REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

PORT AUTONOME DE KRIBI

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

PORT AUTHORITY OF KRIBI

Kribi Port Integrated Renewable Energy Generation Complex

Disclaimer

The information and data provided here is for general information purposes only.

It is important to note that the Port Authority of Kribi (PAK) has made best efforts to provide accurate information as much as possible. The data sets have been provided in good faith and can been used for preliminary assessment of the potential electricity production.

However, due to input data uncertainty, the PAK cannot guarantee the accuracy of information at 100% and shall therefore not be liable for any direct, incidental, consequential, indirect or punitive damages or alleged to have arisen out of the use of data shared in this study.

Plan

I. **Context**

II. **Kribi renewable energy sources considered**

III. **Origin of Biomass**

IV. **Biomass potential energy content**

V. **Solar power technologies**

VI. **Solar energy potential**

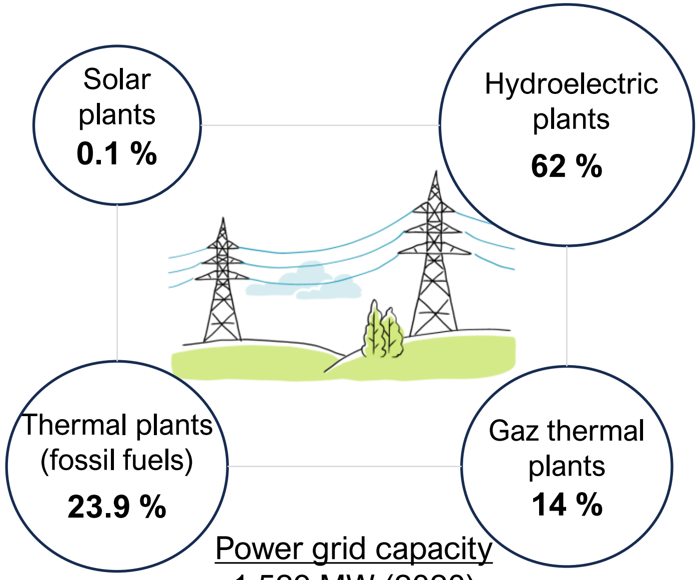
VII. **Kribi Port Integrated Renewable Energy Generation key facilities**

VIII. **Project milestones**

IX. **Project contribution to SDGs**

I. Context

National Power Grid

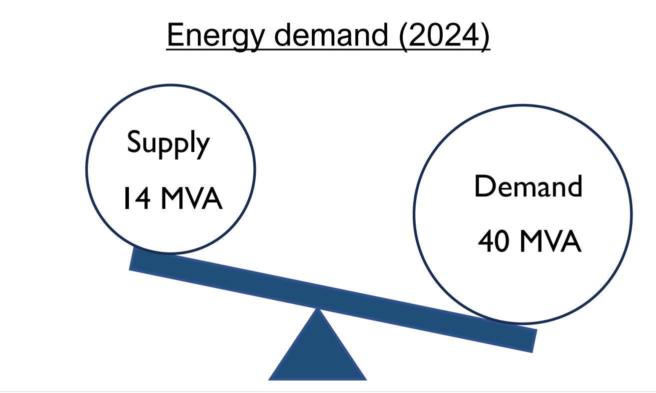


Power grid capacity
1 529 MW (2020)

Demand currently far exceeds supply at the national level.

However, the supply would be improved with upcoming new hydroelectric power plants (Nachtigal, Kikot, etc.).

Port of Kribi infrastructure and industrial zone



The port of Kribi is currently powered by a 30 kV line from the grid which doesn't meet the needs of the port current lessees.

In order to strengthen its power supply, the PAK has adopted a multisource strategy combining both on-grid and off-grid solutions.

The on-grid solution is related to the construction of high voltage lines from the nearest power sub stations to the port domain.

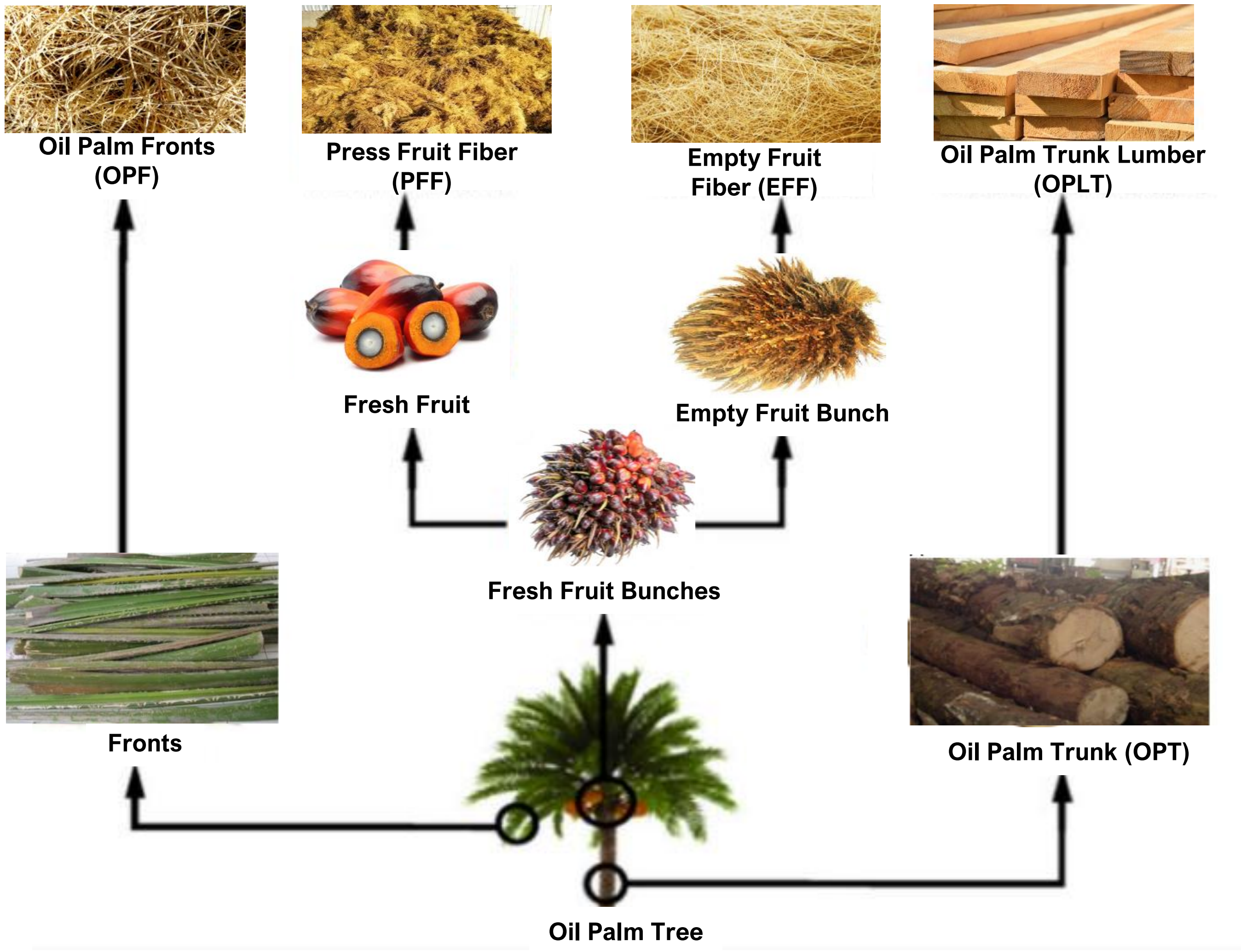
The Kribi Port Integrated Renewable Energy Generation Complex, our focus here, is where off-grid solutions for lessees and onshore power from available biomass and solar radiations, will be established in partnership with key stakeholders.

II. Kribi renewable energy sources considered

Source / technology		Key stakeholders*
Biomass	• Oil palm residues from large oil palm mills in the neighborhood of Kribi.	Companies running the various oil palm mills considered.
	• Wood produced while developing the green Kribi integrated industrial zone of more than 10 000 ha, much of which is still occupied by forest.	Tenant of the port of Kribi deforesting part of the industrial zone to set up their business.
	• Food waste products from hotels, restaurants, companies and homes in Kribi collected by the local company in charge of waste management.	• Tenants of the Kribi industrial zone ; • Company responsible for waste management in Kribi (HYSACAM).
Solar radiation	The two main technologies used in harnessing solar energy, which are the CSP (Concentrated Solar Power) and PV (Photovoltaic) could be applied to this regard.	• Interested tenants of the Kribi industrial zone ; • Solar panels or reflectors providers.

*It is worth mentioning that the stakeholders presented above are the ones directly linked to the project. For the success of those solutions, while developing them, we will work in partnership with government authorities, local company in charge of distributing electrical energy for excess energy off-take, technical partners and financial partners (Multilateral Development Banks, etc.)

III. Origin of Biomass : Oil palm biomass from oil palm mills



- There are two large palm oil mills in the region exploiting large scale oil palm plantations.

- In palm oil mills, during the conversion process of Fresh Fruit Bunches (FFB) into Crude Palm Oil (CPO), several kinds of waste including Empty Fruit Bunch (EFB), Mesocarp Fiber (MF) or Press Fruit Fiber (PFF), Palm Kernel Shell (PKS), Palm Kernel Meal (PKM), and Palm Oil Mills Effluent (POME) are produced.

- During replanting activity in oil palm plantations, biomass including palm front and trunk are produced.

- The biomass considered in this study will be made up of EFB, PKS, Oil Palm Fronts and Oil palm trunk.

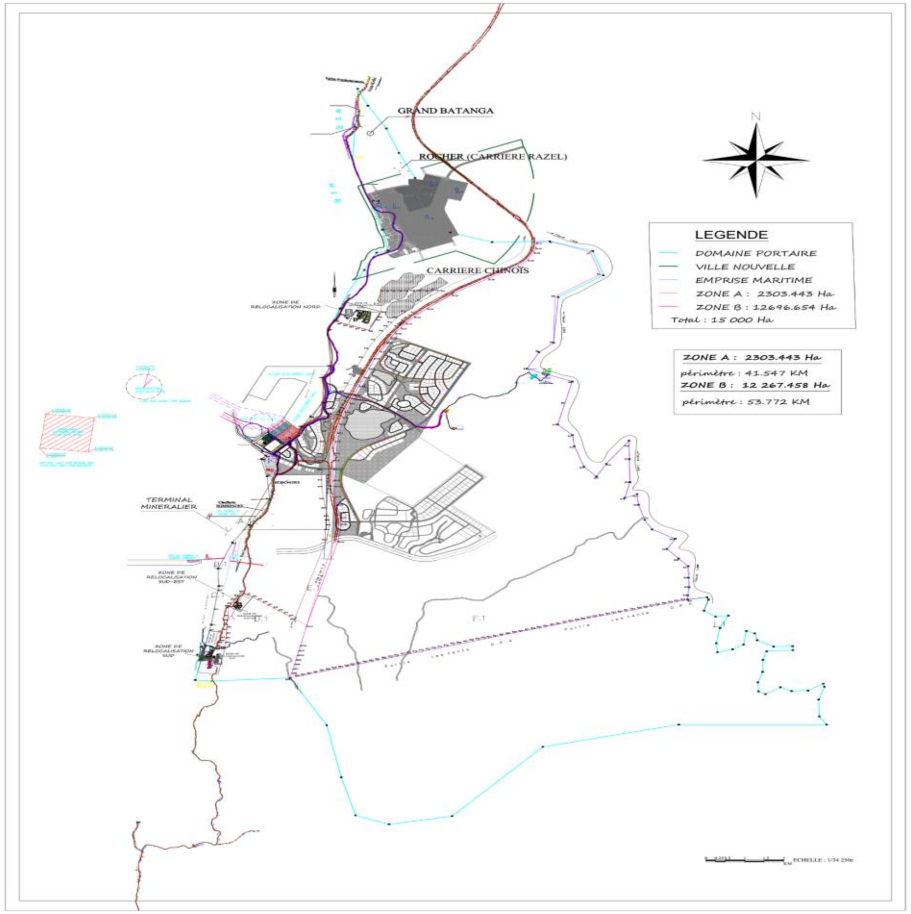
III. Origin of Biomass : Wood logs from the Kribi industrial zone development

- The size of land allocated for the port and its activities by the government is about 15 OOO ha, much of which is still occupy by forest since it is a green port project.

- As of 2023, only about 138.5 ha have been cleared already, the remaining area of land is covered by trees and vegetation.

- For a company or business to be set up in the industrial zone, the area needs to be cleared by removing vegetation and trees occupying the piece of land allocated.

- While clearing the forest to set businesses, the wood extracted would be used as a supplementary source of biomass for electricity generation.



<ins>Boundaries of the port domain</ins>

III. Origin of Biomass : Food waste collected in Kribi

Sample of food waste

Food waste bin

- Currently, the company in charge of collecting and managing waste in Kribi mixes all types of waste material, both the organic and the in organic ones.

- We plan to offer trash cans dedicated to the collection of only waste food or organic matter to the waste management company who would be in charge of distributing them across the city, close to the ones the are currently using to collect trash.

- The estimated number of trash cans required to cover the town is 3 000.

- The collected waste food organic matter would be stored in a warehouse before being sent to a digester to produce biogas through anaerobic digestion.

- Discussions have started with the waste management company in this regard.

IV. Biomass potential energy content – Oil palm residues and wood modeling hypotheses

Parameter	Value
Plant efficiency	30 %
Working hours per day	24
Number of days per year	365
Production of oil palm trunk (tons per ha per year)	10.4
Average production of Fresh Fruit Bunches (FFB) in tons / ha / year	17
Surface area oil palm plantation available in the neighborhood (ha)	34,000
Annual amount of wood that could be obtained from the Kribi port industrial zone (tons)	1,000

Fraction by mass of Fresh Fruit Bunches	Value
Empty Fruit Bunches (EFB)	21.1%
Palm Press Fibre (PPF)	12.7%
Palm kernel Shell (PKS)	6%

- Here are assumptions together with input data we have used to estimate the potential electrical energy which could be generated from oil palm biomass and wood extracted from the Kribi Port Industrial zone.
- Parameters regarding the production per hectare of plantations represent average values.
- For the industrial zone, it is worth mentioning that we have taken the pessimistic scenario where 1000 tons of wood would be produced as a result of the development of the said zone.

IV. Biomass potential energy content – Oil palm residues and wood modeling results*

	Mass produced per year (tons)	Lower Heat Value (MJ/kg)	Annual potential energy content (MWh)	Potential installed power (MW)
Empty Fruit Bunches (EFB)	121,958.0	12.97	439,387.9	15.05
Palm Press Fibre (PPF)	73,406.0	15.06	307,082.0	10.52
Palm kernel Shell (PKS)	32,368.0	18.79	168,943.1	5.79
Oil palm front	353,600.0	15.89	1,560,752.4	53.45
Oil palm Trunk	340,000.0	12.97	1,224,945.4	41.95
Wood from Kribi Port Industrial Zone	1,000.0	18	5,000.0	0.17

- From the analysis made, we can observe that it could be possible to set up a biomass power plant of more 100 MW.
- One of the key aspects to take into account with biomass plants is the moisture content of raw material, which has to be low as possible to ensure optimal performance and safety of the power plant.
- This result will be used in our discussions with oil palm mills for a better selection of the types of oil palm residues needed.

*In order to determine the optimal capacity, a detail financial, legal and supply chain analysis will be carried out subsequently.

IV. Biomass potential energy content – Waste organic material modeling hypotheses

Parameter	Value
Plant efficiency	40%
Working hours per day	24
Number of days per year	365
Population of Kribi	60,000
Food waste generation per capita per annum in Sub-Saharan Africa (kg)	170.0
Average number of hotels and restaurants serving food	100.0
Average annual production of waste organic food per restaurant (kg)	10,000.0
Volume of biogas produced from one kg of organic waste (m3)	0.1
Density of biogas (kg/m3)	1.2
Low heating Value of biogas (MJ/ m3)	22

- Beside is the input data used to estimate the potential electrical energy which could be generated from waste organic food material collected in Kribi.
- The food waste per capita per annum used is the pessimistic value, it could be much more than that.
- As the town is growing we are expecting the contribution of waste from restaurants and hotels to significantly increase in future.

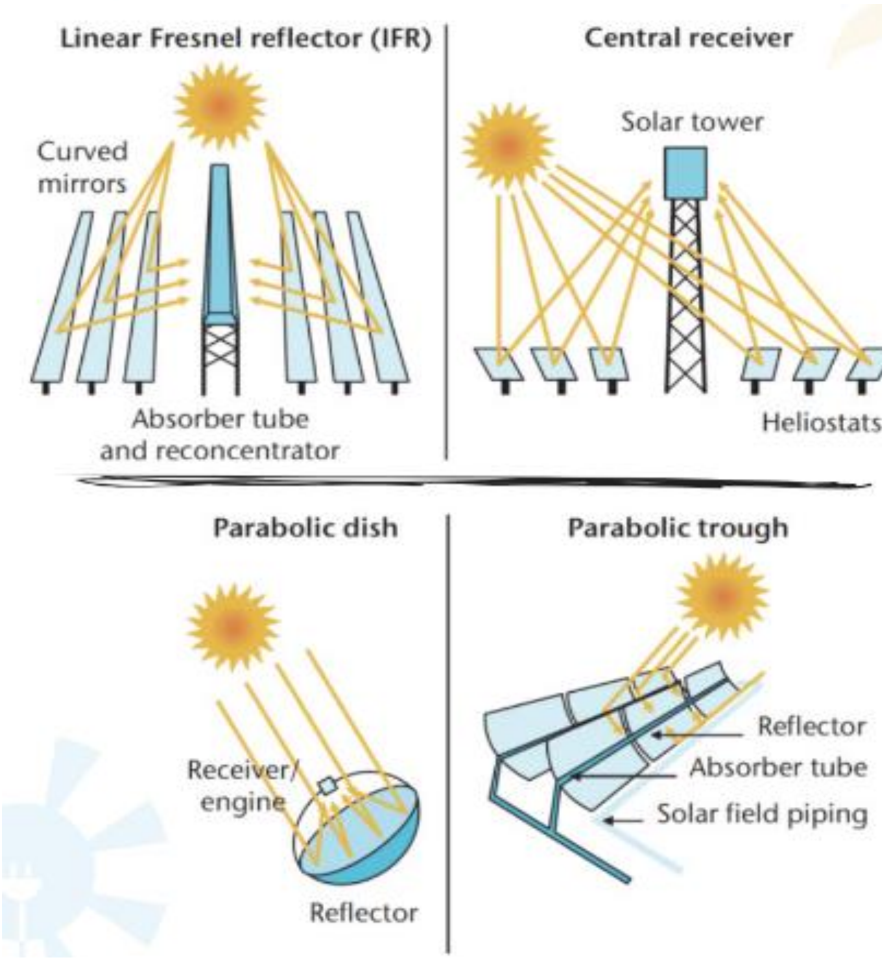
IV. Biomass potential energy content – Waste organic material modeling results*

Results	Value
Annual amount of organic waste (kg)	11,200,000
Annual amount of biogas produced (m3)	1,120,000
Annual energy content of biogas available (MJ)	24,640,000
Annual energy content of biogas available (MWh)	6,844.44
Potential installed power (MW)	0.31

- From the analysis made, we can observe that it could be possible to set up a biomass power plant of about 0.3 MW.
- However, this potential would significantly increase in future owing to the development of the port of Kribi which boosts economic development in the region.
- The supply chain structure required is a complex one, much effort will be required for the smooth operation of this section of the plant.

*In order to determine the optimal capacity, a detail financial, legal and supply chain analysis will be carried out subsequently.

V. Solar power technologies – Concentrated Solar Power (CSP) technology



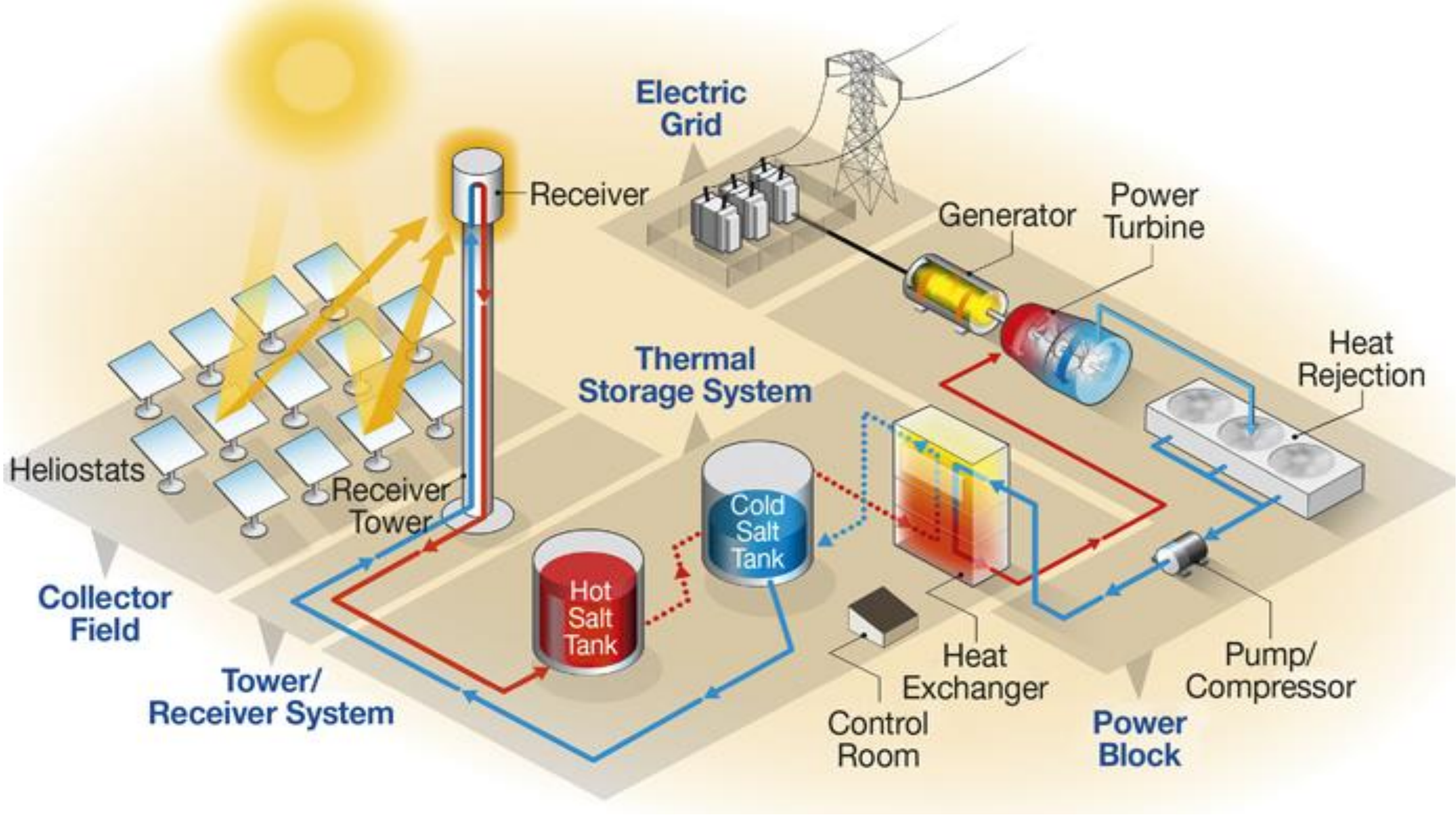
Main types of CSP technologies

Here, solar energy is concentrated onto a receiver containing a Heat-Transfer-Fluid (HTF) which delivers the thermal energy either to a heat storage tank or transfers it, through a heat exchanger, to a working fluid, such as steam, which powers turbines to generate electricity.

Base on the concentrator, we have 4 main systems:

- **Parabolic trough systems –** solar energy is concentrated by curved, trough-shaped reflectors onto a receiver pipe.
- **Power tower systems –** mirrors called heliostats track the sun and focus its energy onto a receiver at the top of a tower.
- **Linear Fresnel systems –** A large number of collectors are set out in rows. The mirrors are laid flat on the ground and reflect the sun on to the receiver pipe above.
- **Parabolic dish systems –** A parabolic-shaped dish acts as a concentrator that reflects solar energy onto a receiver mounted on a structure with a tracking system that follows the sun.

V. Solar power technologies – CSP technology (2 /2)



CSP Plant – Tower model

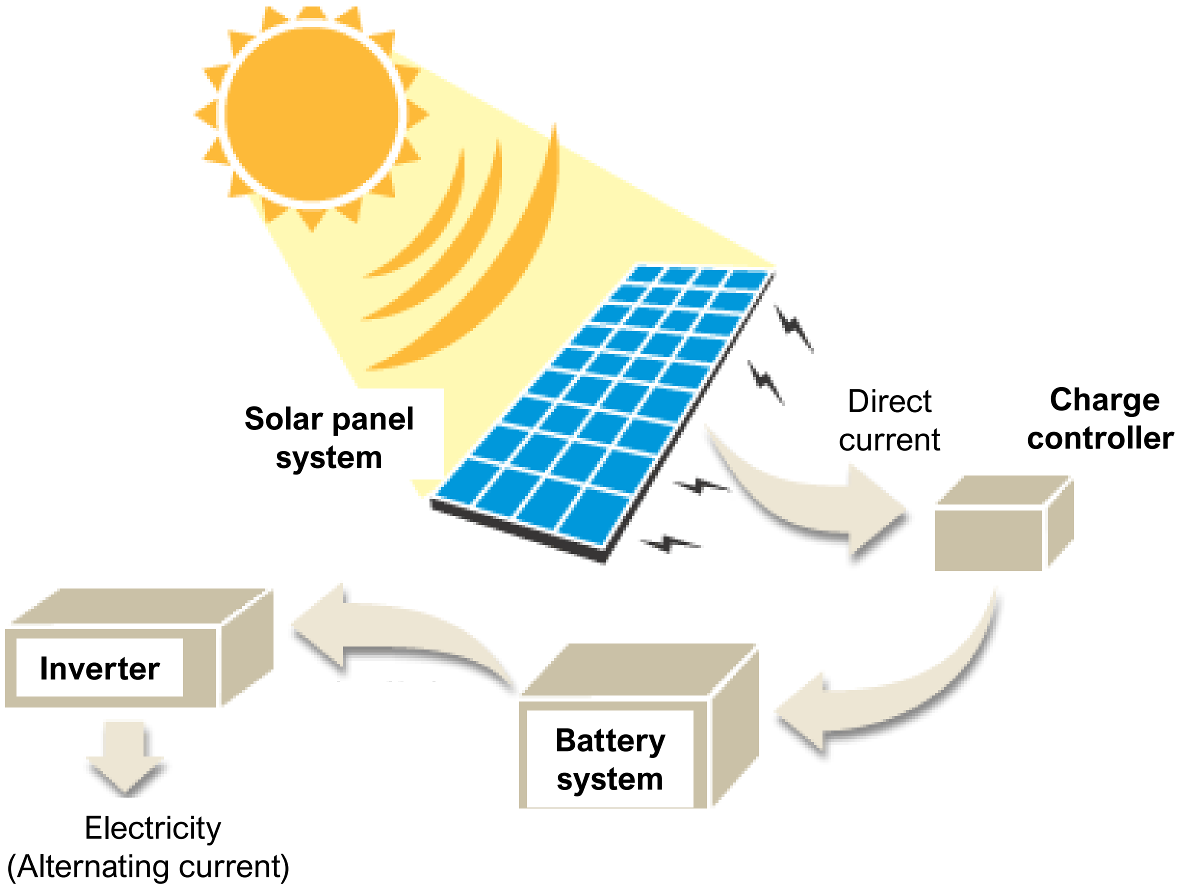
This is an example of a CSP technology using tower systems.

As previously explained, the Heat-Transfer-Fluid (HTF) responsible for electricity generation here is molten salt stored in a tank.

Spain is the leading country worldwide in installing CSP plants with 2 304 MW representing the total capacity (statisca, 2021).

The world biggest CSP power plant is found in Morrocco with a installed capacity of about 580 MW (Helioscsp, 2023).

V. Solar power technologies – PV technology



Typical setup of a PV power plant

This technology converts solar energy into electrical energy using photovoltaic (PV) panels thanks to the photoelectric effect.

A typical system is made up of the key elements below:

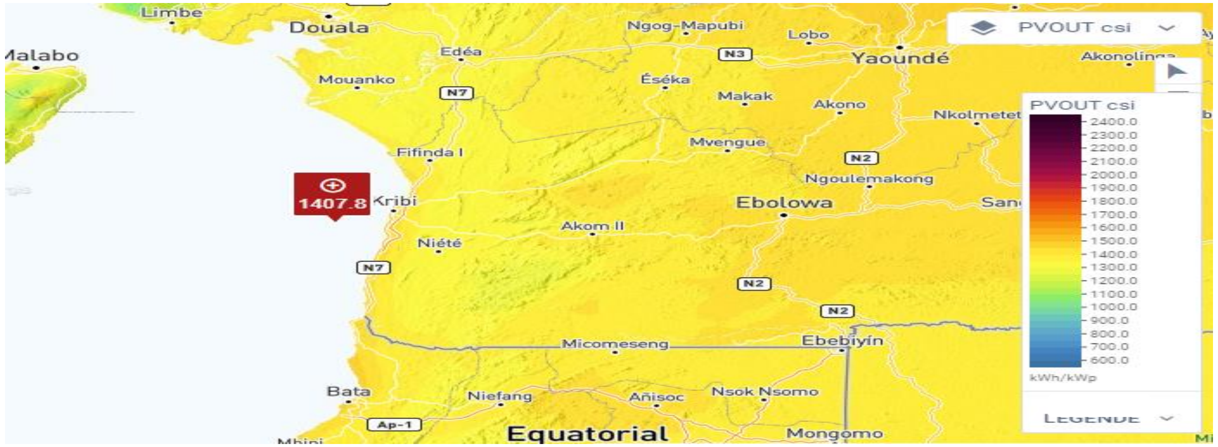
- **Charge controller :** used to keep the battery from overcharging by regulating the voltage and current coming from the solar panel to the battery;
- **Battery system:** made up of batteries to store the excess electricity generated by solar panels;
- **Inverter :** it's a device that converts Direct Current (DC) electricity, which is what a solar panel generates, to Alternating Current (AC) electricity for grid uses.

Large solar parks usually combine both the CSP and PV technologies to generate electricity, as it is case with the largest solar plant in the world which operates at a total capacity of 2 245 MW.

V. Solar power technologies – CSP vs PV technologies

	Concentrated Solar Power (CSP) technology	Photovoltaic (PV) technology
Working Principle	Produce electricity indirectly using thermal energy carried by a Heat-Transfer-Fluid.	Produce electricity directly through the photoelectric effect.
Dispatchability and maintenance cost	Dispatchable on demand and has a relatively low maintenance cost.	Not dispatchable on demand and has a relatively high maintenance cost.
Cost and size of land required	Very expensive and require a larger land area comparatively.	Less expensive and doesn't require much space comparatively.
Energy storage	It is far easier and much cheaper to store thermal energy that could be used at times of low light or no sunlight.	It is difficult and much expensive to store electrochemical energy in batteries which could be used at times of low or no sunlight.
Scale of Power generation	More attractive for large scale power generation thanks to its energy storage ability.	More attractive for small and medium scale power generation because of the difficulty related to energy storage.

VI. Solar energy potential – modeling results*



Average solar irradiations at Mboro - Kribi (Solargis)

Sizing parameters	Annual average value
PVOUT (Specific yield)	1,426 kWh/kWp
Global Horizontal Irradiation (GHI)	1,779.2 kWh / m2
Direct Normal Irradiation (DNI)	1,027.9 kWh / m2
Diffuse Horizontal Irradiation (DHI)	984.2 kWh / m2
Diffuse to Global Factor (D2G)	0.56
Global Tilted Irradiation (GTI)	1,781.1 kWh / m2

In solar energy applications, there are three commonly used parameters: DNI, GHI, and GTI.

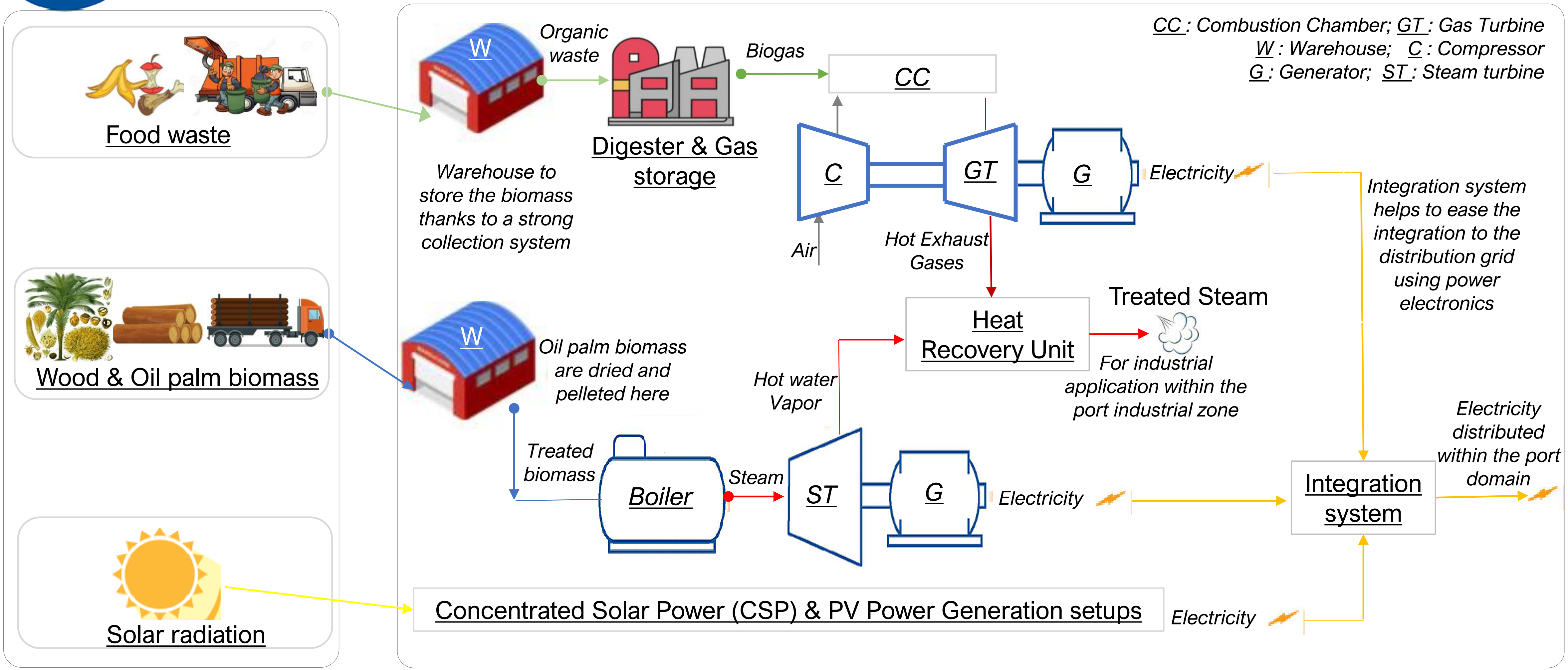
DNI is used in thermal and photovoltaic concentration technology. GHI is used as a reference for climatic zones and for calculating radiation on a tilted plane. GTI is also used as a reference for certain PV applications

The average annual values of the irradiation obtained using the software Solargis, are shown on the table beside. From the specific yield, for each kW peak of the PV unit, about 1 426 kWh could be obtained per year.

It is worth mentioning the mean bias regarding Solargis data is estimated at 0.4% for GHI and 2 % for DNI with respective standard deviations of ± 2.9% and ± 5.2%.

*In order to determine the optimal capacity, a detail financial, legal and land use analysis will be carried out subsequently taking the detail characteristics of monthly irradiations magnitudes (using ground measurements if possible too for data validation)

VII. Kribi Port Integrated Renewable Energy Generation Complex key facilities



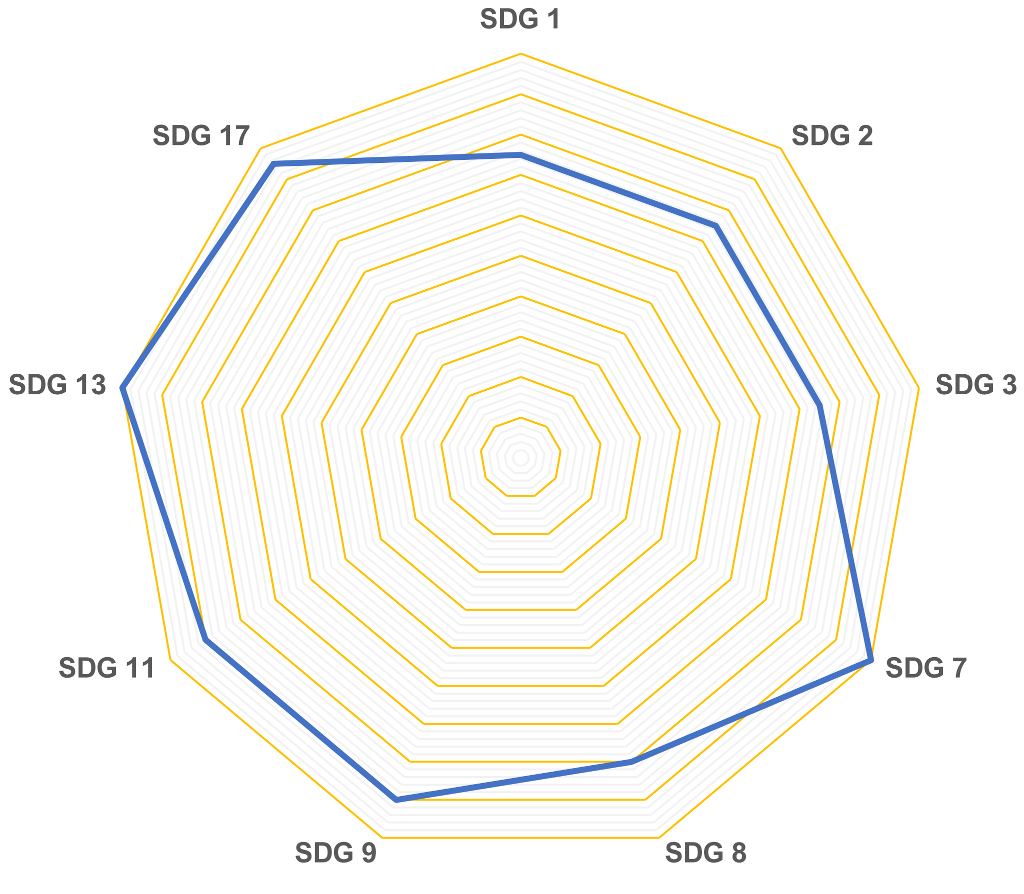
Raw material

Kribi Port Integrated Renewable Energy Generation Complex

VIII. Project milestones

	Phases	Period
1	Plant sizing and configurations regarding biomass available (oil palm residues, waste organic matter and wood) mainly via a detail financial, technical feasibility and supply chain analysis. Also, this study should come out with an optimal phasal execution.	2022 - 2023
2	Solar power plant sizing taking into account different scenarios combining CSP and PV technologies mainly via a detail financial and technical feasibility analysis. Also, integrations systems should be designed at this stage.	2023
3	Interest potential partners on different parts of the project with the aim of establishing the renewable energy generation complex with them.	2023
4	Further discussions with identified key stakeholders and search for financial partners using our tool called IFI2P (Public and Private Investment Financing Initiative of the port of Kribi) which is a platform where financial entities (hedge funds, multilateral development banks, …etc.) visit project initiatives shared and provide funding via equity or debt. As of may 2023 we have more than 10 financial entities already on the platform.	2023 -2025
5	Project execution begins with parts of the project according to the development phases identified in collaboration with all the stakeholders.	2024

IX. Project contribution to SDGs



Contribution intensity

This project will strengthen the supply of affordable and clean energy (SDG 7) within the industrial port zone, hence, this on its own will attract more companies (SDG 9).

The local population would integrate the work force required by those companies. Wages (SDG 8) provided as a reward for labor would help to reduce poverty (SDG 1), reduce hunger (SDG 2) and improve the wellbeing of the indigenous population (SDG 3).

Also, the project as presented, will make the city more sustainable (SDG 11) and can't be done without establishing partnerships with key stakeholders (SDG 17).

Being entirely based on renewable energy, it reduces the amount of greenhouse gases that would have been emitted if instead diesel or other harmful fuels were used to produce electricity (SDG 13).

PORT AUTHORITY OF KRIBI

PO Box 203 Kribi - Cameroon

Email: contact@pak.cm

Web site: www.pak.cm

Tel: +237 222 46 21 04