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B4

Gigawatt Global Cooperatief

20MW Solar Photovoltaic Project near Mount Coffee, Liberia

Feasibility Study

16 July 2019

Technical Report

Report Details

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Glossary

Abbreviation or Term	Definition
CAPEX	Capital Expenditure
EBA	Endemic Bird Area
EPA	Environment Protection Agency
EPML	Environment Protection and Management Law
ESIA	Environmental and Social Impact Assessment
GIS	Geographical Information Systems
HGV	Heavy Goods Vehicle
IBA	Important Bird Area
IRR	Internal Rate of Return
kW	Kilowatt
kWp	Kilowatt Peak
MCHPP	Mount Coffee Hydro Power Plant
MW	Megawatt
MWp	Megawatt Peak
NPV	Net Present Value
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PV	Photovoltaic
TA	Technical Advisor
W	Watt
Wp	Watt Peak
WDPA	World Database on Protected Areas

1 Introduction

Wood was instructed by Gigawatt Global (the Client) to undertake a feasibility study in relation to a potential 20 MWac solar plant near Mount Coffee in Liberia (the Project). The solar plant is planned at a site approximately 4.5 km south of Mount Coffee hydro station (88 MW). The study documented herein assessed the potential for the Project to be connected to the existing substation associated with this hydro station.

The Project is located approximately 23 km north-east of Monrovia, as shown in Figure 1-1.

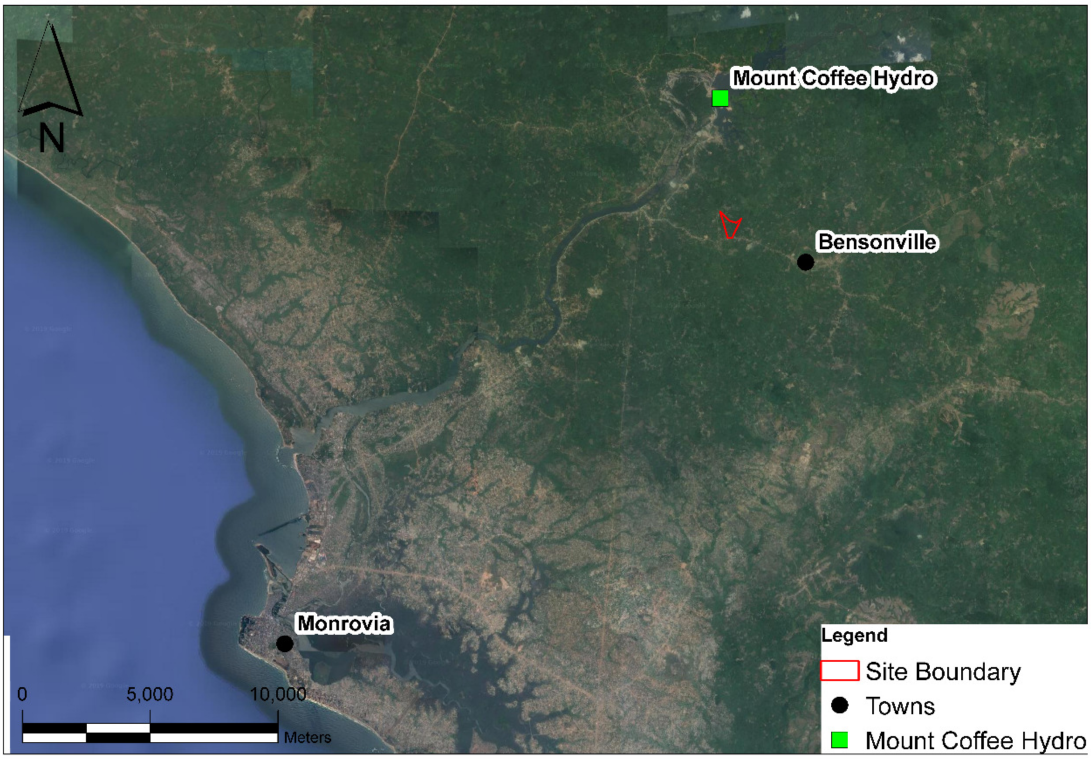

Figure 1-1: Project location

The objective of the feasibility study is to determine the potential opportunities and risks of developing the Project. In particular, the Client is looking for any potential red flags that might prevent the Project from reaching fruition.

2 Site Evaluation and Access Analysis

This site evaluation and access analysis was undertaken based on a preliminary desk-based assessment supplemented by the findings of a site visit which was undertaken on 25 and 27 March 2019.

The site visit focused on the areas within and in close proximity to the site, particularly areas located near the town of Crozierville. The northern, southern, central, and eastern areas of the site were visited. A drone survey was also conducted covering the entire site and the corridor between the site and the nearby Mount Coffee Hydro Power Plant (MCHPP). In addition, a guided tour was also made of the MCHPP. General observations are summarised in the subsections below.

2.1 Site Location and Geographic Description

The site is located within Montserrado County, approximately 23 km north of the capital city of Monrovia (approximate site centre coordinates are 6.459°N, 10.645°W. As can be seen in Figure 2-1, it is also located at approximately 3.8 km south of the MCHPP situated on the Saint Paul River.

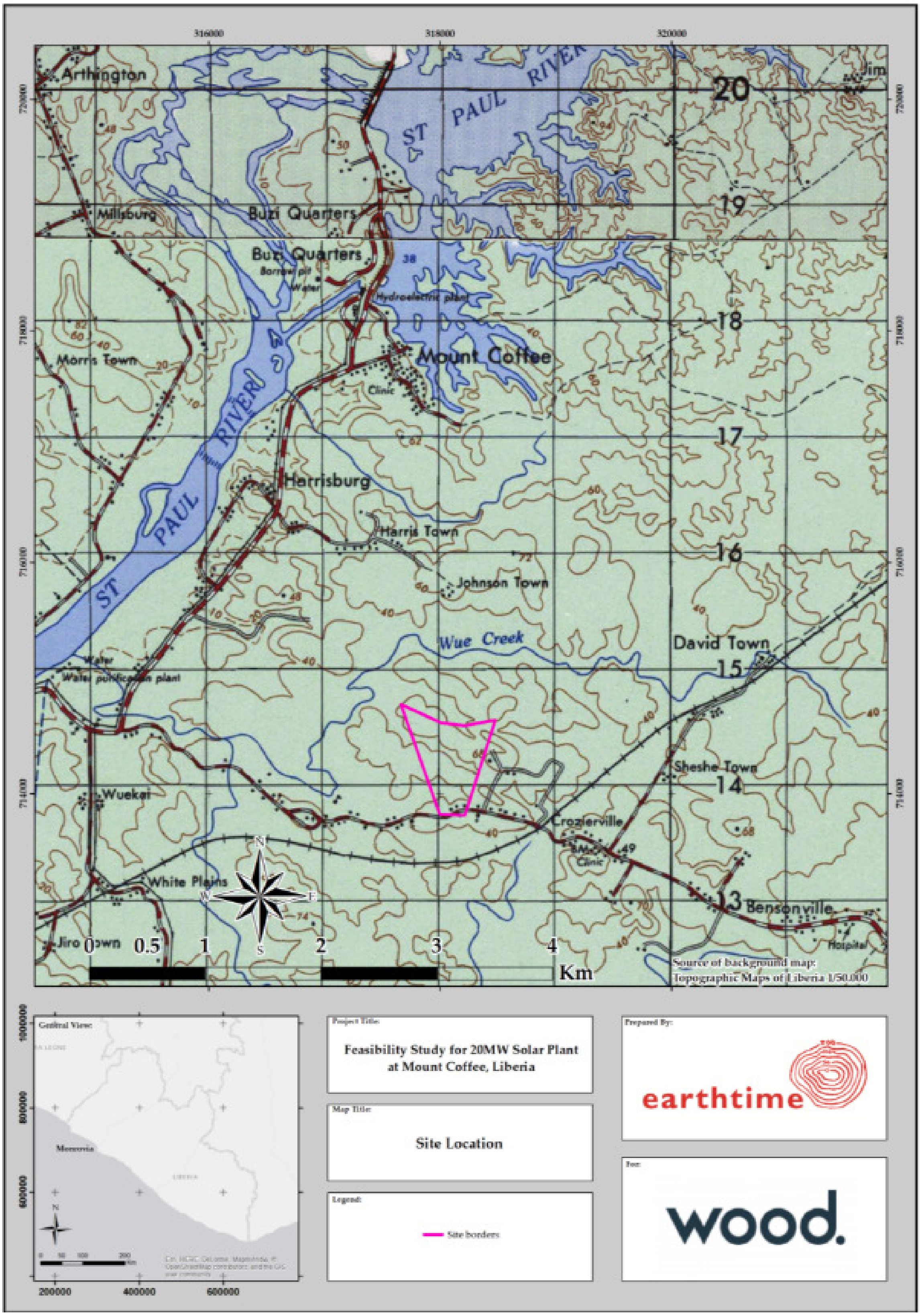

Figure 2-1: Site area

The site covers around 80 acres (32 ha) of privately-owned land and is accessible by a road that borders the length of its southern edge.

2.2 Land Usage

In terms of land use the site is secondary forest/shrub. The presence of some pioneer species indicate that this is not part of the North Guinea rainforest. Pioneer species become established after land has been cleared but naturally die off once the forest re-establishes.

Large areas of bamboo were observed to be present. Bamboo is a very fast-growing species.

Areas have been cleared using the slash and burn method to create farming plots for crops including sugar cane and chillies. The land is owned by a single landowner and there are informal agreements with locals to use the land. It is currently estimated that there is a total of 13 farmed parcels of land within the site area. During the ESIA stage, the number of people with access to the land will be confirmed together with the level of income that is dependent on having access to the land.

Based on data from the World Bank[1], World Food Program[2] and Liberia Institute for Statistics and Geo-Information Services[3] the GDP per capita in Liberia is $694 and the majority of income in rural areas is based on agriculture. The most recent data is from 2017. Total agricultural production is 1,225 kg per hectare for the poorest percentile which is assumed to apply to the Project area. Montserrado holds the lowest average land area cultivated as 0.73 hectares (Ha) per household. The most common crop observed being grown within the site area was maize and WFP data provides indicates a price of $146.55 per tonne based on US (Gulf) maize.

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[1] The World Bank, 2019. Data: Liberia. Data available at: https://data.worldbank.org/country/liberia

[2] World Food Program, 2017. Liberia Market Price Monitor: Price Bulletin Date October 2017. Data available at: https://docs.wfp.org/api/documents/WFP-0000023580/download/

[3] Liberia Institute for Statistics and Geo-Information Services - Government of Liberia, 2018. Liberia - Household Income and Expenditure Survey 2016. Report available at: http://microdata.worldbank.org

The active farm plots identified within the site varied in size from approximately 0.1 Ha to approximately 1.0 Ha. Based on aerial imagery it is estimated that active farms constitute approximately 15% of the total site area. For illustration, and assuming that farm plots are distributed evenly across the site, the footprint of the proposed development (19.9 Ha, as defined in Table 6-1), is estimated to contain approximately 3 Ha of cultivated land (15% of the development footprint). Using the above information, this would equate to a total estimated production in the region of 3.7 tonnes of maize at total cost of approximately $542 per year based on US maize prices.

Therefore, the potential impact of the Project on land use could be in the region of $542 per year plus the initial compensation to be paid to project affected peoples (PAPs). It is estimated that the initial compensation would be the equivalent of one year of production i.e. $542 plus payment for the loss of land. Other crops noted on site were cassava and chilli.

A groundwater well was recorded on site (Figure 2-2).

Possible ecosystem services on the land include gathering of palm oil (small scale production of palm oil observed outside the site area) and potentially some food/fruit. Pineapple was observed growing wild on site.

Figure 2-2: Groundwater well within the site area

2.3 Climate

Liberia has a humid tropical climate. Temperature varies both daily and seasonally, with averages in the range of 20 to 35 degrees centigrade. The hottest daytime temperatures tend to be during the drier months of the northern hemisphere winter.

Rainfall is very high on the coast (typically around 4,500 mm per year at Monrovia), but declines inland. The project site can be expected to experience typical annual rainfall in the range of 2,500 to 3,500 mm. Maximum daily rainfall totals are likely to be around 150 mm in most years, but exceptionally might be greater.

The wet season has significant levels of cloud even at times when it is not raining. Dry season insolation can be reduced periodically as a result of the dust-laden north-easterly Harmattan.

Engineering design will need to address climate issues. Long term changes appear most likely to involve a drier dry season and a wetter wet season, perhaps with greater short-term intensities.

2.4 Environmental Designations

Based on the World Database on Protected Areas (WDPA)[4], the closest environmental designation of national or international importance is Lake Piso Multiple Sustainable Use Reserve, located approximately 18 km to the west-north-west of the site. At this distance, no significant adverse impacts are anticipated.

[4] Protected Plant (2019). Stats: Liberia, Africa. Data viewed at: https://protectedplanet.net/country/LBR

In addition, the Bird Life International database[5] was reviewed. There are no Important Bird Areas (IBAs) within the site boundaries or within 50km of the Project. However, almost the entirety of Liberia is within an Endemic Bird Area (EBA) which is an area of land identified by BirdLife International as being important for habitat-based bird conservation because it contains the habitats of restricted-range bird species. The Upper Guinea Forest EBA is classified as being Critical Priority as a result of major habitat losses[6]. Felling proposed as part of this Project could potentially have implications with regard to the EBA and this issue should be investigated further. However, it is anticipated that the features of importance to the EBA will be focussed within the Liberian IBAs. If this is the case, no significant adverse impacts would be anticipated.

2.5 Flora

Farming in the Crozierville area has degraded the natural vegetation to mixed shrubby land with a few recovering stands of pioneering woody plants, and with many areas dominated by grass with sporadic Bambusa species (Figure 2-3). Typically, the stands of pioneering species include *Anthocleista, Smeathmannia, Anthonotha, Craterispermum,* and *Harungana*, which normally do not produce crowns of substantial shade cover. Grasses are the most common plants observed, especially *Scleria spp*. They are followed by *Bambusa vulgaris, Eleusine indica* and *Rottboellia cochinchinensis* grasses. A period of farming rotation may be of three to four years, and the most common introduced species on site is *Elaeis guineensis*. No endangered tree species were identified in the area surveyed.

[5] Bird Life International (2019) Country profile: Liberia. Available from: datazone.birdlife.org/country/liberia

[6] BirdLife International (2019) Upper Guinea Forests. Available from: datazone.birdlife.org/eba/factsheet/80

Figure 2-3: Site photo showing brushed and burned lands in preparation for farming

2.6 Fauna

In the populated agricultural zone where the site is positioned, only rodents are traceable. Rodents are common in the vast, biologically degraded landscape due in part to regular cassava production, since they are noted for feeding on cassava cuttings and tubers. There were no signs of duikers (native forest antelopes) or large mammal species on site. There were no nesting signs of local protected bird species or migratory ones within the site. The most abundant species recorded on site was Pied crow (*Corvus albus*), further signs of habitat alteration and the presence of human activities. In addition, a single African harrier hawk (*Polyboroides typus*) was recorded flying over the site (Figure 2-4). Rainbow agama (*Agama agama*) was also recorded on site (Figure 2-5). No species recorded on site during the site visit were of conservation concern.

Figure 2-4: African harrier hawk recorded on site

Figure 2-5: Rainbow agama (f) recorded on site

This initial assessment indicates that there will be no significant biodiversity constraints on the development of the site, although this will need to be confirmed in the ESIA process. A number of standard management practices will still be required, such as appropriate lighting to minimise the attraction of night-flying insects.

2.7 Geology

The Monrovia Quadrangle is within the Guinean Shield of West Africa which includes parts of the Liberian and Pan-African age provinces. Geological investigations in Liberia have shown that nearly all of the terrain is underlain by Precambrian crystalline metamorphic rocks which form part of the West African Guinea Shield. The rocks forming this crystalline shield are a series of granite, gneiss, and schist beds which have resulted from metamorphism by tectonic forces acting on a regional scale. The structural features of the rocks in this region are uniform over relatively large areas. Gneissic structure and schistosity dip at high angles in most places and are often vertical.

Geologically, the project location is described on the United States Geologic Survey (USGS) geological map of the region (see detail of this map in Figure 2-6) as a Pre-Cambrian leucocratic, medium to coarse grained, commonly banded biotite-bearing granite to quartz diorite gneiss. The gneiss forms a wide northwest to southeast belt in which the project site is situated. However, due to the tropical weathering, this has decomposed to form a thick laterite and saprolite soil cover, which supported dense vegetation and rain forests over most of Liberia[7].

[7] Tysdal and Thorman (1983). Geologic map of Liberia. U.S. Geological Survey, Reston, Va.

Figure 2-6: Extract from Geological Map of the Monrovia Quadrangle, Liberia (Thorman, 1977, USGS)[8]

A close-up of the rocks described above and found on site is shown in Figure 2-7. This shows less weathered, relatively hard boulders of gneiss emerging from the gradually eroding matrix of more weathered lateritic saprolite.

[8] Thorman, C.H. (1977). Geologic map of the Monrovia Quadrangle, Liberia. U.S. Geological Survey, Reston, Virginia.

From an engineering perspective, these materials tend to be porous but with low percolation rates. They can become quite plastic when saturated. Foundation conditions can vary from firm on areas of less weathered rocks (usually on the raised interfluves), to relatively weak in the more weathered depressional areas.

Figure 2-7: Typical Laterite deposits visible in brushed (cleared) areas

2.8 Topography

The majority of the site is situated on a low altitude undulating landform, as shown in Figure 2-8. This area is crossed by a combination of ridges and drainage channels that mostly flow westward. The ridges rise to around 60 m above sea level with the drainage channels dropping to 25 m above sea level.

Figure 2-8: Drone image showing the undulating terrain of the site

At the time of the site visit, which took place during the dry season, no running streams or swamps were detected within the site boundary. However, the terrain shows that several lowland areas within the site might become inundated during the rainy season which usually extends between May and November. Engineering design should therefore be based on a detailed topographical survey to identify low-lying areas that are likely to be subject to seasonal waterlogging.

Figure 2-9: Dense bushy foliage in lowlands where swamps could develop during rainy periods

2.8.1 Slope and Aspect

An initial constraints analysis exercise utilising geographical information systems (GIS) has been undertaken in order to establish areas of favourable slope and aspect for siting of a solar PV Project.

In the northern hemisphere, installing modules on north facing slopes can decrease energy yields through increased PV module shading, especially between PV module rows (inter-row shading). Inter-row shading may be partly reduced by increasing the row spacing but the side-effect is to reduce capacity for the same project area. The shading effects are increased for lower sun elevations during the mornings and evenings. Favourable slopes for locating PV panels within the northern hemisphere face south. The areas within the Project site boundary with appropriate south facing slopes have therefore been identified.

Whilst the visual impact of PV plants can be low, especially if situated behind hedges or trees, visibility is increased on steep slopes. In addition, steep slopes above 10° of inclination represent a technical constraint for construction, these have therefore been excluded as a constraint to solar PV development.

Both slope and aspect (North-facing slopes are those facing between 315° and 45°. South-facing slopes are those facing between 135° and 225°) have been mapped within GIS utilising freely available global terrain data. The outcome of this initial mapping process is shown on Figure 2-10 and Figure 2-11.

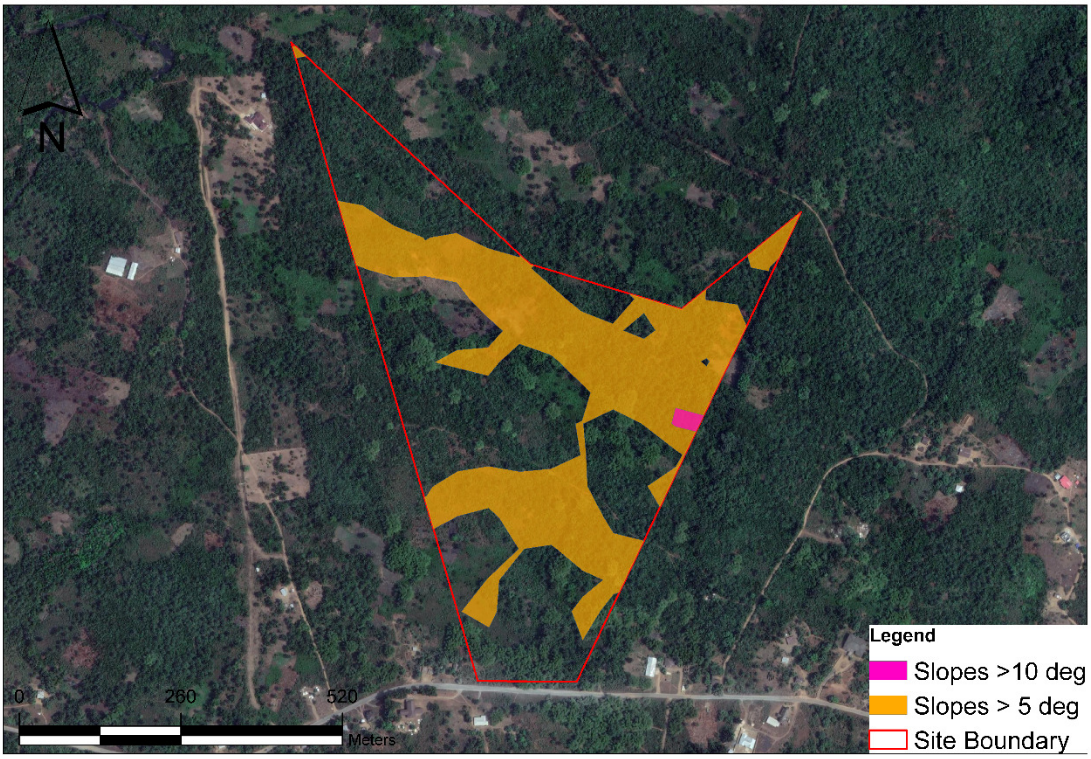

Figure 2-10: Terrain Slope

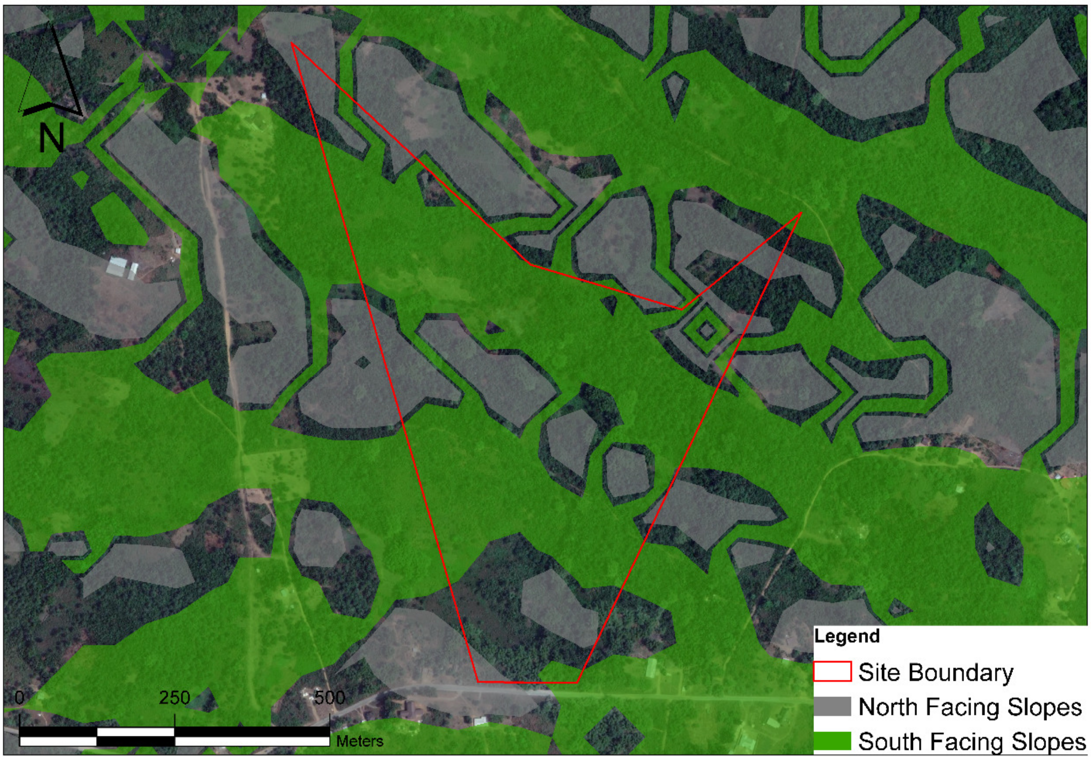

Figure 2-11: Terrain Aspect

As can be seen from these figures, there is only one small area where slopes of 10° or more exist within the site. This should be easily avoided.

2.9 Hydrology

The surface profile of the project area is generally slightly undulating but gently dipping towards the west, as part of the Saint Paul River watershed. Most of the surface water flows first towards the Dayunn Creek, shown in Figure 2-12, found 400m west of the site. The Dayunn Creek is a tributary of the Wue Creek that flows westward passing from the north and west of the site, which is itself a tributary of the Saint Paul River (see Figure 2-1).

The site is crossed by a number of transient waterbodies which were all dry during the time of the site visit. Although there were no evident flood plains, it is likely that water accumulates at the base of shallow depressions or in the ephemeral drainage channels during the rainy season. Design of site works will need to include a detailed drainage and sediment capture system. The hydrology of the Dayunn Creek must also be checked to see if any channel alterations are necessary to accommodate the additional flows from the impermeable surfaces of the photovoltaic panels.

Figure 2-12: Dayunn Creek, as seen from the steel bridge west of site

2.10 Residential Properties

There were no residential properties identified within the site boundaries. However, as shown in Figure 2-13, the Project site is surrounded by small areas of residential development and scattered non-commercial buildings. The closest residential buildings are located less than 50 m from the Project site, at its south-western corner.

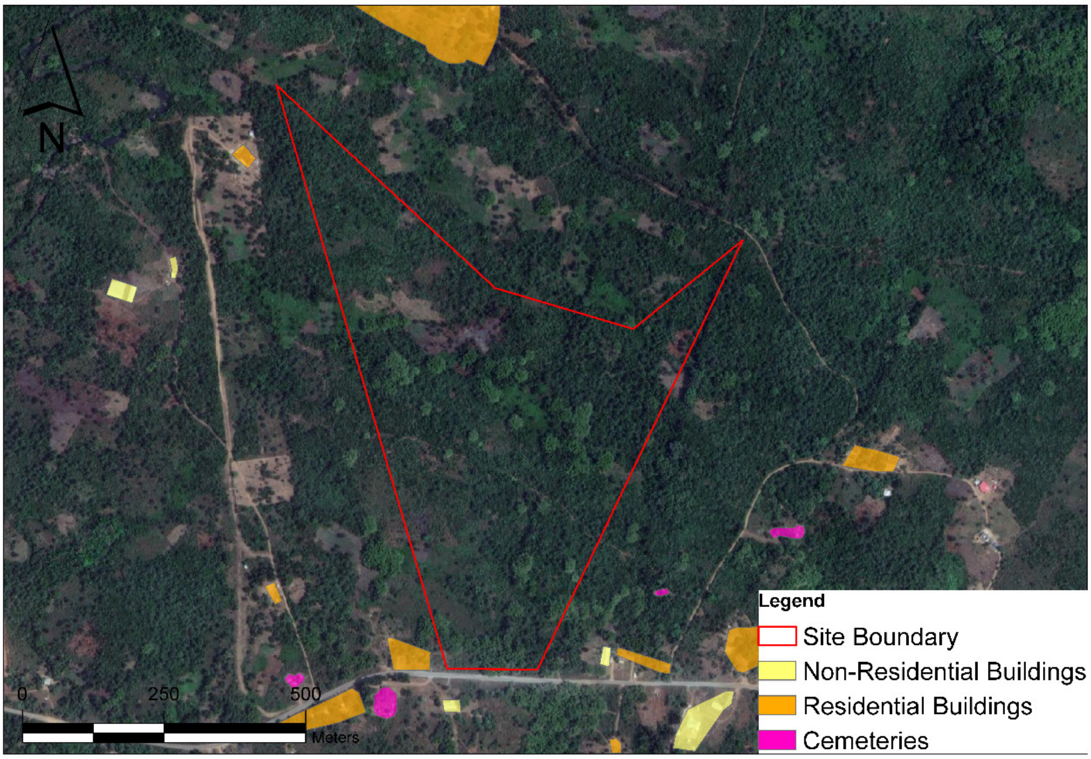

Figure 2-13: Nearby Urban/Residential Development

As there are no residential properties present on the Project site, the main technical consideration in relation to nearby houses will be the potential noise impacts during construction and operation.

There is potential for short term noise impacts on nearby residential properties from activities during construction. This will mainly be from construction traffic and pile-driving of support structures and erection of security fencing.

The solar panels will be silent in operation as there will be no moveable parts required during operation. However, there can be noise levels from the inverter units and from the substation building. The layout will need to be designed such that the noisy elements are sufficiently far from the residential areas to avoid adverse noise impacts – a 500 m separation is a good rule of thumb. More detailed noise modelling will be undertaken as part of the ESIA.

2.11 Cultural Heritage / Archaeology

No known national or international historic environment designations have been identified. A number of graveyards in the area were identified from satellite imagery (as shown in Figure 2-13). An example of these cemeteries is shown in Figure 2-14. As there are no cemeteries located within the site boundary, no direct impacts are anticipated. Where possible, vegetation screening should be maintained or provided to reduce/avoid potential visual impacts on these cemeteries, to preserve their setting.

Figure 2-14: Cemetery as seen from road bordering the southern edge of the site

2.12 Proposed Access Route and Potential Issues

Construction stages will require equipment to be transported to the site for erection of the solar array and associated infrastructure. However, the vast majority of equipment will be brought to the site by standard HGV and the construction period is estimated to be only a few months, so any increase in vehicle movements will be limited and temporary.

MCHPP indicated that during investigations associated with the construction of the hydro plant, the bridges on the road from Bensonville to the east were considered to be unsuitable for construction traffic. Consequently, it is anticipated that access to the Project site for delivery of construction materials and components will be from west along the route described as follows (and shown in Figure 2-15):

- From the Freeport of Monrovia, turn left onto United Nations Drive.

- Continue on United Nations Drive for approximately 4 km
- At New Kru Town, turn right and cross a bridge (Bridge 1)
- Continue on this road for approximately 20 km to the Project site, crossing another smaller bridge (Bridge 2) approximately 400 m before the site.

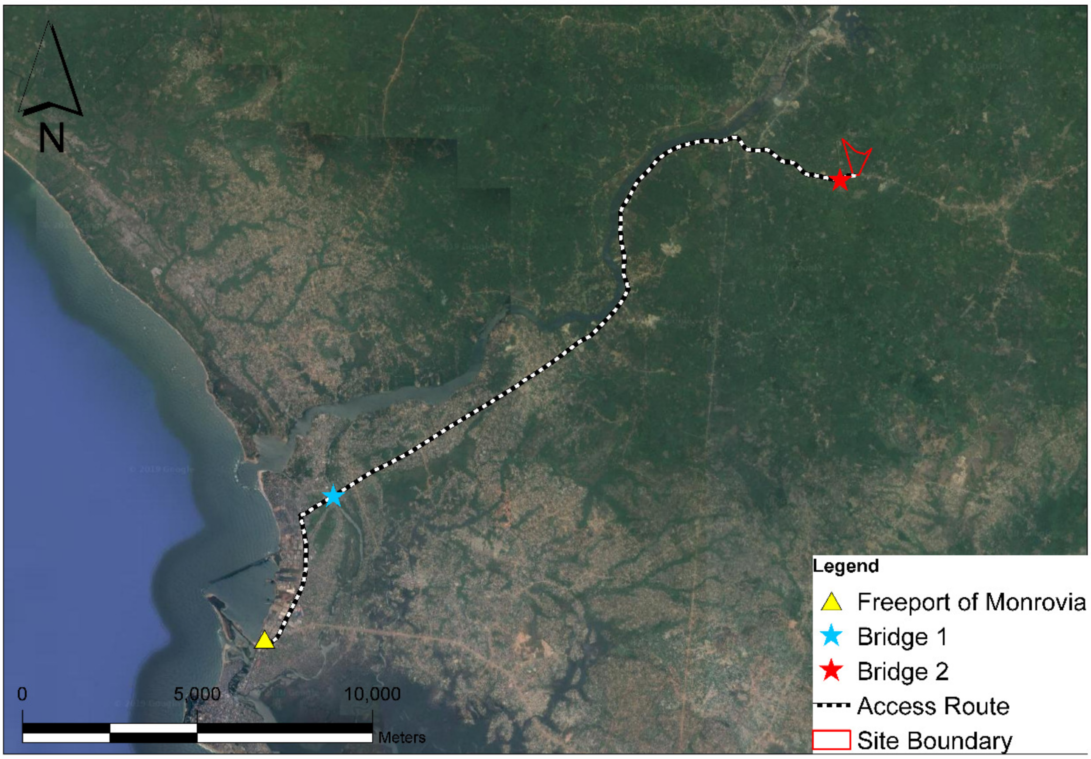

Figure 2-15: Anticipated Access Route

United Nations Drive and the majority of the road to site appear to be in reasonably good condition and should pose little risk for the passage of HGVs. The bridge that is crossed shortly after turning off United Nations Drive (Bridge 1) is unlikely to represent any significant issues, however, it would be prudent to confirm the load bearing capacity of the bridge.

The 3 km stretch of road between the junction with the road leading north to the Mount Coffee hydro station and the Project site may present some potential risks. There is a small bridge (Bridge 2) approximately 400 m from the Project site and its load bearing capabilities and structural condition should be confirmed. It is also understood that a 10 m long section of this road had been washed away in the last rainy season. This has been refilled but possibly not to appropriate standards for construction traffic and it is expected to be washed away again in the next rainy season. Consequently, this section of road should be surveyed, and upgrade work completed if necessary.

3 Electricity Evacuation Analysis

3.1 Background

Generation in Liberia is provided by the 88 MW Mount Coffee hydro plant and a complimentary 38 MW heavy fuel oil plant. Prior to the restoration of the Mount Coffee hydro plant, the sole source of Liberia's electricity generation was a 23 MW diesel plant. Consequently, many hotels, restaurants and office buildings were forced to self-generate electricity[9]. The small national grid, which predominantly provides electricity to Monrovia, is operated by Liberia Electricity Corporation (LEC).

Liberia currently has one of the lowest electricity access rates in the world. However, the Liberian government is working closely with its development partners to rebuild the country's electricity infrastructure. By 2030, the Government of Liberia aims to meet an anticipated peak demand of 300 MW and serve 1 million customers, connecting 70% of the population in Monrovia and providing access to 35% of the rest of Liberia[9,10].

A recent (March 2019) news article[11] reports that: "*The Government of Liberia and the European Union entered into an €18.9 million contract agreement with MBH Power Limited-Nigeria for the design and construction of electricity distribution network in Monrovia to help address the increased demand for energy in various parts of the city.*

The installation of the new power distribution network will allow LEC to connect more homes and increase its customer base, to absorb the increased quantity and much cheaper energy.

The distribution network, according to the agreement, will connect 38,000 small households in Monrovia and its immediate environs, thus contributing to the increase of energy supply to its people."

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[9] USAID (2019). Liberia: Power Africa Fact Sheet. Report viewed at: https://www.usaid.gov/powerafrica/liberia

[10] Rural and Renewable Energy Agency (2016), Rural Energy Strategy and Master Plan for Liberia until 2030. Report viewed at: http://gestoenergy.com/wp-content/uploads/2018/04/LIBERIA-RURAL-ENERGY-STRATEGY-AND-MASTER-PLAN.pdf

[11] Nigeria Electricity Hub (2019). Liberia to Connect 102,000 Households to The Electricity Grid. Article viewed at: www.nigeriaelectricityhub.com/2019/03/11/liberia-to-connect-102000-households-to-the-electricity-grid/ (March 11, 2019)

The CLSG (Cote d'Ivoire, Liberia, Sierra Leone and Guinea) interconnection project is a proposed 225 kV high voltage transmission line approximately 1,360 km in length that will connect Liberia to the West African Power Pool (WAPP). This will enable pooling of power resources across the four countries. The CLSG project is split into two phases. Phase 1 consists of a single-circuit line with a power capacity of 150 MW and Phase 2 provides an additional circuit, increasing the total line capacity to 300 MW. It is understood that the CLSG project will also incorporate the construction of four substations in Liberia to facilitate the development of distribution networks. The four proposed substations are[12]:

- Yekepa (225/33 kV – 40 MVA)
- Buchanan (225/33 kV – 40 MVA)
- Monrovia (225/66 kV – 70 MVA)
- Mano (225/33 kV – 40 MVA)

Although Phase 1 of the CLSG project was scheduled for completion in 2015, a recent (April 2019) news article[13] indicates that it is still under construction and that it is now scheduled for completion in December 2019. The CLSG connection is expected to offer Liberia up to 27 MW spinning reserve from Cote d'Ivoire which would further guarantee an electricity supply to consumers connected to Liberia's distribution network.

3.2 Project Specific Considerations

A preliminary review was conducted to form an understanding of the existing grid infrastructure at Mount Coffee Substation and to investigate potential grid connection options and locations.

Documents reviewed include:

- 66/22 kV Mount Coffee Substation Single Line Diagram - Doc No. LEC/NCC/MC/ELE/DRG/004 Rev C. (Dated 06/10/2016)
- Rural Energy Strategy and Master Plan for Liberia Until 2030 Technical Report (Dated April 2016)
- Annex VIII: List and Maps Per County of Existing/Planned Electrical Infra-Structures (Dated April 2016)

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[12] TRANSCO CLSG (2019). Liberia. Data viewed at: www.transcoclsg.org/liberia/

[13] Front Page Africa (2019). As Liberia Struggles with Electricity Fluctuations, TRANSCO CLSG Project Eyeing December 2019 Start. Article viewed at: www.frontpageafricaonline.com/...

- Annex XI: Overall Energy Supply and Demand for The Period 2020-2030 – Detailed Tables (Dated April 2016)
- Annex XVII: Energy Supply and Demand Detail Per Region and Per County (Dated April 2016)

The SLD (dated 2016) indicated that the transmission voltage of the overhead line to Monrovia is 66 kV with a maximum rating of 5000A and that there was a further overhead line proposed to be constructed from the Mount Coffee substation to Monrovia, which would allow a double circuit 66 kV connection to the capital. This double circuit connection to Monrovia will form the first section of the CLSG installed in Liberia.

It is understood that the Mount Coffee substation has the electrical infrastructure capable to accommodate additional power infeed sufficient to accommodate the Project, as currently the only generator connected via the substation is the 88 MW hydroelectric power scheme. The current SLD shows the substation comprises; two 2500A busbars, four 22 MW generators from the hydroelectric plant, five 66 kV overhead lines and one 22 KV overhead line with all relevant switchgear and protection systems shown. The SLD provided also shows three future connections. It is understood one of these is for the CLSG line and the other two currently remain unreserved. It therefore would be suitable to use one of these bays to connect the proposed solar PV plant to the substation.

A previous study indicated the potential to connect 35 MW of solar PV via the substation. It is understood that this project has not gone ahead. However, this does provide some confidence in the feasibility of successfully connecting the 20 MW solar project.

It is understood that the main restriction to expansion of the electrical network is the limitations of supply due to demand. At present, electricity demand on the grid is the main limitation to the energy produced by the hydro scheme, with the current maximum energy generated understood, based on discussions held during the visit to the MCHPP, to be in the region of 38 MW. The PV scheme would add a secondary source of generation during the dry season but could potentially be restricted due to the limited demand on the electricity grid currently. During the dry season only one generating unit can be utilised from the hydro scheme, limiting the maximum output to 22MW. With the demand from Monrovia being a maximum of 38 MW the discrepancy is currently produced by diesel generators. Installing the solar PV plant would limit the requirement for diesel backup generators, if not remove it entirely.

Ongoing measures by the Liberian authorities to increase the number of grid connected properties/businesses, would help reduce this risk.

The current energy demand of the surrounding areas that are already grid connected are important to make a realistic estimation of potential demand from the Mount Coffee substation as well as the expected future expansion of the distribution network. This information will allow a more in-depth assessment to be conducted into the feasibility and potential export potential of the PV plant.

It is considered likely that the planned CLSG interconnection to WAPP would reduce the limitation on the production of electricity due to demand restrictions.

In conclusion, it is considered that it should be technically feasible to connect a 20 MW solar PV at Mount Coffee substation. It is also expected to be a valuable generation asset particularly during the dry season. However, it is difficult to determine the economic feasibility and overall benefit to the Liberia Electricity Corporation (LEC) network at the current time without additional information to review. Information that would help reduce uncertainty with regard to grid connection feasibility includes:

- An updated SLD of the Mount Coffee substation
- Anticipated increases in demand associated with CLSG connection
- Information on the upgrades to LEC distribution grid infrastructure since 2016 and future planned upgrades
- Project completion dates for the CLSG line from Monrovia

3.2.1 Proposed Connection Route

The proposed connection route from the Project to the Mount Coffee substation is shown in Figure 3-1 below.

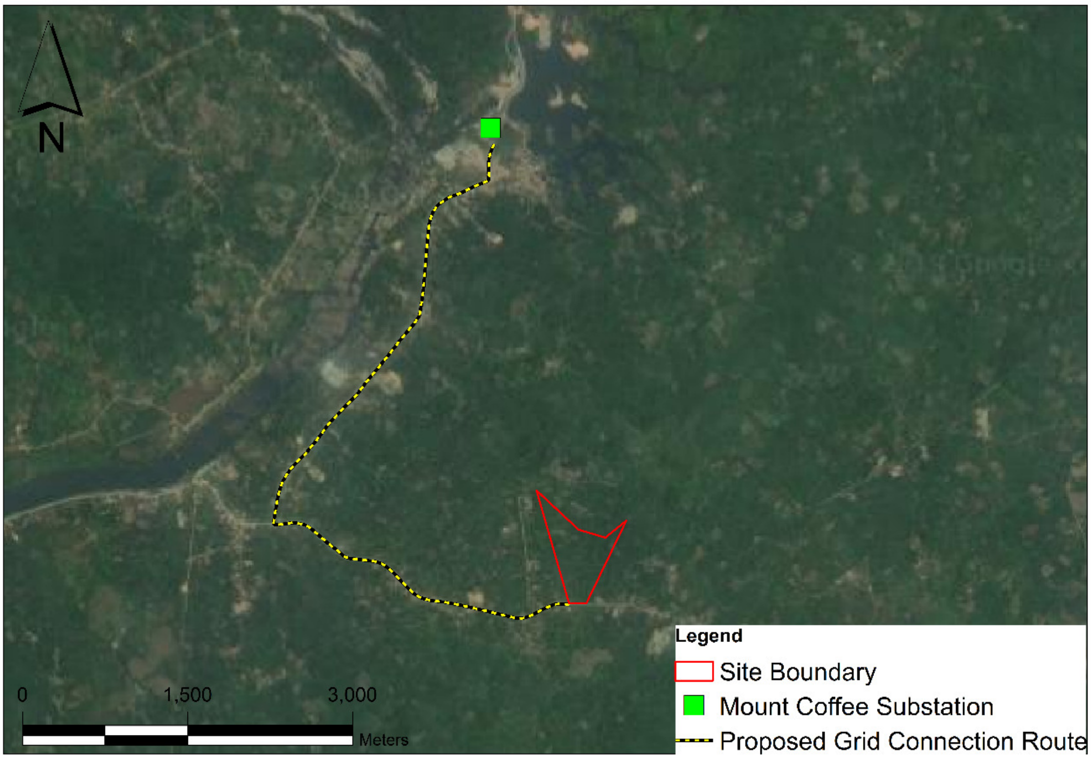

Figure 3-1: Proposed Connection Route

The proposed route would require 7.2 km of overhead line (OHL) and it is proposed that the OHL would be constructed within the wayleave of the existing roads to the substation. Utilising the existing road corridor and wayleaves minimises any requirement for additional land-take and associated resettlement/compensation. This also facilitates easy access to construct the OHL infrastructure. This approach has been successfully adopted in relation to other projects, including for example in Kenya. The width and details of the land rights within the existing road wayleave should be investigated further to confirm feasibility with regard to this Project.

In order to connect to the substation infrastructure, it is considered that OHL of 22 kV or 66 kV would be most appropriate, with the voltage having to be stepped up to 66 kV at the substation if 22 kV line were used. The voltage specification of the OHL may be dependent on LEC requirements.

4 Solar Resource Assessment

4.1 Background

The accuracy of any solar energy yield prediction is strongly dependent on the accuracy of the solar resource dataset. The solar resource of a location may be defined by values of the global horizontal irradiation, direct normal irradiation, diffuse horizontal irradiation and global tilted irradiation. These parameters are described in Table 4-1.

Table 4-1: Solar Resource Assessment Parameters

Parameter	Description
Global Horizontal Irradiation (GHI)	GHI is the total solar energy received on a unit area of a horizontal surface. It includes solar energy received in a direct beam and from radiation scattered off the atmosphere arriving from all directions of the sky (diffuse irradiation).
Diffuse Horizontal Irradiation (DHI)	DHI is the energy received from radiation scattered off the atmosphere arriving from all directions of the sky on a unit area of horizontal surface. DHI values are strongly dependent on weather conditions and the clarity of the air.
Direct Normal Irradiation (DNI)	DNI is the total solar energy received on a unit area of surface directly facing the sun at all times. The direct normal irradiation is of use for solar installations that track the sun and to concentrating solar technologies, as only radiation coming directly from the sun may be focussed by a lens or mirror.
Global Tilted Irradiation (GTI)	In the northern hemisphere, a surface tilted at an angle towards the south receives a higher total annual global irradiation compared to the horizontal plane. The amount of irradiation received is quantified at each tilt angle by the GTI and includes direct and diffuse irradiation along with ground reflected irradiation. The optimal tilt angle varies primarily with latitude and may also depend on local weather patterns and plant layout configurations.
Albedo	Tilted modules also benefit from irradiation reflected from the ground which is dependent on the ground reflectance, or albedo. The ground albedo or reflectance is highly site dependent, with typical grass coverings giving an albedo of approximately 0.2 and fresh snow giving an albedo of approximately 0.8, meaning respectively that 20% and 80% of the irradiation is reflected.

4.2 Horizon Profile

Global tilted irradiation for a specific site location may be reduced if there is significant shading from mountains or obstacles on the far horizon. A review of online satellite imagery and terrain profiling suggests horizon shading will have minor impact on the resource available at the Project site. The horizon shading profile is illustrated on the sun path diagram in Figure 4-1.

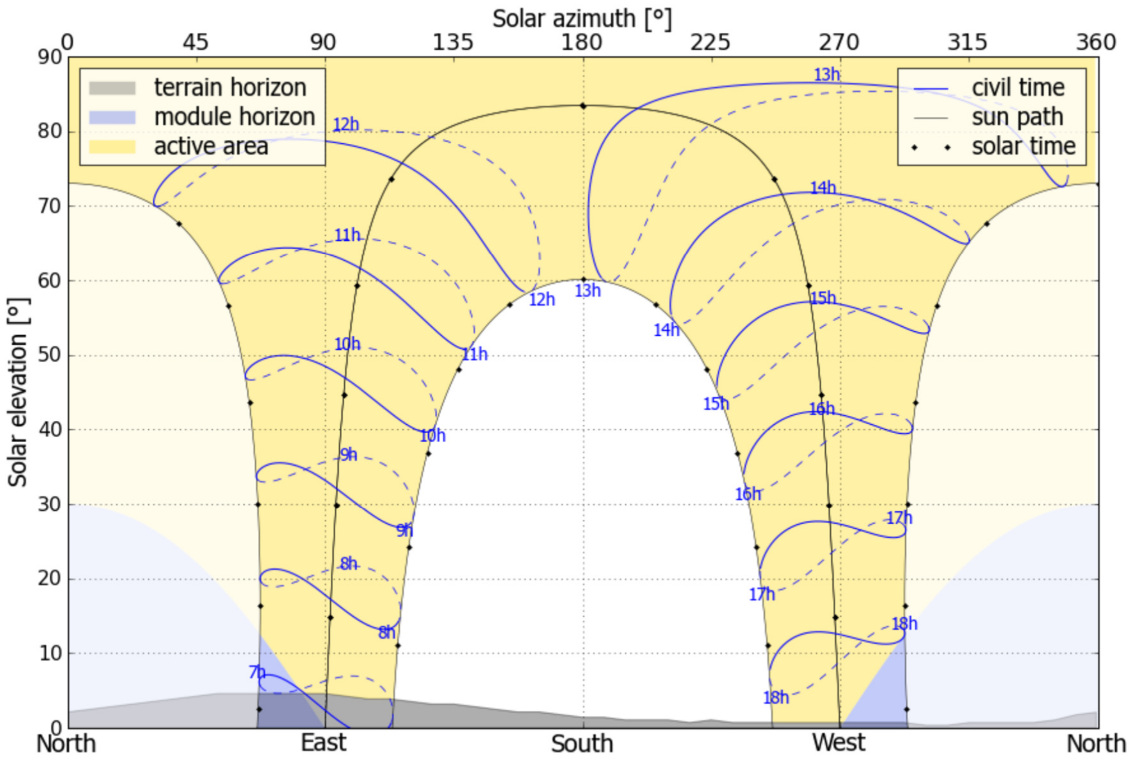

Figure 4-1: Horizon Shading Profile

4.3 Comparison of Resource Databases

There are a variety of sources of historical solar irradiation data that may be utilised to estimate the solar resource. The datasets either make use of ground based measurements at well controlled meteorological stations or use processed satellite imagery. A minimum of 10 years of data is recommended to provide a representative value for the long-term average.

Wood considers irradiation data from five databases which are detailed in Table 4-2.

Table 4-2: Irradiation Databases

Database	Temporal Resolution	Spatial Resolution	TA's Comments
Meteonorm	1991 – 2010	3 km	The nearest MET station to the Project location is too far away and the data are based on 100% satellite data. An uncertainty of 3% is attributed to the site location's resource.
PVGIS Climsaf	1998 - 2013	2.8 km	In Wood's experience, the PVGIS Climsaf database can provide extreme monthly GHI values, and no publicly available validation studies are available for the Project region.
PVGIS SARAH	2007 – 2016	5 km	In Wood's experience, the PVGIS SARAH database can provide extreme monthly GHI values, and no publicly available validation studies are available for the Project region.
Helioclim	2004 – 2015	4 km	In Wood's experience, the HelioClim-3 database can provide extreme (both high and low) monthly GHI values, and no publicly available validation studies are available for the Project region.
SolarGIS PVPlanner	1994 – 2018	0.3 km	The SolarGIS database has been validated against high quality ground-based measurement stations. It also achieved the highest accuracy compared with a number of different resource datasets in an independent study[14]. An uncertainty of 8% has been considered for the site.

[14] P. Ineichen, Five satellite products deriving beam and global irradiance validation on data from 23 ground stations. February 2011.

4.4 Comparison of Resource Datasets

The above irradiation datasets for the Project site have been assessed and compared. As described in Table 4-2, PVGIS SARAH, PVGIS ClimSAF and Helioclim can overestimate or underestimate the solar resource. For this location the stated uncertainty for Meteonorm .is 3% whereas the stated uncertainty for SolarGIS PV Planner is 8%. Given that the closest Meteo station is over 1300 km away, Wood does not consider the Meteonorm uncertainty to be realistic. Therefore, based on our internal methodology, Wood has chosen SolarGIS as the most representative dataset for this location. There is an option of buying SolarGIS Climdata which would provide a more exact uncertainty for the location but this has not been done at this preliminary stage. The results are shown graphically in Figure 4-2.

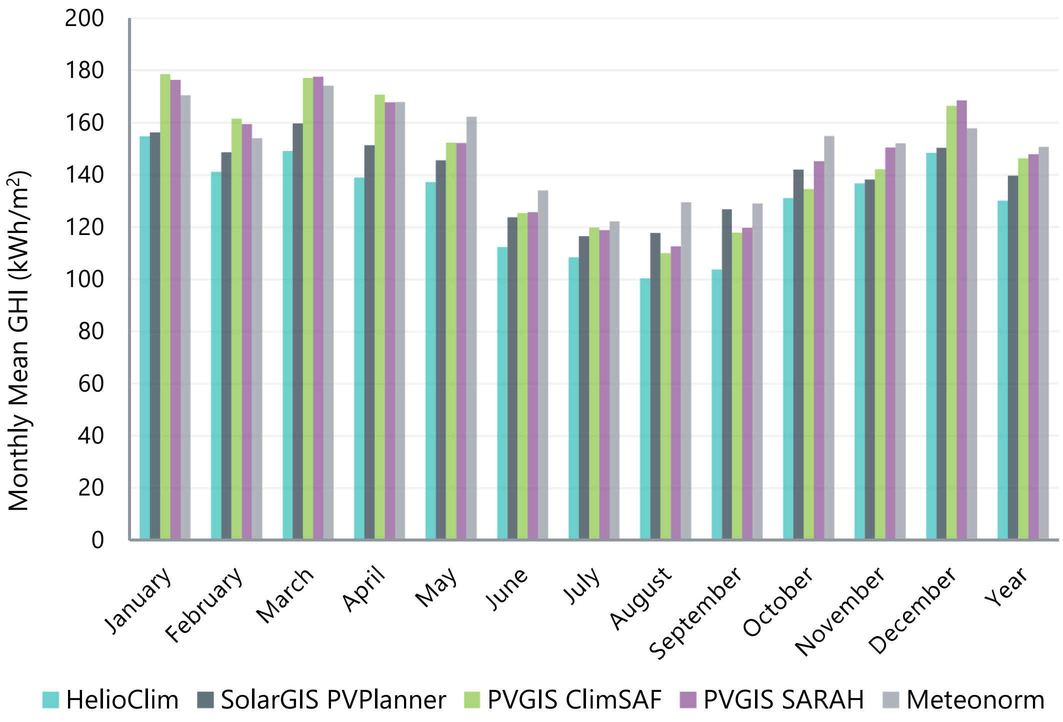

Figure 4-2: Monthly Mean GHI

A summary of the annual values and selected dataset is given in Table 4-3.

Table 4-3: Comparison of Solar Irradiation Datasets

Data Source	Annual GHI (kWh/m^2)	Annual GHI Uncertainty (%)
HelioClim	1,561	Unpublished
SolarGIS PVPlanner	1,676	8%
PVGIS ClimSAF	1,755	Unpublished
PVGIS SARAH	1,773	Unpublished
Meteonorm	1,807	3%
Selected Dataset	**SolarGIS PVPlanner**	

4.5 Solar Resource Monthly Distribution

Horizontal plane and diffuse irradiation data based on long-term monthly averages are presented in Table 4-4 and shown graphically in Figure 4-3.

Table 4-4: GHI Data (source: SolarGIS PVPlanner)

Month	Monthly GHI (kWh/m^2)	Monthly Diffuse (kWh/m^2)	Proportion of GHI to Annual
January	156.2	89.9	9.3%
February	148.6	85.1	8.9%
March	159.6	98.3	9.5%
April	151.2	92.1	9.0%
May	145.5	87.7	8.7%
June	123.6	80.7	7.4%
July	116.4	81.2	6.9%
August	117.6	81.2	7.0%
September	126.7	79.2	7.6%
October	141.9	82.8	8.5%
November	138.1	83.1	8.2%

Month	Monthly GHI (kWh/m^2)	Monthly Diffuse (kWh/m^2)	Proportion of GHI to Annual
December	150.2	88.4	9.0%
Annual Sum	1,675.6	1,029.7	-

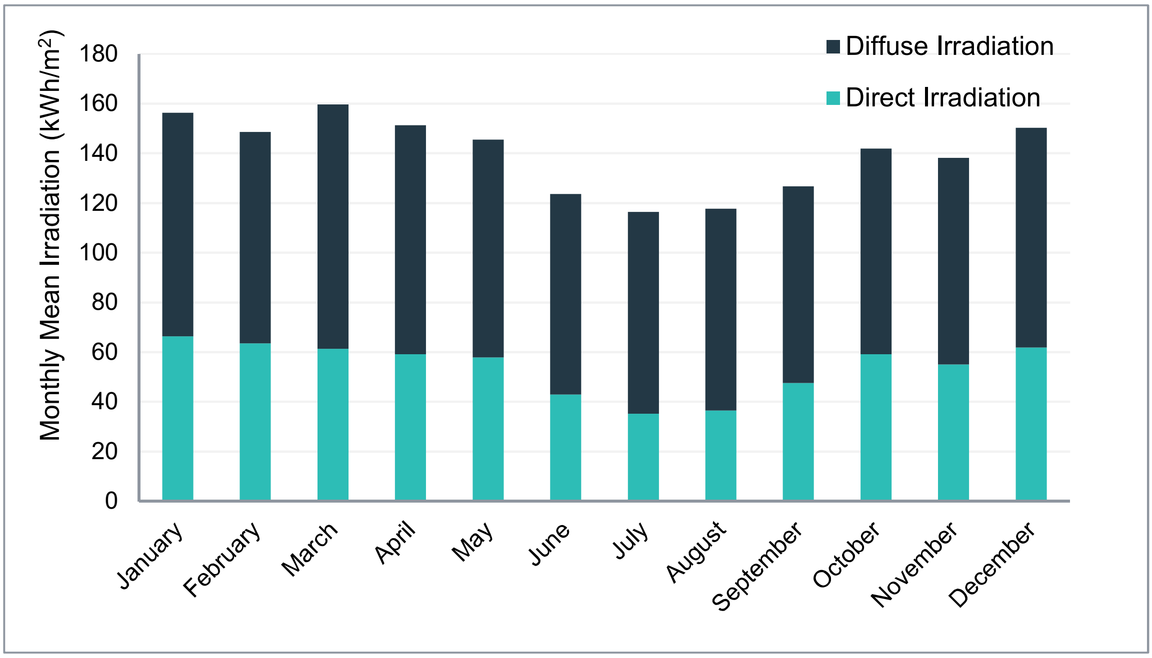

Figure 4-3: Monthly Mean GHI Split

4.6 Temperature Profile

Temperature data are used within the model for the energy yield prediction, principally to calculate module performance due to temperature deviation from Standard Test Conditions (STC). The Project's temperature profile is shown in Table 4-5 below, also taken from the SolarGIS database for consistency purposes.

Table 4-5: Temperature Data (source: SolarGIS)

Month	Average Temperature (°C)
January	26.1
February	26.4
March	6.8
April	26.9
May	26.1
June	24.9
July	24.0
August	23.7
September	24.1
October	24.8
November	25.4
December	25.9
Annual Average	25.4

4.7 Precipitation and Soiling

Wood has obtained monthly precipitation values from the Meteonorm database for the Project location, as illustrated in Figure 4-4. Significant amounts of rainfall can be expected in the summer months with much less occurring in the winter months at the Project location. The reduced precipitation could lead to soiling effects unless a suitable cleaning regime is instituted. Additional study on the causes of soiling would inform the design of the most effective cleaning intervals.

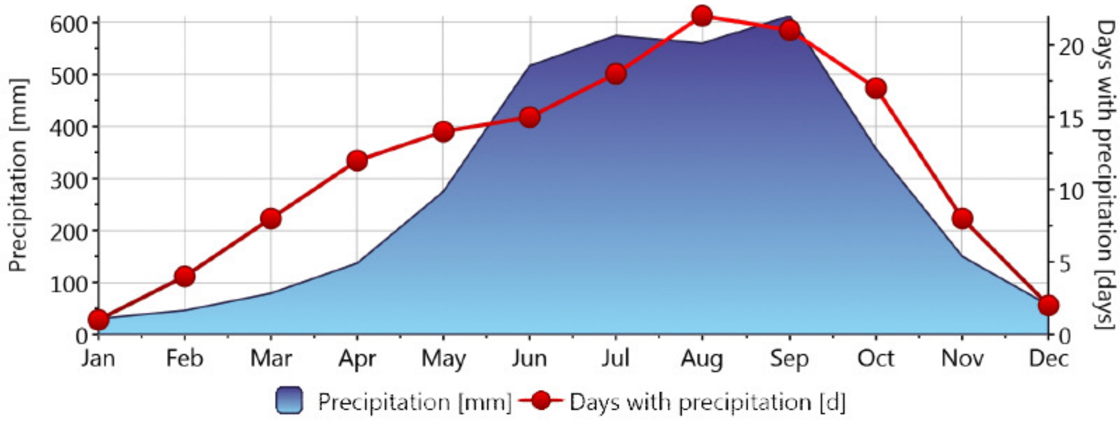

Figure 4-4: Monthly Precipitation Levels

5 Conceptual Basis of Design

Wood has prepared a preliminary capacity estimation based on the areas available for the development of ground-mounted solar PV plant explained below. The equipment specification and indicative energy yield assessment for the specified system are described in the following sections.

5.1 Areas for Development

Wood was provided with a site boundary containing an area of approximately 31.8 ha. The shape of the boundary allows for one field of panels that can be expanded or contracted if required to change the total plant capacity.

At this preliminary stage it has been assumed that the existing vegetation cover will be removed and that there is no significant shading.

5.2 Plant Design Technical Specifications

5.2.1 Mounting Structures

PV modules must be mounted on a structure, to keep them oriented in the correct direction and to provide them with structural support and protection. Mounting structures may be fixed or tracking.

Fixed mounting systems keep the rows of modules at a fixed tilt angle while facing a fixed angle of orientation. Fixed tilt mounting systems are simpler, cheaper and have lower maintenance requirements than tracking systems. They are the preferred option for countries with a nascent solar market and limited indigenous manufacture and maintenance of tracking technology.

Tracking systems follow the sun as it moves across the sky. They are generally the only moving parts employed in a PV power plant. Single-axis trackers alter either the orientation or tilt angle only, while dual-axis tracking systems alter both orientation and tilt angle. Dual-axis tracking systems are able to track the sun more precisely than single-axis systems. In locations with a high proportion of direct irradiation, single or dual-axis tracking systems can be used to increase the annual energy yield by up to 27% for single-axis and 37% for dual-axis trackers (depending on the site and precise characteristics of the solar resource)[15].

However, capital costs of a tracking system will be higher than fixed tilt systems. Operation and maintenance (O&M) costs are also typically higher as a result of the introduction of moving parts and higher overall system complexity.

On average over a year in Monrovia, only approximately 38%[16] of daylight hours would be categorised as sunny (62% cloudy). As shown in Figure 4-3, the proportion of direct trackable irradiation is also relatively low (monthly means ranging from approximately 30% to 40%). In addition, there is a lack of an established solar O&M industry in Liberia and some uncertainty exists regarding the consistency of road conditions in the vicinity of the site. Consequently, it is considered that a fixed tilt system may be most appropriate for the Project.

A fixed tilt system has been assumed for the purpose of this study.

5.2.2 Other Specifications

To ensure that the energy yield assessment for the sites is based on the best plant configuration, Wood has implemented industry best practice for minimising inter-row shading losses while using optimum tilt angle, pitch distance and plant DC/AC ratio based on Wood's extensive experience of large scale PV development. For illustration, Wood has selected example equipment from leading suppliers.

The conceptual design parameters are summarised in Table 5-1.

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[15] IFC (2012) Utility Scale Solar Power Plants: A Guide for Developers and Investors (written by SgurrEnergy, now Wood, on behalf of IFC). Report available at: https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_handbook_solarpowerplants

[16] ClimaTemps (2019). Sunshine & Daylight Hours in Monrovia, Liberia. Data accessed at: www.liberia.climatemps.com/sunlight.php

Table 5-1: Plant Design Technical Specifications

Parameter	Value
Plant Equipment	
PV Modules	58,440 * First Solar 445Wp FS-6445
Inverters	190 kVA Huawei SUN2000-105TL-H1 String Inverter
Nominal power ratio[17]	1.30
Plant Layout	
Azimuth	-90°, 90° (East/West layout)
Tilt angle	15°
Inter-row pitch distance	12.3 m
Module orientation	4 x landscape

[17] Installed DC capacity in kWp divided by installed inverter AC capacity in kVA

6 Conceptual Layout

A conceptual layout design for the Project has been created, based on the location and site boundaries provided by the Client. Wood has used industry best practice as well as the plant design technical specification described in Section 5.2. The following parameters and assumptions have been considered in the conceptual designs:

- East/West system with tilt angles of 15°
- PV arrays (four rows of 24 PV modules in landscape orientation), represented in blue on the layout.
- Main PV plant substation (for grid connection), represented in pink on the layout. An indicative location for the substation was chosen.
- All site fenced areas are assumed available for construction, no allowance has been made for layout constraints such as topography, removal of trees and other vegetation, ground conditions.

The conceptual design results are summarised in Table 6-1.

Table 6-1: Conceptual Layout Design Summary

Site	Values
Number of PV modules	58,440
Installed DC Capacity (MWp)	26.005
Installed AC Capacity (MWac)	19.95
Construction Area (ha)	19.9

Figure 6-1 shows the conceptual layout with further details provided in Appendix A. The most suitable areas for allocating the PV arrays, internal access roads, and substation have been identified. The East/West system was chosen as it is an efficient design for sites located close to the equator as it allows for a flat panel angle to maximise exposure to the sun. It is also space efficient for the capacity which reduces the cost of construction.

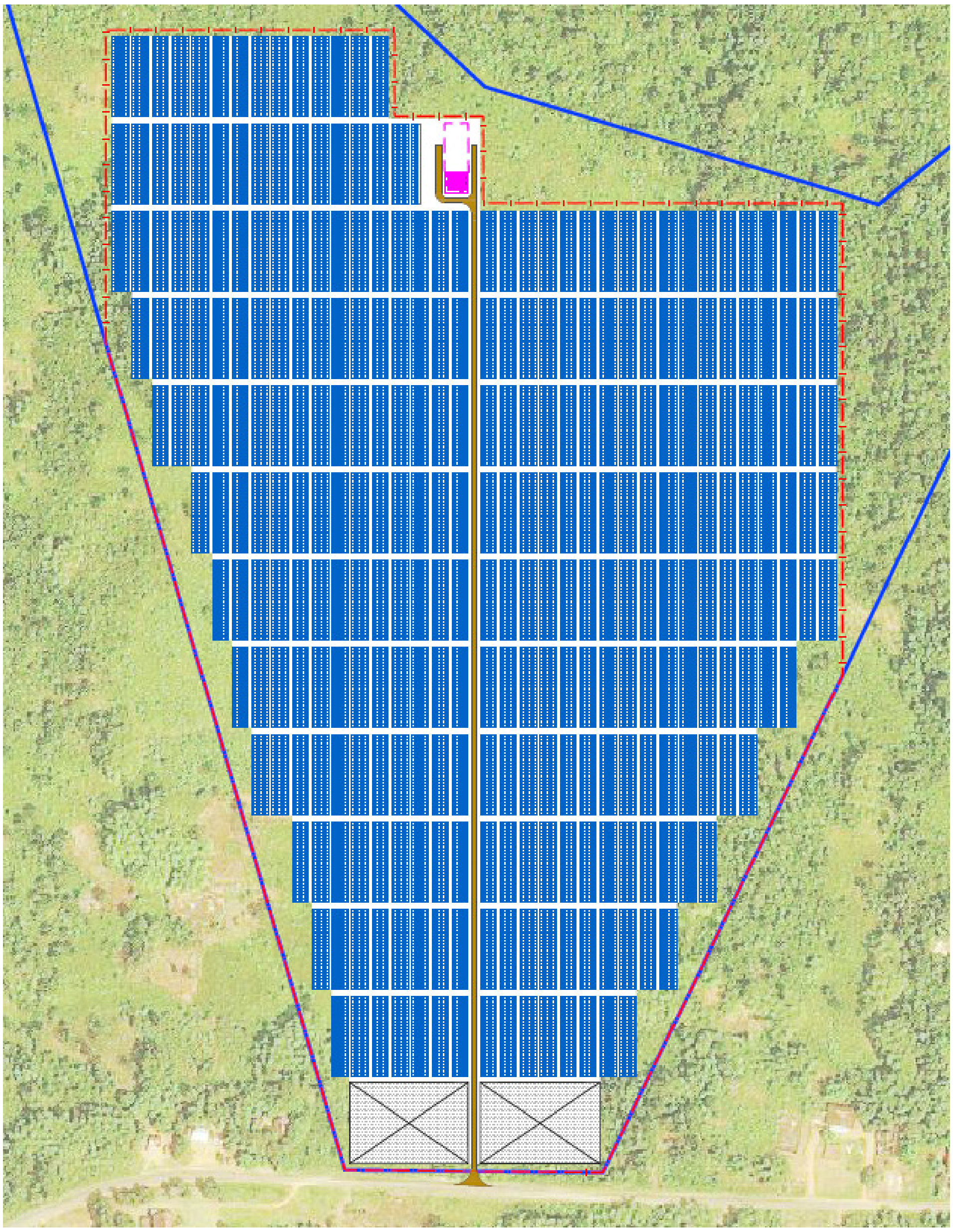

Figure 6-1: Mount Coffee Solar Farm Conceptual Layout

7 Energy Yield Assessment

Irradiation data from the selected dataset was entered into PVsyst along with details of the plant design and potential loss factors in order to undertake an energy yield assessment and calculate first-year and long-term P50 energy yields and Performance Ratio (PR).

7.1 Energy Yield Loss Factors

The performance of a PV power plant, typically quantified by its PR, is defined as its performance over a given time independent of plant capacity or solar resource. The PR is defined as the ratio between the actual AC yield and the theoretical yield that would be generated by the plant if modules converted the irradiation received into useful energy according to their rated capacity. A plant with a high PR value is more efficient at converting solar irradiance into useful power. The PR can vary significantly on a monthly basis as there are many different loss factors which influence it.

The PR quantifies the overall effect of system losses on the rated capacity, typically at the export metering point. Those losses are caused by module, inverter and transformer electrical characteristics and degradation, meteorological parameters (temperature and irradiation including low light efficiency reduction), DC and AC cabling, horizon, electrical and near shading, soiling, auxiliary consumption and availability. These losses are applied based on the TA's knowledge of performance of similar PV plants.

Table 7-1 provides an explanation on how such losses are applied to the yield and what the model inputs are.

Table 7-1: Description of Energy Yield Loss

Loss	Description	TA Project Assumptions
Horizon Shading	The horizon shading loss refers to losses due to mountains or obstacles on the far horizon. This loss can also account for losses due to topography.	Based on the horizon shading profile obtained and site topography, horizon shading losses will have a relatively low impact on the yield.
Near Shading	The near shading loss refers to losses due to trees, buildings or overhead cabling in the proximity of the installation along with inter-row shading.	A simplified 3D model of the plant has been modelled based on the design parameters assumed.

Loss	Description	TA Project Assumptions
Incident Angle Modifier (IAM)	IAM losses account for radiation reflected from front glass when the striking light is not perpendicular.	Based on the module type, a standard ASHRAE model with a b_0 factor of 0.05 has been assumed.
Soiling	Soiling losses are mainly due to dust, sand, pollution, snow and bird droppings soiling the modules. They are principally dependent on a site's precipitation profile, both in terms of quantity and frequency of precipitations, and proposed cleaning schedules.	Based on the site's precipitation profile, anticipated module cleaning strategy and potential nearby sources of soiling, an indicative soiling loss of 3% has been assumed. This is based on the periods of dry weather in the winter months and would be reduced provided a sufficient cleaning regime is enacted.
Low Irradiance	The conversion efficiency of a PV module typically reduces at low light intensities. This causes a loss in output of a module compared with STC. This loss depends on the characteristics of the module and the intensity of the incident irradiance.	Wood used a .PAN file stored within the modelling software's database.
Module Temperature	The output of a PV module is determined at a standard temperature of 25˚C and decreases at higher temperatures.	The power temperature coefficient provided in the .PAN file has been used. A standard constant thermal loss factor of 29 W/m^2K was assumed in the modelling software.
Electrical Shading	Electrical shading losses are due to partial shading of strings. The effect of partial shadings on electrical production of the PV plant differs depending on the module orientation and technology.	Shading loss of 60% is assumed for landscape orientation of modules. This is a standard assumption based on PVSyst recommendation.
Module Quality	Most PV modules do not match exactly the manufacturer's nominal specifications. Modules are provided with a nominal peak power and a given tolerance within which the actual power is guaranteed to lie.	A standard module quality uplift of 0.5% was assumed given the specified module has a positive power tolerance.

Loss	Description	TA Project Assumptions
First Year Degradation	The performance of PV modules decreases with time after the first hours of exposure to sunlight, an effect known as Light Induced Degradation (LID).	In keeping with analysis involving First Solar modules, First Year degradation has not been applied.
Module Mismatch	Losses due to mismatch are related to varying temperature and irradiance conditions and the fact that the modules in a string do not all rigorously present the same current / voltage characteristics; there is a statistical variation between them.	A 0.8% loss at Pmpp was calculated based upon a 3% Gaussian distribution of the IV characteristics of the modules.
DC Cabling	Electrical resistance in the cables between the modules and the input terminals of the inverter give rise to ohmic losses.	DC cabling power loss calculations have not been provided to Wood for review. Therefore, a standard loss factor of 1.0% was applied.
Inverter Performance	Inverters convert from DC into AC with a maximum efficiency at a specific load with lower efficiencies at other loads.	Wood used an .OND file sent by the manufacturer and checked its electrical properties against the provided datasheet.
Power Factor	Revenue can only be generated through export of active power. As such, non-unity power factors affect the effective Project yield, as a power factor less than unity reduces the active power export.	No GCO was provided to Wood for review. Therefore, the power factor is assumed to be at unity.
Grid Export Limitation	When the grid export limitation, typically defined in the Grid Connection Offer (GCO), is lower than the overall plant rated AC capacity, it is safe to assume that the inverters' output will be curtailed to comply with grid requirements.	It is understood that the inverters will not have a curtailed output.
AC Cabling	AC cabling losses account for electrical resistance in the cables from the inverter output to the transformer and main MV switchgear.	AC cabling power loss calculations have not been provided for review. Therefore, a standard loss factor of 1.0% was applied.

Loss	Description	TA Project Assumptions
Transformer	Transformer losses account for the LV / MV transformers. These have constant iron losses and variable resistive / inductive losses.	Constant iron and resistive / inductive losses of 0.1% and 1% have been assumed respectively for the LV/MV transformers.
Auxiliary Consumption	The plant equipment consumes energy during operation. Auxiliary consumption losses account for such equipment's consumption and includes inverter fans, camera surveillance and monitoring systems, auxiliary transformers amongst others.	The auxiliary consumption of the inverters and other equipment has been considered in the simulation.
Availability	This includes plant availability and grid availability. Availability losses constitute periods when the plant does not generate due to failure. Actual plant availability will depend on the stability of the local grid, the diagnostic response time, spare parts and repair response time.	99% availability to account for plant and grid unavailability has been assumed.
Long Term Degradation	The performance of a PV module decreases with time. Module output degradation is typically modelled at between 0.3% and 0.7% per year for crystalline silicon modules.	A long-term degradation rate of 0.4% was assumed for the system.

7.2 Annual Yield Prediction

Table 7-2 summarises the predicted resource, losses and energy yield (P50) for the first year of operation.

Table 7-2: Energy Yield Prediction

Parameter	Value
Peak Power of Plant (kWp)	26,006
Annual GHI (kWh/m2)	1,675
Annual GTI (kWh/m2)	1,642
Maximum Grid Export Capacity (kWp)	Unknown
Operating Power Factor	Unity
Horizon Shading Loss (%)	0.5%
Near-Shadings Loss (%)	3.6%
IAM Loss (%)	2.6%
Soiling Loss (%)	3.0%
Low Irradiance Loss (%)	3.3%
Module Temperature Loss (%)	6.3%
Electrical Shading Loss (%)	0.0%
Module Quality Loss (%)	-0.5%
First Year Degradation Loss (%)	0.0%
Module Mismatch Loss (%)	0.8%
DC Cabling Loss (%)	0.6%
Inverter Performance Loss (%)	1.2%
Energy Yield at Inverter Output (MWh)	34,524
Specific Yield at Inverter Output (kWh/kWp)	1,328
Performance Ratio at Inverter Output (%)	80.8%

Parameter	Value
Auxiliary Consumption (%)	0.3%
AC Cabling Loss (%)	0.5%
Transformer Loss (%)	0.8%
Availability Loss (%)	1.0%
Curtailment Loss (%)	0.0%
P50 Energy Yield (MWh)	33,665
P50 Specific Yield (kWh/kWp)	1,295
Performance Ratio (%)	78.8%

7.3 Monthly Breakdown

The first year P50 energy yield and PR can be broken down by month to assess the variability over the year. These data are given in Table 7-3 and illustrated in Appendix A. Also, an analysis by month of the individual loss factors are presented in the same Appendix.

Table 7-3: Monthly Breakdown of First Year Energy Yield

Month	P50 Yield (MWh)	PR (%)
January	3,168	79.4%
February	3,003	79.2%
March	3,202	78.7%
April	3,034	78.7%
May	2,917	78.8%
June	2,477	78.9%
July	2,340	79.1%
August	2,360	79.0%
September	2,540	78.9%

Month	P50 Yield (MWh)	PR (%)
October	2,845	78.5%
November	2,750	78.1%
December	3,027	78.8%
Year	33,665	78.8%

7.4 Long Term Annual Yield

As modules show a reduced performance with time, the P50 energy yield for the first 20 years were also calculated and are shown in Table 7-4.

Table 7-4: Annual P50 Energy Yield Prediction after Degradation

Year	Energy Exported (MWh)
1	33,665
2	33,530
3	33,396
4	33,262
5	33,129
6	32,997
7	32,865
8	32,733
9	32,602
10	32,472
11	32,342
12	32,213
13	32,084
14	31,955
15	31,828

Year	Energy Exported (MWh)
16	31,700
17	31,574
18	31,447
19	31,321
20	31,196
21	31,071
22	30,947
23	30,823
24	30,700
25	30,577
Total	**802,429**

8 Cost Analysis

Wood has developed indicative Capex and Opex assumptions for the Project, based on the proposed system design and industry experience.

The Client is advised to verify these values with the appropriate procurement and governmental parties.

8.1 Cost of Construction - Capex

The average historic and expected cost of the overall system (excluding development costs, grid connection costs and other administrative costs) and key components used in the construction of a utility-scale PV plant is presented in Figure 8-1. It is noted these are the approximate costs for each of the main construction aspects based on European and global experience. However, pricing in Liberia may be slightly higher due to the relatively low market penetration and scale of the solar PV market within the region. For example, a 8.5 MW project constructed in Rwanda in 2014 was financed for a total cost of $23.7 million, equivalent to $2.79/Wp. Therefore, the cost of a project does not just vary according to the cost of the equipment, but also due to other factors such as the complexity of logistical challenges, cost of financing and the perceived risk to EPC contractors operating in a less developed market.

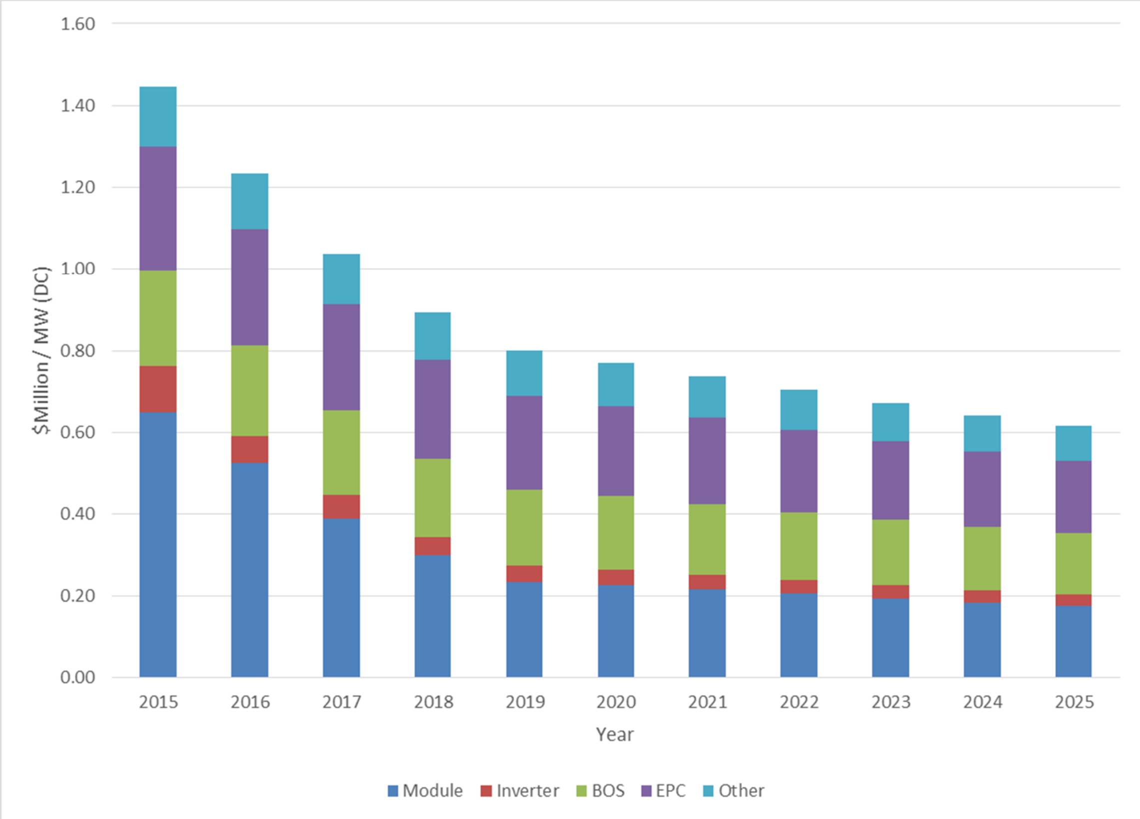

Figure 8-1: Average Capex Costs for Utility-scale Fixed-Axis Solar PV Plants[18]

The above graph indicates that the global average total Capex for utility-scale, fixed-axis solar PV plants is expected to be in the region of $0.8/W in 2019 and $0.74/W by 2021. As discussed above, the equivalent cost may be slightly higher in Liberia.

As well as the system costs, typically wrapped up within an EPC contract, the total Capex will also include other costs including project development and consenting costs, the cost of grid connection, other administrative fees and contingency.

Key site-specific technical variables that could significantly affect the financial viability of a Solar PV development at this location would be the extent of any road upgrading required along the proposed access route, the cost of grid connection, and foundation design for the Project ground conditions.

[18] Source data: BloombergNEF (2019). Not including developer fees, taxes, legal costs, corporate finance fees.

8.1.1 Benchmark Costs (Capex elements)

The benchmark costs for the main Capex elements are shown in Table 8-1, assuming construction were to commence in 2021.

Table 8-1: Capex Assumptions

Item	Cost ($/Wp, unless otherwise stated)	Details
EPC contract	1.0	An indicative assumption based on the current global fixed-tilt PV system costs, increased slightly to indicate anticipated higher costs in Liberia.
Grid connection	$250,000 per km	An indicative assumption based on industry experience. This will be subject to final design. This assumes a 7.2km connection route, and equates to an indicative total of $1.8M ($0.07/Wp).
Development	0.1	An indicative assumption based on experience of similar African projects and industry experience.
Other (including Contingency)	0.1	An indicative assumption based on industry experience.
Total	**1.27**	

The EPC contract element would typically be dominated by the cost of procuring and installing the PV system and includes the indicative cost assumptions in relation to key system components shown in Table 8-2.

Table 8-2: EPC Contract Assumption Breakdown

System Component	Cost ($/Wp)	Details
Modules	0.25	Assumption based on BloombergNEF data and industry experience.
String Inverters	0.07	Assumption based on industry experience.
Mounting structures	0.08	Assumption based on industry experience in relation to E-W oriented arrays.

System Component	Cost ($/Wp)	Details
BOS/Other	0.6	This assumption includes other EPC costs such as design work, transportation, construction and installation of main system components, procurement and construction of access roads and other ancillary infrastructure, SCADA, security and the costs associated with the testing and acceptance process and performance guarantees.
Total	**1.0**	

These Capex assumptions are high-level indicative assumptions, based on industry experience and available data in relation to other similar projects. Financial modelling should be revisited as more confidence is gained in these cost elements in relation to this particular project.

8.2 Cost of Operation and Maintenance - Opex

Expenditure incurred during operation and maintenance of a PV plant in Liberia is not well established. As a nascent market, local O&M contractors may lack appropriate experience. Set-up and training would result in greater expenses, but this could be compensated by lower long-term maintenance cost. On this basis, it has been assumed that costs could be similar to the well-established European market. A breakdown of indicative Opex assumptions is shown in the Table 8-3.

Table 8-3: Opex Assumptions

Cost Item	Annual Cost ($)	Details
O&M Contract	390,000	Operations and maintenance contract including maintenance of equipment, cleaning, ground keeping, etc.
Insurance	39,000	Insurance is required throughout the Project life to mitigate the risks of damage and theft.
Other	39,000	Administration, contingency, etc.
Total	468,000	-

The provision of a maintenance reserve account should also be considered in relation to the cost of replacing inverters during the life of the project.

These Opex assumptions are high-level indicative assumptions, based on industry experience and available data in relation to other similar projects. The O&M Contract assumption is also guided by Client expectations on costs. Financial modelling should be revisited as more confidence is gained in these cost elements in relation to this project.

9 Initial Environmental and Social Impact Analysis

9.1 Environmental and Social Impact Assessment Process in Liberia

9.1.1 Appraisal Process

The Environment Protection Agency (EPA) Act and the Environment Protection and Management Law (EPML), both published in 2003, are the principal pieces of legislation covering environmental protection and management in Liberia. The Act provides the legal framework for the sustainable development, management and protection of the environment by the EPA in partnership with relevant ministries, autonomous agencies and organizations. It also stresses inter-sectoral coordination while allowing for sector-specific statutes.

The EPML defines the specific requirements for performing an ESIA and other measures required to protect the environment in Liberia. An ESIA process flow chart is shown in Figure 1 1. This process is applied prior to issuance of environment permits. The main steps in the process are[19]:

- *Application for ESIA permit* – A formal request, in the form of a letter, is made to the EPA prior to the commencement of project activities.
- *Submission of Project Brief* – Following a response from the EPA, the project proponent is advised to proceed with the Project Brief.
- *Screening* – Screening is a process that is undertaken by the EPA to determine whether a proposal should be subject to an ESIA and if so, to what extent. If it is determined that the project does not require a full ESIA, the permit is issued or denied at this stage. In the case of the Mount Coffee 20 MW solar plant, an ESIA will almost certainly be required because of the likely interpretation of the mandatory ESIA list in Annex 1 (Section 6) of the EPML: this does not specifically mention photo-voltaic power generation plants (which were not envisaged on this scale in 2003), but requires an ESIA of all other forms of energy production.
- *Notice of Intent* – If the project, following screening, is subject to a full ESIA, a notification is made through the media describing the proponent's intention to engage in an undertaking.

[19] Environmental Protection Agency (EPA) of Liberia, 2017. Environmental & Social Impact Assessment Procedural Guidelines.

- *Scoping* – Scoping is undertaken to identify the issues and impacts that are likely to be important and to establish the terms of reference for an ESIA study. This is largely a public consultation exercise. The findings are submitted as a separate report for EPA approval.
- *ESIA preparation* – This involves a number of distinct activities leading to the preparation of the ESIA in the form of a self-standing report for submission to the EPA. It must follow the terms of reference defined in Scoping.
    - *Baseline determination* – Data are collected on the relevant aspects of the physical, biological and socio-economic environments to define the current situation.
    - *Impact analysis* – Impact analysis is the process that will identify and predict the likely effects of the proposal on the current environmental, social and other related conditions.
    - *Evaluation of significance* – This is required to determine the relative importance and acceptability of residual impacts (i.e. impacts that cannot be mitigated).
    - *Mitigation and impact management* – To establish the measures that are necessary to avoid, minimize or offset predicted adverse impacts and incorporate them into an environmental and social management plan or system.
    - *Preparation of an environmental impact statement (EIS) or report* – To document, clearly and impartially, the impacts of the proposal, the proposed measures for mitigation, the significance of effects, and the concerns of the interested public and the communities affected by the proposal.
- *Review of the EIS* – The EPA reviews the report to determine whether it meets its terms of reference, provides a satisfactory assessment of the proposal and contains the information required for decision making.
- *Decision making* – To approve or reject the proposal and to establish the terms and conditions for its implementation.
- *Follow up* – To ensure that the terms and conditions of approval are met; to monitor the impacts of development and the effectiveness of mitigation measures; to strengthen future ESIA applications and mitigation measures and where required, to undertake environmental audit and process evaluation to optimize environmental management.

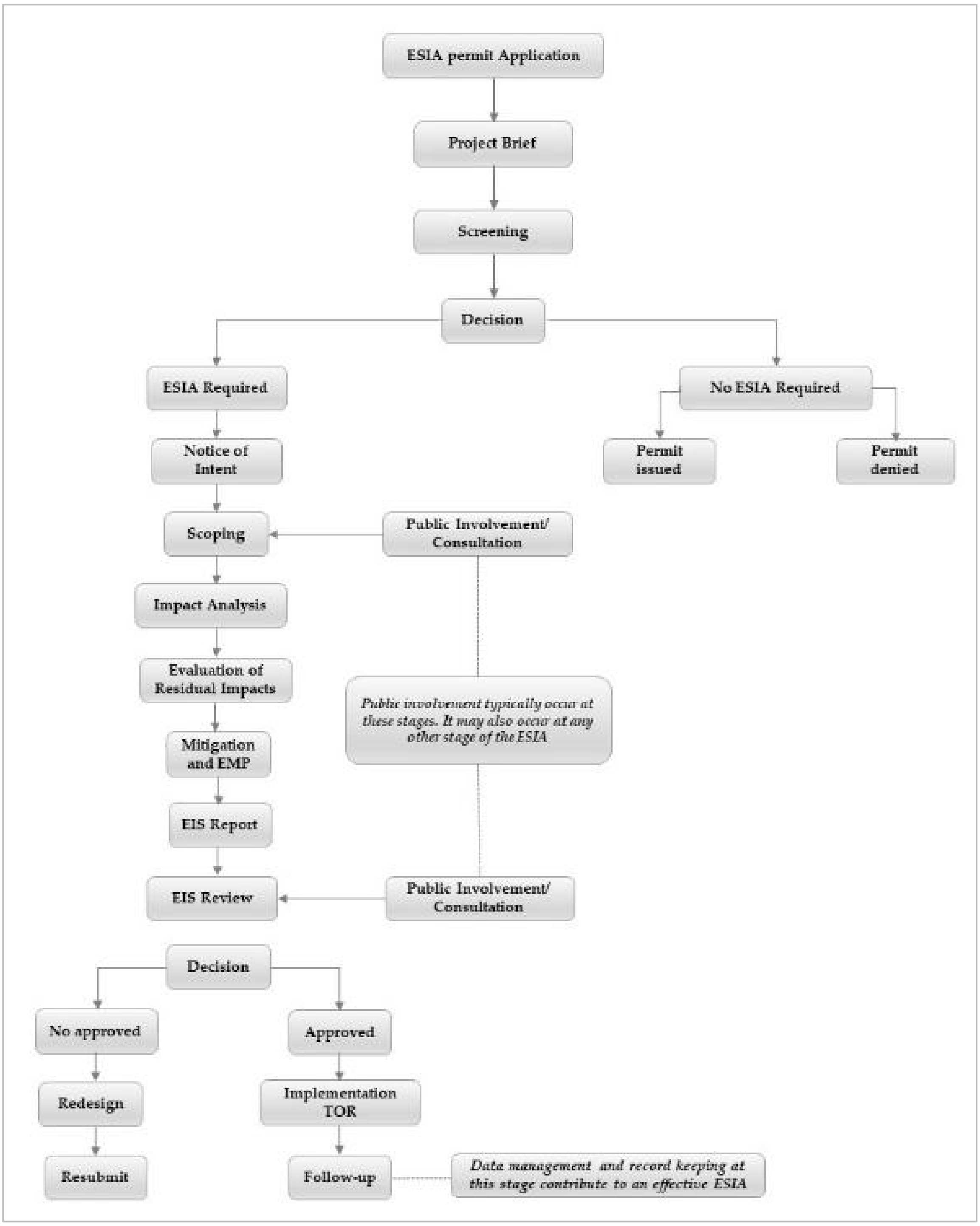

Figure 9-1: ESIA process in Liberia

9.1.2 Public Consultation Requirements

Involvement of the public in the ESIA commences with the launch of the ESIA process and continues throughout its course. The different requirements of the public's involvement throughout the ESIA process are detailed below:

1. After the submission of an application for an ESIA permit, the project proponent should publish a "notice of intent" that states the information that may be necessary to allow the stakeholders or any concerned party to identify their interest in the proposed project or activity. This information should include: the nature of the project, its related activities, its timeframe, its site of operation and the area that may be impacted.
2. Before preparing the ESIA document, the project proponent must conduct public consultations with the potential affected stakeholders. This procedure is called the "scoping process" which aims to: 1) inform the stakeholders about the project's details, its potential impacts on the physical, biological and socio-economic environments, and the mitigation measures that can be taken in order to minimize these impacts; and 2) get the stakeholders' input on the various related issues. By achieving this, the scoping process is also a guiding tool for the project proponent and its consultants. It helps them in identifying the project's impacts, mitigation measures and alternatives, which will form the essential part of the ESIA document. The scoping process consists of publishing the project's details in the affected district's media, holding public meetings to consult directly with the affected communities and stakeholders, and incorporating the views of these stakeholders in the scoping report which is submitted to the EPA.
3. Upon completion of the ESIA study report, the public is invited again to participate in the ESIA review through public consultation meetings. The public's views on the ESIA are taken into consideration by the EPA when deciding whether to approve or reject the project.
4. In some cases, the EPA also decides to hold a public hearing about the project in order to fortify the public's participation. These cases include but are not limited to requests by the public for a public hearing, controversy about the project or expiry of the period stipulated for receipt of comments.

9.1.3 Land Access

It is noted that Liberia has not yet enacted a comprehensive land law. According to existing laws, all lands not previously deeded to a private party are classified as Public Land. To address this issue, the Liberian government started a land reform process in 2009 with the establishment of a Land Commission. In May of 2013, the Land Commission presented a draft Land Rights Policy (LRP)[20]. This draft was officially adopted. Following the validation of the Land Rights Policy in 2013, the Land Commission drafted a Land Rights Bill (LRB) designed to provide a legal framework to implement the LRP. A key provision in the LRB defines four main categories of tenure in Liberia: Private Land, Customary Land, Government Land and Public Land. This provision has strong implications for rural Liberians who currently do not have formalized land rights.

It is understood that an understanding has been reached on the acquisition of the land for the power plant site with the current private landowner. The lease arrangement would be in the form of a lease of private land to another private entity. Based on the provisions of the LRP, the lease must relate to a "lawful purpose". The Project is considered to meet the definition of a lawful purpose and so no issues are anticipated in this regard.

The OHL line route may cross a number of different land ownership types including private and government land. Furthermore, establishment of a wayleave for the transmission line (typically LEC require a wayleave of 75 feet either side of line) will require a detailed survey and compensation process. Although buildings and other activities can remain within the wayleave, there would be some restrictions such the OHL having to be at least 7 m above any buildings and the height of trees being limited to 4 m.

Consequently, there would be some restrictions on what people could do with their land and so some form of compensation would be due. Furthermore, it is understood that under current Liberian law, acquisition and payment of compensation can be made by the Project or can be delegated to an agent, but that land ownership may currently be required to be devolved back to the government. This would in effect constitute a forced acquisition of land (eminent domain).

[20] Land Commission (2013). Land Rights Policy - Approved by the Land Commission Republic of Liberia on May 21, 2013. Report accessed at: http://www.land-links.org/wp-content/uploads/2013/05/Land-Rights-Policy_-Draft_4.14.13_Version-for-Pres-Cabinet-May-17_0.pdf

It is noted that the current law on eminent domain (forced acquisition) in Liberia is deemed by the Land Commission to be inadequate. The Constitution allows for the use of the eminent domain power for "public purposes" and imposes certain requirements, but landowners require additional protections. The policy recommendations contained in the LRP are designed to ensure the Government exercises eminent domain consistent with international best practices and in a manner that balances the Government's constitutional powers with the fundamental constitutional right of Private Land and Customary Land ownership.

According to the Constitution, the Government may expropriate Private Land and Customary Land only for the security of the nation in the event of armed conflict, where the public health and safety are endangered, or for any other public purposes. It is deemed reasonable to assume that the development of a secure energy supply would represent a public purpose and thus would allow the legal expropriation of land.

It is recommended that a more detailed study is undertaken to fully understand the land and lease requirements along the length of the proposed OHL and to align the lease and acquisition processes with existing and proposed legislative requirements, particularly the LRB and its enactment into law. A key principle of the LRP is that owners of Private Land and Customary Land will be provided just and prompt compensation such that, as far as possible, they are in the same [financial] position as they were in before the decision to expropriate. This should be reflected in any compensation arrangement.

It is recommended that, if required, a single resettlement and compensation is applied throughout the Project's areas of influence, which must be defined in a Resettlement Action Plan (RAP) prepared in parallel with the ESIA. As noted above, a key principle of the RAP should be to ensure that PAPs are in at least the same financial position as they were before the decision to expropriate land for the project.

Procedures for the consultation required and fixing of compensation rates can be adapted from similar projects elsewhere but will typically follow the procedure described in Table 9-1.

Table 9-1: Illustrative Liberian Acquisition, Resettlement and Compensation Procedures

Step	Action
1	Define Project's area of influence and identify potential Affected Persons (APs).
2	Identification of the resettlement needed and preparation of Terms of Reference to guide the preparation of a Resettlement Action Plan in compliance with international standards. Support from an experienced local organisation is recommended to facilitate effective and culturally sensitive engagement with APs.
3	The RAP process is discussed with relevant local authorities. Government stakeholders are engaged and the compensation process discussed and agreed with County / City / Borough and Township Land Commissioner and delegates.
4	A community consultation and information plan is prepared as part of the RAP process. Community engagement is undertaken to make communities aware of potential land and asset needs. A public information campaign is activated in relevant areas. Local Consultative Forums are set up.
5	Community and household surveys of asset loss and livelihood sources are undertaken – the needs and rights of men and women should be assessed separately within households; the needs of vulnerable groups such as the elderly and disabled should also be addressed separately.

Step	Action
6	Compensation values are negotiated through community meetings with local Community Chairmen and Elders and APs, and appropriate mitigation programmes are agreed. Compensation with regard to trees of economic value is guided by the Ministry of Agriculture price list dated August 2012.
7	A RAP report is drawn up and must be agreed by the Project management, lenders, relevant local authorities and EPA. The RAP report should list the procedures to be followed, the list of APs and their losses, the entitlement to compensation or other programmes, costs and implementation methodology and partners, and monitoring and evaluation procedures.
8	Agreement through the environmental permitting process to continue with land, asset and resource acquisition.
9	Payment of cash compensation or implementation of replacement land for land taken etc. Payments to be made in public at open meetings and recorded in writing with signatures, and the recipient photographed with the compensation or meeting record confirming alternative compensation. Sufficient time has to be allowed for rebuilding houses, finding land etc. – the time to do this must be recompensed to the AP as undertaking this activity deprives the person of income earning opportunities.

9.1.4 ESIA Process Timing

The timescale for the environmental permitting process is difficult to determine because it is driven in part by the project proponent's organisation (particularly the completion of designs to inform the ESIA) and in part by the EPA's decision-making timings. A statutory 90-day consultation period following the submission of the ESIA report, before a permit can be awarded, is unavoidable. The ESIA data-gathering process can also be extended if it has been determined that further surveys should be undertaken in different seasons. In this case, it would be important to undertake the hydrological assessment during the wet season, between May and September. It should be noted that any additional information requests will trigger an additional 90-day determination period commencing on full receipt of requested information.

In respect of timing, the intense seasonality of rainfall in Liberia, especially in the wetter belt nearer the coast which includes the project site, means that construction can be severely hampered during the wet season. This is particularly serious for foundations and earthworks. This factor means that the scheduling of procurement and contractor mobilization is particularly important to ensure that the good construction conditions in the dry season are maximized, and the timing of the ESIA needs to fit with this.

9.2 Key Issues and Likely ESIA Scope

Based on the preliminary assessment documented herein, it is considered that the Project will almost certainly require a full ESIA, in line with Liberian law.

It is anticipated that the preparation of the full ESIA report will take up to 6 months, followed by a 3-month consultation period. These timescales will be dependent on other aspects of project scheduling and the speed of actions by outside agencies.

Although this preliminary assessment has identified no potential "red flags" or "show-stoppers", there are a number of key issues that will need to be assessed in detail within the ESIA.

Hydrological aspects are considered likely to require careful consideration as part of the ESIA. Surveys will be undertaken to understand the hydrological environment at the site and this will be used to inform the layout design process to ensure that the design adequately addresses the potential for areas to flood during the rainy season and to design appropriate measures to mitigate the risk of pollution to hydrology and hydrogeology features.

Biodiversity and ecological issues are not considered likely to present significant constraints to the Project. However, detailed flora and fauna surveys will be undertaken by a qualified ecologist to formally establish the ecological baseline at the site, against which the potential impacts will be assessed.

A noise impact assessment will also likely be required, including modelling of operational noise propagation, to assess the potential construction and operation impacts on nearby residential properties.

A landscape and visual impact assessment will be undertaken which will include production of a Zone of Theoretical Visibility and wireframe or photomontage visualisations. Where possible, the Project design will maintain or provide vegetation screening around cemeteries to avoid potential significant adverse visual impacts and to preserve their setting.

A traffic and transportation assessment will also be undertaken as part of the ESIA to assess the suitability of the proposed access route for the passage of HGVs, with particular focus on the road in close proximity to the site, including the small bridge that crosses Dayunn Creek.

The ESIA will include further consideration of potential cultural heritage and archaeological impacts. This will involve further desk-based research and consultation with relevant stakeholders to identify known features. The ESIA will also recommend the development of a chance-find procedure to manage the potential for previously unknown features to be discovered during the construction process.

An assessment of potential social impacts will be undertaken which will incorporate a desk-based study and a programme of consultation and engagement activities to identify project-affected people and to gather baseline information on the existing social conditions within the Project's area of influence. This will include consideration of potential resettlement.

9.2.1 Resettlement

The term resettlement refers to both physical and economic displacement. Resettlement is considered involuntary when the project-affected people are not in a position to refuse the activities that result in their physical or economic displacement. This occurs in cases of lawful expropriation or temporary or permanent restrictions on land use, and in negotiated settlements in which the buyer can resort to expropriation or impose legal restrictions on land use if negotiations with the seller fail.

The African Development Bank's Integrated Safeguard System and in particular Operational Safeguard 2 (Involuntary Resettlement: Land Acquisition) (OS2) covers social and cultural impacts involving involuntary loss of land and an access to local natural resources that result in:

- Relocation or loss of shelter by the people residing in the Project area of influence.
- Loss of assets or restriction of access to assets, including national parks and protected areas or natural resources.
- Loss of income sources or means of livelihood as a result of the project, whether or not the people are required to move.

Badly planned or inadequately implemented involuntary resettlement can have long-term adverse consequences—in particular, severe impoverishment risks—for the people affected and for communities in the surrounding region. Assets or income sources may be lost; people may be relocated to settings in which their productive skills are less useful; competition for education, natural resources and other services may be greater, possibly resulting in civil unrest; community institutions and social networks may weaken; kinship groups may be dispersed; and cultural identity, traditional authority and the potential for mutual social responsibility, help, co-operation and cohesion may diminish.

The key objectives of OS2 are:

- Avoid involuntary resettlement where feasible, or minimise resettlement impacts where involuntary resettlement is deemed unavoidable after all alternative project designs have been explored;
- Ensure that displaced people are meaningfully consulted and given opportunities to participate in the planning and implementation of resettlement programmes;
- Ensure that displaced people receive significant resettlement assistance under the project, so that their standards of living, income-earning capacity, production levels and overall means of livelihood are improved beyond pre-project levels;
- Provide explicit guidance to borrowers on the conditions that need to be met regarding involuntary resettlement issues in Bank operations to mitigate the negative impacts of displacement and resettlement, actively facilitate social development and establish a sustainable economy and society; and
- Guard against poorly prepared and implemented resettlement plans by setting up a mechanism for monitoring the performance of involuntary resettlement programmes in Bank operations and remedying problems as they arise.

9.2.1.1 Site Specific Resettlement Considerations

Following the site visit Wood are of the opinion that economic displacement may occur as a result of the Project and that suitable compensation measures would have to be developed. No physical displacement is anticipated.

The land on which the Project would be built is owned by a single landowner and there are informal agreements with locals to use the land. Based on the site visit the most common crop being grown was maize although other crops such as cassava and chilli pepper were recorded. For the purposes of the feasibility study it has been assumed that all farming plots are used for maize production. During the ESIA stage, the number of people with access and how their income is dependent on having access to the land will need to be confirmed.

Any compensation should be based on providing access to a comparable piece of land, compensating for a loss of crops and revenue and general compensation to cover the time and expense of relocating. Should this be required a Livelihood Restoration Plan should be developed in line with International standards.

As discussed in Section 2.2 above it is estimated that the total area of cultivation within the footprint of the proposed development is approximately 3 Ha (approximately 15% of proposed development footprint). This would equate to a total estimated production in the region of 3.7 tonnes of maize with a total revenue value of approximately $542.

Therefore, the potential economic impact of the Project on land use could be in the region of $542 per year plus the initial compensation to be paid to PAPs. It is estimated that the initial compensation would be the equivalent of one year of production i.e. $542. However, the exact figure will have to be confirmed through household surveys at the ESIA stage.

Any future livelihood restoration activities should aim to ensure that total annual revenue of the PAPs currently leasing farming plots within the site area does not fall below a total of $542 (to be confirmed) for all PAPs combined.

Wood also recommend that prior to compensation measures being agreed, and ideally before the Project becomes widely publicised, a cut-off date is communicated to PAPs together with a grievance mechanism. This will ensure that there will be no valid claims for compensation after this cut-off date and hence it will minimise the risk of other individuals leasing land within the Project area with the intention of obtaining compensation payments.

10 Conclusions and Recommendations

This feasibility study highlighted no potential "red flags" or "show-stoppers" with regard to the development of a 20 MWac solar PV project at the identified site. However, a number of key potential issues were identified that will need to be assessed in more detail to confirm the feasibility of the Project.

Key issues requiring further investigation if the Project is to be taken forward include:

- **Grid connection** - Additional information is required to provide certainty regarding the feasibility of connecting the Project to the electricity network at Mount Coffee substation. However, the initial investigation suggests that there is adequate space at the substation to accommodate the connection and ongoing efforts to increase the number of households to the electricity grid will reduce potential restrictions on generation due to current low demand.
- **Capex and Opex** - More certainty should be gained in the Project's Capex and Opex assumptions and more detailed financial modelling undertaken.
- **Potential Environmental and Social Impacts** - A detailed ESIA will be required to fully assess potential environmental and social impacts. Hydrology and ground conditions should be an important area of focus as part of the ESIA.
- **Transmission Line Land and Lease Requirements** - It is recommended that a more detailed study is undertaken to fully understand the land and lease requirements along the length of the proposed OHL and to align the lease and acquisition processes with existing and proposed legislative requirements, particularly the LRB and its enactment into law.
- **Potential Resettlement** - During the ESIA stage, the number of people with access and how their income is dependent on having access to the land will need to be confirmed. If required, compensation should be calculated appropriately, and a Livelihood Restoration Plan should be developed in line with international standards.

Appendix A Plant Layout

Please see accompanying drawing – 803692.GLA.D.001 revision I2

Appendix B First Year Energy Yield, PR and Monthly Loss Factors

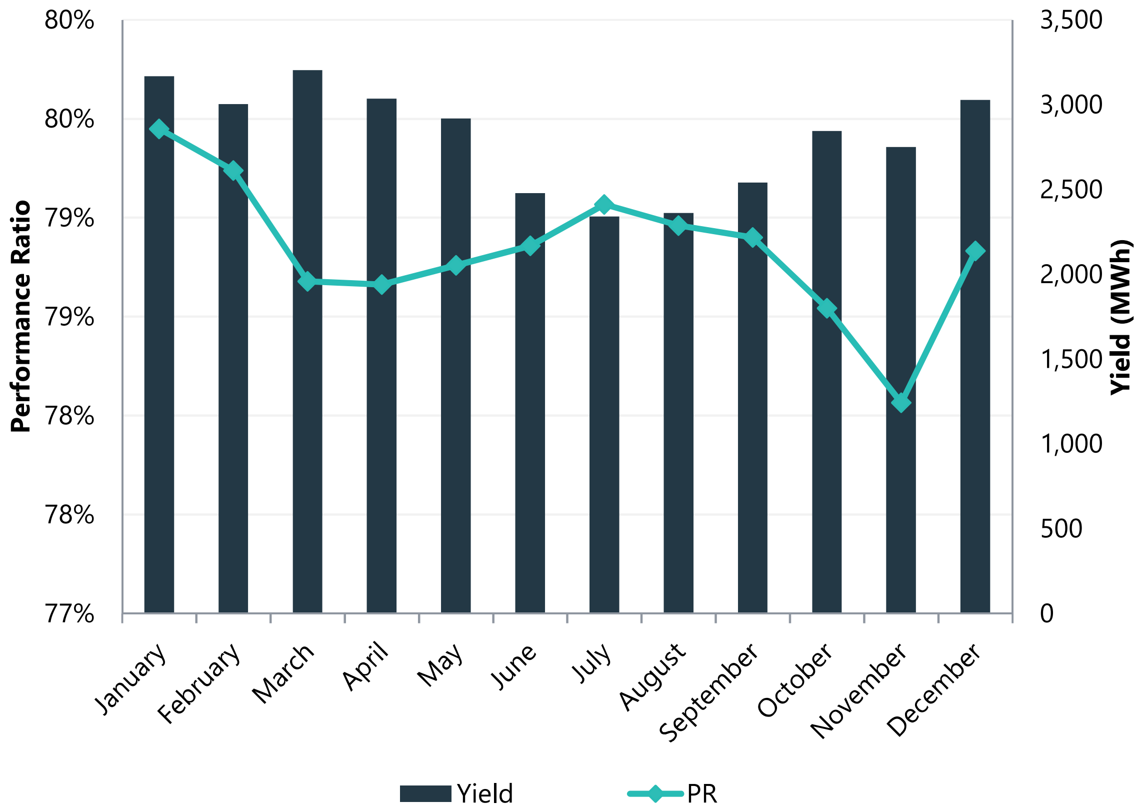

Figure 10-1: First Year Energy Yield and PR

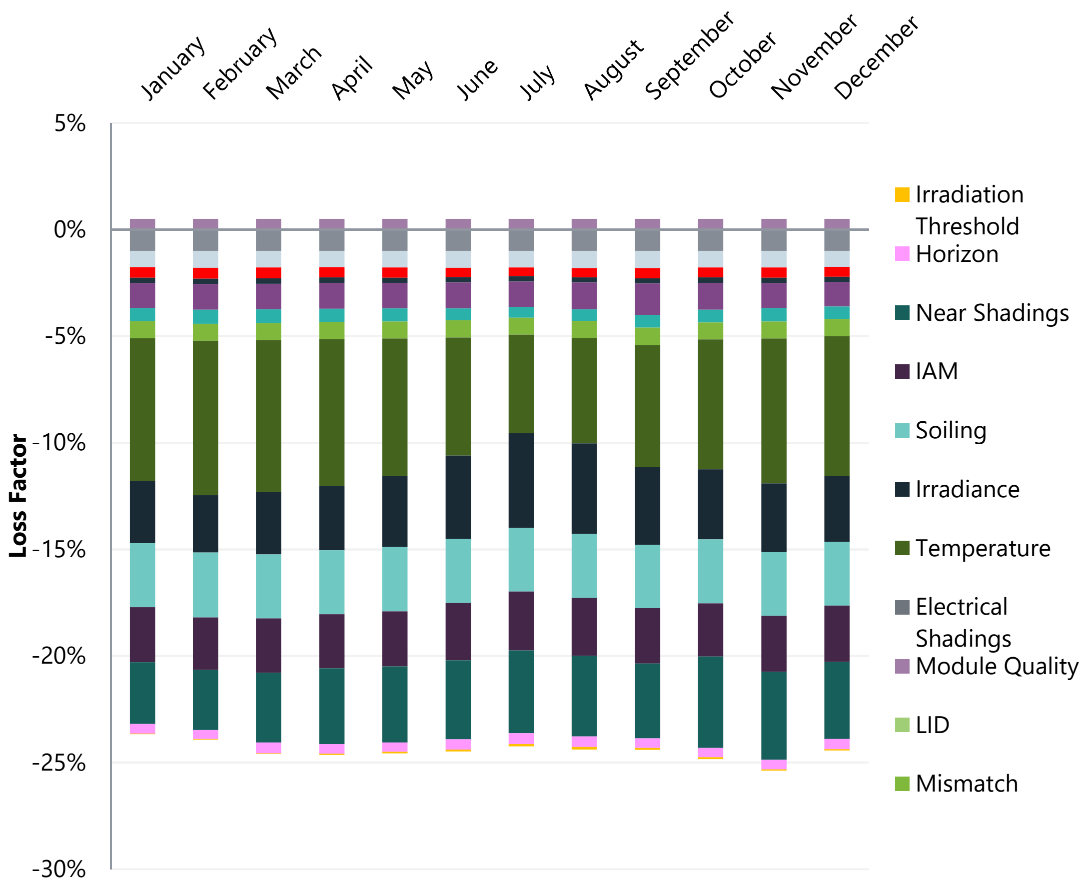

Figure 10-2: PR and Distribution of Monthly Loss Factor

Appendix C PVSyst Report Output

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Grid-Connected System: Simulation parameters

Project : Mount Coffee

Geographical Site	Mount Coffee		Country	**Liberia**
Situation	Latitude	6.46° N	Longitude	-10.64° W
Time defined as	Legal Time	Time zone UT	Altitude	34 m
	Albedo	0.20		
Meteo data:	Mount Coffee	SolarGIS - Synthetic		

Simulation variant : Newest Simulation

	Simulation date	04/06/19 10h28

Simulation parameters	System type	**Rows as domes east-west**		
2 orientations	tilts/azimuths	15°/-90° and 15°/90°		
Sheds configuration	Nb. of sheds	50	Identical arrays	
	Sheds spacing	12.3 m	Collector width	4.93 m
Shading limit angle	Limit profile angle	9.7°	Ground cov. Ratio (GCR)	40.1 %
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Average Height	2.2°		
Near Shadings	According to strings		Electrical effect	60 %
User's needs :	Unlimited load (grid)			

PV Arrays Characteristics (2 kinds of array defined)

PV module CdTe	Model	**FS-6445 Dec2017**		
Original PVsyst database	Manufacturer	First Solar		
Sub-array "Sub-array #1"	Orientation	#1	Tilt/Azimuth	15°/-90°
Number of PV modules	In series	6 modules	In parallel	4870 strings
Total number of PV modules	Nb. modules	29220	Unit Nom. Power	445 Wp
Array global power	Nominal (STC)	**13003 kWp**	At operating cond.	12022 kWp (50°C)
Array operating characteristics (50°C)	U mpp	1034 V	I mpp	11622 A
Sub-array "Sub-array #2"	Orientation	#2	Tilt/Azimuth	15°/90°
Number of PV modules	In series	6 modules	In parallel	4870 strings
Total number of PV modules	Nb. modules	29220	Unit Nom. Power	445 Wp
Array global power	Nominal (STC)	**13003 kWp**	At operating cond.	12022 kWp (50°C)
Array operating characteristics (50°C)	U mpp	1034 V	I mpp	11622 A
Total Arrays global power	Nominal (STC)	**26006 kWp**	Total	58440 modules
	Module area	**144644 m²**	Cell area	132528 m²
Inverter	Model	**SUN2000-105KTL-H1_Mount_Coffee**		
Custom parameters definition	Manufacturer	Huawei Technologies		
Characteristics	Operating Voltage	600-1500 V	Unit Nom. Power	105 kWac
			Max. power (=>25°C)	116 kWac
Sub-array "Sub-array #1"	Nb. of inverters	95 units	Total Power	9975 kWac
			Pnom ratio	1.30
Sub-array "Sub-array #2"	Nb. of inverters	95 units	Total Power	9975 kWac
			Pnom ratio	1.30
Total	Nb. of inverters	190	Total Power	19950 kWac

PV Array loss factors

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Grid-Connected System: Simulation parameters

Array Soiling Losses			Loss Fraction	3.0 %
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Array#1	1.0 mOhm	Loss Fraction	1.0 % at STC
	Array#2	1.0 mOhm	Loss Fraction	1.0 % at STC
	Global		Loss Fraction	1.0 % at STC
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	0.8 % at MPP

Incidence effect (IAM): User defined profile

0°	30°	50°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.990	0.960	0.940	0.890	0.820	0.690	0.000

System loss factors

AC wire loss inverter to transfo	Inverter voltage	800 Vac tri		
	Wires: 3x10000.0 mm²	132 m	Loss Fraction	1.0 % at STC
External transformer	Iron loss (Night disconnect)	25863 W	Loss Fraction	0.1 % at STC
	Resistive/Inductive losses	0.247 mOhm	Loss Fraction	1.0 % at STC

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Grid-Connected System: Horizon definition

Project : **Mount Coffee**

Simulation variant : **Newest Simulation**

Main system parameters	System type	**Rows as domes east-west**		
Horizon	Average Height	2.2°		
Near Shadings	According to strings		Electrical effect	60 %
PV Field Orientation	2 orientations	Tilt/Azimuth = 15°/-90° and 15°/90°		
PV modules	Model	FS-6445 Dec2017	Pnom	445 Wp
PV Array	Nb. of modules	58440	Pnom total	**26006 kWp**
Inverter		SUN2000-105KTL-H1_Mount_Coffee	Pnom	105 kW ac
Inverter pack	Nb. of units	190.0	Pnom total	**19950 kW ac**
User's needs	Unlimited load (grid)			

Horizon Average Height 2.2° Diffuse Factor 1.00

Albedo Factor 100 % Albedo Fraction 0.96

Height [°]	2.2	2.6	2.8	3.2	3.8	4.0	4.4	4.6	4.6	4.6	4.6	4.6	4.6	4.4
Azimuth [°]	-177	-169	-165	-157	-145	-141	-133	-129	-120	-109	-105	-97	-93	-85
Height [°]	3.8	3.8	3.6	3.4	3.2	2.8	2.6	2.2	2.2	2.0	1.8	1.6	1.6	1.4
Azimuth [°]	-73	-69	-61	-57	-49	-37	-33	-25	-21	-13	-9	-1	-1	0
Height [°]	1.4	1.4	1.4	1.2	1.2	1.0	0.8	1.0	1.0	0.8	0.8	0.8	0.8	0.8
Azimuth [°]	1	7	11	19	23	31	35	43	47	55	59	67	71	83
Height [°]	0.8	0.8	0.8	0.8	0.4	0.4	0.6	0.8	0.8	0.8	1.0	1.4	2.0	2.2
Azimuth [°]	91	95	103	107	119	127	131	139	143	155	163	167	175	179

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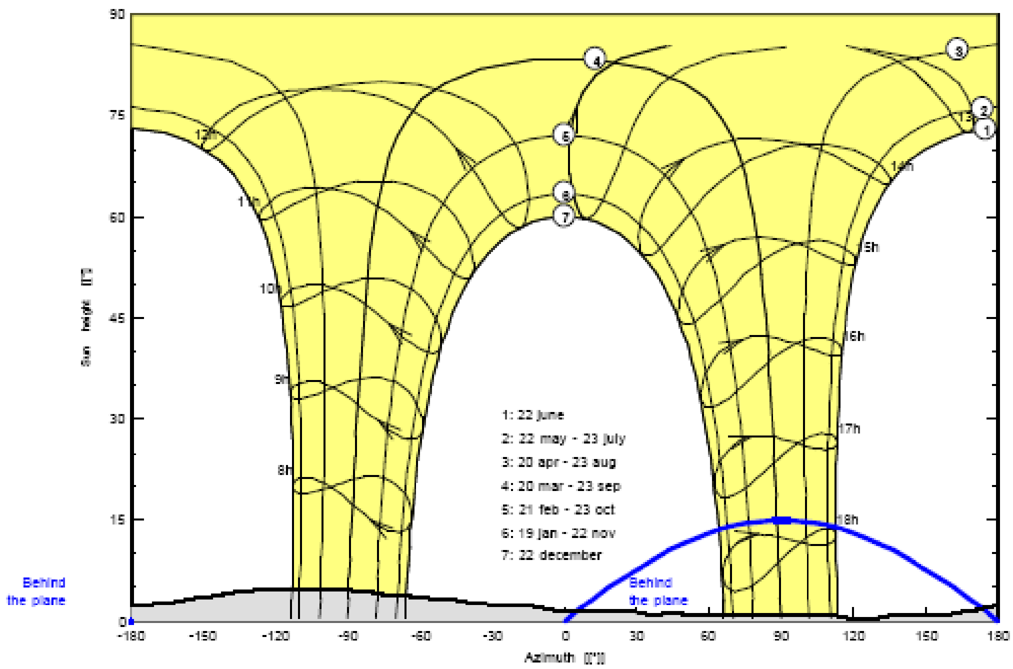

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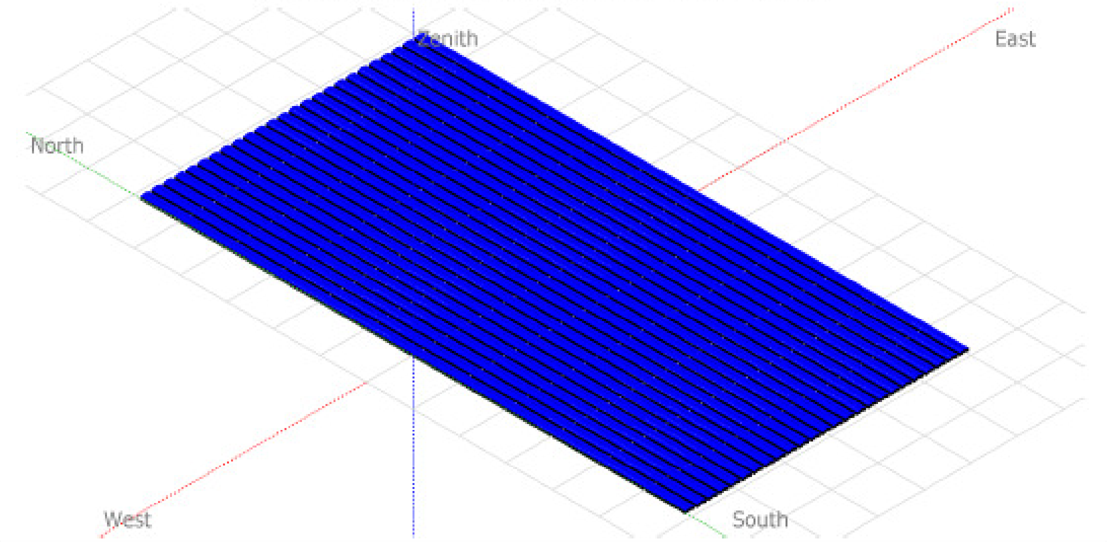
Grid-Connected System: Near shading definition

Project : **Mount Coffee**

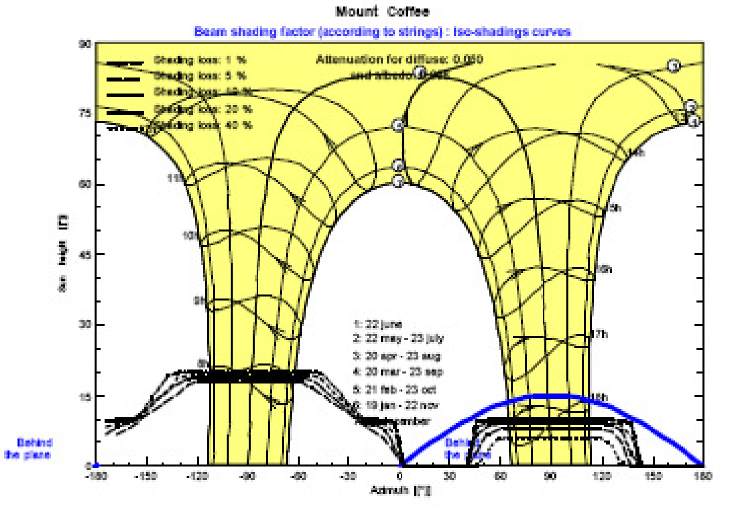
Simulation variant : **Newest Simulation**

Main system parameters	System type	**Rows as domes east-west**		
Horizon	Average Height	2.2°		
Near Shadings	According to strings		Electrical effect	60 %
PV Field Orientation	2 orientations	Tilt/Azimuth = 15°/-90° and 15°/90°		
PV modules	Model	FS-6445 Dec2017	Pnom	445 Wp
PV Array	Nb. of modules	58440	Pnom total	**26006 kWp**
Inverter		SUN2000-105KTL-H1_Mount_Coffee	Pnom	105 kW ac
Inverter pack	Nb. of units	190.0	Pnom total	**19950 kW ac**
User's needs	Unlimited load (grid)			

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



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Grid-Connected System: Main results

Project : **Mount Coffee**

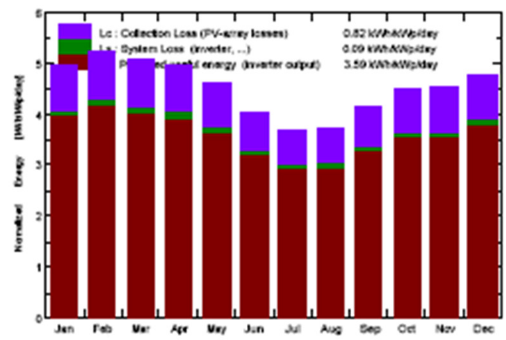
Simulation variant : **Newest Simulation**

Main system parameters	System type	**Rows as domes east-west**		
Horizon	Average Height	2.2°		
Near Shadings	According to strings		Electrical effect	60 %
PV Field Orientation	2 orientations	Tilt/Azimuth = 15°/-90° and 15°/90°		
PV modules	Model	FS-6445 Dec2017	Pnom	445 Wp
PV Array	Nb. of modules	58440	Pnom total	**26006 kWp**
Inverter		SUN2000-105KTL-H1_Mount_Coffee	Pnom	105 kW ac
Inverter pack	Nb. of units	190.0	Pnom total	**19950 kW ac**
User's needs	Unlimited load (grid)			

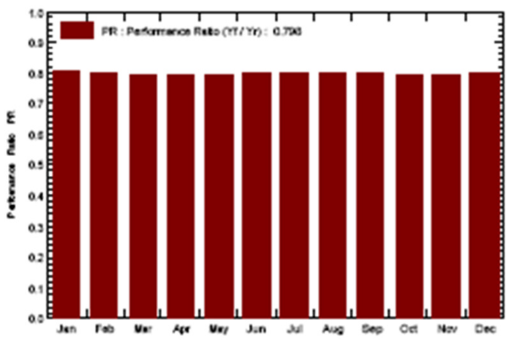
Main simulation results

System Production	**Produced Energy**	**34090 MWh/year**	Specific prod.	1311 kWh/kWp/year
	Performance Ratio PR	79.83 %		

Normalized productions (per installed kWp): Nominal power 26006 kWp



Performance Ratio PR



Newest Simulation

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	156.2	89.90	26.10	153.3	140.1	3287	3208	0.805
February	148.6	85.10	26.40	145.7	133.4	3119	3041	0.802
March	159.5	98.30	26.80	156.5	142.4	3324	3243	0.797
April	151.2	92.10	26.90	148.3	134.6	3148	3073	0.797
May	145.5	87.70	26.10	142.4	129.2	3027	2954	0.798
June	123.6	80.70	24.90	120.8	109.3	2570	2509	0.799
July	116.4	81.20	24.00	113.8	102.7	2426	2370	0.801
August	117.6	81.20	23.70	114.9	103.8	2449	2390	0.800
September	126.7	79.20	24.10	123.8	112.4	2637	2572	0.799
October	141.9	82.80	24.80	139.3	125.5	2951	2881	0.795
November	138.1	83.10	25.40	135.5	122.1	2854	2785	0.791
December	150.2	88.40	25.89	147.7	133.8	3139	3066	0.798
Year	1675.5	1029.70	25.42	1642.1	1489.3	34932	34090	0.798

Legends:

GlobHor	Horizontal global irradiation	GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
T_Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	PR	Performance Ratio

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Grid-Connected System: Special graphs

Project : **Mount Coffee**

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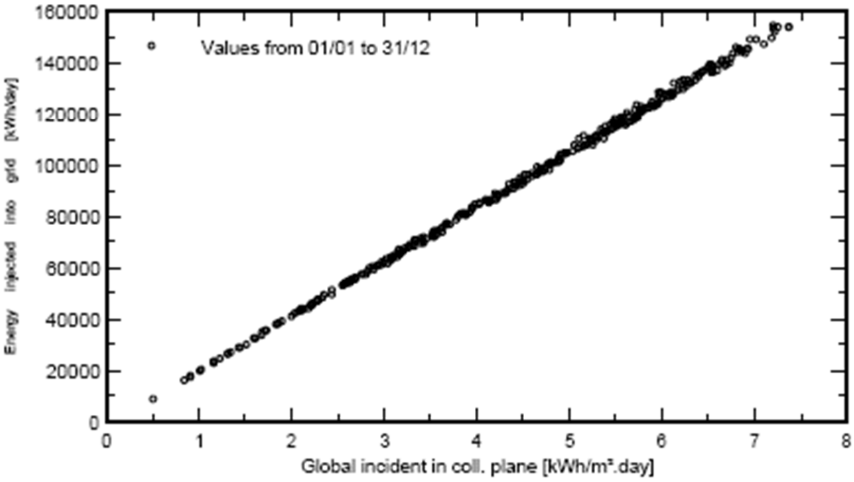
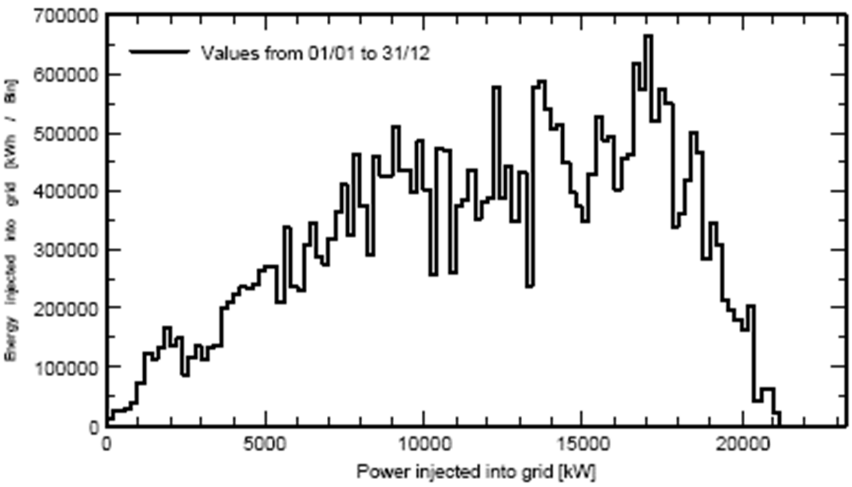
User's needs	Unlimited load (grid)			

Daily Input/Output diagram



System Output Power Distribution



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Grid-Connected System: Loss diagram

Project : **Mount Coffee**

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Loss diagram over the whole year