TOOL 4 JULY 2020

BEST AVAILABLE TECHNOLOGY FOR SOLAR PV CAPTIVE SYSTEMS

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

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

UN environment programme

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 installations refer to the energy generating technologies installed by industrial or commercial organizations on their sites. Those installations are deemed captive as the electricity produced is generated for the industrial 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"

This Tool 4 provides guidelines for the technical development of the PV captive solar installations, based on the best practices currently adopted by the industry and developed by international organizations such as IFC (International Finance Corporation), IEA (International Energy Agency), the German cooperation agency GIZ and the United Nations Development Programme (UNDP)'s CEDRO 4 programme.

Additionally, this tool presents the top listed technology providers prevalent in the market who might be operating in each of the four countries and the characteristics and costs of their systems and identifies various technologies for solar PV systems.

The information provided in this tool is based on best available sources found. It is provided as guidelines to support potential clean captive clients on making an informed decision when selecting solar PV equipment manufacturers and/or installers.

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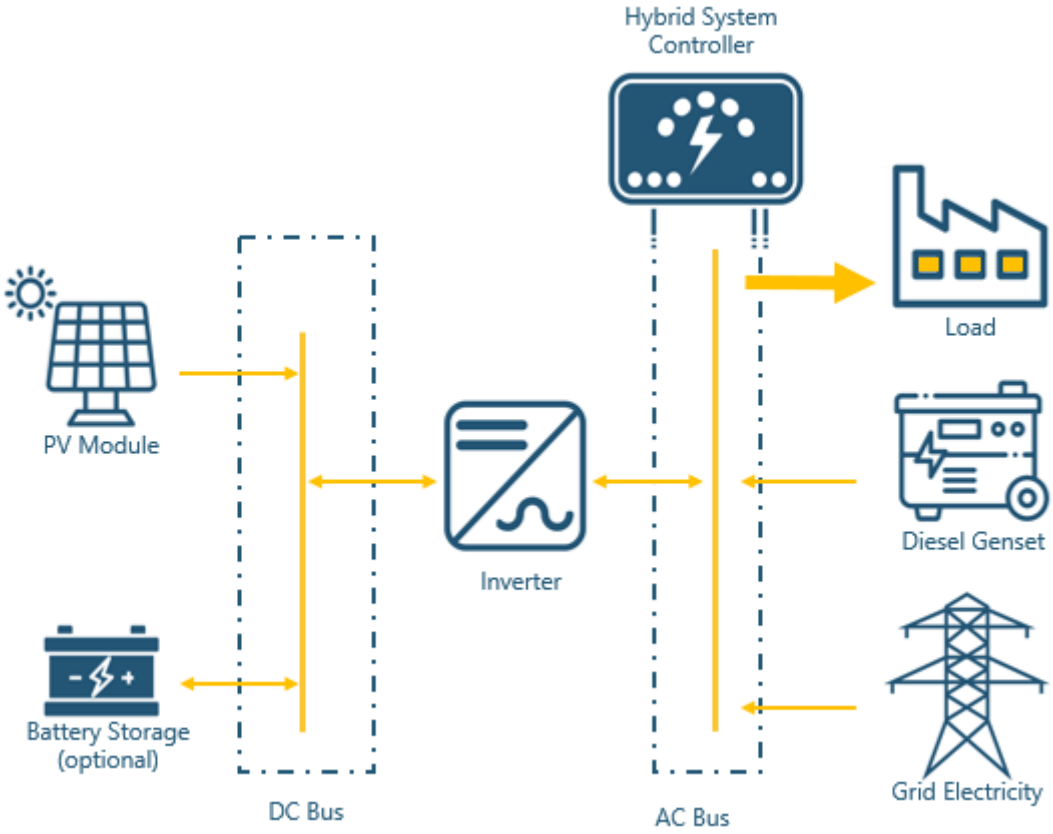
For more information

For more information about this document or on the *Clean Captive Installations for Industrial Clients in Sub-Sahara Africa* project, visit : www.captiverenewables-aftrica.org
or contact: info@captiverenewables-africa.org

2. COMPONENTS OF A SOLAR PV SYSTEM.

This section lays down the main components of a solar PV system and explores different qualitative criteria that can be used to identify high-grade systems amongst the vast variety that is available in the current market. By reducing information asymmetries, initially in favour of installers, it aims to facilitate the selection process and reduce the risk of choosing low-quality systems. The aim of this section is to provide a general overview on the best practices available in the market during the time of publication. As the market for Solar PV is dynamic and continuously developing, the market's evolvement should be considered during the time of implementation. Every solar PV system is composed of five distinct equipment parts, namely i) the PV module, ii) the inverter, iii) the hybrid system controller, iv) the mounting system, and (v) the batteries in case of storage. In the following paragraphs, each of the components is assessed individually based on specific quantitative criteria that have been defined for a more holistic understanding. The design of the system also has an impact on the overall efficiency and recommendations that are listed below.

***FIGURE 1** Solar Diesel Hybrid System Components.*



Additionally, further criteria for screening and identifying acceptable manufacturers must be considered.:

- *Proven product with significant track record* – Manufacturers need to demonstrate a proven product that carries a track record in large, non-recourse commercial projects
- *Production capacity* - The manufacturers' overall production capacity (MW) should be sufficiently large to satisfy the demand
- *Financial stability* – Manufacturers need solvent balance sheets that can provide evidence for financial stability and further reduce any risk of supply shortages.

- *Local presence*. A strong and proven local presence, i.e. a local office with staff, or a widely used brand with strong technical track record suitable for the country conditions as well as experience working internationally are indicators for being well-established in the market

While each country may have design requirement specific to their context, the ten following guidelines can be applied:

- The PV penetration rate in the hybrid system, defined as the ratio between PV peak power and genset nominal power, depends on the design and the area available for the installation, however a ratio of at least 20% is recommended to be targeted to achieve appropriate fuel savings considering the minimum load factor of the genset required to avoid efficiency losses.
- In case of grid connection, the connection of the PV installation should be in accordance to the local grid conditions.
- Roof installations should comply with the local legislation and be based on the roof load analysis to ensure that the roof is suitable and can safely sustain the PV system load
- In case of ground installations, the land topology should be flat and present no risks from groundwater level or other geotechnical aspects such as soil resistivity and suitability for the PV system load.
- Highly efficient modules and inverters should be used to achieve the performance ratio required
- Only one type of PV module is to be used and all modules should have the same rated power to avoid module mismatch and the respective losses
- Voltage drop on the main Direct Current (DC) cable, which is the cable between the PV module and the inverter, should be less than 3% at Standard Testing Conditions (STC) to minimize losses, and 2% at STC between the PV arrays and charge controller, and the charge controller to battery in case of storage
- In general, cables selections and sizing should comply with the national regulations and codes.
- Appropriate maintenance and cleaning plan is required in order to reduce soiling losses. Cleaning of the modules should be done with water having low mineral content.
- It is important that the inverters are well ventilated and are not installed where they are exposed to direct sunlight.

2.1. PV Module

Available PV Module Technology

The solar PV industry is extremely dynamic and innovative thereby resulting in a vast spectrum of different technologies. There are three most relevant types of PV modules:

- *Crystalline Silicon (C-Si)* – these can be further differentiated into Mono-Crystalline and Poly-Crystalline technologies. They differ with regards to sources of silicone and efficiency. Mono-Crystalline technology is made with a single source of silicone, whereas Poly-Crystalline technology is made by blending multiple sources of silicone. With regards to efficiency, Mono-Crystalline panels can exceed 20% in efficiency, in contrast to the 15-18% efficiency for Poly-Crystalline technology which has lower heat tolerance. Costs for C-Si technology have drastically decreased due to (i) technological improvements and (ii) rising demand as PV has high potential for scalability.
- *Thin-Film (TF) panels* - these are flexible and can be put on curved surfaces. However they have extremely low efficiencies and thereby require more space.
- *Concentrator Photovoltaics (CPV)* - these use lenses and mirrors to focus sunlight onto small, highly efficient, multi-junction solar cells and thereby reduce the needed cell area. Since prices cannot yet compete with other technologies, this technology is only profitable for utility-scale projects.
- The relatively high efficiency compared to its cost and reliability makes C-Si currently the dominant PV technology in the market and the most reasonable solution for small and medium scale installations.

PV Module Manufacturer Landscape

Although there are many global actors in the manufacturer landscape, this competitive environment is dominated by a handful of companies and is constantly changing. In order to navigate this dynamic landscape, recommendations for products selection are given below

Recommendations[1]

- Product warranty[2]
  - PV modules performance should be guaranteed for 25 years or for instance, 90% of the minimum peak power after 10 years of supply, and 80% of the minimum peak power after 25 years of supply
  - Manufacturer warranty should apply for a minimum of 10 years
- Power Tolerance (electrical power of the solar panel produced above or below its rated capacity) should be within 0/+3%, and modules should be flash test certificated
- Temperature coefficient (percentage of power reduction per °C rise) should range between -0.3% and -0.5%
- Performance ratio, defined as the percentage of the actually produced solar energy vs the calculated one, should be over 80%. It reflects the overall installation efficiency and losses)
- Losses due to shading, from nearby buildings, trees, etc. or between the PV modules rows, should be less than 1% per year however it should not exceed 4% per year

[1] *based on the best practices currently adopted by the industry and developed by international organizations such as IFC (International Finance Corporation), IEA (International Energy Agency), the German cooperation agency GIZ and the United Nations Development Programme (UNDP)'s CEDRO 4 programme. As noted above, the market is very dynamic, and recommendations might become outdated.*

[2] *PV module manufacturers usually guarantee their product for a period of 10-12 years, which can be extended for a fee. In addition, PV module performance is guaranteed for 25 years. In this sense, the industrial standards are that, after 10 years, the output power shall not be less than 90% of the minimum output power set in the specification and after 25 years this percentage shall not be lower than 80%.*

- The PV module degradation rate, which is the decline of the solar energy output of the module over time, should be less than or equal to 0.7% per year
- PV modules should be certified according to the Standards of the International Electrotechnical Commission (IEC)[3] to ensure the quality and the proper technical performance of the products. The following table lists the most relevant technical specifications in this regard:

STANDARDS	
1	Data sheet and name plate information for photovoltaic modules (EN 50380:2003)
2	Terrestrial PV modules – Design qualification and type approval – Part 1-1: Special requirements for testing of crystalline silicon PV modules (IEC 61215-2:2016)
3	Terrestrial PV modules – Design qualification and type approval – Part 2: Test procedures (IEC 61215-2:2016)
4	UV test of PV modules (IEC 61215-2:2016)
5	Salt mist corrosion testing of PV modules (IEC 61701:2011)
6	PV modules – Ammonia corrosion testing (IEC 62716:2013)
7	PV modules safety qualification – Part 1: requirements for construction (IEC61730-2:2004 + AMD1:2011+AMD2:2013:CSV consolidated version)
8	PV modules safety qualification – Part 2: Requirements for testing (IEC 61730-1:2004+AMD1:2011 CSV, consolidated version)
9	PV modules performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating (IEC 61853-1:2011)
10	Module cables standards: IEC 60502, IEC 60228, 60364-1, 60332-1/2, 60754-1/2 and 61034.

[3] All four partner countries are members of the IEC. IEC certifications apply not only to renewable energy equipment but to almost all engineering products. National standards for solar PV system components are not available as currently very few, if any, modules or inverters are manufactured in sub-Sahara Africa.

Below is a list of "Tier 1" PV module manufacturers established by Bloomberg, published on many online solar review platforms, and updated every year on a quarterly basis. However, Tier 1 methodology differs from one analysis to the other, and other reputable manufacturers are may be active in the four target countries, even though they are not mentioned in the list below, such as Panasonic, Solaria, Winaico, SolarWat and Kyocera and Orb Energy. However, when deciding between alternatives, a case-by-case review of the specific offering by PV manufacturers is to be undertaken

Bloomberg List of Tier 1 Manufacturers of PV modules

To qualify as a Tier 1 Manufacturer, the company needs to demonstrate:

- At least six different projects of 1.5 MW or more in the past two years
- List of projects that have received non-recourse debt financing by six different banks (where available – otherwise additional documentation is needed)
- Ownership of production facilities and the brand name
- not to have filed for bankruptcy, insolvency, or have defaulted on bond payments

List of Tier-1 Solar Panels - March 2020 (Solar Review, 2020)

1	Jinko	11	Seraphim	21	RE Group	31	Ulica Solar
2	Longi	12	Suntech	22	Neo Solar Power/URE	32	Shinsung
3	JA solar	13	Astronergy	23	HT-SAAE	33	Hansol Technics
4	Canadian Solar	14	Znshine	24	Adani/Mundra	34	Hyundai
5	Risen	15	Jinergy	25	Vietnam Sunergy	35	S-Energy
6	Hanwha Q-Cells	16	BYD	26	Boviet	36	Goldi Solar
7	Trina Solar	17	SunPower/Maxeon	27	Lightway	37	Recom
8	GCL Systems	18	LG Electronics	28	Vikram Solar	38	Heliene
9	First Solar	19	Phono Solar	29	Jolywood	39	Sharp
10	Talesun	20	Waaree	30	Hendigan GMEGC		

2.2. Inverter

The primary function of the inverter is to convert Direct Current (DC) generated from solar panels into Alternating Current (AC), which can then be used to power appliances in facilities. The inverter also smartly manages the operations by managing the "dispatch order" of solar power and grid power (for grid-connected systems) or with any back-up sources attached such as batteries.

Recommendations

- The DC to AC conversion incurs some losses, around 2-5% depending on the inverter
- Inverters are the only equipment that will be replaced at least once during the lifetime of a project (most likely within 8-10 years) for a system with no storage
- Inverters have an in-built mechanism for handling voltage fluctuations
- Most inverters now also come with an in-built data monitoring/Wi-Fi device to monitor production remotely/online
- Inverter efficiency varies depending on its manufacturer. Inverters manufactured according to European Efficiency standards have a typical efficiency of 95% and a peak efficiency of 98%
- The power ratio, defined as the DC to AC ratio, relevant for the inverter sizing, depends on the design. It should be in the range of 0.8 to 1.2.
- Inverters standard compliance depends on the type of the inverter used. However, the table below lists the standards of the International Electro technical Commission that most of the inverters top manufacturers comply with.

STANDARDS	
1	Data sheet and name plate for photovoltaic inverters (EN 50524:2009)
2 (in case of grid connection)	• Photovoltaic (PV) systems – Characteristics of the utility interface (IEC 61727) or Requirements for micro-generating plants to be connected in parallel with public low voltage distribution networks (EN 50438). • Islanding prevention measures for utility-interconnected photovoltaic inverters (IEC 62116: 2008)
3	Safety of power converters for use in photovoltaic power systems (IEC 62109-1&2: 2011-201)
4	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency (IEC 61683:1999)

Inverter Warranties

Most inverters (grid-tied) have a standard warranty for 5 years which covers materials and processing defects. The warranty does not cover any consumables and parts that are subject to wear and tear such as fuses, filters, overvoltage protection devices. The warranty does not cover any fires/burning incidents. Most top end brands provide an option to purchase warranty extensions for up to 10, 15 and 20 years.

Inverter Manufacturers

There are multiple brands of inverters and options, primarily of Chinese and European origin. Top manufacturers include Fronius, SMA, SolarEdge, Sungrow, ABB based on failure rate, days to replace units, and warranty offered.

2.3. Hybrid System Controller

A hybrid system consists of more than one source of energy generation. One of the most widely used hybrid systems is PV diesel hybrid system, which combines the generation from solar PV, gensets. PV diesel hybrid systems can be either on-grid or off-grid systems. They can also combine batteries to allow energy storage if needed. The main benefit of the hybrid power systems is that they ensure continuous and reliable power supply even during blackouts for on-grid systems compared non-hybrid systems. In addition to providing several other benefits such as fuel saving, enhanced or increased solar PV generation. These benefits are achieved with the use of hybrid system controller, which can be used for on-grid and off-grid applications.

A hybrid system controller is mainly an energy management tool programmed to allow the coupling of energy generation from the different energy sources used in the system. It also allows the monitoring, controlling and optimization of all the different components used in the system.

For on-grid systems, in the absence of a hybrid system controller, solar PV will not be allowed to generate energy during blackouts. This is mandatory to ensure the safety of the personal who may be operating to fix the grid failure. When using the hybrid system controller, generation form solar PV system will be allowed during blackouts coupled with the generation from gensets or battery systems.

For off-grid systems, the controller enables the optimization of the different generation sources allowing the maximum penetration of solar PV based on the installed capacity, thus leading to fuel consumption optimization.

Using the hybrid system controller may add to the overall system costs. However, they provide several benefits most significantly being the reliability and continuity of the power supply. There are several manufacturers providing such controllers such as elum, SMA, ENCOMBI and Woodward.

Recommendations

- Ensure the compatibility of the chosen controller with the inverter used
- Ensure the compatibility of the chosen controller with the gensets controllers used

- Number of gensets to be connected to the controller, as some controllers may have a limit to the number of gensets to be connected.
- Ensure that the controller allows the use of gensets and solar PV when the grid is down to achieve proper fuel savings and benefit from the functionality of the hybrid power systems.

2.4. Mounting System

Typical guarantees for solar PV mounted systems last for 10-15 years. An extended guarantee can be obtained for up to 25-30 years, in particular to address corrosion problems. In terms of material used, rooftop[4] mounted systems are mainly made of aluminium, while fixed PV systems can be made of steel or aluminium. Trackers are mostly made of steel. Mounting systems are tailored to the installation settings.

2.5. Storage

Batteries can be used for the storage of PV electricity. They are however more suitable for stand-alone systems, i.e. systems that are not connected to the grid, than for grid-connected systems. Moreover, battery storage for PV systems still needs to overcome different barriers such as cost-competitiveness, and the complexity of the design validated performance and safety measures. Below are the main recommendations for selection.

Recommendations

- Currently available technologies for batteries are lead-acid, lithium-ion, flow, nickel-based and sodium-based batteries.
    - Lead-acid batteries are the most used type of technology due to their availability in different sizes and lower upfront costs compared with other technologies
    - Lithium-ion are also increasingly offered by some battery manufacturers, which design specific products for renewable energy systems
    - The efficiency of the batteries depends on the type of technology used, however for lead-acid type it should be greater than 85% and for lithium-ion greater than 95% The battery cycle life, which is the number of times the battery can be charged and discharged before its capacity falls under 80% of its original capacity, depends on the technology used. It should not however be less than 2,000 for lead-acid and 5,000 for lithium-ion
- The battery's depth of Discharge (DoD), which is percentage that refers to the capacity of the battery which has been discharged relative to the overall capacity, varies depending on the technology, It should not however be less than 80%
- If short period usage is needed, it is recommended that lithium-ion batteries be used, due to their fast discharge and recharging process
- The selection of the battery technology should also take into consideration the temperature effect on the DoD and the cycle life
- It is recommended to place the battery in a dry, well ventilated environment
- A typical deep cycle battery has a life span of four to eight years before it should be replaced.

[4] *Most of the roof-mounted systems range from 1 to 100 kW; flat roofs are the only exception, as these systems can range between 50 to 500 kW and have been known to reach more than 1MW when placed on industrial roofs*

The table below lists the standards of the International Electrotechnical Commission that most battery manufacturers comply with.

STANDARDS	
1	Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests (IEC 60896-11 ed1.0); Stationary lead acid batteries - Part 21: Valve regulated types - Methods of test (IEC 60896-21 ed1.0); Stationary lead-acid batteries - Part 22: Valve regulated types (IEC 60896-22 ed1.0)
2	IEC 61427: Secondary cells and batteries for renewable energy storage – General requirements and methods of test Project IEC 61427-1 ed1.0 (Pre-release of the official standard): Photovoltaic off-grid application
3	IEC/TS 62257-8-1 ed1.0: Recommendations for small renewable energy and hybrid systems for rural electrification - Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries

There are numerous battery manufacturers currently active in the solar PV installation market. More information regarding the storage options products, their application, and country of origin can be found on online platforms for solar products, such as ENF Solar's (ENF, 2020).

3. INSTALLERS OF PV-SYSTEMS

The landscape of installers (ENF, 2020) varies in the four partner countries. To select a reliable installer, it is crucial to consider national standards or licensing schemes. Those will not only ensure high qualitative standards but also that national regulations are met. When selecting installers, the following recommendations are suggested:

Recommendations

- Licensing or industry-led certifications
- Price
- Number of employees
- Track record of installed systems in the country or region (e.g. completion certificates)
- Proper system design that ensures meeting the demand requirements and avoiding unnecessary oversizing of the system
- Availability after installation for Operations & Maintenance (O&M) requirements and warranties

The most relevant national schemes in the four partner countries are presented below.

Kenya

Kenya has developed a very strict licensing scheme that lays down a threefold classification of PV system technicians: T1 (small, single battery), T2 (medium size, inverter), T3 (grid-connected). Requirements of eligibility include both, educational background and practical experience.

An installer company will have to prove the permanent employment of at least one licensed PV technician to get an installer license. Depending on the size and the type of projects the installer company wants to be permitted to conduct, it applies to three types of licenses (C1, V1, V2,)[5], which in turn require different licensed PV technicians. For instance, in order to design and do installation work for PV systems, a C1 license with a class T3 technician is required. Licenses expire after one year and must be renewed.

Following installation, a completion certificates must be issued by law providing the following requirements; the date of installation, details of the person installing, details of the owner, in addition to location, capacity and warranty upon commissioning of the solar PV system (GoK, 2012). There are currently 485 licensed installers in the publicly available official government register (EPRA, 2018)

Ghana

With the Renewable Energy Act of 2011, the installation and maintenance of renewable energy facilities, including solar PV systems, falls under a licensing requirement. The requirements for the application are listed in the renewable energy license manual published by the Energy Commission (ECG, 2012).

There are 106 licensed PV system installers listed on the Energy Commission website as those recommended for residential PV systems (ECG, 2020). There is however no recommended list of installers provided for commercial and industrial uses. Best practices would be to contact the published list of installers for residential purposes to enquire their ability to install systems for commercial and industrial captive uses, as well as assessing other installers which are not listed in terms of practical experience and professional training as well.

South Africa

South Africa does not have an official licensing scheme for installers. There is however a reputable industry-led non-mandatory quality label and certification programme, named "The PV Green Card". Certified installers are registered in the PV Green Card database. By providing trainings, the programme ensures that high industry standards regarding relevant national and municipal electrical regulations are complied with and high proficiency of certified installers is maintained. It urges installers to document the undertaken work in accordance to set standards and to provide the client with all relevant details of a project as well as a checklist of all required installation steps. Furthermore, it assures compliance with national wiring codes that require licensing and proof of registration.

To select a suitable installer in South Africa, it is highly recommended to resort to the PV Green Card database in order to find an installer who follows the required standards and has high technical proficiency.

Nigeria

In Nigeria, licensing is necessary for a number of energy services, however not specifically for solar PV installation services. Electricity generation, transmission, system operation, distribution and trading are licensed by the government. In the absence of licensed installers, it is recommended to assess installers in terms of practical experience (track record) and professional training.

[5] *C1 licence enables the holder to preform activities related to design and installation of PV systems, in this case the technicians should be holding T3 licences. V1 license enables the holder to carry out activities related to distribution, promotion or sale of solar PV system in addition to design and installation activities. While V2 enables the holder to carry out activities related to manufacture or import of solar PV system components (GoK, 2012)*

4. SOLAR PV SYSTEM COSTS

Total costs for solar PV systems including installation can vary from USD 1.0/Wp to USD1.6/Wp, depending on the project-specific characteristics such as location, size of system, installer, type of equipment, etc. This table below presents indicative price ranges (USD/Wp) and indicative weights of the main system components. Other costs include installation and soft costs (such as system design, permitting).

SYSTEM COMPONENT	USD/WP (INDICATIVE RANGE)	% (INDICATIVE)
PV modules	0.4-0.7	40%
Inverter	0.1-0.2	10%
Mounting structure	0.1-0.2	10%
Other costs	0.4-0.5	40%
Total	**1.0-1.6**	**100%**

For illustration purpose, the project fact sheet of a 329 kWp solar PV system for a supermarket in Ghana installed in 2017 is presented here. It shows a total turnkey cost, i.e. including equipment, installation, permits, etc., of USD1.2/Wp, a total of USD399,634 .(Bettervest, 2020)

Project Fact Sheet

Shop N Save Project: A 329.4kWp Solar PV System (for energy generation and supply only – no storage).

System specification/price schedule:

This solar plant will **ONLY generate and supply energy (no storage)** to Shop & Save.
The intended solar plant will consist of **Solar Panels and PV Inverters.**
The monthly energy production for this solar plant is estimated at **41,174kWh.**

Art. No.	Qty.	Description
SPH-0265E	1243	Solar Modules Type & Rated Power: Phono Solar 265W Origin: China
SM1120000	1	Set of mounting system Extruded stainless steel material Origin: Germany
PSB25TL-30	11	PV Inverter Type: SMA Sunny Tripower STP 25000TL-30 Origin: Germany
PVD1602K	1	PV Diesel Hybrid Solution with SMA Cluster Controller Origin: Germany
IN-1130000	1	Set of installation materials Origin: Various EU countries
ELSP-11415	1	Electrical safety and protective devices Origin: Various EU countries
-	-	20 years Extended Warranty on PV Inverters
-	-	Installation

Turnkey cost of installation: **USD 399,634.00** (EUR 377,066.00)

5. CONCLUSION

This tool provides an overview of the technical guidelines applicable for a solar PV installation design based on the best practices followed by international organizations. General guidelines have also been provided for the selection of individual system components and manufacturers. Finally, the document has presented indicative system costs, advised for possible installers in the four countries and provided further recommendations for selecting those.

As indicated above further information regarding PV modules characteristics, prices and possible products comparison is widely available online which could be particularly helpful as the market evolves very rapidly. As examples, the global market on SolarQuotes (SQ 2020) provides information on solar products but does not cover Africa region. The platform ENF Solar (ENF, 2020), does cover the Africa region (and other regions globally) and is also a platform for solar products.

Specialized institutions in each of the four partner countries can also help with the selection of best available technologies. Below is a list of institutions with a technical background:

Kenya: The Kenya Renewable Energy Association: This is a non-for-profit organization which supports the development of the renewable energy sector. (http://web.kerea.org/)

Ghana and Nigeria: The ECOWAS Centre for Renewable energy and Energy Efficiency (ECREEE) provide services regarding knowledge management and awareness, in addition to other activities. (http://www.ecreee.org)

Nigeria: The Renewable Energy Association of Nigeria: A non-for-profit organization established by the stakeholders of the renewable energy sector. It aims to support the development and growth of the renewable energy industry. (http://rean.org.ng)

The Standard Organization of Nigeria (SON) as also some provisions for the solar industry, as well as a mandate of quality control of products, weights and measures.

South Africa: The South African Photovoltaic Industry Association (SAPVIA) is a non-profit organization that provides support specifically for the photovoltaic industry in South Africa. (https://www.sapvia.co.za)

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GoK (2012) *The Energy (Solar Photovoltaic Systems) Regulations, 2012 -Legal Notice No. 103,* Government of Kenya

SQ (2020), *Solar Panel Comparison Table*, SolarQuote, https://www.solarquotes.com.au/panels/comparison/compare-solar-panels/

Solar Review (2020), *Latest Tier 1 Solar Panels List 2020 (Q1, Q2 update)*,https://review.solar/latest-tier-1-solar-panels-list-2020/

For more information

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Visit the project website
www.captiverenewables-africa.org

ABOUT THE UNITED NATIONS ENVIRONMENT PROGRAMME

UN environment programme

The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system, and serves as an authoritative advocate for the global environment. Our mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

For more details see www.unenvironment.org

ABOUT FRANKFURT SCHOOL

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

Frankfurt School of Finance & Management is a research-led business school, which offers educational programmes covering finance, economics and management. Frankfurt School experts manage advisory and training projects on financial matters in emerging markets and developing countries, especially on topics related to microfinance and renewable energy finance. In 2011 Frankfurt School established a collaborating centre with UN Environment - the Frankfurt School UNEP Collaborating Centre for climate and sustainable energy finance.

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