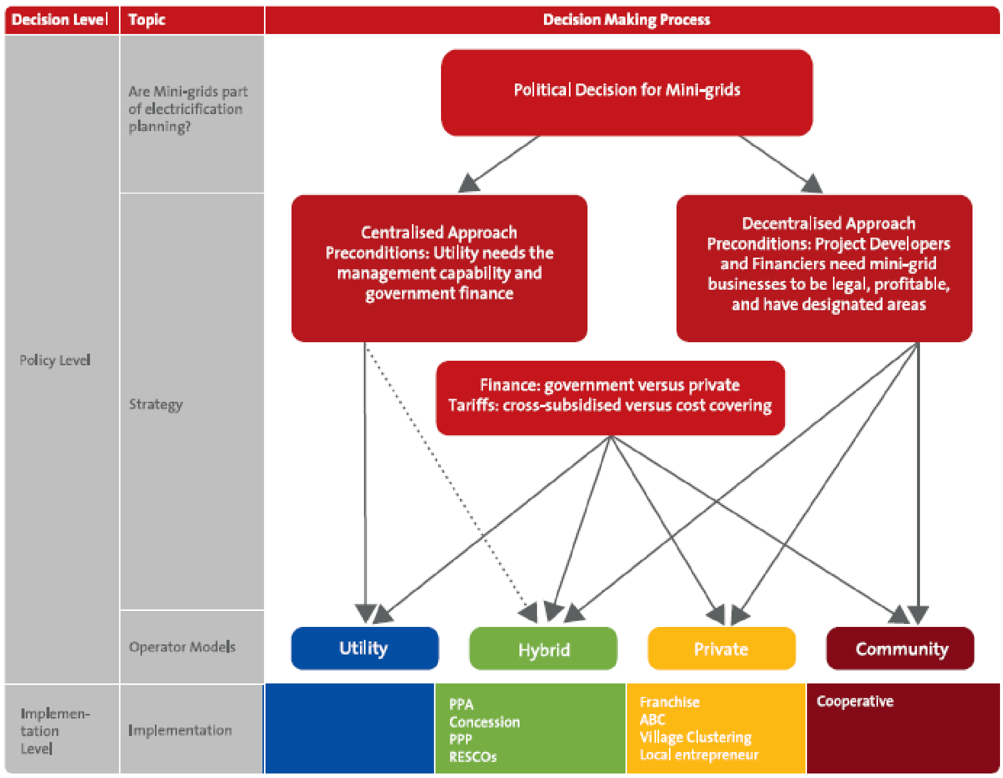


Figure 13: Decision tree for mini-grids (source: EUEI/RECP 2014)

The four basic options present different outcomes regarding government control and speed of delivery, as shown in Figure 14. The utility model (when public utilities) has the highest government control while the private model is faster in terms of mini-grid deployment. Each option is discussed further in the remainder of this section.

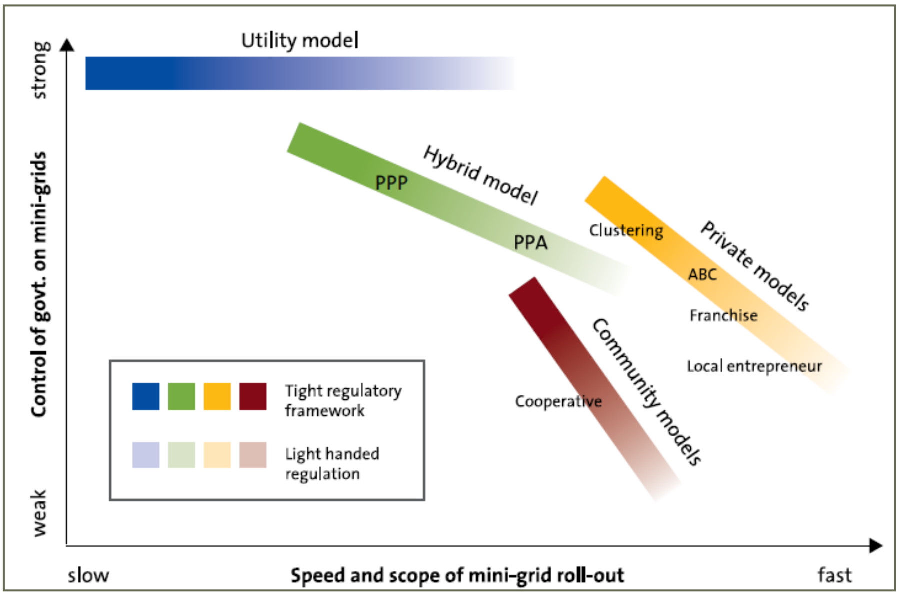


Figure 14: Model comparison (source: EUEI/RECP 2014)

8.2.1. Public (Utility) model

Under the public/utility model, the utility is the owner and operator of the mini-grid generation and distribution. The utility also finances the plant typically with public funds. Service fees for public models are generally lower than cost-recovery ones based on the levelized cost of energy (LCOE). Therefore, to ensure the utility can cover its cost of capital, it must either cross-subsidize the costs from other customers (i.e. national grid customers) or seek an external subsidy.

On the positive side of such a model is that utilities are experienced in operating distribution grids, have access to financial resources and usually have local technical capacity (although such technicians have to be deployed in remote areas). The drawback of the public model is that cross-subsidies are not a sustainable strategy, resulting in poor maintenance and lack of funds for component replacement (such as batteries). Some international experiences in some African countries provide examples of this problem (Kenya Power in Kenya for instance).

8.2.2. Private model

In this model, a private developer invests in, constructs, owns and operates mini-grids (in other words BOO model – build, own, operate). Since such projects are capital intensive, the funds might be equity, loan and/or grants. If regulation allows and customers agree, service fees are cost-reflective allowing investors to obtain reasonable return on their investments.

There are a number of strategies that private mini-grid operators have pursued in order to make this business model more attractive. For example, when selecting mini-grid sites, developers often prefer those with at least one larger customer (known as “anchor” customer), providing them with some more certain revenues. This is often known as ABC model, where operators prioritize Anchor customers, then Businesses, then Communities. In addition to this strategy, clustering mini-grid sites (that is, operating more than one mini-grid in a given service area) allows for more efficient O&M and provides economies of scale, which is crucial to obtain an attractive cash flow for investors.

In general terms, the private models can deliver a profitable investment for a private entity, especially if the upfront capital costs are partially subsidized. However, the success of such a model requires the customers to be able and willing to pay the service fees and consume enough electricity for the cash flow to turn positive. In addition, even if the model is fully private, there are also significant policy and regulatory risks to be considered. For example, if government decides to extend the national grid up to such mini-grid locations, or in other cases nationalize the concessions that were given to private companies (as the case of Mali).

8.2.3. Community model

In this model, community members (usually organized under the legal entity of a cooperative) manage the decentralized system and are also responsible for the collection of the service fees and the operation and maintenance. The community-based or cooperative model essentially operates the same way as the private model, with cost-reflective fees, but some adjustments to the cost inputs.

This scheme presents various advantages. The most important one is that the owners are also the consumers, so the smooth operation and management of the system is of their direct interest. Also, the absence of any private investor and any obligation to generate additional profits minimizes the service fees paid by the consumers. In this case the fees are set in such a way as to cover running costs, pay back any existing loan and create a reserve for future expenses, such as the replacement of batteries or inverters after the end of their lifetime.

However, in a community-based model where the cooperative (or other community form) maintains the infrastructure plant, issues can arise in case of technical problems due to lack of skills within the community, which is often the case. In order to avoid such matters, it is important to give emphasis on the capacity building of the village, which can be time and resource consuming, something which can be done by an external (public or private) contractor. Besides technical aspects, capacity building should also focus on the social and economic aspects of the mini-grid.

8.2.4. Public-private partnership (PPP) model

PPPs are considered as the most flexible and better suited model for large mini-grids. Under a PPP model, there are different stakeholders financing, building and operating the assets.

In mini-grid projects, the public entity (Government, Ministry of Energy, Rural Electrification Agency or similar) typically retains the ownership of the distribution grid, and in some cases might also own the generation assets. Typically, the public entity may lease or give a concession to a private actor to ensure the management and operation of the mini-grid and collects revenues, taking a number of commercial risks through this process. Sometimes private operators might also be involved since the construction phase, either solely as contractors or also as investors, recovering these funds through mini-grid operation later on.

The following table displays three common schemes, where the role of public and private actors differs.

Table 36: Various PPP models (source: Inensus, modified by Author)

	Type A	Type B	Type C
Public entity	Procures, owns and installs generation and distribution assets. Commercializes electricity to the end-users.	Procures and owns generation and distribution assets	Procures and owns distribution assets
Private entity	O&M under a Power Purchase Agreement	Installation, O&M and commercialization of electricity to end users	Invests in, installs, operates and maintains generation assets, sells electricity to end customers
End users service fee	Usually national uniform fee	Usually cost-reflective	Cost-reflective

Starting from left to right, Type A is the scheme with the highest degree of public involvement, with the private entity only ensuring technical O&M and getting paid a fixed price for the electricity generated. In this case, the commercial and demand risk, as well as any differences between the power purchase agreement (PPA) price and the end user fee are borne by the public actor.

In type B model, the private actor gets additional responsibilities as the commercial operation (end-user sales, customer management, technical losses, etc.) is part of its role. This entails higher commercial risks but also provides an incentive to perform efficiently and be able to generate profits out of the mini-grid operation.

Finally, in Type C model, the private party develops the generation assets with private funds, alleviating the financial burden for the public entity. In this model, it is particularly important that the service fee is cost-reflective, taking into account that it must recover not only O&M costs but also the initial investment made by the private entity.

8.3. Setting of the service fee

As mentioned throughout the previous chapter, service fees are another critical aspect as they influence:

- The affordability of the service: depending on the rules of connection and fees per connection, ATP (Ability to Pay)/WTP (Willingness to pay)
- The efficient use of the services: lower fees are not an incentive for smart and efficient use of electricity
- The financial sustainability of the project: the lower the fees, the more subsidies will be needed

Thus, it is crucial to consider the alternative service fee schemes and values applicable when making decisions about intervention strategies.

The decision on the most appropriate service fee scheme and value depends on several aspects and is not within the scope of this work, however, the following table introduces some of the possibilities.

Table 37: Comparative table of the different analyzed tariff schemes

	Flat fee	Power-based fee	Credit energy- based fee	Pre-paid energy- based fee	Service-based fee
How it works	The users pay a fix amount, normally per month, independently of the amount of energy they consume.	The fee is established according to the maximum power (current) available to the users and monthly payment is made on the basis of this power level. The power available to the consumer is predetermined based on existing or desired appliances and the regularity of their use: in such a way an indirect and approximate estimation of the consumed energy is done	The users pay the units of electricity they have consumed based on a bill they receive after an operator has read the meter and delivered a bill.	The users purchase units of electricity in advance from the operator and insert the card or token into the meter or enter the number through a pushbutton pad incorporated on the unit: this credits the user meter with the number of units purchased and when they run out of units their supply shuts down.	The users subscribe periodically, normally monthly, from the operator, days of electricity service with a number of daily units, described as the user's Energy Daily Allowance (EDA) and a maximum power limit. "Dispenser" is the equipment (meter) that implements such EDA concept into users' premises
Operator Management System	Simplified management system/ reduced cost: no need to read the meters, complete the accounting, produce and deliver the bills, but the operator must collect the revenue in each billing period	Simplified management system/ reduced cost: no need to read the meters, complete the accounting, produce and deliver the bills, but the operator must collect the revenue in each billing period	Complex management system/ increased cost: need to read the meters, complete the accounting, produce and deliver the bills and collect the revenue in each billing period	Simplified management system/ reduced cost: no need to read the meters, complete the accounting, produce and deliver the bills and collect the revenue in each billing period An organization for local sales of the pre-paid electricity is needed	Simplified management system/ reduced cost: no need to read the meters, complete the accounting, produce and deliver the bills and collect the revenue in each billing period An organization for local sales of the pre-paid electricity is needed
Overdue payments, disconnection and reconnection process and fees	Overdue payments can happen and be a burden for the management, O&M costs If any user does not pay his/ her bill, he or she will have to be disconnected and then reconnected if and when cash is again available.	Overdue payments can happen and be a burden for the management, O&M costs If any user does not pay his/ her bill, he or she will have to be disconnected and then reconnected if and when cash is again available. Promoter and the user have to bear the cost of these activities	Overdue payments can happen and be a burden for the management, O&M costs If any user does not pay his/ her bill, he or she will have to be disconnected and then reconnected if and when cash is again available. Promoter and the user have to bear the cost of these activities	Overdue payments are avoided Neither the user nor the operator has to bear any disconnection and reconnection cost The automatic disconnection of the user can avoid bad feelings that may arise if the operator disconnects the user	Overdue payments are avoided Neither the user nor the operator has to bear any disconnection and reconnection cost The automatic disconnection of the user can avoid bad feelings that may arise if the operator disconnects the user

	Flat fee	Power-based fee	Credit energy- based fee	Pre-paid energy- based fee	Service-based fee
	Promoter and the user have to bear the cost of these activities Apart from the cost, on a community based management system bad feelings and misunderstandings can arise posing a serious threat to the project sustainability	Apart from the cost, on a community based management system bad feelings and misunderstandings can arise posing a serious threat to the project sustainability	Apart from the cost, on a community based management system bad feelings and misunderstandings can arise posing a serious threat to the project sustainability		
Financial planning from Promoter's point of view	Clear and easy financial planning as far as it is based on periodical fixed incomes. If additionally there is a commitment to purchase each month the service for the users then the operator financial planning is even easier	Clear and easy financial planning as far as it is based on periodical fixed incomes. If additionally there is a commitment to purchase each month the service for the users then the operator financial planning is even easier	Challenging financial planning for the mini-grid operator as far as each consumer is free to consume or not the electricity A double-tier fee with a fixed and a variable part could mitigate this risk although not enough to overcome the challenge	Challenging financial planning for the operator as far as each consumer is free to purchase or not the electricity at any moment A double-tier fee with a fixed and a variable part could mitigate this risk Nevertheless it would oblige the operator to complicate its management system, increasing the costs to be covered by the fee and negatively affecting the simplicity of the management system	Clear and easy as far as it is based on periodical pre-paid incomes in the framework of a commitment built on a contract for each user
Users friendly	The users know in advance how much they are going to pay This fee scheme has the challenge that the users might not be able to pay always the bills due to the difficulties from local families to make monthly payments even for smaller and regular/fixed amounts	The users know in advance how much they are going to pay This fee scheme has the challenge that the users might not be able to pay always the bills due to the difficulties from local families to make monthly payments even for smaller and regular/fixed amounts It is possible to mitigate this challenge by establishing	Difficult financial planning for the users: possible high illiteracy rate, some users, may have difficulty understanding how to read the meter and, therefore, the charge they are required to pay. This can result in unexpectedly high bills that are beyond their means to pay	It offers low-income users the ability to more closely manage their consumption and make smaller, more regular payments that are often better matched to their cash flow, in a similar way they purchase other energy supplies, such as kerosene, candles, batteries, or wood	The users know in advance how much they are going to pay This fee scheme has the challenge that the users have to commit to periodically purchase the electricity service and this is challenging due to the difficulties from local families to make monthly payments even for smaller and regular/fixed amounts

	Flat fee	Power-based fee	Credit energy- based fee	Pre-paid energy- based fee	Service-based fee
	It is possible to mitigate this challenge by establishing shorter payment timeframes based on local conditions and offering the users the facility to pay in advance the electricity services for several months when they have cash availability	shorter payment timeframes based on local conditions and offering the users the facility to pay in advance the electricity services for several months when they have cash availability	In some cases it can lead to exploitation by fraudulent meter readers. The misunderstanding created by these situations can create tensions in the community and pose a serious threat to the project sustainability To overcome these challenges customers need some training on how to use meters.	The burden is on the user to go to the operator office to purchase electricity The meter has normally a user-friendly interface and displays the available units The relation between expense and appliance usage is straightforward and can facilitate energy conservation In any case customers need some training on how to use meters.	It is possible to mitigate this challenge by establishing shorter payment timeframes based on local conditions and offering the users the facility to pay in advance the electricity services for several months when they have cash availability The burden is on the user to go to the operator office to purchase electricity The smart meter must have a user-friendly interface and displays the units available The relation between expense and appliance usage is straightforward and can facilitate energy conservation In any case customers need some training on how to use meters.
User overload prevention	Normally the load demand is limited by installing current limiters, while in other projects only verbal agreements without technical intervention is used Nevertheless the latter approach is typically ineffective at restricting load.	Normally the load demand is limited by installing current limiters, while in other projects only verbal agreements without technical intervention is used Nevertheless the latter approach is typically ineffective at restricting load.	The meters are normally equipped with electrical current limiters or electronic circuit breakers to limit the amount of power that can be drawn.	The meters are normally equipped with electrical current limiters or electronic circuit breakers to limit the amount of power that can be drawn.	The dispenser has a built in main circuit breaker including a maximum current overload protection
User electricity consumption limitation	The risk of “free-riding” associated to electricity misusing and over-consumption is very high as far as no incentives for energy efficiency and the	The risk of “free-riding” associated to electricity misusing and over-consumption is very high as far as no incentives for energy efficiency and the	There are no restrictions on the amount of energy a customer can consume The risk is the over-consumption mitigated by	There are no restrictions on the amount of energy a customer can consume The risk is the over-consumption mitigated by	• The dispenser is designed specifically to limit the user electricity consumption to the contracted energy daily allowance

	Flat fee	Power-based fee	Credit energy- based fee	Pre-paid energy- based fee	Service-based fee
	rational use of electricity exist.	rational use of electricity exist.	the fact the users pay for the electricity they consume. In this case the over-consumption could probably be less continuous than for flat rate and power-based fees and related instead with special events	the fact the users pay for the electricity they consume. In this case the over-consumption could probably be less continuous than for flat rate and power-based fees and related instead with special events	
Type of device to enforce and facilitate the application of the fee scheme	Sometimes there is not any device Normally current limiters are installed	Sometimes there is not any device Normally electrical current limiters i.e. fuses, miniature circuit breakers, positive temperature coefficient thermistors or electronic circuit breakers are installed	Credit meter	Pre-paid meter	• Electricity dispenser
Facility to operate	Normally when the current limiters disconnect the users due to power over-demand a technician has to go to the connection point and reconnect the user	Normally when the current limiters disconnect the users due to power over-demand a technician has to go to the connection point and reconnect the user	Some users, may have difficulty understanding how to read the meter and, therefore, the charge they are required to pay No O&M is required	The meter has normally a user-friendly interface and displays the available units No O&M is required	The dispenser has normally a user-friendly interface and displays the available units No O&M is required

9. Discussion of results

This document provides information, results and criteria to base the discussion of the most adequate strategy to provide sustainable electricity services to the communities living in the Upper Suriname region. With more detailed studies a higher level of accuracy can be achieved, however, the study scope is appropriate for such an early planning stage. This document provides technical and financial results of different scenarios, with the limitations that a desk study has, and also assesses quantitatively and qualitatively other environmental and social criteria, probably important in Suriname.

The decision of an electrification project does not depend on a single criterion since the stakeholders are several and varied, and the implications are in the technical, financial, social and environmental areas. It also depends on other political and legal aspects which are beyond the reach of this consultancy.

Some comments can be highlighted to feed the discussion. The summarized spider chart is brought again for discussion:

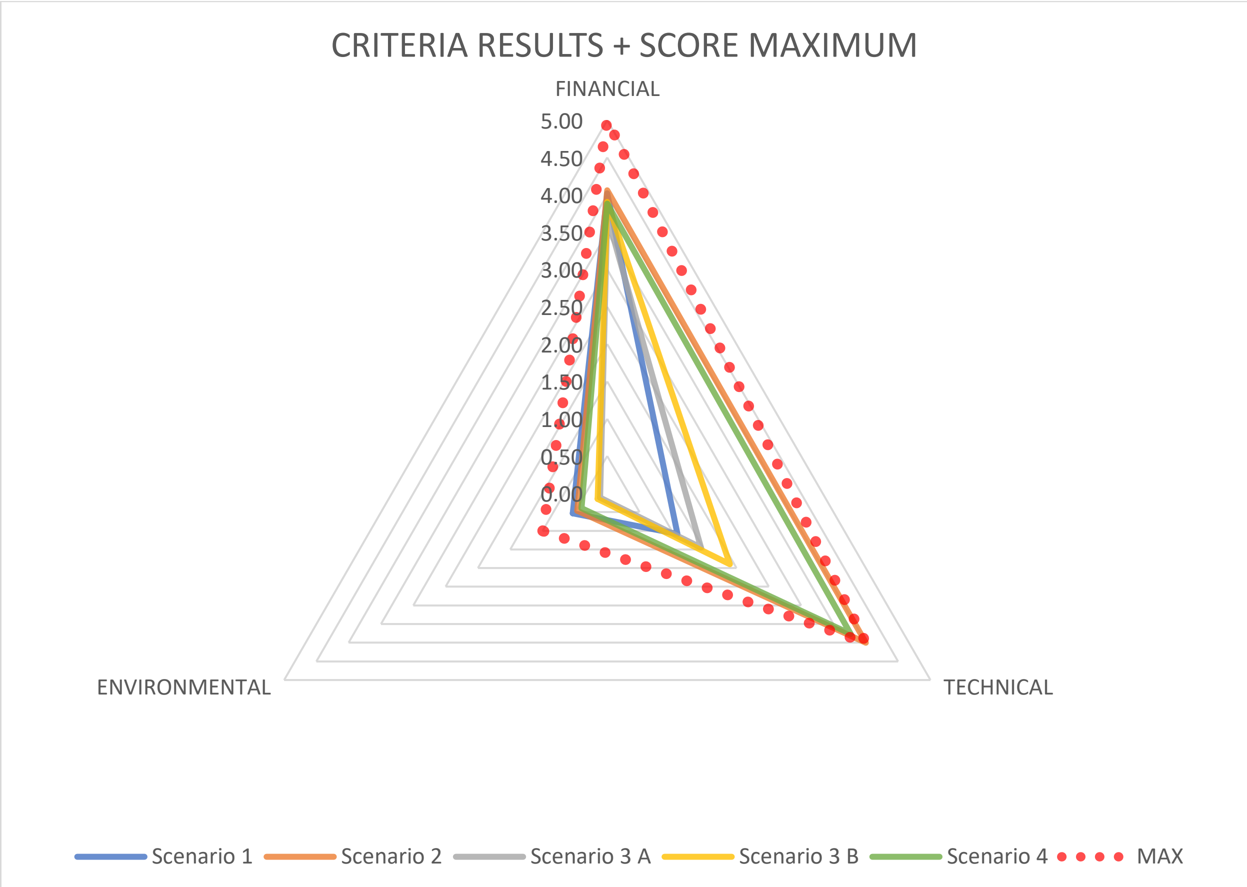


Figure 15: Summarized spider weighted comparison graph for all scenarios

Furthermore, an additional all-solar scenario has been defined and simulated, but has not been included in the multi-criteria analysis. This scenario shows that it is feasible to supply the demand of the villages purely with solar power, by applying demand side management measures and increasing the storage capacity of the mini-grids. An all-solar scenario has other direct and indirect benefits resulting from the elimination of diesel generators and dependency on fossil fuel, besides having lower costs:

- The absence of diesel generators results to zero CO2 emissions and noise
- Lower operational needs
- Elimination of the need for fuel, and also elimination of the associated logistics costs and dependency

As a conclusion, from the quantitative point of view, based on the methodology presented and the relative weight allocated to financial, technical and social/environmental criteria, Scenario 2 is recommended. The qualitative criteria also support this recommendation. Beyond this, a 100% solar scenario can also be considered.

Other conclusions drafted from this study include:

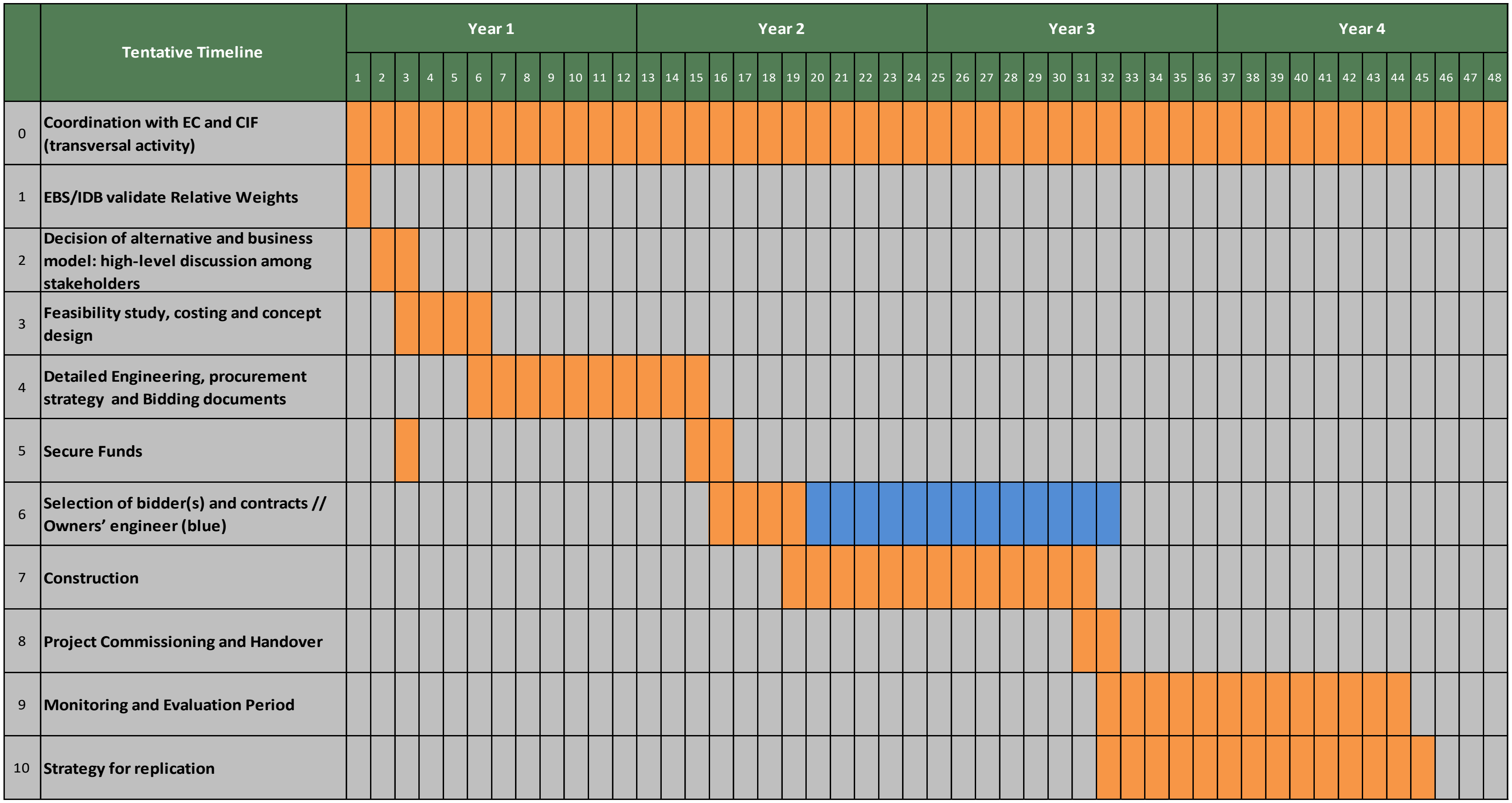
- Demand requirements in the target communities are largely unknown and estimates based on Atjoni/Pokigron demand data have been used, corrected by EBS/IDB's knowledge of the region. Demand assessment, besides being a critical step in delivering successful projects, is also a methodological tool to involve the final users of such a remote service, within the project. This has implications in the way capacity building, user buy-in and other considerations are given. Although possible deviations between foreseen demand and actual demand can be corrected using metering and control equipment, experience shows that consultation with communities is a necessary step.
- The scenarios with high "solar fraction", Scenario 2 and Scenario 4 rate high in technical aspects due to the low dependence on diesel. Besides, this implies a low LCOE as a result of the combination between CAPEX and OPEX. In comparing with other grid-extension scenarios, Scenario 3B has higher LCOE and 22 times higher land use than Scenario 2. Under Scenario 2, the mini-grid footprint can be decreased even more by introducing the concept of a multi-use building and installing the PV generator on a *pergola*, providing shade to the technical house and creating a shaded are for the community.
- Overall, in the spider chart, the "broadest area" covered is by the Scenario 2. It must be recalled that this graph does not include the qualitative criteria.
- The grid extension scenarios 3A and 3B have higher CAPEX and LCOE than Scenario 2 given the cost of grid extension and its operation. Scenario 4 would combine the advantages of single mini-grids with the extension of the Atjoni grid towards 3 more villages.
- It must be noted that grid extension and use of transformers adds losses to the system, which should be considered as "additional demand", thus increasing the size and capacity of infrastructure. From a PV-based perspective, any additional demand, especially losses, are to be avoided. This study has not calculated detailed losses and thus this qualitatively hampers grid extension scenarios.
- GHG emissions are also related to diesel use, thus, high solar-fraction scenarios score high (Scenarios 2 and 4 score better than Scenario 3B). Scenario 2 has the lowest GHG from operation, followed by Scenario 4, Scenarios 3B and 3A have approximately five times and seven times GHG.
- Land use has only been considered from the permanent infrastructure such as PV plants, technical buildings, right-of-way of grid extension. Thus, the diesel scenario tops this rank. Then, the solar PV mini-grids scenario has approximately 20 times lower land-use than the grid extension scenarios 3A and 3B. As said, the mini-grid PV plants could be integrated into infrastructure/buildings, such as a shade-providing pergola, reducing the value-less land use.
- A couple of comments related to the above, and linked with the implementation of the projects, are those regarding the management model and the service fees. In both cases, the final decision may eventually depend on a political decision, however, strong arguments can be given for some management model recommendations, schemes of service fees and value recommendations: these have strong implications in the sustained service in remote areas. In the case of off-grid, isolated PV-based mini-grids, the management model should include a certain level of locals' participation in O&M; besides, fees must be affordable but not low enough to provoke inefficient use of electricity. Energy Efficiency must be at the forefront of remote electricity service deployment and should be part of the business model of the operating entity.

10. Steps forward

The consultants suggest that the following steps be followed towards the implementation.

0. Coordination with European Commission and CIF (transversal activity)
1. EBS/IDB validate Relative Weights
2. Decision of alternative and business model: high-level discussion among stakeholders
3. Feasibility study, costing and concept design: Development of TOR for the Detailed Electrification Study consultancy. This feasibility study will include a detailed demand study with site visits and concept design of the solution. Also, it will include a grid study for the PV interconnection locations and potential grid issues, a detailed design, environmental and impact assessment according to local regulations, detailed costing and cost-reflective fee calculation. Furthermore, it will recommend the procurement strategy and prepare the bidding documents for tendering.
4. Detailed Engineering, procurement strategy and Bidding documents (can be the same contract)
5. Secure Funds: will be a transversal activity for both the consultancies and the construction
6. Selection of bidder(s) and contracts // Owner's engineer: Contracts can include an EPC for the project implementation and, optionally, a 1-2 year period of operation and maintenance of the grids and hand-over to the final operator (EBS or other). Additionally, a technical assistance by an Owner's Engineer can be considered as a complementary contract for the overall supervision and implementation of the project.
7. Construction
8. Project Commissioning and Handover
9. Monitoring and Evaluation Period
10. Strategy for replication

A tentative timeline is shown below (depends specifically on the scenario selected):


Tentative Timeline
Year 1
Year 2
Year 3
Year 4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
0 Coordination with EC and CIF (transversal activity)
1 EBS/IDB validate Relative Weights
2 Decision of alternative and business model: high-level discussion among stakeholders
3 Feasibility study, costing and concept design
4 Detailed Engineering, procurement strategy and Bidding documents
5 Secure Funds
6 Selection of bidder(s) and contracts // Owners’ engineer (blue)
7 Construction
8 Project Commissioning and Handover
9 Monitoring and Evaluation Period
10 Strategy for replication

11. Annexes

11.1. Estimated Daily Load Profiles of the Communities

1. **Gingeston**

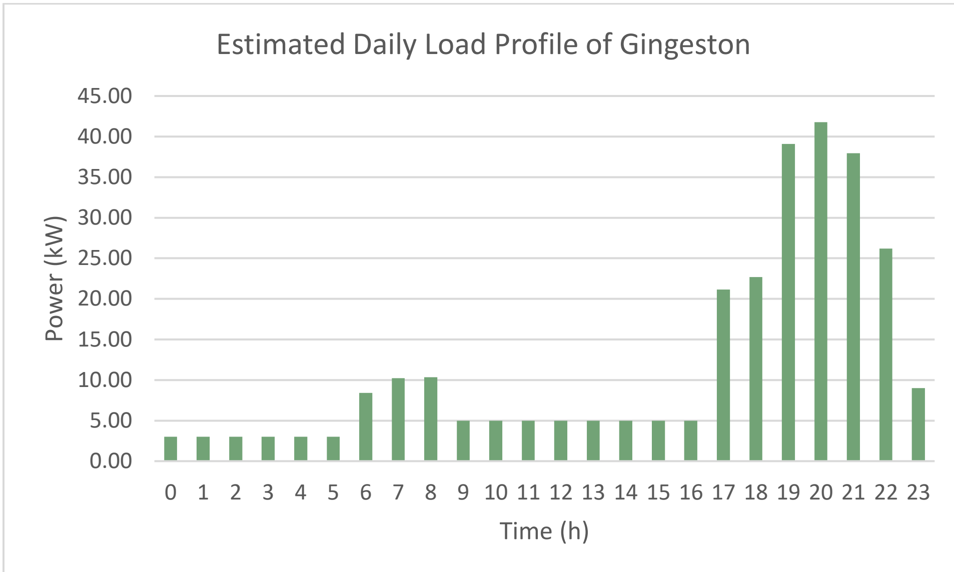


Figure 16: Estimated Daily Load Profile of Gingeston

2. **Pambooko**

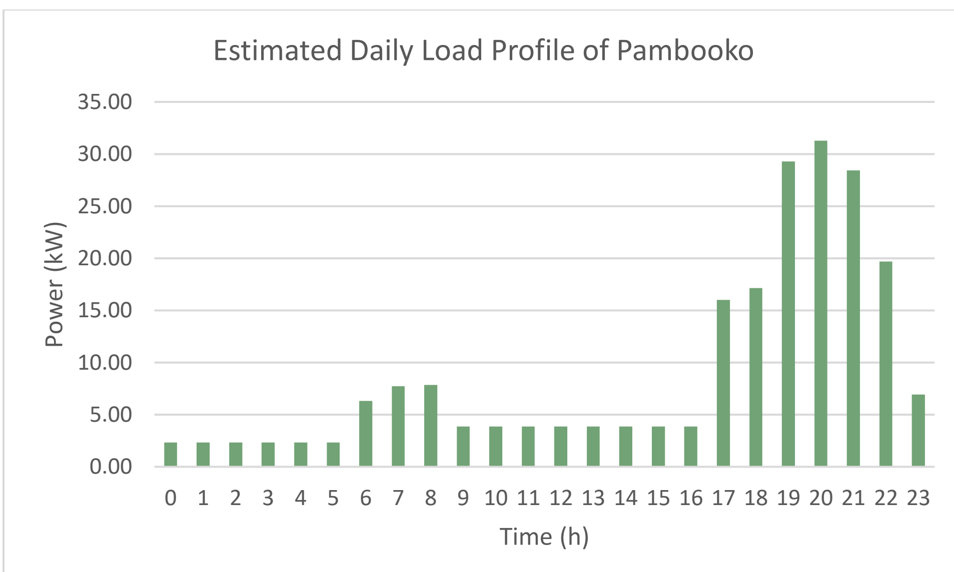


Figure 17: Estimated Daily Load Profile of Pambooko

3. **Abenaston**

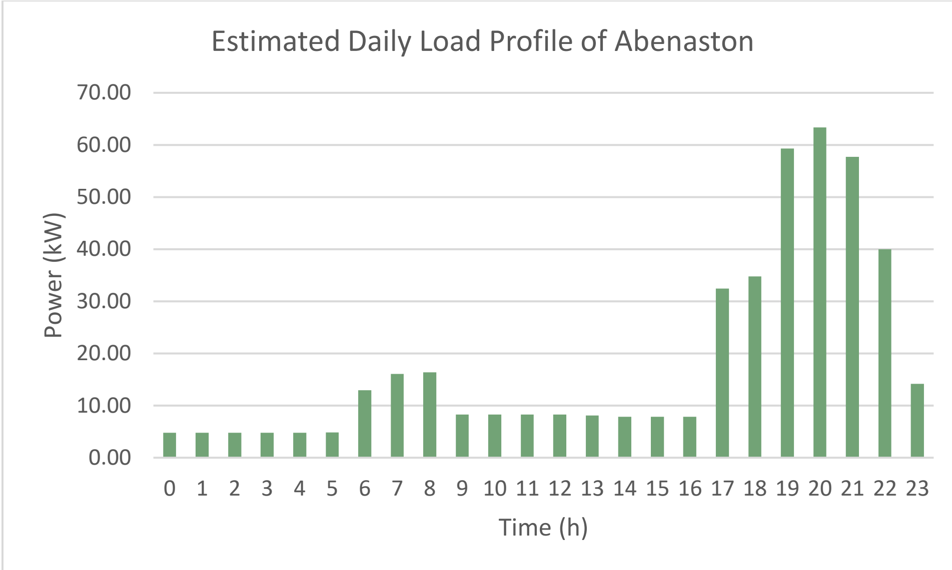


Figure 18: Estimated Daily Load Profile of Abenaston

4. **Amakakonde**

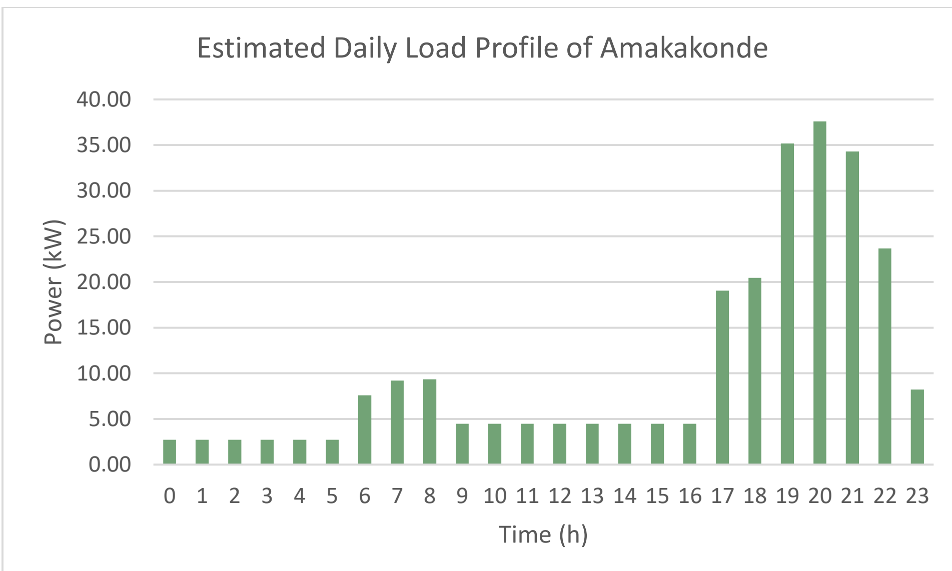


Figure 19: Estimated Daily Load Profile of Amakakonde

5. **Kajapaati**

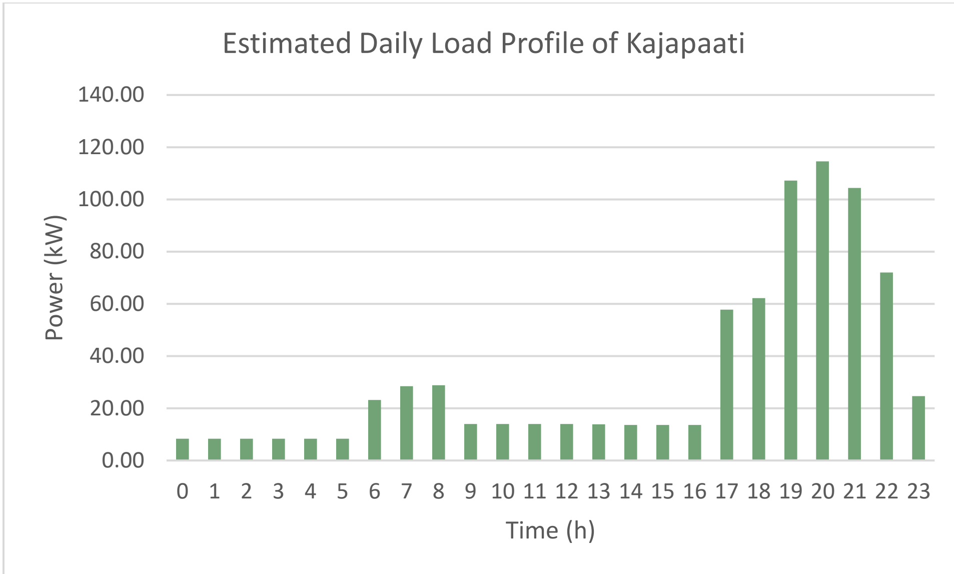


Figure 20: Estimated Daily Load Profile of Kajapaati

6. **Jawjaw**

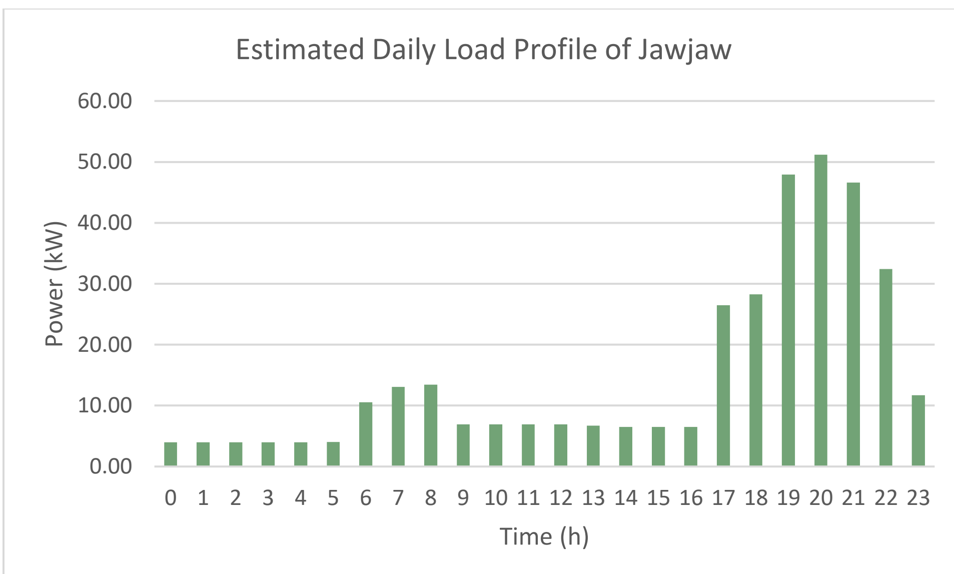


Figure 21: Estimated Daily Load Profile of Jawjaw

7. **Lespaansie**

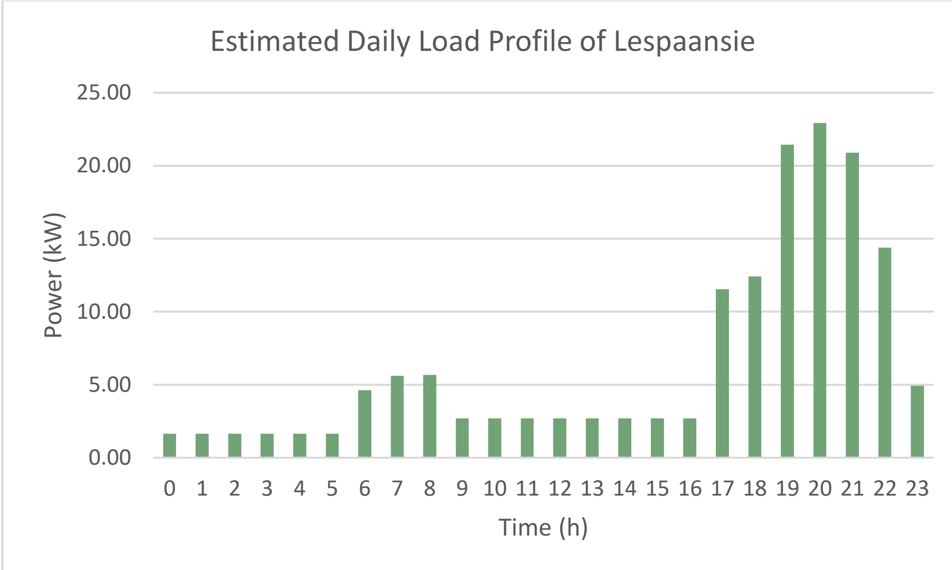


Figure 22: Estimated Daily Load Profile of Lespaansie

8. **Adawai**

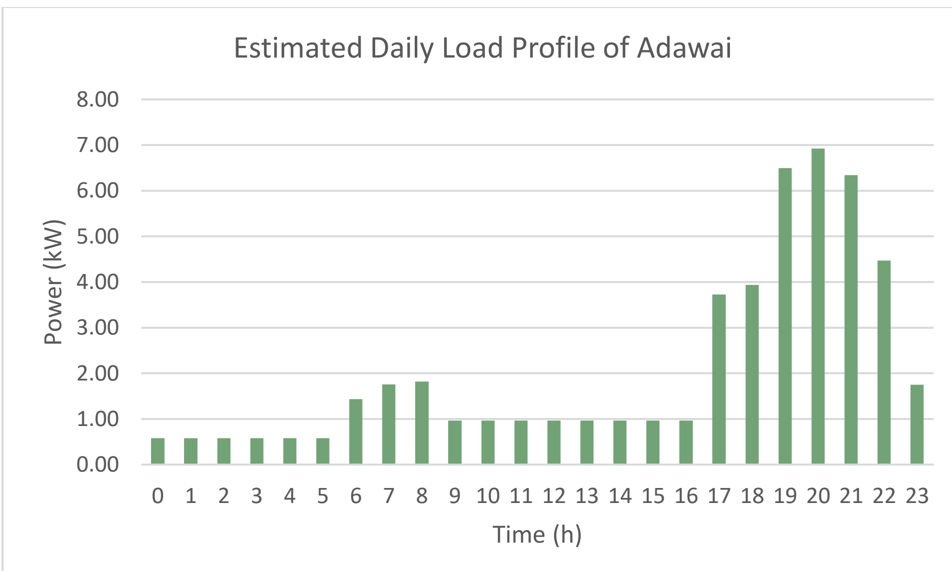


Figure 23: Estimated Daily Load Profile of Adawai

9. **Gunsi**

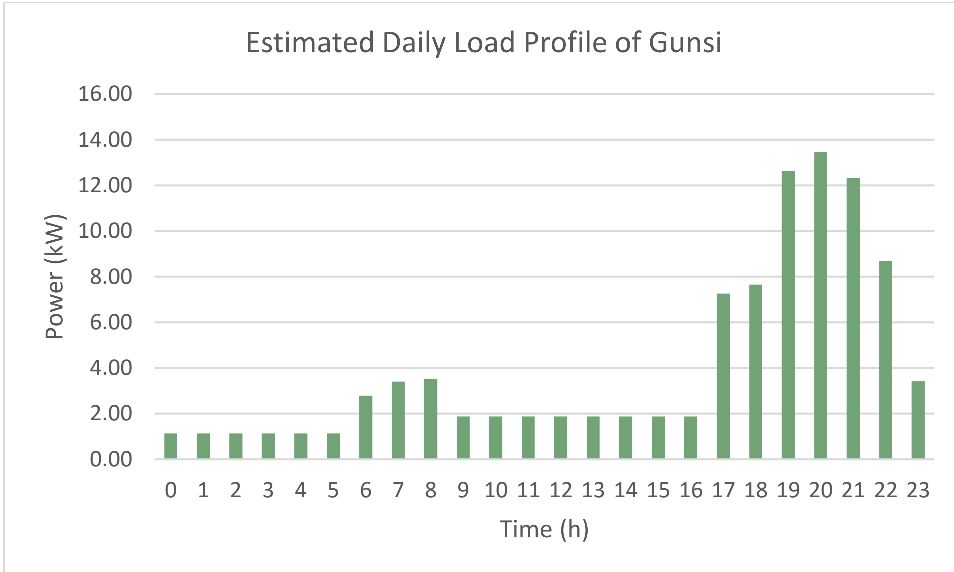


Figure 24: Estimated Daily Load Profile of Gunsi

10. **Nieuw Aurora / Tjalikondë / Ladoani**

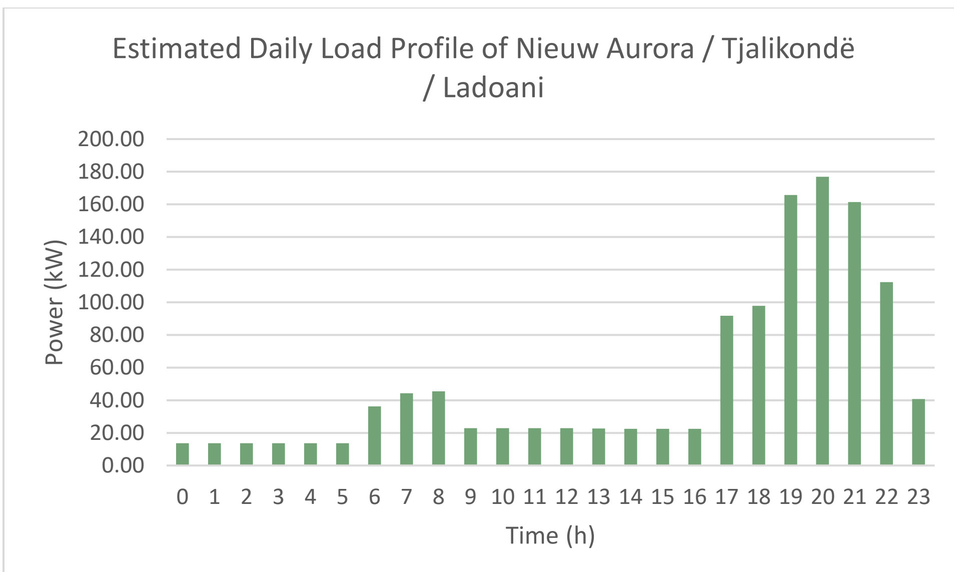


Figure 25: Estimated Daily Load Profile of Nieuw Aurora / Tjalikondë / Ladoani

11. **Atjoni / Pokigron**

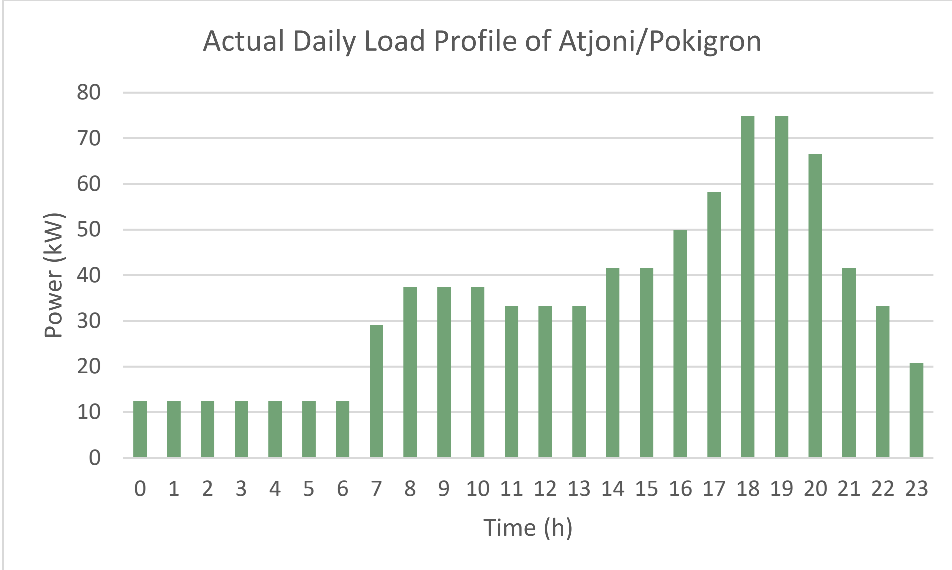


Figure 26: Actual Daily Load Profile of Atjoni/Pokigron

11.2. Total Daily Load Profile

It is presented below the total daily load profile all communities including Atjoni/Pokigron:

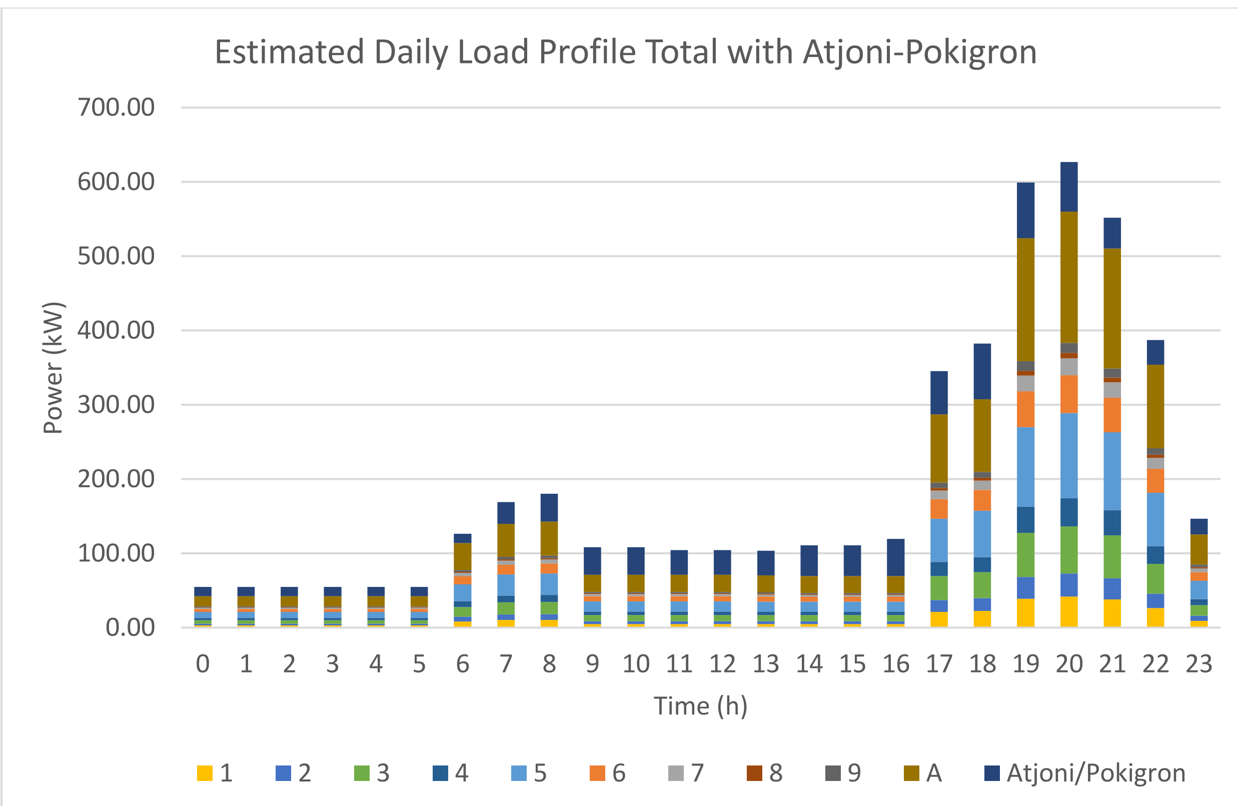


Figure 27: Estimated Daily Load Profile of Atjoni/Pokigron and the 12 targeted communities; 1-Gingeston; 2-Pambooko; 3-Abenaston; 4-Amakakonde; 5-Kajapaati; 6-Jawjaw; 7-Lespaansie; 8-Adawai; 9-Gunsi; A-Ladoani/Tjalikondë/Niew Aurora

11.3. Cost assumptions

	Scenario 1-2 – Individual mini-grids			Scenario 3		Scenario 4
Costs	**Atjoni**	**From Gingeston to Kajapaati**	**From Jawjaw to Niew Aurora**	**3A: EBS scenario**	**3B: All villages under 1 mini-grid**	**Grid extension to upper villages, mini-grids for remaining**
Cost increase due to distance	0%	10%	28%	0%		
GENERAL INFORMATION						
Discount rate	10%					
Inflation rate	3%					
Accepted annual capacity shortage	0%					
Project Lifetime	25 years					
COMPONENTS						
PV Array (modules + inverter)						
Price (USD/kW)	1,090.32	1,199.35	1,395.61	1,090.32	1,090.32	1,090.32
PV Module O&M Cost (USD/kW/year)	10					
Lifetime (years)	25 years					
Inclination angle	5º					
Azimuth	0º					
Hybrid Inverter						
Price (USD/kW)	782.50	860.75	1,001.59	782.50	782.50	782.50
O&M Cost (USD/kW/year)	20					
Lifetime (years)	25					
Battery						
Price (USD/kWh)	160.30	176.33	205.19	160.30	160.30	160.30

	Scenario 1-2 – Individual mini-grids			Scenario 3				Scenario 4	
Costs	**Atjoni**	**From Gingeston to Kajapaati**	**From Jawjaw to Niew Aurora**	**3A: EBS scenario**		**3B: All villages under 1 mini-grid**		**Grid extension to upper villages, mini-grids for remaining**	
O&M Cost (USD/kWh/year)	10								
Diesel Generator									
Initial Price (USD/kW)	365	401.5	467.2	365					
O&M Cost (USD/kW/hour)	0.045								
Distribution line									
AMKA grid (USD/15 km)	300,000								
Meter cost (USD)	362								
Land clearing (USD/kWp)	400								
Container (USD per 40'' container, 1 for each 100 kWp)	8,000								
Design (USD per plant)	5,000								
Commissioning (USD per plant)	3,000								
MV equipment									
	-	-	-	Upgrade PS Pokigron	100,000	Upgrade PS Pokigron	100,000	Upgrade PS Pokigron	100,000
				Extra Step-up-capacity	50,000	Extra Step-up-capacity	50,000	Extra Step-up-capacity	50,000
				12 kV overhead line 21 km	3,150,000	12 kV overhead line 21 km	3,150,000	12 kV overhead line 6.7km	1,005,000

	Scenario 1-2 – Individual mini-grids			Scenario 3				Scenario 4	
Costs	**Atjoni**	**From Gingeston to Kajapaati**	**From Jawjaw to Niew Aurora**	**3A: EBS scenario**		**3B: All villages under 1 mini-grid**		**Grid extension to upper villages, mini-grids for remaining**	
				Land clearing for 12 kV ROW (21 km)	500,000	Land clearing for 12 kV ROW (21 km)	500,000	Land clearing for 12 kV ROW (6.7 km)	159,524
				Mast transformers 31 pcs.	310,000	Mast transformers 31 pcs.	310,000	Mast transformers 7 pcs.	70,000
				4 river crossings	320,000	4 river crossings	320,000	1 river crossing	80,000
				Contractor	800,000	Contractor	800,000	Contractor	800,000
				Logistics incl. transport (21 km)	500,000	Logistics incl. transport (21 km)	500,000	Logistics incl. transport (6.7 km)	159,524t
O&M Costs (USD/km)	-	-	-	2,030 from Atjoni to Gingeston 2,233 from Gingeston to Kajapaati 2,598 from Jawjaw to end					