Energy baseline development, tariff study and tool, O&M plan and manual and capacity building for the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau

TASK 3 – Tariff study

Final report

Prepared for:

UNIDO

May 2018

Project:	Energy baseline development, tariff study and tool, O&M plan and manual and capacity building for the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau
Client:	United Nations Industrial Development Organization
Consultant:	Trama TecnoAmbiental
Project code	UNIDO Purchase order (PO) number 3000050690 TTA Project code CI-17-0028

TARIFF STUDY

DELIVERABLE #3: Tariff study

Related Documents	Type of document	Draft/final	Date of submission
Inception report	PDF	Final	19/9/2017
Annex 1 – Chief questionnaire	Word	Draft	19/9/2017
Annex 2 – End-user questionnaire	Word	Draft	19/9/2017
Annex 3 – IPP questionnaire	Word	Draft	19/9/2017
Task 2 Report - Energy baseline v.2	Word	Draft	12/1/2018
Task 2 Report - Energy baseline	Word & PDF	Final	22/2/2018
Task 2 Tool - Energy baseline	Excel	Final	22/2/2018

Financed by: United Nations Industrial Development Organization

PRESENTATION

This report is the Deliverable #3 from the technical assistance offered to UNIDO for the development of the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau

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Abbreviations	Explanation
ABREC-SABER	African Biofuel and Renewable Energy Company
ADPP	Ajuda de Desenvolvimento de Povo para Povo
ARPU	Average revenues per user
ACDB	Associação Comunitária de Desenvolvimento de Bambadinca
ATP	Ability to pay
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EU	European Union
GEF	Global Environmental Facility
GHG	Greenhouse Gas
KPI	Key performance indicator
kWh	Kilowatt-hour
kWp	Kilowatt peak (refers to installed photovoltaic capacity in STC)
MWh	Megawatt-hour
O&M	Operation and maintenance
PV	Photovoltaic
PSH	Peak sun hours
STC	Standard test conditions
TTA	Trama TecnoAmbiental
TOU	Time of use
UF	Utilisation factor
UNIDO	United Nations Industrial Development Organization
WAEMU/UEMOA	West African Economic and Monetary Union
WTP	Willingness to pay

1. Project background

Following the Call for Proposals issued by the United Nations Industrial Development Organization (UNIDO) in July 2017, Trama TecnoAmbiental (TTA) was awarded a contract for the "Energy baseline development, tariff study and tool, O&M plan and manual and capacity building for the 500 kWp solar PV mini-grid in Bissorã, Guinea Bissau". The main objective of this project is to develop the soft issues around the 500 kWp solar PV mini-grid to ensure a sustainable and durable project.

This project is part of the Global Environmental Facility (GEF). The GEF Project (ID 5331) entitled "Promoting investments in small to medium scale renewable energy technologies in the electricity sector of Guinea-Bissau" is executed by UNIDO in close partnership with the Ministry of Energy and Industry of Guinea Bissau, the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) and the Small Island Sustainable Energy and Climate Resilience Organization (SIDS DOCK).

In this context, UNIDO, the West African Economic and Monetary Union (WAEMU/UEMOA) and the African Biofuel and Renewable Energy Company (ABREC-SABER) are partnering for the construction of a solar PV hybrid mini-grid for the city of Bissorã with a total installed solar PV capacity of 500 kWp. The company Prosolia Africa has been contracted to undertake the required civil works and turn-key installation of the power station.

2. Introduction to the tariff study

After the completion of the first two tasks (inception report and energy baseline), this report develops a tariff framework proposal for the Bissora mini-grid. As a general consideration this tariff framework should facilitate the sustainable operation and maintenance of the mini-grid, while at the same time electricity remains affordable for users.

The structure of the tariff study report is as follows:

- Section 3 provides an overview of tariff regulations and structures in Guinea Bissau, both at grid level (EAGB in Bissau) and in two other autonomous mini-grids (Bambadinca and Contuboel). From a regulatory perspective, there shouldn't be any particular constraints for the tariff design in Bissora.
- Based on this country-level overview, Section 4 discusses different tariff approaches that have been used in other mini-grid projects and that could theoretically be considered for Bissorã. Pros and cons in each case are presented, and a preliminary tariff approach is identified.
- Section 5 presents the methodology and assumptions used in order to build the tariff tool, describing the different costs incurring during the development and operation of the mini-grid to be recovered and presenting the expected demand evolution (for the estimation of revenues over time).
- Section 6 builds on the previous two sections, developing further the tariff approach identified in Section 4 and assessing the specific tariff levels that might be required in the light of cost and demand assumptions from Section 5.
- Section 7 identifies some tariff related aspects that will require further attention in upcoming tasks, namely during the definition of the management model.
- Finally, Section 8 is a brief introduction of the excel-based tool which accompanies the present report (*Financial model Bissorã*)

3. Overview of country context

Relevant country-level energy sector partners are the National Directorate of Energy (Direção Geral de Energia, DGE), as part of the Ministry of Energy and Industry (MEI), as well as the Energy and Water Public Company (Electricidade e Águas de Guinea-Bissau, EAGB).

The national grid is relatively small, covering only Bissau and its surroundings. Other towns in the country are served either by local diesel gensets (Bafata, Gabu) or PV mini-grids (Bambadinca, Contuboel). There is an approved plan at regional level to interconnect Guinea and Senegal, funded by OMVG. This network will pass close to Bissora (around 10-15 km) but no clear dates for its construction could be collected. Linked to this new infrastructure, there are national plans to electrify up to 14 towns (included Bissora), but again no clear deadlines seem to be available.

From a tariff perspective, there is no country-wide harmonized tariff structure. EAGB has its own tariff scheme while each of the different mini-grids have different tariffs. In this context, there are no specific regulatory constraints for the tariff design of Bissora, which can then be defined based on operational considerations and local priorities and needs. Still, tariffs from other PV mini-grids can provide a first indication of what electricity services might cost and people are willing to pay.

3.1. EAGB tariffs

EAGB runs the main grid in Bissau. The tariffs below are as of March 2014, unchanged since 1996. A recent study to increase these tariffs, in order to more accurately reflect the real costs of the service, has not been formally adopted.

Table 1: AEGB tariffs as of 2014

Tariff			**Unit**	**Euro**	**FCFA**[1]
Normal tariff	Low voltage	Fix monthly fee for monophasic connection	Connection point	5,56	3.707
		Fix monthly fee for triphasic connection	Connection point	33,37	22.247
		First block: energy consumption < 200 kWh/month	kWh	0,19	127
		Second block: energy consumption > 200 kWh/month	kWh	0,37	247
	Medium voltage	Fix monthly fee	Connection point	8,90	5.933
		Active on-peak electricity	kWh	0,19	127
		Active off-peak electricity (from 00:00 to 8:00)	kWh	0,15	100
Special Tariff	Low voltage social tariff	Fix monthly fee	Connection point	1,40	933
		First block: energy consumption < 50 kWh/month	kWh	0,12	80
		Second block: energy consumption 50- 200 kWh/month	kWh	0,24	160

[1] Conversion rate as of 27/04/2018 (EUR/FCFA = 0.0015)

Tariff			Unit	Euro	FCFA[1]
		Third block: energy consumption > 200 kWh/month	kWh	0,49	327
	Low voltage companies and business tariff	Fix monthly fee for monophasic connection	Connection point	63,10	42.067
		Fix monthly fee for triphasic connection	Connection point	300,39	200.260
		Active on-peak electricity	kWh	0,24	160
		Active off-peak electricity (from 00:00 to 8:00)	kWh	0,20	133

3.2. Tariffs in other PV mini-grids

In Bambadinca's mini-grid, the operator (ACDB) applies a simple pre-payment scheme with time-of-use (TOU) tariffs and a distinction between normal and social tariffs. The tariffs were initially approved in 2014 and then they were revised downwards in 2015, as shown in the following table.

Table 2: Bambadinca tariffs

Homologated tariff in 2014 (FCFA/kWh)			
Time window	**09:01-19:00**	**19:01-24:00**	**24:01-09:00**
Normal tariff	400	500	900
Social tariff	400	400	900
Homologated tariff in 2015 (FCFA/kWh)			
Time window	**09:01-19:00**	**19:01-24:00**	**24:01-09:00**
Normal tariff	256	320	576
Social tariff	256	256	576

Additionally, the residential and institutional clients pay a connection fee of 15.000 FCFA; the commercial ones a one-off 30.000 FCFA.

These tariff levels seem to be widely affordable, as the number of connections has been gradually growing up to more than 600 (as of early 2018) and the demand is close to the PV plant output.

In Contuboel mini-grid, the operator (FRES GB) charges a binomial tariff, with a fixed monthly fee and a variable fee per kWh. According to information shared by the EU delegation in Bissau (the EU funded part of this mini-grid) and confirmed by FRES, the applied tariffs start at 3000 CFA/monthly for the fixed fee and at 400 CFA/kWh for the variable fee. Please see table below for details.

Table 3: Contuboel tariffs

Available power [kW]	Connection fee [FCFA]	Tariff scheme		
		Monthly fee (FCFA)	Day tariff per kWh (10h-17h) [FCFA]	Night tariff per kWh (17h-24h) [FCFA]
1,5	25.000	3.000		
2,2	30.000		400	700
3,3	35.000	5.000		

(Source: Contuboel case study shared by EU, 2014. Data confirmed by FRES)

3.3 Current tariffs in Bissorã

Currently, a private diesel genset provides to a number of residential, commercial and institutional users limited electricity service of 4 hours per day. Households are charged a flat monthly fee of 15.000 FCFA/month for lights, phone chargers and other basic loads, while businesses pay 25.000 FCFA/month for additionally supply a fridge. Public institutions (police, school, hospital, etc.) do not pay for electricity.

4. Benchmark of tariff structures

This section presents five different tariff structures that are commonly found in rural electrification projects and could be potentially used in Bissorã operation. Those are:

- Flat tariff
- Power-based tariff
- Energy- based tariff
- Binomial tariff
- Service-based tariff

Further adjustments of those tariffs, such as block rate structure or time of use (TOU) schemes will be also presented and analysed as possible alternatives for the Bissorã mini-grid.

4.1. Flat tariff

With this arrangement the user pays a fix amount, normally per month, independently of the amount of energy they consume. The demand can be limited by installing current limiters. Some categorisation can be done on demand segmentation and result in different flat tariffs to the various consumer groups, i.e. households, businesses and institutions.

Pros:

- Capital costs are low since there is no need for meter procurement
- Operation costs are minimal since there is no need to read the meters. Also, transactions do not happen continuously but only during the fixed intervals of time and O&M costs are reduced.
- The revenues of the operator are fixed every month, allowing for secure financial planning.
- Clients can also plan their monthly expenses for energy beforehand, since those do not vary.

Cons:

- Payments are fixed and independent of the amount of electricity consumed, which makes this scheme unsuitable for mini-grids with limited amount of electricity generation, such as solar-based ones. There are no incentives for energy efficiency and rational use of electricity.
- Overdue payments can happen; thus a strong client policy is needed to be placed to prevent such events.

- For solar-based mini-grids, uncontrolled electricity consumption may cause deep discharging of the batteries, often decreasing their lifetime considerably. Also, the generator (if available) will have to provide additional electricity and soar the operation costs of the mini-grid.
- Since the subscription is fixed all over the year, the clients may face challenges to pay their bill if their income is seasonal.
- There is a risk for multiple illegal connections from one connection point, especially if the flat tariff is relatively high. This can greatly affect the revenues of the operator.
- If consecutive payment failures occur (according to client policy), the operator has to disconnect the client, something which creates additional costs.

4.2. Power-based tariff

A power-based (or capacity) tariff is established according to the contracted power of the users and payment is made according to periodic intervals (e.g. USD/kW/month). The contracted power normally reflects the energy needs of the client.

Most of the positive and negative attributes of this tariff scheme are similar to those of the flat tariff, since both are independent of the amount of kWh consumed and are paid in regular intervals.

The specific benefit of power-based tariffs vs flat tariffs is that demand is a bit more constrained according to the contracted power, somehow mitigating (if only partially) the risk of overconsumption. Also, tariffs can be more personalised and specific to the needs of the customer. On the other hand, it does require to adapt meters for each level of contracted power and to monitor its adequate use.

4.3. Energy-based tariff

This tariff is related to the real energy consumed by the client (USD/kWh) over a billing period, whether it is a pre-paid or post-paid scheme. There are also variations of energy-based tariffs:

- **Time of Use tariff**: kWh can have a different price according to the time of day or the season of the year, in order to incentivise consumption during certain periods of time. For instance, in PV-hybrid mini-grids in residential communities with night peak loads, price discrimination can lead to higher electricity prices during night time, when more expensive electricity is taken from the batteries, and lower prices during daytime when consumption is direct from the PV panels. This leads to a smoother load curve, as shown in Figure 1 (red bars):

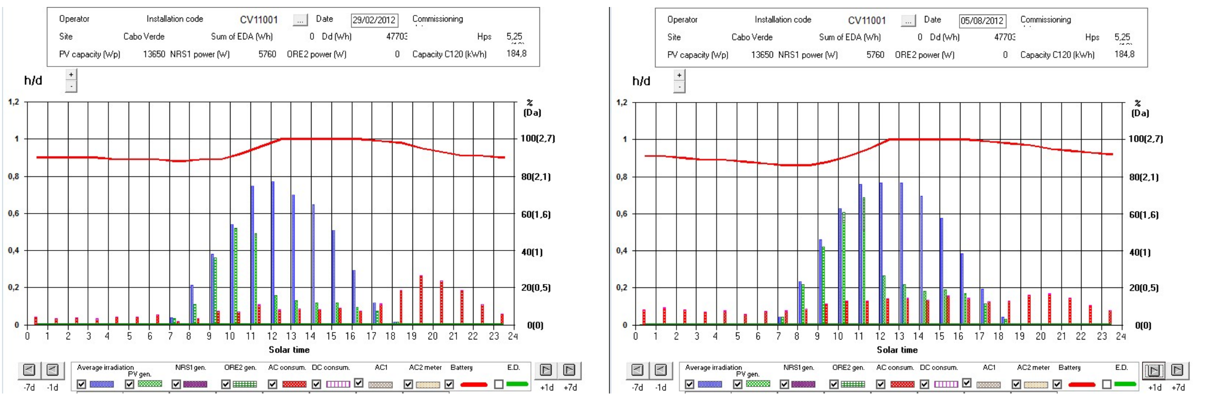

Figure 1: Effect of TOU pricing in Monte Trigo microgrid in Cabo Verde: load curve before (left) and after (right).

- **Increasing block rate structure:** The electricity price increases as the amount of electricity consumption increases within a specific period of time. This scheme promotes energy efficiency by penalising excess consumption and has particular benefits in mini-grids if the available generation is very limited. However, this scheme does not incentivize commercial or productive activities with higher electricity demand.

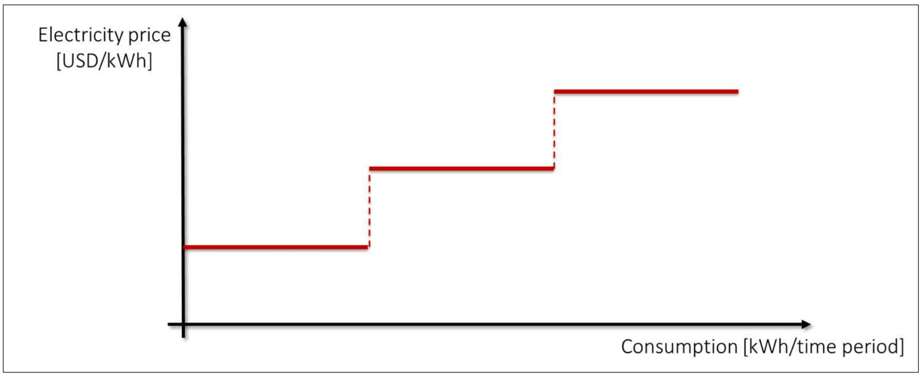

Figure 2: Increasing block rate structure

The pros and cons of the energy-based tariff are listed below:

Pros:

- It gives strong incentives for energy conservation and energy efficiency since clients can save money by limiting their electricity consumption (and this is generally easy to understand in any context).
- It is a popular scheme among clients of rural mini-grids for its simplicity and transparency: they only pay for what and when they consume.
- Illegal multiple connections and free-riding risks are eliminated since payments are directly related to consumption.
- Service is provided as long as clients have sufficient credit, without been disconnected when they do not top up. Therefore, neither the user nor the operator have to bear any disconnection and reconnection costs. The automatic disconnection when not topping up is understandable and does not generate negative feelings in the client.

Cons:

- From the operator perspective, there is less certainty about the generated cash flows and the ability to recover O&M costs of the mini-grid.
- Financial planning is challenging also for clients since their expenses are not fixed.
- Post-payment schemes impose additional risks coming from potential uncontrolled consumption that could lead to unexpected high bills that are beyond the means of the client.
- Individual electricity meters are necessary in order to record the consumption for billing purposes. Those can be either sold to the customers as part of the connection fee or rented out for a fixed monthly fee.
- In post-payment schemes, operation expenses are high due to necessary meter readings. In pre-payment billing scheme, a point of sell is necessary for the clients to purchase their credit, which increases O&M costs.

4.4. Binomial tariff

A binomial tariff is basically a combination of the energy-based and power-based tariff and offers the benefits of both schemes. Clients bare a double fee: a per-kWh term for the electricity consumption and a periodic fixed fee, which can be related to the contracted power.

To practically apply such a scheme, the operator can link the fixed and variable fee to the fixed and variable cost of electricity production: the fixed fee can be related to the salaries and amortisation of components, while the variable fee can be calculated based on the diesel cost of the gensets, for instance.

The binomial tariff has the great advantage that the clients pay according to their electricity use and at the same time the operator can better plan the collection of the necessary funds for the viable operation and maintenance of the mini-grid. Nonetheless, there should be a careful study and definition of the level of both terms. If the fixed term is relatively high, then there is a risk of various end-users connecting illegally through one registered legal connection.

4.5. Service-based tariff

This tariff scheme is a combination of all the above. For a periodic subscription fee (usually a month), the operator offers a complete service to the clients, which can be defined by the hours of continuous energy supply, a certain amount of energy that can be consumed within a day and a power limitation. Additional components can be included in the service such as the renting of efficient appliances, the usage of community loads such as a water pump or an internet café.

This scheme combines the advantages and disadvantages of the flat tariff and the binomial tariff. Financial planning is accurate both for the operator and the clients, meter readings are not necessary and operational expenses are minimised. An additional, unique advantage is that since it is a tier-based scheme, the maximum aggregated electricity demand of all the clients is a constant and should always be lower than the production capabilities of the mini-grid.

Nonetheless, in order to apply such a tariff scheme, advanced metering solutions are needed with embedded or remote energy control capabilities. The available meters purchased in Bissorã are simple prepayment ones and would not allow for such scheme.

4.6. Preliminary tariff structure recommendation

Once the advantages and disadvantages of different tariff structures have been presented, as well as the impossibility of using service-based tariffs in the Bissora mini-grid, the recommendation of this study would be to further explore energy-based or binomial tariffs as the best available schemes in this case.

More specifically, a binomial structure (which sometimes raises customers' opposition because of the fixed fee) was already discussed during the previous mission to Bissora, and, as far as the fixed fee remains affordable, representatives from the local community expressed their agreement with such approach.

5. Methodology and assumptions

Beyond the specific tariff structure proposed, defining financially viable tariffs requires the previous assessment of costs and of demand (energy sales) figures.

In the case of costs, this study only considers those that have to be borne once the mini-grid starts operating. That is, the initial investment has been already paid from other sources and does not have to be included in the tariff calculation. However, replacement of specific components lasting less than the 20 years' project lifetime has to be taken into account.

In addition to such future CAPEX costs, a PV mini-grid such as Bissora has both fixed and variable O&M costs. Due to the fact that fuel needs are limited (unless the plant is undersized), fixed O&M are typically higher than variable O&M, something that creates both risks and opportunities for operators as they have to be paid regardless of demand and revenue levels.

When it comes to demand, the assumptions used are based on the results of the previous Task (Energy Baseline), but a rather conservative estimate regarding the increase of connections over time is used. In addition, estimates regarding future expansions and demand growth per customer are also presented.

The following subsections develop the methodology in more detail, describing the different costs and demand assumptions that were used. All of these are open to discussion and could be modified or updated if required.

5.1. Cost assumptions

5.1.1. Fixed O&M costs

Fixed O&M costs include salaries and other costs that are not directly linked to PV output or energy sales levels. Salaries are expected to be the most significant annual O&M cost in the context of the Bissora mini-grid. In order to estimate them, information about the O&M personnel in the Bambadinca mini-grid has been collected and critically assessed. Information about salary levels was checked during the mission to Bissora.

The following table provides a list of personnel that would be required for the O&M of the Bissora mini-grid. This list is indicative and would be adapted by the final operator of the mini-grid. This includes both technical staff, in charge of the generation plant and the distribution grid, as well as commercial and administrative staff dealing with customers and revenue collection.

SALARIES	Number	Dedication (as %)	Gross salary (EUR/month)	Total (EUR/year)
Professional administrator	1	50%	800	4800
Professional technician	1	50%	800	4800
Local administrator	1	100%	300	3600
Salesperson	2	100%	180	4320
Local technician - PV plant	2	100%	300	7200
Local technician - Grid and connections	2	100%	300	7200
Caretaker/guard	2	100%	100	2400
Subtotal Salaries				**34320**

Table 3: Personnel cost estimate

In addition to personnel, the following table captures other Fixed O&M costs, for which comparison with Bambadinca was also performed.

Table 4: Other fixed O&M cost estimates

OTHERS	Quantity		Annual Cost	Total (EUR/year)
Travelling	-		500	500
Marketing and communication	-		1000	1000
Office rental	-		300	300
Car	1		2000	2000
Motorbike	1		1000	1000

Legal support	-		600	600
Remote monitoring service	1		3000	3000
Insurance, wayleave and permit	0,2%	(As % of CAPEX)	4664	4664
Spares/small repairs	0,1%	(As % of CAPEX)	2332	2332
TOTAL				**15395**

Adding the figures from these two tables, plus a 5% contingencies margin, the resulting Fixed O&M estimate for Bissora would be 52.201 EUR/year.

5.1.2. Variable O&M costs

The only significant variable O&M cost would be the cost of diesel for the genset, if required. The current estimate is that the PV plant is able to provide a solar fraction of 95% of total demand, while the genset covers the remaining 5%. This is a rather conservative estimate, especially for the first years of operation where demand is expected to be considerably lower that the PV output. Using this 5% Diesel fraction results in annual costs or around 2.600 EUR in year 1, 7.000 EUR in year 4 (when all 470 connections are operative and plant capacity is used at around 50%) and 20.000 € in year 20 (with plant close to 100% capacity), meaning that this is a relatively minor cost when compared with Fixed O&M costs above.

Cost of replacing components

Some of the mini-grid components will require replacement during the 20-year period, meaning that additional investments will be needed. This can be a major problem for ensuring the sustainability of the project, and thus tariff analyses have to take into account how to generate such additional funds over time. The following table shows the lifetime and the approximate cost of the main mini-grid components, highlighting in green those needing replacement within the project lifetime.

Table 5: Component replacements cost estimate

Component	Unit	Quantity	Unit cost (EUR)	Total cost (EUR)	Lifetime (years)	Reposition rate	Variation cost index (per year)
PV panels	unit	1.887	205	386.352	20	100%	-2%
Grid inverters	unit	18	3.803	68.451	11	100%	0%
Battery inverters	unit	54	3.192	172.362	11	100%	0%
Batteries	unit	432	604	260.996	7	100%	-3%
Battery racks	unit	18	1.279	23.024	20	100%	0%
PV structure	unit	1.887	41	76.755	20	100%	0%

Component	Unit	Quantity	Unit cost (EUR)	Total cost (EUR)	Lifetime (years)	Reposition rate	Variation cost index (per year)
Cabling	set	1	101.570	101.570	20	100%	0%
Protections and accessories	set	1	71.591	71.591	20	100%	0%
Genset	unit	1	31.536	31.536	10	100%	0%
Genset accessories	set	1	6.754	6.754	20	100%	0%
Communications	set	1	5.473	5.473	20	100%	0%
MV grid	m	3.000	16,5	49.500	10	50%	0%
LV grid	m	11.500	12,285	141.278	10	50%	0%

The reposition rate estimates the fraction of each component that needs to be replaced, and the cost variation index seeks to provide an indication of how market costs are expected to evolve annually in each case. As shown in the table, the single largest investment will be required for battery replacements at years 7 and 14, but other significant investments need to take place around year 10.

5.1.3. Cost of additional connections

In addition to the costs above, which represent the minimum required to keep the mini-grid operative over the 20-year period, the previous field trip to Bissora suggested that there is interest from the community and technical potential for increasing the number of connections beyond the initial 470. In order not to apply higher charges to customers that join the mini-grid in a later stage, it is recommended to assess the investments that such expansion would require and how they will be recovered. The following table presents the scenario that has been considered, with a first expansion only requiring additional connections and meters and a second expansion also requiring additional LV lines.

Table 6: Mini-grid expansion cost estimate

Mini-grid expansion costs	Unit	Quantity	Unit cost (EUR)	Total cost (EUR)	Year
Additional meters-Phase 1 (no grid extension needed)	unit	200	80	16.000	5
Additional meters-Phase 2 (requires grid extension)	unit	200	80	16.000	10
Grid extension (LV) for Phase 2	m	4.000	12	48.000	10

Actually, from a financial perspective, while these expansions will require investment from the operator, their payback time due to additional revenues is estimated to be less than one year for Phase 1 (meters only) and between

3 and 4 years for Phase 2, meaning that in practice they do have a positive impact on tariff levels. That is, by broadening the customer base and increasing demand, tariffs can be lower.

5.2. Demand assumptions

From the perspective of demand for each customer category, figures are based on the results from the Energy Baseline study. However, in order to estimate energy sales per year, additional assumptions are required in terms of the evolution of the number of connections and the demand growth per customer.

In order to be rather conservative when forecasting annual revenues, it is estimated that the 470 connections are gradually added, starting at 40% of them at year 1 and reaching 100% of them at year 4. Thus, the effective demand at year 4 matches the Base Scenario from the Energy Baseline study. In this situation the PV plant is used at 52% of its capacity. From that point, there are two further drivers of demand growth:

- The expansion of the mini-grid to new customers in two phases (years 5 and 10) described just above. For these new customers (likely to be mostly residential, since other types of users are already connected in greater proportion from the beginning) an average demand of 400 kWh/year is assumed.
- A further 2% annual increase of demand per customer, a figure in line with demand growth per customer in other rural mini-grid and grid extension projects.

Using these assumptions, the following graph shows the evolution of demand against the PV plant output (100% meaning that demand equals the PV plant output).

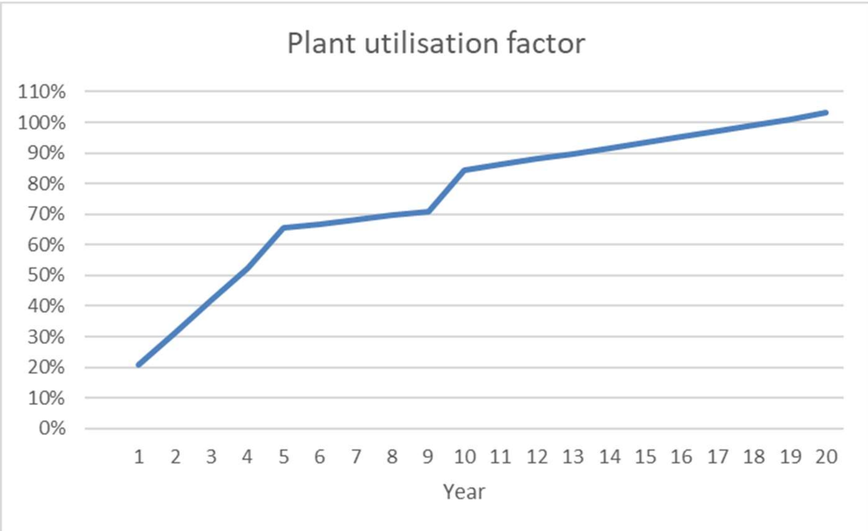

Figure 3 Evolution of demand

6. Analysis of tariff proposal

6.1. Results

Once demand assumptions have been developed it is possible to calculate the revenues associated to different tariff schemes. Then these revenues can be compared against costs in order to assess the potential viability and profitability of such tariff designs. As argued in section 4 this tariff analysis will mostly consider two different tariff schemes: energy-based tariffs and binomial tariffs. However for comparative purposes some of the tables below also display the flat tariff option. A one-time connection fee of 30€ (~20.000 CFA) has been included in all the options shown below. This fee could be increased or reduced as part of the final tariff negotiation.

Taking this into account, the following table shows four different tariff settings that would provide similar profitability (NPV~0 for a discount rate of 15%) for the operator. Options 1 and 4 correspond to flat and energy-based tariffs respectively, while options 2 and 3 represent two different binomial tariff options.

Table 7: Tariff options (A)

		Option 1	Option 2	Option 3	Option 4
Tariff scheme	**Unit**	**Flat**	**Binomial**	**Binomial**	**Energy-based**
Flat fee	€/month	14	6	3	-
Variable fee	€/kWh	-	0,14	0,19	0,24
Average payment per connection	€/month	14	14	14	14
Average payment per household	€/month	14	10	8,4	6,8
Impact on revenues if demand is 20% lower		0	-10%	-15%	-20%

As it can be seen, all four options represent a similar average payment per connection (14 €/month), something which is required to reach a similar profitability level. However, tariffs that incorporate a variable fee take actual consumption into account and allow smaller consumers (e.g. households) to pay less. In addition, and as argued before, incorporating a variable fee provides a clear signal for consumers to use electricity efficiently.

The energy-based option would be ideal when it comes to these two aspects, but it has the drawback that revenues become less predictable, as they are purely based on consumption. And given that some form of binomial tariff (keeping the flat fee affordable) was already discussed and well considered by the local community during the visit to Bissora (February 2018), this could be a viable option for the Bissora mini-grid.

Going beyond the tariff structure discussion, the tariff levels in the table above present a more specific problem when annual cash flows are assessed in more detail. In fact, while the Net Present Value (NPV) over 20 years presents a reasonable value, most of these profits come from the latest operation years (where demand is highest and no more component replacements are needed). As an example of this observation, the figure below shows the evolution of NPV for tariff option 3.

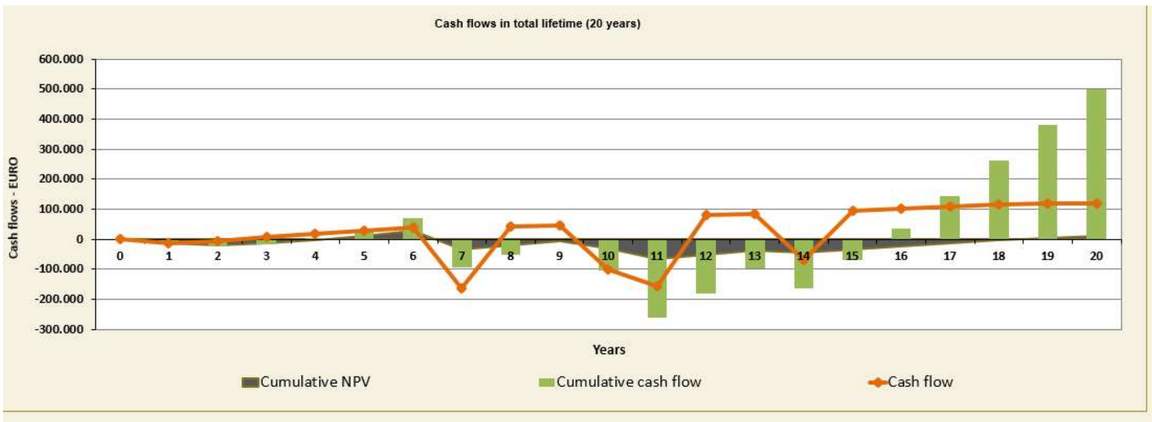

Figure 4: Cash flow over project lifetime for tariff option 3

Given this, it might be wiser to define a slightly higher tariff that allows to better recover costs during the first operation years, and eventually define as well some criteria for tariff revision in the future. The following table is an adaptation of the table above with the four tariff options, where tariff levels have been adjusted to ensure that cumulative cash flows remain positive over the whole project lifetime.

Table 8: Tariff options (B)

		Option 5	Option 6	Option 7	Option 8
Tariff scheme	**Unit**	**Flat rate**	**Flat + variable**	**Flat + variable**	**Variable only**
Flat fee	€/month	18	6	3	-
Variable fee	€/kWh	-	0,2	0,25	0,30
Average payment per connection	€/month	18	18	18	18
Average payment per household	€/month	18	11,2	10,1	8,5

With these updated figures, the average payment per connection goes up to 18 € per month. But if tariff options 7 or 8 are used, the monthly cost increase for households versus options 3 or 4 respectively would be below 2 €, with tariffs remaining at affordable levels (as it will be seen later when comparing with other mini-grids in the country). Using tariff option 7 as an example, the following figure shows NPV over project lifetime, now always positive.

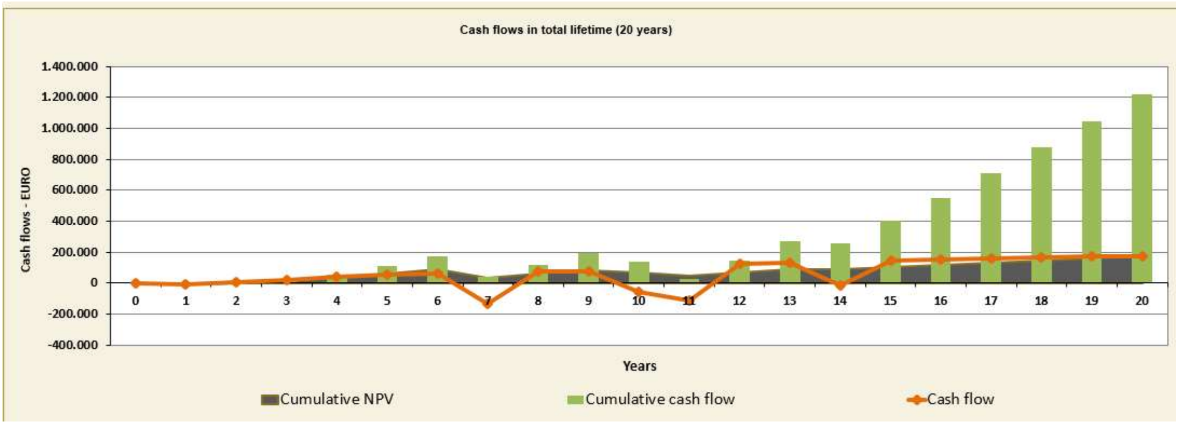

Figure 5: Cash flow over project lifetime for tariff option 7

Different periods can be identified in the figure above:

- During years 1 to 3, given that demand is still low, the operator would only be able to recover annual O&M, but not to make significant savings for future replacements.
- From year 4 to 7, cash flows start to increase and eventually allow to make savings for most of the first battery replacement, which takes place in year 7.
- Years 8 to 14 show a similar pattern as the mini-grid provides enough profits to pay for diverse replacements that would be expected during this time.
- Finally, years 15 to 20 provide higher profits for the operator as demand has kept growing and is now close to the PV plant output, and no more replacements are needed.

Based on these results, **this study preliminary findings would be that tariff options 7 (binomial) or 8 (energy-based) allow for a viable O&M model while remaining affordable for most users**. The following table provides a comparison with current genset tariffs in Bissora and with Bambadinca and Contuboel tariffs, as well as a comparison of the total monthly expenses in each case.

Table 9: Proposed tariff vs other tariffs in Guinea Bissau

Tariff elements	Unit	Proposed binomial tariff	Proposed energy tariff	Bissora thermal plant[2]	Bambadinca[3]	Contuboel[4]	EAGB (normal/social)
Flat fee	€/month	3	-	23	-	4,5	5,56 / 1,4
Variable fee	€/kWh	0,25	0,30		0,39	0,61	0,19 / 0,12
Total payment*	€/month	10,1	8,5	23	11	22	11

(*) For a household consuming 28.25 kWh/month

The existence of a flat fee, such as in Option 3 and 7, can be perceived negatively by the customers when it is not carefully designed and properly explained. For customers to bare it with minimum criticism, this flat fee can be associated to the meter rental or access to the street lighting. It would be even possible to include some energy allowance in the flat fee; however, the limitations of the energy meter would complicate the customer administration.

Another important aspect to be considered during the design of the tariffs is the comparison amongst the similar projects (in this case, Bambadinca and Contuboel) or the main grid. While all three are autonomous, solar-based mini-grids, their funding and operation and business model are not the same; thus, neither the structure, nor the tariff level can be directly comparable. Some projects are subsidised, while others are realised with private funds and the tendency is that more private operators will enter the mini-grid market. It is mostly probable that the next to follow will have less public funds and, thus, will require to cover a higher fraction of the investment.

6.2. Tariff refinement options

So far the tariff options presented are as simple as possible, seeking to facilitate its understanding by local customers and actors, estimate and demonstrate the cashflows under various scenarios as well as the to reduce the administrative costs related to billing and commercial management. However, there are a number of additional levers that could be used in order to refine the tariff framework if necessary. As a general rule, additional complexity in the tariff framework should be justified by some specific reason or objective to be achieved, and the costs of implementation carefully assessed. In any case, the tariffs should be thoroughly explained to the customers so any misunderstandings are avoided and they are not interpreted as hidden costs.

Time of Use: As the Bambadinca example shows, different day and night tariffs can be set up in a mini-grid in order to encourage daytime demand. The rationale behind this is that daytime demand is directly supplied by the PV, and is thus effectively cheaper to meet comparing to night loads which are supplied by the batteries or diesel gensets. In a solar-based mini-grid, tariffs should reflect the real time costs and incentives should be given to increase demand during daytime and limit it at night, so deep discharges of

[2] Cheapest monthly rate available is 15,000 CFA
[3] Cheapest tariff available
[4] Cheapest tariff available

the batteries or running of the diesel gensets are avoided. Furthermore, setting a cheaper daytime tariff and a more expensive night tariff would encourage productive/commercial activities

Different power based fee levels: as in the Contuboel case (or the EAGB tariff), several flat fee brackets could be set up in order to differentiate customers depending on their power needs. For example, the tariff fees suggested above for Bissora could be applied for a standard connection, with up to 1 or 1,5 kW of power available. Users requiring a higher capacity could be included in an upper flat fee band. However, it is not expected that this differentiation would increase revenues that significantly, and it could require additional technical costs in adapting the meters and in monitoring its correct application.

6.3. Sensitivity against demand levels

Real demand levels and its evolution over time (including potential mini-grid expansions) are the most significant factors affecting the mini-grid profitability. The following figure shows the NPV for the operator in year 10 for different demand figures, as compared with current assumptions.

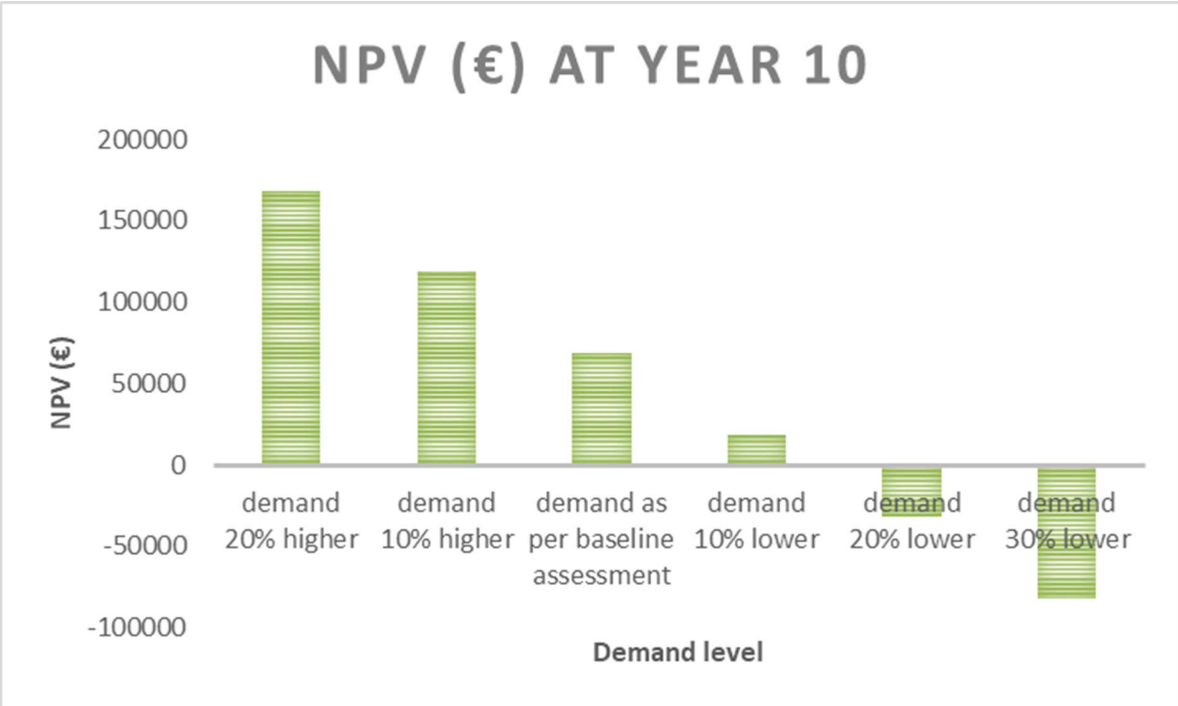

Figure 6: NPV sensitivity to different demand levels

Given that current demand estimates and connection rates are rather conservative, it is more likely that real demand figures will be higher, thus generating more benefits for the operator. In fact, the opportunity to achieve greater profitability in such scenario will likely act as an incentive for any operator to connect the initial 470 customers as fast as possible, as well as to facilitate mini-grid expansions. In order to ensure that customers also benefit from this situation, tariff revision mechanisms could be designed in order to gradually reduce tariffs if demand grows faster than expected, (while still incentivizing the operator to add new customers to the mini-grid).

On the other hand, if demand is lower than expected it might not be so popular (or viable altogether) to raise tariffs to compensate for it. But in this case, as argued just above, the operator would have a strong interest in bringing new customers (beyond the initial 470) to the grid and specific measures could be designed to support this, as well as to boost the existing or new innovative commercial uses. Additionally, batteries and other components could last a bit longer in such low demand scenario, allowing the operator to save some extra funds before having to replace them and diesel consumption would be kept to a minimum.

7. Next steps

This document has provided an overview of the factors (regulatory, cost related, demand related) that need to be taken into account when defining the tariff framework for the Bissora mini-grid, as well as a preliminary proposal of tariff levels that would allow for its commercial operation and maintenance over time.

Based on this proposal, next steps would involve consultation or relevant stakeholders and decision-making on some specific issues:

- Confirmation of tariff levels to be applied, both flat and variable rates.
- Discussion of available tariff refinement options (time of use tariffs, increasing flat rates based on capacity) and decision on whether to include any of them.

Moreover, such consultation process should also address several relevant aspects at the intersection between the tariff study and the management model:

- Tariff revisions: when they should happen and how to conduct them (for example, which factors have to be assessed: demand, real O&M costs, etc.).
- Replacement of components: how to ensure that revenues are used for the intended goals. For example, when it comes to battery replacements or additional connections, how to make sure that funds are there when needed. As a potential solution, an agreement can be reached with component suppliers so that some tariff revenues are directly channelled to them over time.
- Service level indicators/requirements for the operator, and potential penalties.
- Need for a local committee in Bissora that acts as the focal point for such kind of questions.