TOOL 3

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USER MANUAL FOR THE FINANCIAL MODEL TO ASSESS THE VIABILITY OF CAPTIVE SOLAR PV SYSTEMS FOR BUSINESSES

CICSA
CLEAN CAPTIVE INSTALLATIONS FOR INDUSTRIAL CLIENTS IN SUB-SAHARA AFRICA

Frankfurt School
FS-UNEP Collaborating Centre
for Climate & Sustainable Energy Finance

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INTRODUCTION

This tool is published under the project titled "Clean Captive Installations for Industrial Clients in Sub-Saharan Africa" developed in four partner African countries: Ghana, Kenya, Nigeria and South Africa.

The Project

The project aims to demonstrate the economic and financial viability of clean captive energy installations for industries and to enhance their adoption in the four partner countries and beyond to the entire continent. Captive energy installations refer to the energy generating technologies installed by commercial or industrial organization on their sites. Those installations are deemed captive as the electricity produced is generated for the industrial's plant's own use and sometimes for neighbouring communities. Clean captive installations refer to those installations powered by renewable sources of energy such as solar or industrial waste. . Captive power plants can operate off-grid or can be connected to the grid to feed in excess generation.

Renewable energy captive installations alleviate the pressure to generate electricity from national grids and reduce industrial clients' needs to rely on private supplementary fossil-fuelled generators, which are expensive to run. These clean captive installations are frequently referred to as the second generation of renewable energy business models, as they do not rely on national governments' incentivizing policies to enhance the deployment of clean energy technologies.

The "Clean Captive Installations for industrial Clients in Sub-Sahara Africa" project will strengthen the ability of partner countries to move towards low carbon-emitting development strategies. It also contributes to several Sustainable Development Goals, including Climate Action (SDG 13), Responsible Consumption and Production (SDG 12), Affordable and Clean Energy (SDG 7) and Industry, Innovation and Infrastructure (SDG 9). The project will raise awareness among industry players, financiers and governments, and will support the dissemination of clean modern energy technology through business models tailored to the national contexts and beyond throughout sub-Saharan Africa.

This project is part of the International Climate Initiative (IKI) of Germany. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supports this initiative based on a decision adopted by the German Bundestag.

The implementing team of the project comprises the United Nations Environment Programme (UNEP) in partnership with its collaborating centre at Frankfurt School of Finance & Management (Frankfurt School).

The project's activities fall under four components:

- Component 1: Baseline studies and awareness raising
- Component 2: Economic and financial tools and assessments
- Component 3: Realization of pilot projects in the four partner countries
- Component 4: Knowledge dissemination and outreach

The Tool

This tool falls under Component 2. Under this component four main tools are provided as follows:

- Tool 1: "Financing guidelines and business models for solar PV captive systems"
- Tool 2: "Metrics for assessing the financial viability of renewable energy systems/Cost Benefit Analysis of renewable energy programmes"
- Tool 3: "User Manual for the preliminary financial model to assess the viability of solar pv captive systems for businesses"
- Tool 4: "Best Available Technology (BAT) for solar PV captive systems"

The aim of this Tool 3 is to describe how to use a sample financial model that has been created under Component 2. This document also provides information that needs to be considered in order to develop an "ownership-based" solar PV model.

Please note:

- The technical terms referred to in this document are defined in annex and are further illustrated in Tool 4: "Best Available Technology (BAT) for solar PV captive systems", which provides the technical guidelines.
- This document refers to a financial model which is a sample generic model and does not take into account specific rules and regulations, financing constraints, and other specifications that may be prevalent currently or in the future in each of the four partner countries
- The financial model in reference is a simple ownership model. It does not consider back-up diesel generator in the final LCOE calculation as it looks as the solar system as a standalone entity

In our experience, generic publicly available models do not meet the levels of sophistication that actual projects require given their transaction-specificity. Any minor changes in regulations, or financing costs, would significantly alter the viability of the project.

Hence we strongly recommend that each solar PV project develops its own bespoke model based on the business model being implemented, direct ownership or third party financing, on the regulations of the relavant country and financing availabilities, as many input considerations would vary. All of these would make this sample model redundant and misleading in use.

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1. MODEL INPUTS

1.1. Overview

There are some primary requirements needed in order to be able to conduct the financial assessment of solar PV projects. Those requirements can be categorized as follows:

Solar costs: This will establish the total cost of the system for the life of the project and individual component cost like inverter costs and batteries which need to be replaced in later years[1]

- The cost of the system including the breakdown.
- Breakdown is important for solar panels, inverters, controllers and batteries (in case of stand-alone system). Rest of the cost can be clubbed together. If the breakdown is not given, then rule of thumb cost appropriation[2] can be used

Technical solar specification: This will establish the total potential output of the system

- Identifying the system size
- Generation Utilization (allowing a further conservative estimate of solar yield in case of power outages and losses)
- Total Generation Potential, given a specific location. Ballpark figures can be used if it is just a preliminary analysis

Electricity prices: This will establish unit prices that will work with the system cost (see Point number 1 above) to establish total savings of the system for the life of project

- Grid tariff rates such as energy and demand charges
- Any alternate generation cost (that solar will substitute)
- Net-Metering benefit
- Future price increase (annual increase)

Usage patterns: This will establish correct electricity price appropriation and will work together with solar costs and electricity prices together to give accurate savings

a. Percentage of usage that will consume from solar system directly
b. Percentage of production that will be extra (sent back to the grid in case of net metering)
c. Percentage of solar generation that is lost
d. Percentage of solar energy used to substitute the generation from Gensets

Financing costs: This will establish the financing cost for the project. This model assumes a direct ownership with a debt and equity financing structure

- Total financing rate
- Tenor of the loan
- Down payment amount

[1] *Please refer to Tool 4: "Best Available Technology (BAT) for Solar PV Captive Systems" for more technical clarification.*

[2] *For a grid mounted system, equipment combined represent approximately over 52% of total CAPEX depending on the country, region and market maturity (Source: IRENA 2018) and other costs, such as installation and soft costs, represent the remaining. An approximation of the costs is provided in Tool 4 based on an example from Ghana. In case of batteries, their cost needs to be added to the CAPEX. Estimate cost for batteries will range from USD 473/kWh to USD 1,260/kWh for lithium-ion batteries (Source: IRENA 2017). This cost varies according to the battery technology used, region and country.*

Macro-economic outlook / other assumptions: This will establish any running costs and, from there, the Net Present Value of the system

- Cost of Equity and Corporate Tax rate to determine the Weighted Average Capital Cost (WACC)/Discount Rate)
- Operation & Maintenance (O&M) costs and annual increase (inflation based)

The following section provides a detailed illustration on how the above-mentioned requirements are utilized in the model.

1.2. Model Input Sheet

The input sheet is divided in six categories: Assumption for grid electricity, Assumptions for solar system, CAPEX and OPEX assumptions, Financing Assumptions, Other assumptions and Solar Production Profile.

The model is created in such a manner that all cells in Yellow are user inputs while all cells in **Grey** are automatic calculations.

Only input figures in the Yellow cells. The method of input is stated in each section of the model as there are two input methods; a choice from a drop-down list or user entry. The option for drop down list is only available in the section related to the grid electricity assumptions.

1.2.1. Assumption for grid electricity

Electricity prices

Grid tariff rates (per kWh)		
Energy tariff paid (per kWh)	*Input*	
Future annual grid price increase	*Input*	

<u>Energy tariff paid (per kWh):</u> Based on the energy bill, the energy tariff prices are to be entered. If the energy tariff entered are "pre-tax" amounts, then LCOE calculation should also be "pre-tax" by maintaining tax amount as 0%.

Each of the target countries will have their own tariff structure and this is reflected in the tabs marked "Kenya", "Ghana", "Nigeria", and "South Africa".

<u>Future annual grid price increase</u>: This is the annual average electricity price increase which will be applied to the variable/peak rate identified in the model to calculate revenues from Direct Consumption.

1.2.2. Assumption for solar system

System Assumptions

System size (kWp)	*Input*	
Generation utilisation	*Input*	
Generation potential (kWh/kW)	*Input*	
Annual panel degradation	*Input*	
Panel life	*Input*	

<u>System size (kWp)</u>: The size of the system being considered for the project (in KW)

Generation utilisation: This is the amount of solar generation utilized; if you want to see conservative numbers then this number could be changed to a lower percentage. However, in the Sensitivity section a sensitivity analysis is provided that gives different outputs at different Generation Utilization. Generally, this figure can be lower if you want to consider the effect of power breakdowns during the day (as solar will stop working during such breakdowns assuming that it is connected to the grid and the grid is down).

Annual panel degradation: This is the annual solar panel degradation factor. This ranges from 0% to 1% however this can be set at 0.5% based on global averages.

Panel life: This is the total useful life of the panels and normally this is between 20-25 years.

System Usage

Solar generation utilisation		
Solar PV immediate consumption	*Input*	
Solar PV deferred consumption	*Input*	
Solar PV lost	*Input*	
Solar generation used to substitute back-up gens	*Input*	
Total utilisation	*Calculation*	**0.0%**

The section solar generation utilisation provides the consumption pattern for the facility and ascertains the different revenue streams. As there is no net-metering benefits, which is currently the case in the four partner countries of the Clean Captive Installations project, the most relevant cells are Solar PV immediate consumption, Solar PV that is lost and Solar generation used to substitute back-up gensets. Batteries can also be used in which case solar PV deferred consumption line would need to be filled in. However, usage of batteries would increase the cost of installation.

Solar PV immediate consumption: Identify the percentage of solar generation utilized or consumed directly. This should never be above 75% since some of the units will eventually be excess and net-metered. Unless the case is of a large industrial user whereby the running load is, for example, 800KW which is everyday throughout the year and only 100KW of solar is installed. In that case almost all of the solar will be utilized directly. However other consumers like commercial businesses will have off-days/low consumption days. The units accounted for this category will be assigned a higher price - since it will also avoid taxes - so it has to be selected carefully and should not be overestimated.

Solar PV deferred consumption: Identify the percentage of solar generation which are sent back to the grid and are in excess of grid consumption level. These will be rare cases in case the facility is used throughout the year. However there may be cases such as schools, residential houses with seasonal vacancies and industries that are shut off in few seasons. There may be months where majority of the units will be sent back to the grid making these units higher than the units consumed from the grid.

Solar PV lost: Identify the percentage of excess solar generation which cannot be utilized or sent to the grid either due to the absence of net metering or limited grid capacity. In the case when net metering is available, the losses are reduced as the excess is being sent to the grid and then the losses are re-calculated. This is considered in the model.

Solar generation used to substitute back-up gensets: Identify the percentage of solar generation which substitutes any backup power source like generators. This is for the cases where the grid-tied solar is also tied/synced with generator. Some units will then be used to substitute the units from the generator. This can be in the case for large commercial/industrial for largescale generators and where generators are used extensively (due to load-shedding or load-management) to justify the added cost of the controllers required.

1.2.3. *CAPEX and OPEX assumptions:*

CAPEX

System costs per kWp		***in USD***
Cost of panels	*Input*	
Cost of inverter	*Input*	
Mounting structure, cabling, installation, acces	*Input*	
Net metering compliance (if any)	*Input*	
Generator sync controller	*Input*	
Other costs	*Input*	
Total costs per kWp	*Calculation*	**0**
Total system costs (Capex)	*Calculation*	**0**

Identify the cost breakdown for each component of the system cost. This is usually provided in the commercial or financial offer from the developer. In case the cost breakdown is not given refer to **BAT document section 4** for approximate cost estimations.

Replacement capex		
Frequency of inverter replacement (years)	*Input*	
Amount for inverter replacement every 10 yea	*Calculation*	**0**
Number of times inverter needs replacement	*Calculation*	**n.a.**
Cost of inverter replacement at 10th period	*Calculation*	**0**
Cost of inverter replacement at 20th period	*Calculation*	**0**

Frequency of inverter replacement (in years): This is how frequently the inverter will need to be replaced. Most inverters can last between 8-12 years depending on the make. Generally, this can be kept at "10".

Amount for inverter replacement every 10 years: This is the cost of inverter replacements and is based on the price of the inverter.

Number of times inverter needs replacement: If the Solar PV panel lifetime is 25 years and the inverters last for 10 years, then the inverters will need replacement at end of year 10 and end of year 20 – i.e. they will be replaced two times.

Cost of inverter replacement at 10th period and 20th period: This refers to the cost of future inverter replacements.

Depreciation

Depreciation period (years)	*Input*	
Depreciation method	*Assumption*	**Straight line**
Replacement capex depreciation (years)	*Input*	
Depreciation method	*Assumption*	**Straight line**

Depreciation period (in years): This refers to the number of years the capex will be depreciated for. Based on individual countries' regulations, accelerated depreciation might be allowed, thereby providing tax incentives for investing in own solar PV assets.

Replacement capex depreciation (in years): This refers to the number of years the replacement inverters will be depreciated for.

Depreciation method: In this model, a simple straight-line depreciation of asset (both capex and replacement capex) is assumed.

OPEX

Opex		
Insurance costs (on panels)	*Input*	
Insurance period (years)	*Input*	
Insurance costs (on panels) in amount per annum	*Calculation*	
Insurance annual costs increase	*Input*	
O&M costs (currency/kWp)	*Input*	
O&M annual costs increase	*Input*	

Insurance cost (on panels): Identify insurance costs that can be applied to the cost of the panels. Panels are equipment with longer life and are therefore often insured.

Insurance period (in years): Identify the tenor for insurance cover.

Operations & maintenance costs (MU/kWp); Identify annual O&M cost per kWp. Some amount should be considered for occasional break–down / wire replacement and cleaning.

1.2.4. Financing assumptions

Cost of equity	*Input*	
Re-financing rate	*Input*	
Spread	*Input*	
Cost of debt	*Calculation*	**0.0%**
Loan tenor (in years)	*Input*	
Grace period (in years)	*Input*	
Down payment (%)	*Input*	
Down payment (equity amount)	*Calculation*	**0**
Loan from bank	*Calculation*	**0**
Total investment	*Calculation*	**0**
		No error
Marginal corporate tax rate	*Input*	
Cost of capital (WACC)	*Calculation*	**0.00%**

Cost of equity: This is the required rate of return for equity investors. Since this project is "ownership-based model" the cost of equity would be the minimum IRR that would be acceptable for the equity investor who is also the owner of the asset.

Re-finance rate: The refinance rate as applicable per central banking ruler per country. This could be changed to market rate.

Spread: Enter the bank spread/margin over the refinance rate (if available). If the market rate was used in the re-finance rate, than "0" could be used for the spread value or it could be left blank.

Cost of debt: This will be automatically calculated as (re-financing rate + spread).

Loan tenor (in years): Identify the tenor of the loan.

Grace period (in years): Is the maximum period after the due date during which the payments may be made without having any penalties imposed upon by the debt provider.

Down payment (%): Identify the percentage of equity/down payment required from the investor/owner. The respective down payment value (MU), Loan from bank value (MU) & Total investment value (MU) will automatically be calculated.

Marginal corporate tax rate: Identify the prevalent marginal corporate tax rate.

Cost of capital (WACC): This is the weighted average cost of capital which is calculated based on cost of equity, cost of debt, capital structure of the investment and the applicable marginal corporate tax rate. This is used as the discount rate for project cash flows.

1.2.5. Other assumptions

CO_2 Savings (kg/kWh)	Input	0.74

$C0_2$ savings (kg/kWh): Identify the prevalent carbon emission savings (kg) per unit of solar PV electricity generated depending on the country and/or diesel genset replacement. As an indication :

- Diesel genset replacement: 0.6 kg/kWh of CO_2 on average.
- Africa's average CO_2 emission factor from grid electricity is 0.74 (Brander, 2011). Detailed grid emission factor per country are listed below:

Country	Emission factor (kgCO2/kWh)
Ghana	0.214767509
Kenya	0.332297783
Nigeria	0.43963136
South Africa	1.069026617
Africa's average	0.73576632

1.2.6. Solar Production Profile

Hours of irradiation: This is the duration of sunshine hours for each month of the year and can be obtained from reliable online sources based on location[3].

The model then calculates the expected kWh for 1KW system and for the specified system based on the system size entered by the user in Assumptions for solar system. The graph shows the solar generation for each month based on the entered system size. This calculation for energy generated from solar is preliminary to provide an overview of the expected energy generation and cannot be considered as a final value as there are no considerations of losses or other system limitations. If a detailed technical analysis has been performed, the exact energy generation for each month can be used.

[3] *Such as https://power.larc.nasa.gov/data-access-viewer/ which is developed by NASA. The data can be downloaded as an excel file, by specifying the latitude and the longitude of the establishment location and choosing solar geometry under the select parameters.*

2. MODEL OUTPUT SHEET

Returns and other metrics			
Project IRR (pre-financing costs)	*Calculation*	14.59%	in %
Equity IRR	*Calculation*	21.67%	in %
NPV of project cash flows	*Calculation*	195,506	in USD
NPV of cash flows to equity holders	*Calculation*	43,624	in USD
LCOE (pre-tax)	*Calculation*	0.08	in USD/kWh
Simple payback period	*Calculation*	9.00	in years
Monthly Debt Service Payment	*Calculation*	3,118	in USD
Monthly gross saving for first year	*Calculation*	4,456	in USD
CO_2 savings	*From "Inputs" sheet*	167,856	in kg/year

The returns and other metrics shown in the above figure are example values.

The model output sheet should compute the following metrics:

- Project IRR (%) – The Internal Rate of Return for the project
- Equity IRR (%) – The Internal Rate of Return for the project, including financing costs.
- NPV of project cash flows – The Net Present Value of discounted project cash flows
- NPV of cash flows to equity holders - The Net Present Value of discounted cash flows to equity holders
- LCOE (pre-tax) – the Levelized Cost of Electricity for the project. In other words, the average cost of the electricity unit produced by the solar PV plant.
- Simple Payback Period in years for the project
- Monthly Debt Service is the monthly instalment paid by the power customer
- Monthly Gross Savings for first year: the average monthly gross saving based on the first year's generation
- CO_2 Savings – the annual carbon emission saved due to the solar project

3. SENSITIVITY SHEET

The sensitivity sheet provides the impact on an output (see above) by varying two model inputs. In doing so, the user will be able to simulate some uncertainties in the input values of the model, hence helping to take informed decisions. In doing so, it also helps assessing the risk of a certain project.

Three outputs are sensitised:

- Payback period (years)
- Monthly Gross Savings (MU)
- IRR (%)

Two sets of inputs are simultaneously sensitized:

- Panel Degradation & Generation Utilization
- Electricity Price Increase (%) & Generation Utilization

Sample below shows

- Monthly gross savings for 1st year, given varying solar generation utilisation and panel degradation
- Monthly gross savings for 1st year, given varying solar generation utilisation and electricity price increase

Monthly gross savings for 1st year given varying solar generation utilisation and panel degradation

Monthly gross		Generation utilisation (considering grid power outages)				
	4,455.53	80.00%	85.00%	90.00%	95.00%	100.00%
Panel Degradation	1.00%	4,433.14	4,433.14	4,433.14	4,433.14	4,433.14
	0.80%	4,442.10	4,442.10	4,442.10	4,442.10	4,442.10
	0.60%	4,451.05	4,451.05	4,451.05	4,451.05	4,451.05
	0.40%	4,460.01	4,460.01	4,460.01	4,460.01	4,460.01
	0.20%	4,468.97	4,468.97	4,468.97	4,468.97	4,468.97

Monthly gross savings for 1st year given varying solar generation utilisation and electricity price increase

Monthly gross		Generation utilisation (considering grid power outages)				
	4,455.53	80.00%	85.00%	90.00%	95.00%	100.00%
Electricity price increase	0.00%	4,325.76	4,325.76	4,325.76	4,325.76	4,325.76
	2.00%	4,412.28	4,412.28	4,412.28	4,412.28	4,412.28
	4.00%	4,498.79	4,498.79	4,498.79	4,498.79	4,498.79
	6.00%	4,585.31	4,585.31	4,585.31	4,585.31	4,585.31
	8.00%	4,671.82	4,671.82	4,671.82	4,671.82	4,671.82

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ANNEX: GLOSSARY OF TERMS

AC	Alternating Current
DC	Direct Current
Direct Consumption	Units consumed directly by the system, just as they are produced (rather than exporting it to the grid or letting it pass through the system meter)
DISCO	DIStribution COmpany; utility that distributes electricity and collects bill payments
Genset	Generator that converts heat into mechanical energy, mostly fossil-fuelled
GST	General Sales Tax
Inverter	Device that converts DC power to AC
KVA	Kilo-volt Ampere; a measure of apparent power
KW	Kilowatt; unit of power
kWh	Kilowatt-hour; unit of electricity consumption
Mono/Mono-crystalline	Type of solar panels that are made with a single source of silicon
MU	Monetary Unit
Net-Metering	Billing mechanism that allows energy system owners to supply electricity to the grid in return for credits/payments
Poly/Poly-crystalline	Type of solar panels that are made from multiple sources of silicon
PV	PhotoVoltaic
WACC	Weighted Average Cost of Capital

For more information

CLEAN CAPTIVE INSTALLATIONS FOR INDUSTRIAL CLIENTS IN SUB-SAHARA AFRICA

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