**Section 6.0 - Employer’s Requirements**

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**ABBREVIATIONS**

|  |  |  |
| --- | --- | --- |
| AC  ADB | -  – | Alternate Current  Asian Development Bank |
| CAPEX  DC | –  ­- | Capital Expenditure.  Direct Current |
| BESS | – | Battery Energy Storage System. |
| FENAKA | – | the Utility responsible for electricity, water and sanitation |
| GUI | – | Graphical User Interface |
| RE | – | Renewable Energy. |
| PV  SCADA  SWA  SS  PCMS | -  \_  \_  \_  \_  \_ | Photovoltaic  Supervisory control and data acquisition  Steel wire armoured  Substation  PV/Diesel Hybrid Plant Control and Monitoring System |

WEIGHTS AND MEASURES

|  |  |  |
| --- | --- | --- |
| kW | – | Kilowatt |
| kWh | – | Kilowatt-hour |
| MW | – | Megawatt |

# Haa Alif Atoll Plant and Services

## General

### The aim of the present tender is to implement hybrid PV-diesel genset power generation system with storage battery and rehabilitate the existing grids on 14 islands located in the Haa Alif Atoll, Maldives. The systems shall be implemented in existing diesel powered grid supply system. The systems shall provide a cost efficient, environment friendly and uninterruptible power supply.

The specific islands are listed in Table 1.

|  |  |
| --- | --- |
| **Ha-Alif Atoll (GPS: 6°53'14.39" N 73°06'26.40" E)** | |
| **Island Code** | **Island Name** |
| A01 | Thuraakunu |
| A02 | Uligam |
| A05 | Molhadhoo |
| A06 | Hoarafushi |
| A07 | Ihavandhoo |
| A08 | Kelaa |
| A09 | Vashafaru |
| A10 | Dhidhdhoo |
| A11 | Filladhoo |
| A12 | Maarandhoo |
| A13 | Thakandhoo |
| A14 | Utheemu |
| A15 | Muraidhoo |
| A16 | Baarah |

Table 1: Ha-Alif Atoll List of islands

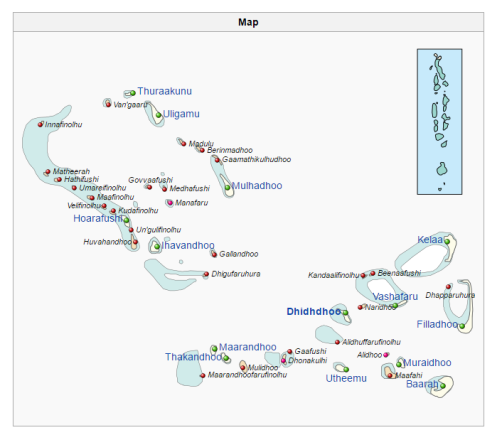


Figure 1: Map of the islands of Haa Alif Atoll – Source: Google Earth

## Scope of work

### The scope of supply, works and services shall cover, but not limited to the following:

* assessment of the site and site characteristics.
* development, detailed design, engineering (including equipment specifications), coordination of sub bidders, permitting, procurement, manufacturing, factory testing, supply of all equipment (also including spare parts, consumable, special tools and handling equipment, etc.), transport to site, storage on site, erection, construction, commissioning and performance testing of the systems.
* works and services related to preparation, civil, mechanical, electrical, instrumentation and control (I&C) and communication works including all required equipment for the execution of these works and services,
* providing security on site during construction as per insurance requirements and the security technical specifications of the Employer and per all applicable codes and standards
* 12 months operations and maintenance with training of personnel according to Employer´s requirements
* occupational health, safety and environment for construction and operation of the plant

### The Bidder shall be responsible for detailed design, engineering and building of the overall system, consisting of:

* PV system with PV modules, grid tied inverters, mounting system, string combiner boxes, trenching, DC cabling, AC cabling, monitoring system and controller, UPS, communication cables, earthing and lightning protection, AC distribution boards, DC distribution boards, electricity meters, electrical connection to the existing system, implementation into the local SCADA system
* Battery system (if applicable, compare with Chapter 2, Site Specifications) with batteries, bidirectional battery inverters (if applicable grid building inverters), battery racks, monitoring system and controller, UPS, DC cabling, AC cabling, communication cables, earthing, AC distribution boards, DC distribution boards, electricity meters and sensors, electrical connection to the existing system, implementation into the local SCADA system
* Diesel generator system, if a replacement or revitalisation of the existing system is required as per Chapter 2, Site Specifications. The diesel generator system includes the diesel generators, fuel piping and storage, safety installations, fuel flow meters and sensors (also existing gensets shall be equipped), exhaust system, monitoring and genset controller (automated system to synchronise gensets and run on fuel optimized combination), UPS, AC cabling, communication cables, earthing, AC distribution boards, electricity meters, electrical connection to the existing system, implementation into the local SCADA system.
* Upgrade the existing Grid infrastructure which include but not limited to replacement of cables in the existing LV distribution network in line with the expected future increase in load, replacement of Distribution boxes identified based on the conditional assessment, modification/replacement of existing distribution boxes to replace terminations as per the revised cable sizes or due to new in-feed from the proposed PV , modification of existing spare LV feeder in the main LV distribution board of the Power house for direct connection of PV, extension of main LV distribution board of the Power house for direct connection of PV, modification of Feeder pillars of the Distribution substations for direct connection of PV.

### It is the sole responsibility of the Bidder to design, engineer and plan all related work and installations, buildings, sub-systems, elements, system facilities, equipment, services, including system hardware and software.

### The Bidder shall collect and investigate all basic data which are needed for a proper design, planning and engineering. This includes, but is not limited to:

* conduct site visits and basic evaluation needed for a proper design and engineering
* survey of existing rooftops with regards to condition and suitability for proposed installations
* review of static calculations and where such are not available static verification of the buildings / roof tops
* survey for suitability of proposed installation locations for equipment like batteries, inverters, controllers and other devices
* soil investigations in case buildings, ground mounted structures or foundations shall be build.
* survey related to the grid upgrade works which include but not limited to cable routes of the distribution network in each Island, Low Voltage Distribution boxes, LV distribution boards in Power house, Feeder Pillars in substations, MV distribution network (where applicable) etc.

### The Bidder is responsible for import, transport, storage and handling of any equipment and material needed for installation and implementation of services.

### The Bidder shall provide complete engineering data, calculations, drawings, reports, manuals for Employers review, approval and records.

### The Bidder is responsible for the construction and implementation of the systems according to the design approved by the Employer. This includes, but is not limited to:

* PV system
* Battery energy storage system (if applicable, compare with Chapter 2, Site Specifications)
* Diesel generator system
* Grid improvement
* Buildings
* Other works

### The Bidder shall include in its scope all facilities and equipment necessary for the generation of power from the system and all works and services including workshop and store equipment, special tools and handling equipment, spare parts, consumables, etc. necessary for complete, safe, reliable, and efficient operation and preventive and corrective maintenance of the system.

### Additionally a data communication cable (Fiber) between the power house and Island Council Office shall be installed for future central SCADA connectivity purposes.

### The scope includes also works not explicitly stated in Section 6 or elsewhere in the Tender Documents but which are reasonably required for the installation and operation of the systems according to Good Engineering Practice.

### All deliveries and works shall meet or exceed applicable requirements set forth by the latest edition of the following international and national codes and standards. In addition, all local rules and regulations shall be strictly adhered in all respects.

* ISO/IEC
* EN
* ISA (International Society of Automation)
* IEEE
* ITU (International Telecommunication Union)
* Maldives local regulations

No claims for extras will be considered in respect of failure by the Bidder to comply with any of the above.

### All equipment shall be brand new and manufactured by reputable manufacturers and shall be subject to Employer’s review and approval. Used, reconditioned or salvaged equipment or material shall not be allowed. All equipment used in connection with the Project shall be of proven design for the intended use of the equipment. As a general principle, the latest, commercially proven, most modern and up-to-date technologies will be selected and licensing terms agreed with the objective of maximizing value to the Employer. The bidder shall submit equipment manufacturer authorization letter with the bid.

### All parts of the Plant shall be suitable in every respect for continuous operation at maximum efficiency as well as part loads and minimum load, under consideration of the climatic conditions peculiar to the site and environmental restrictions.

### The Bidder shall apply a well-established component classification and identification system. The international SI system of units shall be used for design, drawings, diagrams, instruments, etc.

### Project language is English. This applies also to any kind of documents, drawings, manuals, etc.

### The individual islands are described in detail in Chapter 2. Any specification which is not provided in Chapter 2 but needed for a proper design, engineering, implementation, O&M services and any related work shall investigated by the Bidder.

# Site Specifications

## General

### The following section describes the specific island and its site conditions as well as climate logical parameters for the atoll.

### The Bidder is responsible for its own investigations to establish sufficient and accurate information for the design of the Plant. The Bidder shall visit the proposed Sites and shall ascertain the nature and location thereof and all conditions which may affect design/layout of the PV Plant and the project costs.

### The Bidder shall make its own assessment of any and all of the information provided in this Bid and collect own information. Neither the Employer nor any representative or advisor is responsible for the accuracy or completeness of any such information.

## Logistic

### The Contractor is free to choose the seaport of entrance. There are three of these seaports. Upon arrival at one of these ports the Employer will take care of clearance. After clearance it is the Contractor’s obligation to continue delivery up to the final destination at the respective islands. The seaports have limited availability to rearrange the supply into smaller consignments suitable for the islands. Some islands have limited lifting facilities.

## Climatic conditions

### This chapter describes the climatological conditions of the Haa Alif Atoll, which should be applied for all islands within this tender.

### The meteorological input data set for the simulation with PVsyst is mandatory to be used so that all Bidders base their yield forecast on the same irradiation and temperature values. The values of following table were generated using source files from 3TIER.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Global Horizontal Irradiation (GHI) | Diffuse Horizontal Irradiation (DHI) | Ambient temperature |
|  | kWh/m²/day | kWh/m²/day | °C |
| Jan | 5.690 | 2.221 | 26.9 |
| Feb | 6.297 | 2.167 | 27.2 |
| Mar | 6.591 | 2.361 | 28.0 |
| Apr | 6.195 | 2.679 | 28.7 |
| May | 5.577 | 2.685 | 28.6 |
| Jun | 5.100 | 2.560 | 28.3 |
| Jul | 5.343 | 2.676 | 27.5 |
| Aug | 6.383 | 2.560 | 27.6 |
| Sep | 5.840 | 2.535 | 27.8 |
| Oct | 6.586 | 2.086 | 27.6 |
| Nov | 4.209 | 2.316 | 27.4 |
| Dec | 5.074 | 2.203 | 26.9 |
| Year | 5.74 | 2.42 | 27.7 |

Table 2: Ha-Alif Atoll Solar resource and meteorological data

### The following graphic representation confirms the very constant temperature and solar irradiation over the year, which is due to location of the Maldives close to the equator. March-April are the warmest and sunniest months. The rainy season from May to July explains the slightly lower GHI.

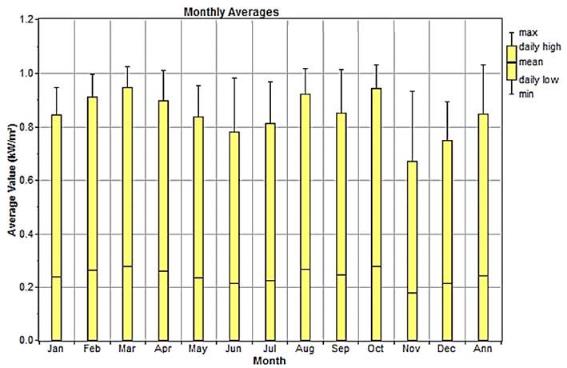


Figure 2: Ha-Alif Atoll Average value [kWh/m2] at the project location

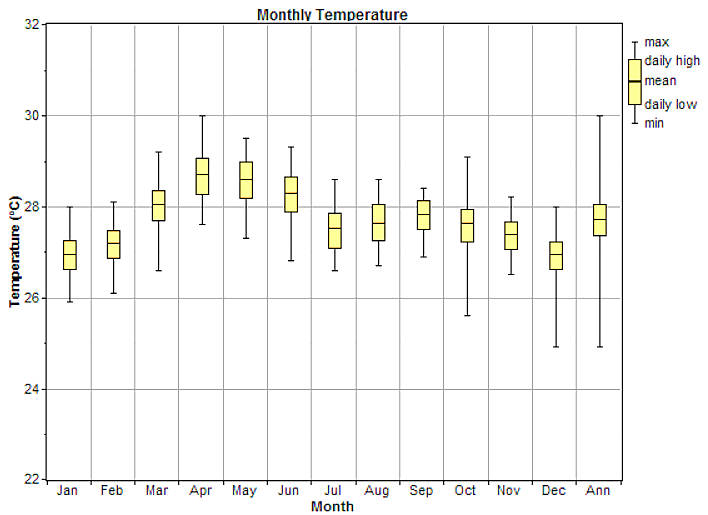


Figure 3: Ha-Alif Atoll Ambient temperature at the project location

### The following graphic shows the probability of horizontal global radiation for the last 15 years.

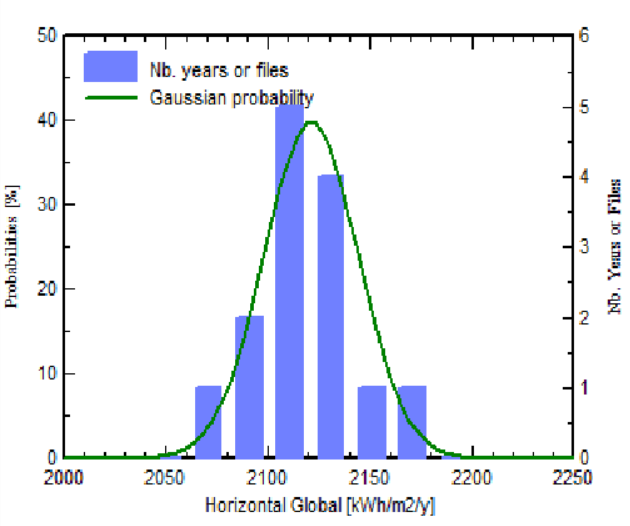


Figure 4: Ha-Alif Atoll Probability of Horizontal Global Radiation for the last 15 years

## Load Demand, Grid Infrastructure and Existing Diesel GenSets

### **Load Demand**

### The islands show fluctuating energy consumption usually with morning (around 12 am) and evening (around 10 pm) peaks. Last few years recorded data show little seasonality.

### A yearly demand load growth for each particular island has been estimated with data provided by the utility. The considered planning horizon is 2022.

### **Existing Diesel GenSets**

### Some new Diesel Gensets are operating in the islands while some others are inefficient and well past their lifespan. In general, most of the new generators can be used, however some instances they are not correctly sized for PV integration.

### **Grid Infrastructure**

### Power distribution networks consists of LV three phase and neutral, PVC insulated and PVC sheathed cable buried underground along the side of the sandy roads. Distribution cables originate from the power station main control panel and terminate on distribution boxes mounted on household boundary walls. The distribution losses are usually above 15%.

## Types of hybrid systems and general behaviour

### The Tender differentiate between two different types of systems. The two systems to be used are:

* Type B: PV / Diesel / Grid support battery system
* Type C: PV / Diesel / Grid forming battery system

### **Type B Hybrid system: PV/Diesel/Grid support battery**

#### Type B islands are equipped with battery storage systems, which are designed to give grid support to the system and can be used as a backup to overcome cloud-shading effects in the PV panels. Existing gensets may not supply enough inertia to the system when outages or abrupt changes in the output of renewable energy (PV) occur. This may result into instantaneous fluctuations in frequency leading to system instability. In these cases the control device (governor control) of an existing gent set may not be able to follow such abrupt change, and unless countermeasures are implemented like demand side management, the frequency may deviate from the pre-specified values. For these systems, a battery for grid support will be considered.

#### Diesel generator forms the grid and provides all ancillary system functions. The PV plant is seen as a negative load by the diesel generators and injects its produced energy into the grid.

#### A power plant controller is installed to ensure grid stability and maintain the operation of synchronized diesel generators above a defined minimum load (usually 25-30%) by curtailing output power of the PV inverters when needed. The power plant controller will constantly calculate the spinning reserve needed from the diesel generators and communicate with them.

#### The communication between the hybrid system controller (located in the powerhouse) and the PV inverters is performed using Fiber Optic Cable (FOC) for large distance (above ~80m).

#### An additional short-term power battery is included in the system (generally above 30 min energy reserve). It increases grid stability and allows higher PV penetration by switching-off bigger generators when system stability allows it.

#### The battery is used to stabilize the grid when required against sudden power fluctuation (from the load and/or the PV plant) and it should have enough energy to start an additional diesel generator if required.

#### Additionally a data communication cable between the inverters and the Hybrid System Controller shall be installed for SCADA purposes.

#### The following picture shows the schematic block diagram for Type B systems

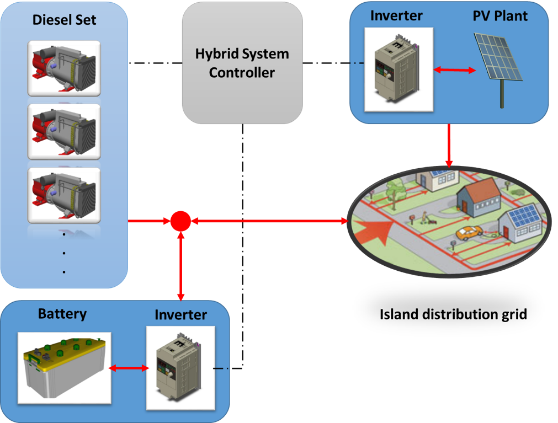


Figure 5: Ha-Alif Atoll Schematic Block Diagram of Type B System

### **Type C Hybrid system: PV/Diesel/Grid forming battery**

#### Type C islands consider from high to very high renewable energy shares where, for certain periods of the day, -usually several hours a day- all energy consumed by energy demands comes from PV generation plants. The energy storage is designed and sized in this case for power stability support as well as for energy provider in case of long periods of lack of solar energy. Type C islands are dominated by battery inverter (grid-forming) although diesel is always there to provide energy during periods of the day where the PV/Battery energy is not enough to meet the demand. This type of islands usually corresponds to relatively small islands.

#### During certain hours of daytime, the PV/battery system provides 100% of the load and the PV generation excess is used to charge the battery. If battery is at maximum State of Charge (SOC) and PV output power is higher than the loads in the system, the PV power can be curtailed by frequency droop control.

#### The battery is discharged during the night until the defined minimum State of Charge (SOC) is reached.

#### Diesel generators are used as backup and started up to provide energy to the load when the SOCmin of the battery is reached.

#### The communication between power plant controller (located in the powerhouse) and the PV inverters can be performed via frequency droop to curtail the active power when needed.

#### If necessary, data communication cable between the inverters and the Power Plant Controller shall be installed for SCADA purposes.

#### The following picture shows the schematic block diagram for Type C systems

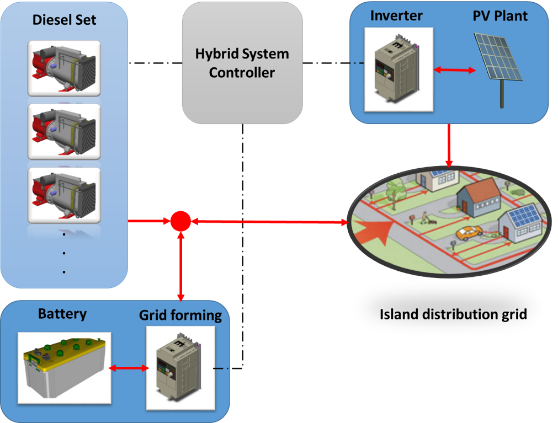


Figure 6: Ha-Alif Atoll Schematic Block Diagram of Type C System

## Summary of the hybrid systems to be built

### The Contractor shall implement the described systems on the 14 islands as summarized in the table below.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Island | System Type (1) | 2016 Load kW (peak, average peak) | 2022 Load kW (peak, average peak) | Size PV kWp (STC) | Battery Size | Existing Diesel GS  kW | New Diesel GS Capacity to be installed kW | Discarded Diesel GS (\*) kW | Diesel Proposed for Hybrid (\*\*) |
| A-01 Thuraakunu | Type B | 80, 70 | 100, 87 | 100 | 60 kWh, 100 kW, 2C | 60, 128, 160 | 50 | 60 | 50 (new), 128 (existing), 160 (existing) |
| A-02 Uligamu | Type C | 79, 60 | 98, 75 | 126 | 240 kWh, 100 kW, 1C | 49, 128, 165 | 80 | 49 | 80 (new), 128 (existing), 165 (existing) |
| A-05 Molhadhoo | Type C | 48, 29 | 57, 35 | 60 | 120 kWh, 100 kW, 1C | 40, 48, 60 | 50 | 40 | 50 (new), 48 (existing), 60 (existing) |
| A-06 Hoarafushi | Type B | 400, 340 | 540, 459 | 330 | 150 kWh, 300 kW, 2C | 200, 200, 250, 600 | 350 | 200, 200 | 350 (new), 250 (existing), 600 (existing) |
| A-07 Ihavandhoo | Type B | 383, 331 | 513, 443 | 320 | 150 kWh, 300 kW 2C | 160, 250, 350 | 250, 450 | 160, 250 | 250 (new), 450 (new) 350 (existing) |
| A-08 Kelaa | Type B | 260, 165 | 338, 215 | 200 | 100 kWh, 200 kW, 2C | 120, 200, 236 | - | - | 120 (existing), 200 (existing), 236 (existing) |
| A-09 Vashafaru | Type C | 70, 52 | 81, 43 | 120 | 240 kWh, 100 kW, 1C | 80, 80, 160 | 60, 80 | 80, 160 | 60 (new), 80 (new), 80 (existing) |
| A-10 Dhidhdhoo | Type B | 712, 540 | 960, 729 | 246 | 150 kWh, 300 kW 2C | 400, 400, 508, 600 | 500, 800 | 508, 400, 400 | 500 (new), 800 (new), 600 (existing) |
| A-11 Filladhoo | Type C | 90, 71 | 112, 88 | 140 | 280 kWh, 100 kW 1C | 60, 80, 160 | 70 | 60 | 70 (new), 80 (existing), 160 (existing) |
| A-12 Maarandhoo | Type C | 85, 66 | 95, 75 | 142 | 280 kWh, 100 kW 1C | 50, 50, 90, 160 | 60 | 50, 50 | 60 (new), 90 (existing), 160 (existing) |
| A-13 Thakandhoo | Type C | 56, 36 | 64, 41 | 91 | 180 kWh, 100 kW 1C | 32, 58, 150 | 60, 70 | 32, 150 | 60 (new), 70 (new), 58 (existing) |
| A-14 Utheemu | Type C | 115, 82 | 132, 94 | 150 | 280 kWh, 120 kW, 1C | 80, 160, 200 | 100 | 200 | 100 (new), 80 (existing), 160 (existing) |
| A-15 Muraidhoo | Type C | 90, 53 | 100, 60 | 139 | 240 kWh, 100 kW, 1C | 120, 150 | 60, 80 | 120 | 60 (new), 80 (new) 150 (existing) |
| A-16 Baarah | Type B | 140, 128 | 180, 160 | 162 | 70 kWh, 120 kW, 2C | 68, 120, 300 | 90, 60 | 68, 300 | 90 (new), 60 (new), 120 (existing) |

Table 3: Ha-Alif Atoll summary of hybrid systems

(\*) Discarded Diesel GS due to lifetime, poor efficiency or to be transferred to other islands (\*\*), The adopted solution take advantage as much as possible the existing diesel gensets . (\*) Discarded ( 1) System type B- ESS for grid support, type C-ESS for grid forming system.

## A01 Thuraakunu Island

### General

#### The Thuraakunu is the northern-most island in Maldives, one of the fourteen inhabited islands of Haa Alif Atoll and is geographically part of the Ihavandhippolhu Atoll in the Maldives. It is an island-level administrative constituency governed by the Thuraakunu Island Council. It stretches over 900 meters in length at a width of 380 meters. The island is 329 km away from Male. The urbanized area is in the middle part of the island. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 1 hour by speed boat from Hanimaadhoo Airport.



Figure 7: Thuraakunu Island locations of the PV sites and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 7°6′18″N 72°54′07″E |
| Inhabitants (approx.) | 686 |
| Harbour type | Harbour |
| Airport | Domestic Hanimaadhoo airport |

Table 4: Thuraakunu Island identification and general data

### Grid Infrastructure

#### The power house in Thuraakunu Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1263 kWh/day, which is equivalent to an average power consumption of 70 kW. Maximum registered load value of 80 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality. A new block is under construction in school and expected to consume 5kW. Expected load increase per year is 5%.

#### The following load profiles shall be considered for sizing.

Figure 8: Thuraakunu Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  6BT3.9G-1 | | Cummins  6CTA8.3G2 | Cummins  6BTAA3.9 |  |
| Engine power rating (continuous) | 60kW | | 160kW | 128kW |  |
| Alternator power rating | 75KVA | | 200KVA | 160KVA |  |
| Hours of operation / date of installation | 51570  October 2003 | | 5466  August 2014 | 6676  September 2013 |  |
| General maintenance performed | Yes | | No | No |  |
| Required upgrade / replacement | Yes | | - | - |  |

Table 5: Thuraakunu Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### Existing 60kW Generator Set ( Cummins 6BT3.9G-1) shall be removed and replaced due to lifetime, poor efficiency. The utility will take care of this removed generator set.

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

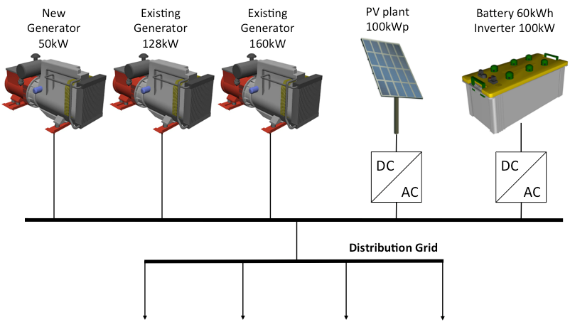


Figure 9: Thuraakunu Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Thuraakunu Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type B system design (Grid support battery)
* Diesel Generators: New: 50kW, Existing: 128 kW 160 kW.
* Roof-mounted PV: 100kWp
* Li-Ion based battery storage system: 60kWh and 100kW (2C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 27% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

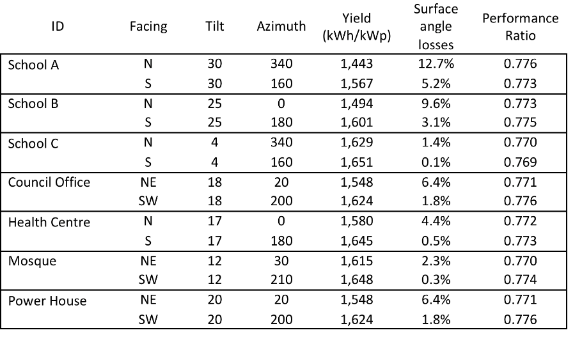


Table 6: Thuraakunu Island technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 100 | 1,605,84 |

Table 7: Thuraakunu Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 166,243 | 114,072 | 52,171 | 31.4 | 4.355 |

Table 8: Thuraakunu Island PV plant Fuel Savings summary

### Overview of possible installation locations

#### The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A01-3 | School Roof A1 | 5,500 | 13,000 | 7 | x | 51 |
| A01-4 | School Roof A2 | 5,500 | 13,000 | 7 | x |
| A01-5 | School Roof B1 | 5,750 | 20,500 | 12 | X |
| A01-6 | School Roof B2 | 5,750 | 20,500 | 12 | X |
| A01-7 | School Roof C1 | 4,750 | 9,500 | 5 | X |
| A01-8 | School Roof C2 | 15,000 | 5,500 | 8 | X |
| A01-9 | Council Roof A1 | 5,750 | 13,000 | 7 | X | 15 |
| A01-10 | Council Roof A2 | 5,750 | 13,000 | 7 | X |
| A01-11 | Health Centre Roof A1 | 8,750 | 12,500 | 11 | X | 22 |
| A01-12 | Health Centre Roof A2 | 8,750 | 12,500 | 11 | X |
| A01-13 | Mosque Roof A1 | 9,000 | 10,500 | 9 | X | 19 |
| A01-14 | Mosque Roof A2 | 9,000 | 10,500 | 9 | X |
| A01-15 | Powerhouse Roof A1 | 5,700 | 9,000 | 5 | X | 15 |
| A01-16 | Powerhouse Roof A2 | 5,700 | 9,000 | 5 | X |
| A01-17 | Powerhouse Roof B1 | 5,700 | 4,400 | 3 | X |
| A01-18 | Powerhouse Roof B2 | 5,700 | 4,400 | 3 | X |
| **Summary** |  |  |  | **122** |  | **122** |

Table 9: Thuraakunu Island roofs/ground and maximum PV power installable

#### Buildings and roofs

| **Item** | School | Council Office | Health Centre | Mosque | Powerhouse |
| --- | --- | --- | --- | --- | --- |
| Owner | Ministry of Education | Island Council | Ministry of Health | Mosque | FENAKA |
| Available Roof Area (L x W) in meters | A - 5.5m x 33m x 2  B – 5.75m x 20.5m x 2  C – 4.75 m x 9.5m x 2 | 5.75m x 13m x 2 | 8.75mx12.5m x 2 | 9mx10.5m x 2 | 5.7mx9m x 2  5.7mx4.4m x 2 |
| Available surrounding areas | Refer to Site layout | Refer to Site layout | Refer to Site layout | Refer to Site layout | Refer to Site layout |
| Height of building | A-5.663  B-5.721 | 4.8m | 6.5m | 5.4m | 5.8m |
| Age of the building | 20 years | 20 Years, roof renovated | 10 years, roof renovated | 20 years, roof renovated | 14 years |
| Type of Roof | Gable | Gable | Gable | Gable | Gabble + Bonnet |
| Direction of Gable | A,C- 71° E  B- 72° E | 108° E | 99° E | 122° SE |  |
| Direction of Roof(s) (Azimut) | A,C- 342° N  B- 182° S  D- 40° N | 18° N  198° S | 110° N  172° S | 32° NE  216° SW |  |
| Roof Material | Lysaght corrugated metal sheets | Lysaght corrugated metal sheets | Lysaght corrugated metal sheets | Lysaght corrugated metal sheets | Lysaght corrugated metal sheets |
| Roof profile (make a detailed sketch) | lysaght | | | | |
| Slope | 1. 30° 2. 25° 3. 4° | 18° | 17° | 12° |  |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 7°06'12.99" N 72°53'57.18" E  DB No.C4 | 7°06'13.04" N 72°53'53.28" E  DB No.B6 | 7°06'15.78" N 72°53'59.54" E  DB No.C2 | 7°06'16.52" N 72°53'56.53" E  DB No.B4 | - |
| Size of next grid connection point, space available, cable dimensions | 35sqmm 4 core, space available | 25sqmm 4 core, space available | 35sqmm 4 core, space available | 35sqmm 4 core, space available | - |
| Distance to Power House | 475m | 610m | 300m | 360m | - |
| GPS coordinates | 7°06'11.45" N 72°53'56.96" E | 7°06'12.43" N 72°53'53.54" E | 7°06'16.98" N 72°53'59.19" E | 7°06'17.39" N 72°53'57.32" E | 7°06'20.10" N 72°54'05.48" E |
| Soiling of roof (1=clean, 5=very dirty) | A-2  B,C- 1 | 1 | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Cement Wall and Concrete Columns | Cement Wall | Cement Wall and Concrete Columns | Cement Wall and steel pipe as columns | Cement Wall and Concrete Columns |
| Layer Structure of Roof | 200x50mm wooden truss @3.3m and 100x50mm battens @750mm | 100x50mm wooden rafters @750mm and 50x38mm battens @600mm | 100x50mm wooden rafters @750mm and 50x38mm battens @600mm | 100x50mm wooden rafters @750mm and 50x38mm battens @600mm | Steel truss |
| Type of near shading obstacles | No major obstacles. Small trees near C can be trimmed. | Two tall trees and few trees on west side of the building | Coconut trees on west side inside boundary wall 22m from building, 13m high. | No shade | Coconut trees on north side of boundary wall |
| Access to the Roof | Portable ladder | Portable ladder | Portable ladder | Portable ladder | Portable ladder |

Table 10: Thuraakunu Island Buildings for PV installation

## A02 Uligam Island

### General

#### The Uligam is the northern-most island in Maldives, one of the fourteen inhabited islands of Haa Alif Atoll and is geographically part of the Ihavandhippolhu Atoll in the Maldives. It is an island-level administrative constituency governed by the Uligam Island Council. It stretches over 2500 meters in length at a width of 800 meters. The island is 327 km away from Male. The urbanized area is in the middle part of the western side of the island. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 1 hour by speed boat from Hanimaadhoo Airport.



Figure 10: Uligam Island buildings available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 7°05′00″N 72°55′40″E |
| Inhabitants (approx.) | 514 |
| Harbour type | Harbour |
| Airport | Domestic Hanimaadhoo airport |

Table 11: Uligam Island identification and general data

### Grid Infrastructure

#### The power house in Uligam Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

#### Currently the powerhouse is in a temporary location, new power house planned to be built within next one or two years.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1048 kWh/day, which is equivalent to an average power consumption of 44 kW. Maximum registered load value of 79 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality. New custom building is to be built next year and may consume 5kW. 40 new housing sites are under construction (may take 2 to 3 years). Average household demand is around 600W. Expected load increase per year is 5%.

#### The following load profiles shall be considered for sizing.

Figure 11: Uligamu Island Typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Volvo  TAD 722 EG | | Cummins  6CTA-8.3-G1-1 | Deutz  BF4L 914 |  |
| Engine power rating (continuous) | 165kW | | 128kW | 49kW |  |
| Alternator power rating | 200KVA | | 160KVA | 62KVA |  |
| Hours of operation / date of installation | 14-Dec-14  27749hrs | | 03-Nov-13  8349hrs | 26-Jan-10  24697hrs |  |
| General maintenance performed | Dynamo service  14/12/2014 | | Dynamo service  29/10/2015 | Engine Overhaul , 2013 |  |
| Required upgrade / replacement | Yes | | - | Yes |  |

Table 12: Uligam Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel genset due to lifetime, poor efficiency or to be transferred to other islands is the genset rated at 49 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16.The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

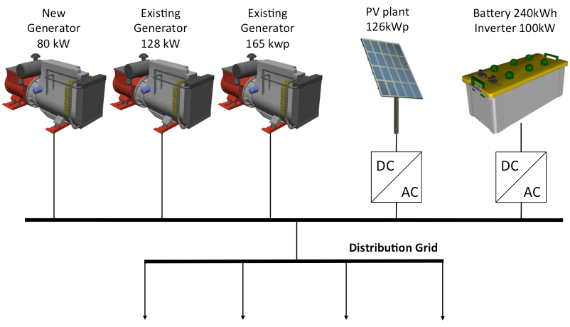


Figure 12: Uligamu Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Uligam Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 80kW, Existing 128 kW and 165 kW.
* Roof-mounted PV: 126kWp
* Li-Ion based battery storage system: 240kWh and 100kW, 1C

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 42% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

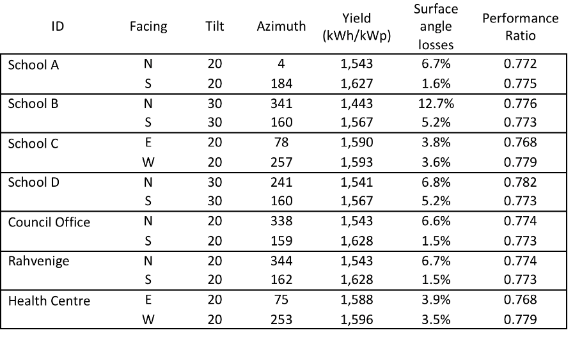


Table 13: Uligamu Island technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 126 | 1,573.6 |

Table 14: Uligamu Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.*, fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 142,152 | 73,916 | 68,236 | 48 | 5.5 |

Table 15: Uligamu Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A02-1 | Council Roof A1 | 4,500 | 15,000 | 7 | x | 14 |
| A02-2 | Council Roof A2 | 4,800 | 15,000 | 7 | x |
| A02-3 | School Roof A1 | 4,800 | 27,500 | 13 | x | 74 |
| A02-4 | School Roof A2 | 5,750 | 20,500 | 12 | x |
| A02-5 | School Roof B1 | 5,600 | 13,800 | 8 | x |
| A02-6 | School Roof B2 | 5,600 | 13,800 | 8 | x |
| A02-7 | School Roof C1 | 6,300 | 14,200 | 9 | x |
| A02-8 | School Roof C2 | 6,300 | 14,200 | 9 | x |
| A02-9 | School Roof D1 | 4,700 | 17,000 | 8 | x |
| A02-10 | School Roof D2 | 4,700 | 17,000 | 8 | x |
| A02-11 | Rahvehige A1 | 5,250 | 15,000 | 8 | x | 16 |
| A02-12 | Rahvehige A2 | 5,250 | 15,000 | 8 | x |  |
| A02-13 | Health Centre Roof A1 | 6,250 | 17,800 | 11 | x | 22 |
| A02-14 | Health Centre Roof A2 | 6,250 | 17,800 | 11 | x |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Summary** |  |  |  | **126** |  | **126** |

Table 16: Uligam Island roofs/ground and maximum PV power installable

#### Buildings and roofs

| **Item** | **Council Office** | **School** | **Rahvehige** | **Health Centre** |
| --- | --- | --- | --- | --- |
| Owner | Island Council | Ministry of Education | Island Council | Ministry of Health |
| Available Roof Area (L x W) in meters | 4.5m x 15m  4.8m x 15m | A – 4.8m x 17.5m x 2  B – 5.6m x 13.8m x 2  C – 6.3m x 14.2m x 2  D – 4.7m x 17m x 2 | 5.25m x 15m x 2 | 6.25m x 17.8m x 2 |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to site layout |
| Height of building | 4.08 m | 5 to 5.4m | 4.75m | 4.88m |
| Age of the building | 25 yrs.(renovated roof) | 1. 25 yrs. (roof renovated, all others less than 10 years) | 15 years | 10 years |
| Type of Roof | Gable | Gable | Gable | Gable |
| Direction of Gable | 73 ° E | B/D - 77 ° E  A - 90 ° E  C - 353° N | 73 ° E | 165 ° S |
| Direction of Roof(s) (Azimut) | 338 ° N  159° S | B/D - 160 ° S, 341° N  A - 184° S, 4°N  C - 78°E, 257°W | 162°S  344°N | 253°W  75°E |
| Roof Material | Lysaght corrugated steel sheets | Lysaght corrugated steel sheets | Lysaght corrugated steel sheets | Lysaght corrugated steel sheets |
| Roof profile (make a detailed sketch) | lysaght | | | |
| Slope | 17° | B,D-27°, A-23°, C-18° | 17° | 16° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | C-04  7°05'09.98" N 72°55'28.25" E | B-04  7°05'12.66" N 72°55'29.76" E | C-04  7°05'09.98" N 72°55'28.25" E | A-03  7°04'59.20" N 72°55'33.39" E |
| Size of next grid connection point, space available, cable dimensions | 16 sqmm cable  Better to replace the box with a larger size. | 16 sqmm cable  Better to replace the box with a larger size. | 16 sqmm cable  Better to replace the box with a larger size. | 16 sqmm cable  Better to replace the box with a larger size. |
| Distance to Power House |  |  |  |  |
| GPS coordinates | 7°05'11.22" N 72°55'28.62" E | 7°05'12.12" N 72°55'29.28" E | 7°05'12.18" N 72°55'28.11" E | 7°04'59.45" N 72°55'32.88" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Cement Wall | Cement Wall and Concrete Columns | Cement Wall | Cement Wall and Concrete Columns |
| Layer Structure of Roof | 100x50mm wooden rafters @750mm and 50x38mm battens @600mm | 200x50mm wooden truss @3.3m and 100x50mm battens @750mm | 100x50mm wooden rafters @750mm and 50x38mm battens @600mm | 100x50mm wooden rafters @750mm and 50x38mm battens @600mm |
| Bearing Capacity |  |  |  |  |
| Type of near shading obstacles | Trees on South side of the building. | Only 1 tree blocking part of sea (11.5 ft high tree) | School building height shall be considered. | 100m tall East tall large trees. |
| Access to the Roof | Portable ladder | Portable ladder | Portable ladder | Portable ladder |
| Describe existing lightning protection equipment | Installed on telecom tower on west side  5ft away from roof. | - | - | - |
|  |  |  |  |  |
|  |  |  |  |  |

Table 17: Uligam Island Buildings for PV installation

## A05 Molhadhoo Island

### General

#### The Mulhadhoo is one of the inhabited islands of Haa Alif Atoll and is geographically part of the Ihavandhippolhu Atoll in the Maldives. It is an island-level administrative constituency governed by the Mulhadhoo Island Council. It stretches over 2600 meters in length at a width of 840 meters. The island is 319 km away from Male. The urbanized area is in the middle part of the western side of the island. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 1 hour by speed boat from Hanimaadhoo Airport.



Figure 13: Molhadhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 7°00′45″N 72°59′45″E |
| Inhabitants (approx.) | 374 |
| Harbour type | Harbour |
| Airport | Domestic Hanimaadhoo airport |

Table 18: Molhadhoo Island identification and general data

### Grid Infrastructure

#### The power house in Molhadhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 575 kWh/day, which is equivalent to an average power consumption of 24 kW. Maximum registered load value of 48 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality. Expected load increase per year is 3%.

#### The following load profiles shall be considered for sizing.

Figure 14: Molhadhoo Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Perkins (DK51301) | | Cummins (6BT9.5 G20) | Duetz (F6L912) |  |
| Engine power rating (continuous) | 40kW | | 60kW | 48kW |  |
| Alternator power rating |  | |  |  |  |
| Hours of operation / date of installation | 10036 | | 7576 | 30157 |  |
| General maintenance performed | Yes; Motor 2014 | | No | No |  |
| Required upgrade / replacement | Yes | | - | Yes |  |

Table 19: Molhadhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 40 kW and 48 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

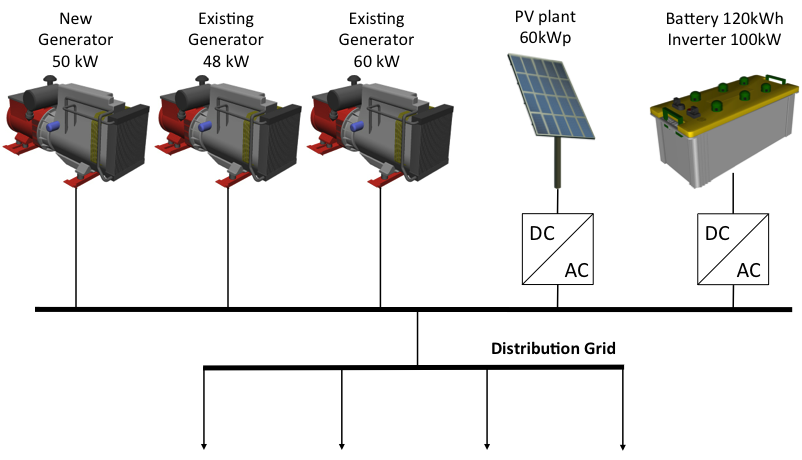


Figure 15: Molhadhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Molhadhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 50kW, Existing 48 kW and Existing 60kW
* Roof-mounted PV: 60kWp
* Li-Ion based battery storage system: 120kWh and 100 kW

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 39% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

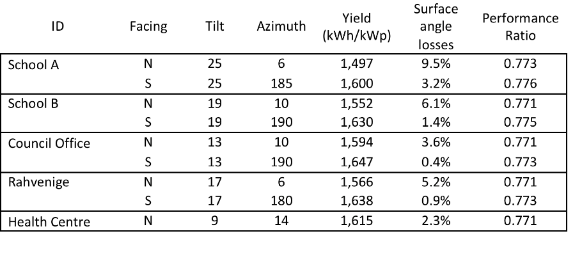


Table 20: Molhadhoo Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** | **Capacity Factor** |
| **PV Plants** | 60 | 1,623.09 | 17.9 |

Table 21: Molhadhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.*, fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 83,629 | 43,575 | 40,054 | 47.9 | 4.94 |

Table 22: Molhadhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A05-1 | Health Centre Roof A1 | 9,300 | 16,000 | 15 | x | 15 |
| A05-2 | Council Office A1 | 6,400 | 22,000 | 14 | x | 28 |
| A05-3 | Council Office A2 | 6,400 | 22,000 | 14 | x |
| A05-4 | School A1 | 5,750 | 13,700 | 8 | x | 53 |
| A05-5 | School A2 | 5,750 | 13,700 | 8 | x |
| A05-6 | School B1 | 6,000 | 11,000 | 7 | x |
| A05-7 | School C1 | 5,750 | 26,400 | 15 | x |
| A05-8 | School C2 | 5,750 | 26,400 | 15 | x |
| A05-9 | Island Council A1 | 6,700 | 20,000 | 13 | x | 27 |
| A05-10 | Island Council A2 | 6,700 | 20,000 | 13 | x |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Summary** |  |  |  | **123** |  | **123** |

Table 23: Molhadhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **Health Centre** | **Council Office** | **School** | **Rahvehige** |
| --- | --- | --- | --- | --- |
| Owner | Ministry of Health | Island Council | Ministry of Education | Island Council |
| Available Roof Area (L x W) in meters | 9.3mx16m | 6.4mx22m x 2 | A – 5.75mx13.7m x 2  B – 6mx11m  C – 5.75mx26.4m x 2 | 6.7mx20m x 2 |
| Available surrounding areas | refer to site layout | refer to site layout | refer to site layout | refer to site layout |
| Height of building | 4.9m | 3.86m | A/C - 5.786m  B - 4.6m | 4.35m |
| Age of the building | 12 | 15 | 15 | 70  (Roof renovated ) |
| Type of Roof | Gable | Gable | Gable | Gable |
| Direction of Gable | 104°E | 99°E | A-90°E  B-99°E | 97°E |
| Direction of Roof(s) (Azimut) | 14°N | 10°N,190°S | A-185°S,6°N  B-190°S,10°N | 6°N,180°S |
| Roof Material | Lysaght  Corrugated  Sheet metal | Lysaght  Corrugated  Sheet metal | Normal  Corrugated  Sheet Metal | Normal  Corrugated  Sheet Metal |
| Roof profile (make a detailed sketch) | Refer to roof layout | Refer to roof layout | Refer to roof layout | Refer to roof layout |
| Slope | 9° | 13° | A-25°  B-19° | 17° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 18m from C2  7°00'49.88" N 72°59'49.90" E | 40m from C1  7°00'50.35" N 72°59'47.67" E | 110m from C1  7°00'50.35" N 72°59'47.67" E | Rah |
| Size of next grid connection point, space available, cable dimensions | 50sqmm, 4 core | 70sqmm, 4 core | 70sqmm, 4core | 50sqmm, 4 core |
| Distance to Power House | 460m | 420m | 485m | 96m |
| GPS coordinates | 7°00'50.32" N 72°59'50.03" E | 7°00'51.13" N 72°59'48.46" E | 7°00'53.46" N 72°59'48.84" E | 7°00'40.81" N 72°59'47.07" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | A/C-1  B-5 (Rusted) | 2 |
| Support Structure of Roof (take pictures of support) | Concreted columns and cement walls | Concreted columns and cement walls | Concreted columns and cement walls | Cement walls |
| Layer Structure of Roof | 100mmx50mm wooden rafters @750mm  50mmx38mm battens @600mm | 100mmx50mm wooden rafters @750m  50mmx38mm battens @600mm | 200mmx50mm wooden truss @3300mm  100mmx50mm battens @750mm | 100mmx50mm wooden rafters @750mm  50mmx38mm battens @600mm |
| Bearing Capacity |  |  |  |  |
| Type of near shading obstacles | 1 Coconut palm on NE side | Huge tree on south side | Small tree on south side. Can be removed if required. | No shadow  Small trees only. |
| Access to the Roof | Portable ladder | Portable ladder | Portable ladder | Portable ladder |
| Describe existing lightning protection equipment | - | - | - | - |
|  |  |  |  |  |
|  |  |  |  |  |

Table 24: Molhadhoo Island Possible Buildings for PV installation

## A06 Hoarafushi Island

### General

#### The Hoarafushi is one of the inhabited islands of Haa Alif Atoll and is geographically part of the Ihavandhippolhu Atoll in the Maldives. It is an island-level administrative constituency governed by the Hoarafushi Island Council. It stretches over 1750 meters in length at a width of 450 meters. The island is 317 km away from Male. Except the northwest side, the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 45 minutes by speed boat from Hanimaadhoo Airport.



Figure 16: Hoarafushi Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°58′50″N 72°53′45″E |
| Inhabitants (approx.) | 3204 |
| Harbour type | Harbour |
| Airport | Domestic Hanimaadhoo airport |

Table 25: Hoarafushi Island identification and general data

### Grid Infrastructure

#### The power house in Hoarafushi Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 6236 kWh/day, which is equivalent to an average power consumption of 260 kW. Maximum registered load value of 410 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality.

#### New Desalination Plant Installation planned for 2016. Sewerage system installed and ready to use (4 pump stations and 2 out falls). In addition Council guest house, 2 Private Guest House, Police Building under construction. These new development will result additional load. Expected load increase per year is 10%.

#### The following load profiles shall be considered for sizing.

Figure 17: Hoarafushi Island Typical daily load profile

### Diesel generators

#### Four Diesel generators of different sizes are installed on the island..

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  NT 855 G4) | | Cummins  NT 855 G6 | Cummins  NT 855 G6 | Cummins  KTA 38 G2 |
| Engine power rating (continuous) | 200kW | | 200kW | 250kW | 600 kW |
| Alternator power rating | 250kVA | | 250kVA | 312.5kVA | 750 kVA |
| Hours of operation / date of installation | 2002  71493hrs | | 2002  65918hrs | 2002  23314hrs | 2014  3888hrs |
| General maintenance performed | 17 May 2014 | | 24 May 2015 | 31 May 2014 |  |
| Required upgrade / replacement |  | |  |  |  |

Table 26: Hoarafushi Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 200 kW and 200 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

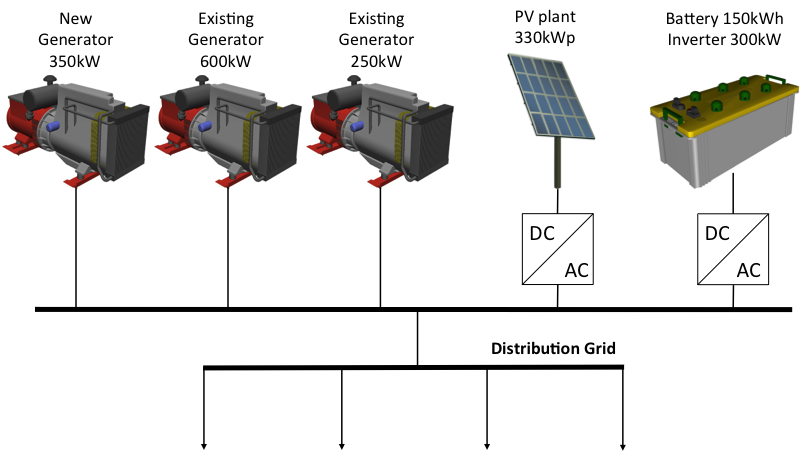


Figure 18: Hoarafushi Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Hoarafushi Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type B system design (Grid support battery)
* Diesel Generators: New 350kW, Existing 600kW and Existing 250kW
* Roof-mounted PV: 230kWp
* Ground-mounted PV: 100kWp
* Li-Ion based battery storage system: 150kWh and 300kW (2C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 18% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

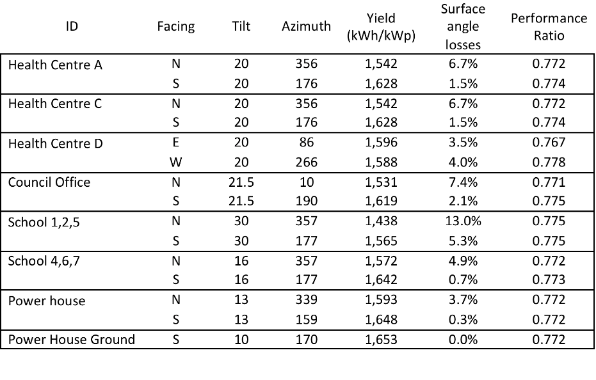


Table 27: Hoarafushi Island technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 330 | 1,596.9 |

Table 28 Hoarafushi Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.*, fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 846,254 | 615,891 | 230,363 | 27.2 | 4.25 |

Table 29: Hoarafushi Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A06-1 | Council Office A1 | 14,500 | 5,700 | 8 | x | 17 |
| A06-2 | Council Office A2 | 14,500 | 5,700 | 8 | x |
| A06-3 | School A1 | 4,560 | 26,000 | 12 | x | 122 |
| A06-4 | School A2 | 4,560 | 26,000 | 12 | x |
| A06-5 | School B1 | 5,500 | 22,000 | 12 | x |
| A06-6 | School B1 | 5,500 | 22,000 | 12 | x |
| A06-7 | School C1 | 4,700 | 20,000 | 9 | x |
| A06-8 | School C2 | 4,700 | 20,000 | 9 | x |
| A06-9 | School D1 | 6,800 | 18,000 | 12 | x |
| A06-10 | School D2 | 6,800 | 18,000 | 12 | x |
| A06-11 | School E1 | 7,800 | 20,000 | 16 | x |
| A06-12 | School E2 | 7,800 | 20,000 | 16 | x |
| A06-13 | Health Centre Roof A1 | 7,600 | 14,000 | 11 | x | 51 |
| A06-14 | Health Centre Roof B1 | 4,900 | 14,000 | 7 | x |
| A06-15 | Health Centre Roof C1 | 4,500 | 14,000 | 6 | x |
| A06-16 | Health Centre Roof C2 | 4,500 | 14,000 | 6 | x |
| A06-17 | Health Centre Roof D1 | 4,600 | 22,500 | 10 | x |
| A06-18 | Health Centre Roof D2 | 4,600 | 22,500 | 10 | x |
| A06-19 | Powerhouse A1 | 5,700 | 19,000 | 11 | x | 44 |
| A06-20 | Powerhouse A2 | 5,700 | 19,000 | 11 | x |
| A06-21 | Powerhouse B1 | 5,700 | 8,800 | 5 | x |
| A06-22 | Powerhouse B2 | 5,700 | 8,800 | 5 | x |
| A06-23 | Powerhouse C1 | 6,000 | 10,300 | 6 | x |
| A06-24 | Powerhouse C2 | 6,000 | 10,300 | 6 | x |
| A06-25 | Powerhouse Ground Mount D1 | 50,000 | 20,000 | 100 | x | 100 |
| **Summary** |  |  |  | **334** |  | **334** |

Table 30: Hoarafushi Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | Council Office | School | Health Centre | Powerhouse |
| --- | --- | --- | --- | --- |
| Owner | Island Council | Ministry of Education | Ministry of Health | Fenaka |
| Available Roof Area (L x W) in meters | 14.5mx5.7m x 2 | 1: 4.56m x 26m x 2 nos  2: 5.5m x 22m x 2 nos  4: 7m x 20m x 2 nos  6: 8m x 18m x 2 nos  7: 8m x 20m x 2 nos | A -7.6mx14m x 1 nos  4.9mx14m x 1 nos  C - 4.5mx14m x 2 nos  D - 4.6m x 22.5m x 2 nos | ER: 5.7m x 19m x 2 nos  CR: 5.7m x 8.8m x 2 nos  OF: 6m x 10.3m x 2 nos |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to Site Layout |
| Height of building | 5m | 1/2/5: 5m 4: 8m, 5: 6.4m, 6/7: 11m | 5m | 6 |
| Age of the building | 25 year | 10 to 18 years | 20 years | 16 years |
| Type of Roof | Gabble | Gabble | Gabble | Gabble |
| Direction of Gable | 100°E | 87°E | A/C: 86°E  D : 356°N | 249°W |
| Direction of Roof(s) (Azimut) | 10°N, 190°S | 357°N, 177°S | A/C: 356°N, 176°S  D: 86°E, 266°W | 159°S, 339°N |
| Roof Material | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets |
| Roof profile (make a detailed sketch) | lysaght | | | |
| Slope | 21.5° | 1: 31°, 2: 27°, 5: 28°  4/6/7: 16° | 20° | 13° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 45m from C7  6°58'55.65" N 72°53'43.01" E | 35m from B4  6°59'03.11" N 72°53'42.24" E | 65m from E9  6°58'48.15" N 72°53'43.78" E | - |
| Size of next grid connection point, space available, cable dimensions | 70sqmm, Space available | 70sqmm, Space available | 50sqmm, Space available | - |
| Distance to Power House | 545m | 430m | 760m | - |
| GPS coordinates | 6°58'54.75" N 72°53'42.53" E | 6°59'03.59" N 72°53'40.43" E | 6°58'46.85" N 72°53'43.26" E | 6°59'00.73" N 72°53'52.54" E |
| Soiling of roof (1=clean, 5=very dirty) | 3 | 1 | 1 | 3 (Repainting is required) |
| Support Structure of Roof (take pictures of support) | Concrete columns and Cement Walls | Concrete columns and Cement Walls | Concrete columns and Cement Walls | Concrete columns and Cement Walls |
| Layer Structure of Roof | 4”x2” rafters @ 750mm, 2”x1.5” battens @ 600mm | 8”x2” Wooden Truss @3300mm  4”x2” Battens @ 600mm | 4”x2” rafters @ 750mm, 2”x1.5” battens @ 600mm | Steel truss, drawings attached. |
| Bearing Capacity |  |  |  |  |
| Type of near shading obstacles | - | Small trees only. Can be trimmed if required | 7 to 8 meter tall coconut trees on west side. | - |
| Access to the Roof | By portable ladder | By portable ladder | By portable ladder | By portable ladder |
| Describe existing lightning protection equipment | - | - | - | Photo attached |
|  |  |  |  |  |

Table 31: Hoarafushi Island Buildings for PV installation

### Possible areas for Ground mount PV installation

| **Item** |  | **Powerhouse** | **Area 2** | **Area 3** | **Area 4** |
| --- | --- | --- | --- | --- | --- |
| Owner |  | Fenaka |  |  |  |
| Size of area(L x I) |  | 50x20m |  |  |  |
| Possible site for car port/ shading roof in public area like harbour, school, etc. |  |  |  |  |  |
| Distance to next grid connection point |  | - |  |  |  |
| Size of next grid connection point, space available, cable dimensions |  | 100A Spare feeders available. |  |  |  |
| Distance to Power House |  | - |  |  |  |
| GPS coordinates |  | 6°59'00.73" N 72°53'52.54" E |  |  |  |
| Area borders for ground mounted PV installation |  | Refer to site layout |  |  |  |
| Borders of area according to plans |  | Refer to site layout |  |  |  |
| Surface soil composition |  | Soft |  |  |  |
| Ground composition |  |  |  |  |  |
| Slope of area |  | flat |  |  |  |
| Distance to Obstacles (shading) |  | - |  |  |  |
| Size of Obstacles (if any) |  | - |  |  |  |
| Site Protection Measures (if required) |  | - |  |  |  |
| Describe existing lightning protection equipment |  | Picture attached |  |  |  |

Table 32: Hoarafushi Island ground for PV installation

## A07 Ihavandhoo Island

### General

#### The Ihavandhoo is an inhabited island in Maldives. It is located in the northern-most geographic atoll in the country, and is administratively part of Haa Alif Atoll. It is an island-level administrative constituency governed by the Ihavandhoo Island Council. It stretches over 880 meters in length at a width of 860 meters. The island is 300 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The harbour can accept only boats up to 30m lengths. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 30 minutes by speed boat from Hanimaadhoo Airport.



Figure 19: Ihavandhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | [6°57′17″N 72°55′33″E](https://tools.wmflabs.org/geohack/geohack.php?pagename=Ihavandhoo_%28Haa_Alif_Atoll%29&params=6_57_17_N_72_55_33_E_type:isle_region:MV) |
| Inhabitants (approx.) | 3071 |
| Harbour type | Harbour, 30m Local Boats only |
| Airport | Domestic Hanimaadhoo airport |

Table 33: Ihavandhoo Island identification and general data

### Grid Infrastructure

#### The power house in Ihavandhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 6252 kWh/day, which is equivalent to an average power consumption of 260 kW. Maximum registered load value of 380 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality.

#### This is a developing island and lot of people are building new houses and people are investing on air conditions. A new pre-school. (Estimated load: 5 to 8kW) and water plant extension (Estimated load: 20kW) is due to be completed soon. Expected load increase per year is 8%.

#### The following load profiles shall be considered for sizing.

Figure 20: Ihavandhoo Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island..

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  NT 855 G6 | | Volvo  TAD 722 GE | Cummins  KTA19-G3 |  |
| Engine power rating (continuous) | 250kW | | 160kW | 360kW |  |
| Alternator power rating | 350kVA | | 160kVA | 450VA |  |
| Hours of operation / date of installation | 29,335 hrs | | 34878 hrs | 5639 hrs |  |
| General maintenance performed | Top overhaul done after 16,865hrs | | Top overhaul done after 27,685hrs | No |  |
| Required upgrade / replacement |  | |  |  |  |

Table 34: Ihavandhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 160 kW and 250 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

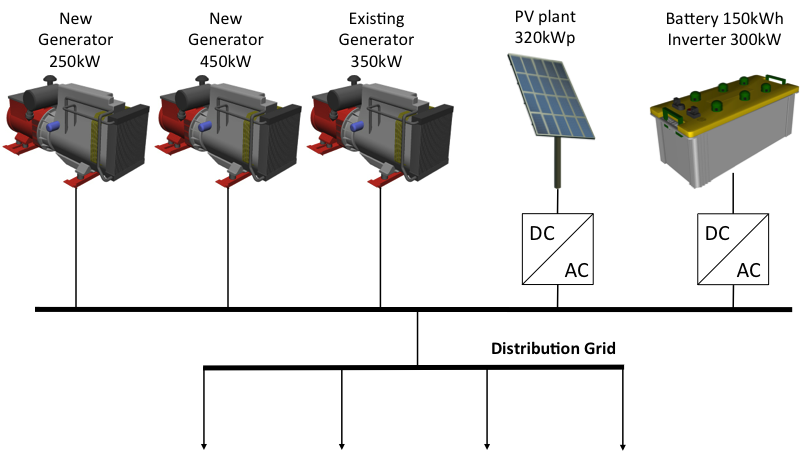


Figure 21: Ihavandhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Ihavandhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type B system design (Grid support battery)
* Diesel Generators: New 250kW, New 450kW and existing 350kW
* Roof-mounted PV: 320kWp
* Li-Ion based battery storage system: 150kWh and 300kW (2C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 18% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

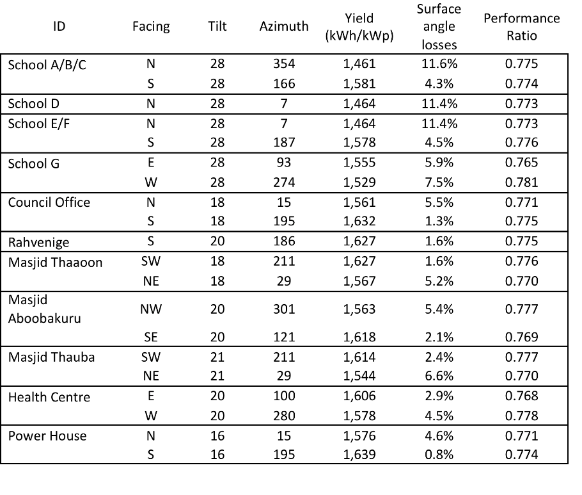


Table 35: Ihavandhoo Island technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 320 | 1568,59 |

Table 36 Ihavandhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.*, fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 848,430 | 599,777 | 248,653 | 29.3 | 4.4 |

Table 37: Ihavandhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A07-1 | Council Office A1 | 7,000 | 15,500 | 11 | x | 22 |
| A07-2 | Council Office A2 | 7,000 | 15,500 | 11 | x |
| A07-3 | Rahvehihiya B | 9,000 | 18,000 | 16 | x | 16 |
| A07-4 | Masjid Thaaoon C1 | 7,000 | 10,000 | 7 | x | 14 |
| A07-5 | Masjid Thaaoon C2 | 7,000 | 10,000 | 7 | x |
| A07-6 | Masjid Aboobakuru D1 | 7,000 | 11,500 | 8 | x | 16 |
| A07-7 | Masjid Aboobakuru D2 | 7,000 | 11,500 | 8 | x |
| A07-8 | Masjid Thauba E1 | 10,200 | 12,500 | 13 | x | 26 |
| A07-9 | Masjid Thauba E2 | 10,200 | 12,500 | 13 | x |
| A07-10 | Health Centre Roof A1 | 9,200 | 11,000 | 10 | x | 73 |
| A07-11 | Health Centre Roof A2 | 9,200 | 11,000 | 10 | x |
| A07-12 | Health Centre Roof B1 | 6,600 | 6,600 | 4 | x |
| A07-13 | Health Centre Roof B2 | 6,600 | 6,600 | 4 | x |
| A07-14 | Health Centre Roof C1 | 9,200 | 24,000 | 22 | x |
| A07-15 | Health Centre Roof C2 | 9,200 | 24,000 | 22 | x |
| A07-16 | School A1 | 5,500 | 32,000 | 18 | x | 162 |
| A07-17 | School A2 | 5,500 | 32,000 | 18 | x |
| A07-18 | School B1 | 6,500 | 22,000 | 14 | x |
| A07-19 | School B1 | 6,500 | 22,000 | 14 | x |
| A07-20 | School C1 | 5,500 | 32,000 | 18 | x |
| A07-21 | School C2 | 5,500 | 32,000 | 18 | x |
| A07-22 | School D1 | 9,200 | 19,000 | 17 | x |
| A07-23 | School E1 | 5,000 | 13,000 | 7 | x |
| A07-24 | School E2 | 5,000 | 13,000 | 7 | x |
| A07-25 | School F1 | 4,000 | 20,500 | 8 | x |
| A07-26 | School F2 | 4,000 | 20,500 | 8 | x |
| A07-27 | School G1 | 4,000 | 20,500 | 8 | x |
| A07-28 | School G2 | 4,000 | 20,500 | 8 | x |
| A07-29 | Powerhouse A1 | 5,300 | 23,000 | 12 | x | 22 |
| A07-30 | Powerhouse B1 | 4,200 | 23,000 | 10 | x |
| **Summary** |  |  |  | **351** |  | **351** |

Table 38: Ihavandhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **Council Office** | **Rahvehihiya** | **Masjid Thaaoon** | **Masjid**  **Aboobakuru** | **Masjid Thauba** | **Health**  **Centre** | **School** | **Powerhouse** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Owner | Island Council | Island Council | Ministry of Islamic Affairs | Ministry of Islamic Affairs | Ministry of Islamic Affairs | Ministry of Health | Ministry of Education | Fenaka |
| Available Roof Area (L x W) | 7m x 15.5m x 2 | 9m x 18m (useful area) | 7m x 10m x 2 | 7m x 11.5m x 2 | 10.2m x 12.5m x 2 | 9.2m x 11m x 2  6.6m x 6.6m x 2  9.2m x 24m x 2 | A – 5.5m x 32m x 2  B - 6.5m x 22m x 2  C – 5.5m x 32m x 2  D – 9.2m x 19m  E - 5m x 13m x 2  F - 4m x 20.5m x 2  G - 4m x 20.5m x 2 | 5.3mx23m  4.2mx23m |
| Available surrounding areas | Refer to Site Layout | Refer to Site Layout | Refer to Site Layout | Refer to Site Layout | Refer to Site Layout | Refer to Site Layout | Refer to Site Layout | Refer to site layout |
| Height of building | 5m | 5.4m | 5m | 5m | 6m | 6.1m | A – 5.5m, B – 8.6m  C – 5.6m, D - 4.7m  E – 5.8m, G/F – 10m | 5.8m |
| Age of the building |  |  |  |  |  |  |  |  |
| Type of Roof | Gabble | Gabble | Gabble | Gabble | Gabble | Gabble | A to F: Gabble  G/F : Bonnet | Gabble |
| Direction of Gable | 105°E | 96°E | 301°NW | 211°SW | 301°NW | 10°N | A/B/C - 79°E  D/E/F - 95°E  G - 5°N | 105°E |
| Direction of Roof(s) (Azimut) | 195°S, 15°N | 186°S | 211°SW, 29°NE | 301°NW, 121°SE | 211°SW, 29°NE | 100°E, 280°W | A/B/C: 354°N, 166°S  D: 7°N  E/F: 7°N, 187°S  G: 93°E, 274°W | 195°S, 15°N |
| Roof Material | Lysaght Corrugated sheet metal | Lysaght Corrugated sheet metal | Lysaght Corrugated sheet metal | Lysaght Corrugated sheet metal | Lysaght Corrugated sheet metal | Lysaght Corrugated sheet metal | Lysaght Corrugated sheet metal except roof C | Lysaght Corrugated sheet metal |
| Roof profile (make a detailed sketch) | lysaght | | | | | | |  |
| Slope | 18° | 20° | 18° | 20° | 21° | 20° | 28° | 16° |
| Distance to next grid connection point | 40m from G1  6°57'00.99" N 72°55'34.55" E | 35m from D2  6°57'03.99" N 72°55'35.12" E | 53m from F4  6°57'07.42" N 72°55'37.62" E | 35m from F9  6°57'14.16" N 72°55'40.53" E | 10m from A4  6°57'09.58" N 72°55'29.96" E | 30m from A1  6°57'02.23" N 72°55'28.30" E | 15m from D8  6°57'14.19" N 72°55'37.30" E | - |
| Size of next grid connection point, space available, cable dimensions | 70sqmm, 4 core  Space available | 70sqmm, 4 core  Space available | 70sqmm, 4 core  Space available | 35sqmm, 4 core  Space available | 35sqmm, 4 core  Space available | 50sqmm, 4 core  Space available | 35sqmm, 4 core  Space available | - |
| Distance to Power House | 175m | 315m | 465m | 730m | 310m | 100m | 610m | - |
| GPS coordinates | 6°57'01.72" N 72°55'33.56" E | 6°57'04.41" N 72°55'35.55" E | 6°57'06.26" N 72°55'37.05" E | 6°57'14.69" N 72°55'39.62" E | 6°57'09.58" N 72°55'30.64" E | 6°57'02.83" N 72°55'27.52" E | 6°57'15.33" N 72°55'37.34" E | 6°57'00.91" N 72°55'28.80" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 1 | 1 | 1 | 1 – A/B/D/E/F/G  5 – C (Need to replace) | 1 |
| Support Structure of Roof (take pictures of support) | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall |
| Layer Structure of Roof | 100x50mm wood rafters @750mm  50x38mm battens @600mm | 100x50mm wood rafters @750mm  50x38mm battens @600mm | 100x50mm wood rafters @750mm  50x38mm battens @600mm | 100x50mm wood rafters @750mm  50x38mm battens @600mm | 100x50mm wood rafters @750mm  50x38mm battens @600mm | 100x50mm wood rafters @750mm  50x38mm battens @600mm | 200x50mm wood truss @3300mm  100x50mm battens @750mm | Steel Truss and steel purlins |
| Bearing Capacity |  |  |  |  |  |  |  |  |
| Type of near shading obstacles | No significant obstacles | No significant obstacles | No significant obstacles | No significant obstacles | No significant obstacles | No significant obstacles | Refer to building heights. Some buildings may block | No obstacles |
| Access to the Roof | Portable ladder | Portable ladder | Portable ladder | Portable ladder | Portable ladder | Portable ladder | Portable ladder | Portable ladder |
| Describe existing lightning protection equipment | - | - | - | - | - | - | - | Lightning rod fixed middle of powerhouse above 1.5m from the highest point. |
|  |  |  |  |  |  |  |  |  |

Table 39: Ihavandhoo Island Possible Buildings for PV installation

## A08 Kelaa Island

### General

#### The Kelaa is one of the inhabited islands of Haa Alif Atoll and geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Kelaa Island Council. It stretches over 3,060 meters in length at a width of 1,040 meters. The island is 308 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The harbour can accept only boats up to 30m lengths. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 20 minutes by speed boat from Hanimaadhoo Airport.



Figure 22: Kelaa Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°57′35″N 73°12′46″E |
| Inhabitants (approx.) | 2278 |
| Harbour type | Harbour, 20m Local Boats only |
| Airport | Domestic Hanimaadhoo airport |

Table 40: Kelaa Island identification and general data

### Grid Infrastructure

#### The power house in Kelaa Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 3195 kWh/day, which is equivalent to an average power consumption of 133 kW. Maximum registered load value of 215 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality.

#### There are new sewerage system (20kW) and Youth centre (10kW) installation to be completed in few months’ time. Expected load increase per year is 5%.

#### The following load profiles shall be considered for sizing.

Figure 23: Kelaa Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island..

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  6CTA8.3G2 | | Cummins  NT855-GA | Cummins  QSL9-G5 |  |
| Engine power rating (continuous) | 120kW | | 200kW | 236kW |  |
| Alternator power rating | 150kVA | | 250kVA | 295VA |  |
| Hours of operation / date of installation | 2007  38,367hrs | | 2015  3,812hrs | 2011  16,340hrs |  |
| General maintenance performed | Top overhaul done after 16,865hrs | | Top overhaul done after 27,685hrs | No |  |
| Required upgrade / replacement |  | |  |  |  |

Table 41: Kelaa Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The are no discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

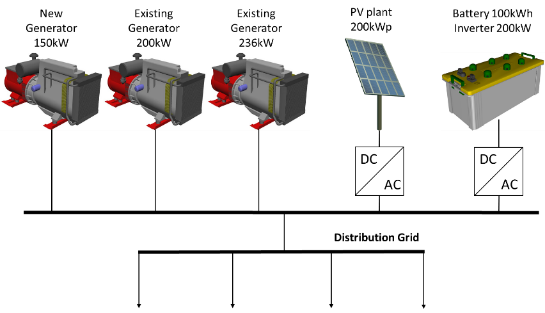


Figure 24: Kelaa Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Kelaa Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type B system design (Grid support battery)
* Diesel Generators: Existing 150kW, existing 200kW and 236kW
* Roof-mounted PV: 200kWp
* Li-Ion based battery storage system: 100kWh and 200kW (2C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 23% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

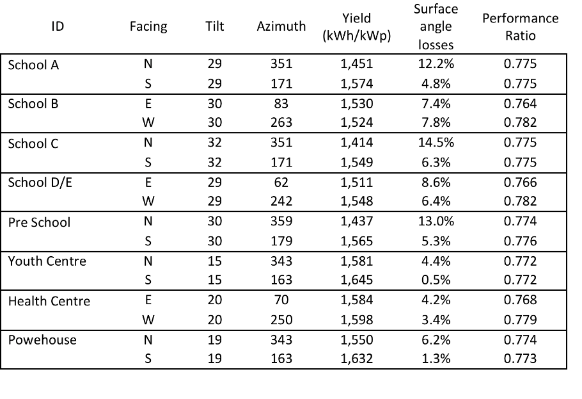


Table 42: Kelaa Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 200 | 1565,87 |

Table 43 Kelaa Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table bellow were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 381,175 | 290,530 | 90,645 | 23.8 | 4.35 |

Table 44: Kelaa Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A08-1 | Powerhouse A1 | 4.500 | 24.000 | 11 | x | 22 |
| A08-2 | Powerhouse A2 | 4.500 | 24.000 | 11 | x |
| A08-3 | Health Centre Roof A1 | 8.000 | 18.000 | 14 | x | 29 |
| A08-4 | Health Centre Roof A2 | 8.000 | 18.000 | 14 | x |
| A08-5 | School A1 | 7.000 | 31.500 | 22 | x | 185 |
| A08-6 | School A2 | 7.000 | 31.500 | 22 | x |
| A08-7 | School B1 | 5.500 | 39.000 | 21 | x |
| A08-8 | School B1 | 5.500 | 39.000 | 21 | x |
| A08-9 | School C1 | 5.700 | 42.500 | 24 | x |
| A08-10 | School C2 | 5.700 | 42.500 | 24 | x |
| A08-11 | School D1 | 6.000 | 30.000 | 18 | x |
| A08-12 | School D2 | 6.000 | 30.000 | 18 | x |
| A08-13 | School E1 | 5.600 | 12.500 | 7 | x |
| A08-14 | School E2 | 5.600 | 12.500 | 7 | x |
| A08-15 | Pre School A1 | 6.300 | 18.000 | 11 | x | 23 |
| A08-16 | Pre School A2 | 6.300 | 18.000 | 11 | x |
| A08-17 | Youth Centre A1 | 7.800 | 26.000 | 20 | x | 41 |
| A08-18 | Youth Centre A2 | 7.800 | 26.000 | 20 | x |
| **Summary** |  |  |  | **299** |  | **299** |

Table 45: Kelaa Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | Powerhouse | Health Centre | School | Pre School | Youth Centre |
| --- | --- | --- | --- | --- | --- |
| Owner | Fenaka | Ministry of Health | Ministry of Education | Island Council | Ministry of Youth |
| Available Roof Area (L x W) in meters | 4.5m x 24m x 2 | 8m x 18m x 2 | A: 7mx31.5m x 2  B: 5.5m x 39m x 2  C: 5.7m x 42.5m x 2  D: 6m x 30m x 2  E: 5.66m x 12.5m x 2 | 6.3m x 18m x 2nos | 7.8m x 26m x 2  (useful area, bonnet roof)  Concrete works completed and soon roofing will be completed, |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to Site Layout | Refer to Site Layout |
| Height of building | 6.3m | 5.5m | C: 6.6m, B: 5.4m, A: 5.6m  D: 5.9m, E: 3.2m | 5.8m | 6.3m |
| Age of the building | 8 years | 15 years | A/D: 10 years  BCE: 20 years | 25 years | new |
| Type of Roof | Gabble | Gabble | Gabble | Gabble | Bonnet |
| Direction of Gable | 73°E | 160°S | C: 81°E, D/E: 332°SE,  A: 80°E, B: 353°N | 89°E | 73°E |
| Direction of Roof(s) (Azimut) | 163°S, 343°W | 250°W, 70°E | C: 351°N, 171°S  D/E: 62°E, 242°W  A: 350°N, 170°S  B: 263°W, 83°E | 359°N, 179°S | 163°S, 343°W |
| Roof Material | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets |
| Roof profile (make a detailed sketch) | lysaght | | | | |
| Slope | 19° | 20° | A: 29°, B: 30°, C: 32°,  D: 27°, E: 30° | 30° | 15° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | - | 17 m from E1  6°57'32.06" N 73°12'43.07" E | 77m from D1 | 30m from E2X1  6°57'36.97" N  73°12'46.26" **E** | In front of Powerhouse |
| Size of next grid connection point, space available, cable dimensions | 2 nos of 150Amps free feeders available in Powerhouse Panel | 4Cx70sqmmm Cable  Space available | 4Cx50sqmmm Cable | 4Cx35sqmmm Cable | 2 nos of 150Amps free feeders available in Powerhouse Panel |
| Distance to Power House | - | 210m | 240m | 400m | 50m |
| GPS coordinates | 6°57'27.11" N 73°12'43.64" E | 6°57'32.17" N 73°12'41.44" E | 6°57'33.81" N 73°12'43.70" E | 6°57'35.98" N  73°12'45.84" E | 6°57'28.55" N  73°12'42.77" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 2 | 2 | 1 |
| Support Structure of Roof (take pictures of support) | Concrete Columns and Ce-ment Walls | Concrete Columns and Ce-ment Walls | Concrete Columns and Ce-ment Walls | Concrete Columns and Cement Walls | Concrete Columns and Cement Walls |
| Layer Structure of Roof | Steel Truss and C-Purlin | 4”x2” Rafters @ 750mm  2”x1.5” Batten @ 600mm | 8”x2” Truss @ 3300mm  4”x2” Batten @ 750mm | 8”x2” Truss x 6 nos  3”x2” Batten x 14 nos | 6”x2” Truss @ 3000mm  3”x3” Batten @ 550mm |
| Bearing Capacity | - | - | - | - | - |
| Type of near shading obstacles | - | Lot of trees on west side 8m away from roof. 7 to 9m high. | 20m wide tree between block A and D. Other small trees covering small part in roofs can be trimmed. | - | Only small trees which will be trimmed after completing the roof. |
| Access to the Roof | By portable ladder | By portable ladder | By portable ladder | By portable ladder | By portable ladder |
| Describe existing lightning protection equipment | Photo Attached | - | - | - | - |

Table 46: Kelaa Island possible Buildings for PV installation

## A09 Vashafaru Island

### General

#### The Vashafaru is one of the inhabited islands of Haa Alif Atoll and geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Vashafaru Island Council. It stretches over 1,950 meters in length at a width of 220 meters. The island is 303 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The size of the harbour is about 152 meter. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 20 minutes by speed boat from Hanimaadhoo Airport.



Figure 25: Vashafaru Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°58′50″N 72°53′45″E |
| Inhabitants (approx.) | 894 |
| Harbour type | Harbour, 152m length |
| Airport | Domestic Hanimaadhoo airport |

Table 47: Vashafaru Island identification and general data

### Grid Infrastructure

#### The power house in Vashafaru Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1085 kWh/day, which is equivalent to an average power consumption of 46 kW. Maximum registered load value of 57 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality.

#### Island Council have plans to lease land for tourism related business. But there is no firm timeline for this. Expected load increase per year is 3%.

#### The following load profiles shall be considered for sizing.

Figure 26: Vashafaru Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Deutz  1013EC | | Cummins  6CTA8.3G2 | Cummins  6BT5.9G2 |  |
| Engine power rating (continuous) | 80kW | | 160kW | 80kW |  |
| Alternator power rating | 100kVA | | 200kVA | 100VA |  |
| Hours of operation / date of installation |  | |  |  |  |
| General maintenance performed | No | | No | No |  |
| Required upgrade / replacement |  | |  |  |  |

Table 48: Vashafaru Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 80 kW and 160 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

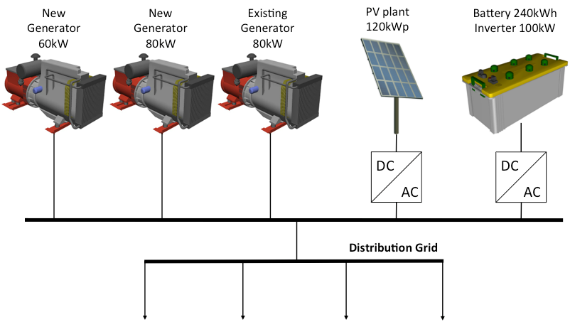


Figure 27: Vashafaru Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Vashafaru Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 60kW, new 80kW and existing 80kW
* Roof-mounted PV: 120kWp
* Li-Ion based battery storage system: 240kWh and 100kW (1C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 38% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

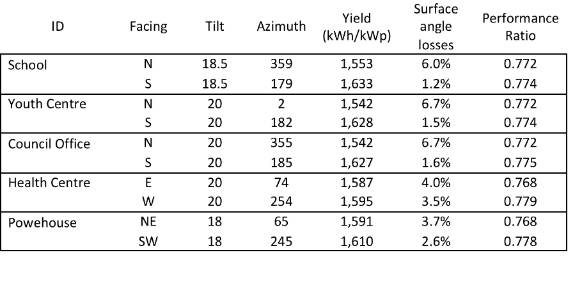


Table 49: Vashafaru Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 120 | 1612,78 |

Table 50 Vashafaru Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.*, fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 137,580 | 81,779 | 55,801 | 40.5 | 5.09 |

Table 51: Vashafaru Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A09-1 | Powerhouse A1 | 5.000 | 25.000 | 13 | x | 25 |
| A09-2 | Powerhouse A2 | 5.000 | 25.000 | 13 | x |
| A09-3 | Health Centre Roof A1 | 11.000 | 8.500 | 9 | x | 19 |
| A09-4 | Health Centre Roof A2 | 11.000 | 8.500 | 9 | x |
| A09-5 | School A1 | 4.750 | 51.000 | 24 | x | 67 |
| A09-6 | School A2 | 4.750 | 51.000 | 24 | x |
| A09-7 | School B1 | 5.200 | 18.000 | 9 | x |
| A09-8 | School B1 | 5.200 | 18.000 | 9 | x |
| A09-15 | Youth Centre A1 | 5.750 | 14.000 | 8 | x | 16 |
| A09-16 | Youth Centre A2 | 5.750 | 14.000 | 8 | x |
| A09-17 | Council Office A1 | 4.900 | 23.000 | 11 | x | 23 |
| A09-18 | Council Office A2 | 4.900 | 23.000 | 11 | x |
| **Summary** |  |  |  | **150** |  | **150** |

Table 52: Vashafaru Island roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **Powerhouse** | **Health Centre** | **School** | **Youth Centre** | | **Council Office** |
| --- | --- | --- | --- | --- | --- | --- |
| Owner | Fenaka | Ministry of Health | Ministry of Education | Ministry of Youth | | Island Council |
| Available Roof Area (L x W) in meters | 25x5m x 2nos | 11x8.5m x 2nos | 51x4.75m x 2nos  18x5.2m x 2nos |  | 14x5.75m x 2nos | 23x4.9m x 2nos |
| Available surrounding areas | Refer to site layout and pictures | Refer to site layout and pictures | Refer to site layout and pictures | Refer to site layout and pictures | | Refer to site layout and pictures |
| Height of building | 7m | 5.5m | 5.5m | 5.8m | | 5.5m |
| Age of the building | Newly Constructed | 12years | Large building :15 years  Small building: 7 years | 15 years | | 15 years |
| Type of Roof | Gabble | Gabble | Gabble | Gabble | | Gabble |
| Direction of Gable | 155°SE | 164°S | 89°E | 92°E | | 85°E |
| Direction of Roof(s) (Azimut) | 245°SW, 65°NE | 254°W, 74°N | 179°S, 359°N | 2°N, 182°S | | 355°N, 185°S |
| Roof Material | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Trapezoidal Steel Sheets | | Lysaght Trapezoidal Steel Sheets |
| Roof profile (make a detailed sketch) | lysaght | | | | | |
| Slope | 18° | 20° | 18.5° | 20° | | 20° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | - | 55m from DB-B5 | 35m from DB-B5 | 25m from DB-B2 | | 35m from DB-B2X1 |
| Size of next grid connection point, space available, cable dimensions | - | 25sqmm cable  Box too small and shall be replaced | 25sqmm cable  Box too small and shall be replaced | 25sqmm cable  Box too small and shall be replaced | | 25sqmm cable  Box too small and shall be replaced |
| Distance to Power House | - | 330m | 275m | 250m | | 290m |
| GPS coordinates | 6°53'47.72" N 73°09'48.41" E | 6°53'55.27" N 73°09'49.05" E | 6°53'47.34" N 73°09'41.15" E | 6°53'52.01" N 73°09'43.48" E | | 6°53'52.78" N 73°09'44.38" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | Small roof : 1  Long roof: need to replace 70% of roofing sheets | 2 | | 1 |
| Support Structure of Roof (take pictures of support) | Concrete columns and cement block walls | Concrete columns and cement block walls | Concrete columns and cement block walls | Concrete columns and cement block walls | | Concrete columns and cement block walls |
| \*\*Layer Structure of Roof | Steel truss and C-Purlin | 4”x2” wooden rafters @ 750mm  2”x1.5” battens @ 600mm | 8”x2” wooden truss @ 3m and 4”x2” @ 750mm | 4”x2” wooden rafters @ 750mm  2”x1.5” battens @ 600mm | | 4”x2” wooden rafters @ 750mm  2”x1.5” battens @ 600mm |
| Bearing Capacity |  |  |  |  | |  |
| Type of near shading obstacles | - | 7m tall vegetation on west side of the building | - | - | | - |
| Access to the Roof | Portable ladder | Portable ladder | Portable ladder | Portable ladder | | Portable ladder |
| Describe existing lightning protection equipment | - | - | - | - | | - |

Table 53: Vashafaru Island Possible Buildings for PV installation

## A10 Dhidhdhoo Island

### General

#### The Dhidhdhoo is the capital of Haa Alif Atoll in the Maldives. It is an island-level administrative constituency governed by the Dhidhdhoo Island Council. The island lies on the north western tip of Thiladhunmathi Atoll and is separated from the Ihavandhippolhu Atoll by the deep Gallandhoo Kandu channel. It stretches over 2,000 meters in length at a width of 350 meters. The island is 305 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The size of the harbour is about 152 meter. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 25 minutes by speed boat from Hanimaadhoo Airport.



Figure 28: Dhidhdhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°53′24″N 73°6′24″E |
| Inhabitants (approx.) | 4000 |
| Harbour type | Harbour, 390m length |
| Airport | Domestic Hanimaadhoo airport |

Table 54: Dhidhdhoo Island identification and general data

### Grid Infrastructure

#### The power house in Dhidhdhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 9145.5 kWh/day, which is equivalent to an average power consumption of 381 kW. Maximum registered load value of 650 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality.

#### New School building (8kW), Preschool (5kW) and Carpentry (10kW) are already completed, waiting to be connected to the grid. There is also new Apartment complex with 250 units 90% completed and estimated additional load is about 125kW. Expected load increase per year is 12%.

#### The following load profiles shall be considered for sizing.

Figure 29: Dhidhdhoo Island typical daily load profile

### Diesel generators

#### 4 Diesel generators of different sizes are installed on the island.

#### New synchronizing panel with generator controller for four generators shall be installed as part of this grid upgrade project.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  KTA-38G2 | Cummins  KTA19-G4 | CAT | Cummins  QSX15G8 |
| Engine power rating (continuous) | 600kW | 400kW | 508kW | 400kW |
| Alternator power rating | 750kVA | 600kVA | 635kVA | 500kVA |
| Hours of operation / date of installation | 7180hrs | 77000hrs | 21252hrs | 15163hrs |
| General maintenance performed | No | Exact data not available. Genset moved from another island | No | No |
| Required upgrade / replacement |  |  |  |  |

Table 55: Dhidhdhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 508 kW 400 kW and 400 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

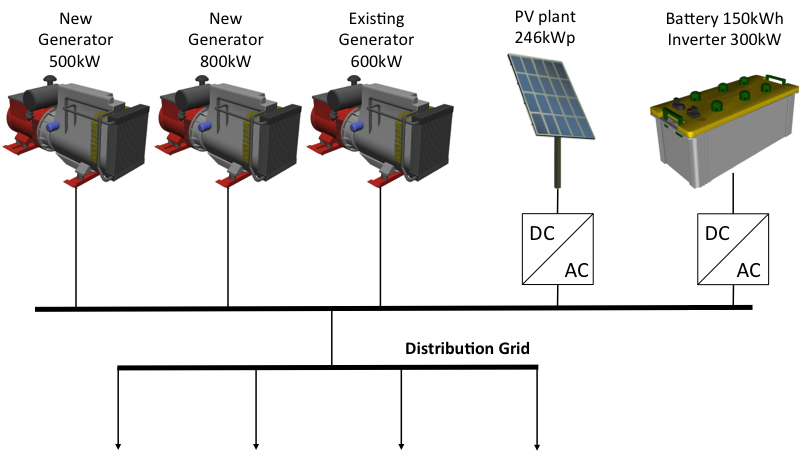


Figure 30: Dhidhdhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Dhidhdhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type B system design
* Diesel Generators: New 500kW, new 800kW and existing 600kW
* Roof-mounted PV: 246kWp
* Li-Ion based battery storage system: 150kWh and 300kW (2C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 9% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

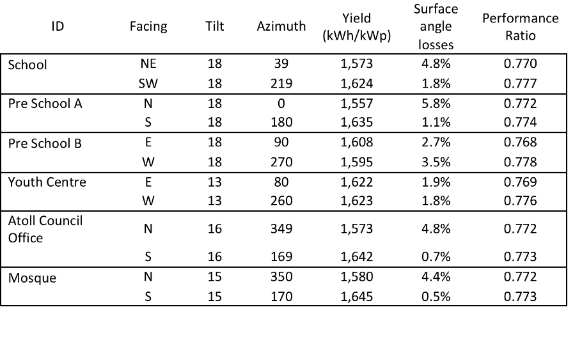


Table 56: Dhidhdhoo Island technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 246 | 1606.23 |

Table 57 Dhidhdhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 1,538,906 | 1,076,611 | 462,295 | 30 | 4 |

Table 58: Dhidhdhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A10-1 | Atoll Council Office A1 | 27.000 | 7.500 | 20 | x | 41 |
| A10-2 | Atoll Council Office A2 | 27.000 | 7.500 | 20 | x |
| A10-3 | Mosque | 11.000 | 7.600 | 8 | x | 17 |
| A10-4 | Mosque | 11.000 | 7.600 | 8 | x |
| A10-5 | School A1 | 29.000 | 10.000 | 29 | x | 68 |
| A10-6 | School A2 | 35.000 | 11.000 | 39 | x |
| A10-7 | Pre School A1 | 46.000 | 5.600 | 26 | x | 74 |
| A10-8 | Pre School A2 | 46.000 | 5.600 | 26 | x |
| A10-15 | Pre School B1 | 20.500 | 5.500 | 11 | x |
| A10-16 | Pre School B2 | 20.500 | 5.500 | 11 | x |
| A10-17 | Youth Centre A1 | 20.500 | 10.200 | 21 | x | 47 |
| A10-18 | Youth Centre B1 | 30.600 | 8.600 | 26 | x |
| **Summary** |  |  |  | **246** |  | **246** |

Table 59: Dhidhdhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **Atoll Council Office** | **Mosque** | **School** | **Pre School** | **Youth Centre** |
| --- | --- | --- | --- | --- | --- |
| Owner | Atoll Council | Ministry of Islamic Affairs | Ministry of Education | Island Council | Youth Ministry |
| Available Roof Area (L x W) in meters | 27x7.5m x 2nos | 11mx7.6m x 2nos | D: 29x10m  G: 35mx11m | A: 46x5.6m x 2nos  B: 20.5x5.5m x 2 nos | A: 20.5x10.2m  B: 30.6x8.6m |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to Site Layout | Refer to Site Layout |
| Height of building | 5.4m | 5m | 10m | 5.5m | 4.2m |
| Age of the building | 15years | 18 years | 8years | 1 year | 5 years |
| Type of Roof | Gabble | Gabble | D: Bonnet  G: Circular Roof | Gabble | A: Bonnet  B: Gabble |
| Direction of Gable | 79° | 80° | 129° | A:90°  B: 0° | 170° |
| Direction of Roof(s) (Azimut) | 169°, 349° | 170°, 350° | 39°, 219° | A: 0°, 180°  A: 90°, 270° | 80°, 260° |
| Roof Material | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets |
| Roof profile (make a detailed sketch) | lysaght | | | | |
| Slope | 16° | 15° | 18° | 18° | 13° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 110m from Substation No.02  6°53'04.49" N 73°06'49.66" E | 370m from Substation No.02  6°53'04.49" N 73°06'49.66" E | 150m from Substation No.02  6°53'04.49" N 73°06'49.66" E | 160m from Substation No.01  6°53'32.92" N 73°06'31.71" E | 600m from Substation No.02  6°53'04.49" N 73°06'49.66" E |
| Size of next grid connection point, space available, cable dimensions | 160A, 3-pole MCCB | 160A, 3-pole MCCB | 160A, 3-pole MCCB | 160A, 3-pole MCCB | 160A, 3-pole MCCB |
| Distance to Power House | 440m | 730m | 500m | 800m | 990m |
| GPS coordinates | 6°53'06.09" N 73°06'51.11" E | 6°52'56.80" N 73°06'54.51" E | 6°53'04.73" N 73°06'53.63" E | 6°53'30.44" N 73°06'34.96" E | 6°52'49.31" N 73°06'57.13" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Concrete Columns and Brick Walls | Concrete Columns and Brick Walls | Concrete Columns and Brick Walls | Concrete Columns and Brick Walls | Concrete Columns and Brick Walls |
| Layer Structure of Roof |  |  |  |  |  |
| Bearing Capacity |  |  |  |  |  |
| Type of near shading obstacles |  |  |  |  |  |
| Access to the Roof | By portable ladder | By portable ladder | By portable ladder | By portable ladder | By portable ladder |
| Describe existing lightning protection equipment | Photo Attached | - | - | - | - |

Table 60: Dhidhdhoo Island possible Buildings for PV installation

## A11 Filladhoo Island

### General

#### The Filladhoo is one of the inhabited islands of Haa Alif Atoll and geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Filladhoo Island Council.This island lies on a large reef and it has a large sandy projection that stretches northwards to Dhapparu, formerly a separate island.. It stretches over 5,850 meters in length at a width of 1,450 meters. The island is 303 km away from Male. The central north west part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. There is a natural inner harbour in this island. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 15 minutes by speed boat from Hanimaadhoo Airport.



Figure 31: Filladhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°52′38″N 73°13′39″E |
| Inhabitants (approx.) | 1065 |
| Harbour type | Natural inner harbour in this island |
| Airport | Domestic Hanimaadhoo airport |

Table 61: Filladhoo Island identification and general data

### Grid Infrastructure

#### The power house in Filladhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1297 kWh/day, which is equivalent to an average power consumption of 54 kW. Maximum registered load value of 97 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality. Expected load increase per year is 5%.

#### The following load profiles shall be considered for sizing.

Figure 32: Filladhoo Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  30/11/2007  6BT5.9-G5 | Cummins  6BT5.9-G2 | Cummins 01/06/2014 6CTAA8.3-G2 |  |
| Engine power rating (continuous) | 60kW | 80kW | 160kW |  |
| Alternator power rating | 75 kVA | 100 kVA | 200 kVA |  |
| Hours of operation / date of installation | 34830  16/8/2008 | 8141  22/06/2014 | 3410  26/12/2014 |  |
| General maintenance performed | Yes | No | No |  |
| Required upgrade / replacement |  |  |  |  |

Table 62: Filladhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensetsdue to lifetime, poor efficiency or to be transferred to other islands is the gensets rated at 60kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

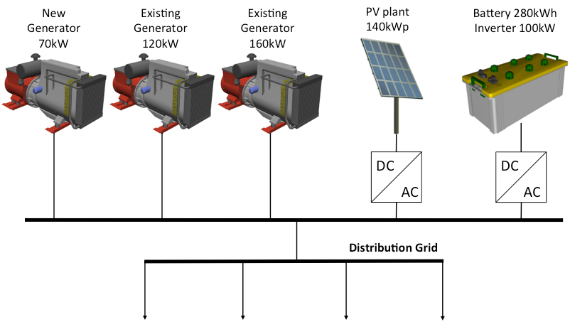


Figure 33: Filladhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Filladhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 70kW, Existing 80kW and existing 160kW
* Roof-mounted PV: 140kWp
* Li-Ion based battery storage system: 280kWh and 100kW (1C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 35% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

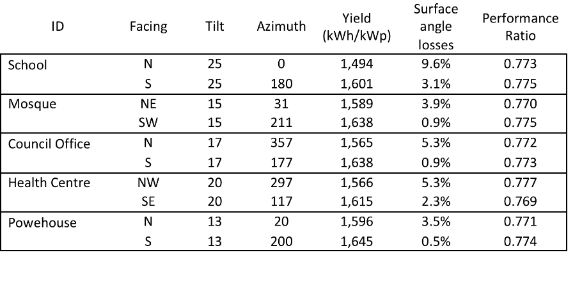


Table 63: Filladhoo Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 140 | 1608.29 |

Table 64 Filladhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.*, fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 215,304 | 126,406 | 88,898 | 41.3 | 4,77 |

Table 65: Filladhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A11-1 | Powerhouse | 28,000 | 17,000 | 48 | x | 48 |
| A11-2 | Island Council | 21,000 | 11,000 | 23 | x | 23 |
| A11-3 | School A1 | 11,000 | 23,000 | 25 | x | 109 |
| A11-4 | School B1 | 11,000 | 20,000 | 22 | x |
| A11-5 | School C1 | 11,000 | 14,000 | 15 | x |
| A11-6 | School D1 | 11,000 | 18,000 | 20 | x |
| A11-7 | School E1 | 11,000 | 24,000 | 26 | x |
| A11-8 | Mosque A1 | 10,870 | 8,000 | 9 | x | 17 |
| A11-9 | Mosque A2 | 10,870 | 8,000 | 9 | x |
| A11-10 | Health Centre B1 | 11,000 | 7,500 | 8 | x | 18 |
| A11-11 | Health Centre A2 | 11,000 | 8,500 | 9 | x |
| **Summary** |  |  |  | **198** |  | **215** |

Table 66: Filladhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **Powerhouse** | **Council** | **School** | **Mosque** | **Health centre** |
| --- | --- | --- | --- | --- | --- |
| Owner | Fenaka | Island Council | Ministry of Education | Ministry of Islamic Affairs | Ministry of Health |
| Available Roof Area (L x W) in meters | 28x17m | 21x11m | A- 11x 23m  B- 11x 20m  C- 11x 14m  D- 11x 18m  E- 11x 24m | 10.7x8m x 2nos | 11x7.5m  11x8.5m |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to site layout | Refer to site layout |
| Height of building | 6m | 5m | 5 to 6m | 5.5m | 6m |
| Age of the building | 7 years | 20 years | A- 28Y, B- 8Y  C- 2Y, D- 10Y  E- 17Y | 20 years | 13 years |
| Type of Roof | Gabble | Gabble | Gabble | Gabble | Gabble |
| Direction of Gable | 110°E | 87° E | 90° E | 301° | 27° NW |
| Direction of Roof(s) (Azimut) | 200°S  20°N | 177° S/ 357° N | 0°N, 180°S | 211° SW/ 31° NE | 297° NW  117° SE |
| Roof Material | Lysaght trapezoidal Steel Sheets | Lysaght trapezoidal Steel Sheets | Lysaght trapezoidal Steel Sheets | Lysaght trapezoidal Steel Sheets | Lysaght trapezoidal Steel Sheets |
| Roof profile (make a detailed sketch) | lysaght | | | | |
| Slope | 13° | 17° | A/C: 28°  B: 25° | 15° | 20° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | Direct Connection to Powerhouse | 35m from DB-D4  6°52'44.06" N 73°13'41.77" E | 35m from DB-D3  6°52'42.67" N 73°13'40.60" E | 25m from DB-B4  6°52'47.03" N 73°13'46.16" E | 55m from DB-B5  6°52'48.50" N 73°13'48.52" E |
| Size of next grid connection point, space available, cable dimensions | - | 4Cx35sqmm | 4Cx35sqmm | 4Cx35sqmm | 4Cx35sqmm |
| Distance to Power House | - | 400m | 400m | 410m | 515m |
| GPS coordinates | 6°52'36.73" N 73°13'46.81" E | 6°52'44.56" N 73°13'41.49" E | 6°52'43.65" N 73°13'39.63" E | 6°52'47.10" N 73°13'45.54" E | 6°52'49.38" N 73°13'47.69" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall | Concrete Columns and Cement Wall |
| \*\*Layer Structure of Roof | - | - | - | - | - |
| Bearing Capacity | - | - | - | - | - |
| Type of near shading obstacles |  |  |  |  |  |
| Access to the Roof | Portable Ladder | Portable Ladder | Portable Ladder | Portable Ladder | Portable Ladder |
| Describe existing lightning protection equipment | - | - | - | - | - |

Table 67: Filladhoo Island Possible Buildings for PV installation

## A12 Maarandhoo Island

### General

#### The Maarandhoo is one of the inhabited islands of Haa Alif Atoll and is geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Maarandhoo Island Council. It stretches over 1,080 meters in length at a width of 520 meters. The island is 303 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The harbour in this island is about 60 meter long. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 15 minutes by speed boat from Hanimaadhoo Airport.



Figure 34: Maarandhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°51′18″N 72°58′59″E |
| Inhabitants (approx.) | 1020 |
| Harbour type | Harbour is about 60 meter long |
| Airport | Domestic Hanimaadhoo airport |

Table 68: Maarandhoo Island identification and general data

### Grid Infrastructure

#### The power house in Maarandhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1366 kWh/day, which is equivalent to an average power consumption of 57 kW. Maximum registered load value of 64 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years’ data recorded show little seasonality. Expected load increase per year is 3%.

#### The following load profiles shall be considered for sizing.

Figure 35: Maarandhoo Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 |
| --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  NTA855-G1B | Cummins  4BT3.9G4 | Cummins  6CTAA8.3-G2 |
| Engine power rating (continuous) | 250kW | 50kW | 160kW |
| Alternator power rating | 318.5kVA | 62.5kVA | 200kVA |
| Hours of operation / date of installation | Installed  July 2016 | -  2006 | 9068hrs  26-10-2014 |
| General maintenance performed | No | No | No |
| Required upgrade / replacement |  |  |  |

Table 69: Maarandhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 50 kW.

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

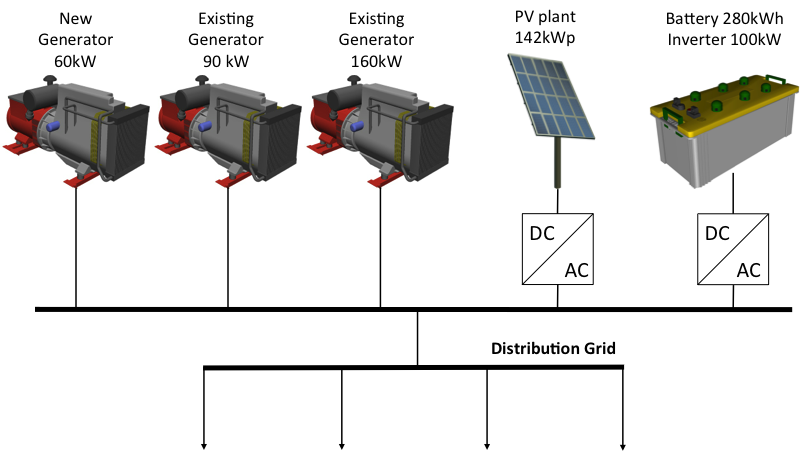


Figure 36: Maarandhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Maarandhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 60kW, Existing 90kW and 160kW
* Roof-mounted PV: 142kWp
* Li-Ion based battery storage system: 280kWh and 100kW (1C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 29% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

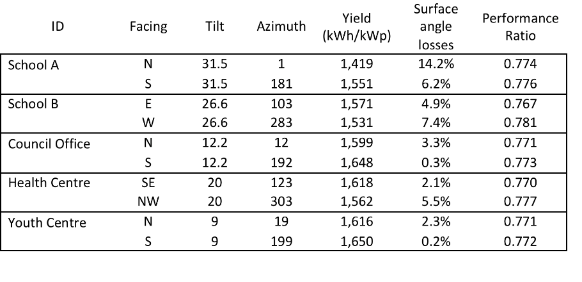


Table 70: Maarandhoo Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 142 | 1569.09 |

Table 71 Maarandhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 231,839 | 137,409 | 94,430 | 40.7 | 4.68 |

Table 72: Maarandhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A12-1 | School A1 | 33.000 | 5.650 | 19 | x | 68 |
| A12-2 | School A2 | 33.000 | 5.650 | 19 | x |
| A12-3 | School B1 | 27.000 | 5.750 | 16 | x |
| A12-4 | School B2 | 27.000 | 5.750 | 16 | x |
| A12-5 | Council Office A1 | 15.500 | 4.750 | 7 | x | 15 |
| A12-6 | Council Office A2 | 15.500 | 4.750 | 7 | x |
| A12-7 | Health Centre A1 | 12.000 | 8.500 | 10 | x | 20 |
| A12-8 | Health Centre A2 | 12.000 | 8.500 | 10 | x |
| A12-9 | Youth Centre A1 | 8.000 | 4.900 | 4 | x | 38 |
| A12-10 | Youth Centre A2 | 8.000 | 4.900 | 4 | x |
| A12-11 | Youth Centre B1 | 8.000 | 7.400 | 6 | x |
| A12-12 | Youth Centre B2 | 8.000 | 7.400 | 6 | x |
| A12-13 | Youth Centre C1 | 13.400 | 4.900 | 7 | x |
| A12-14 | Youth Centre C2 | 13.400 | 4.900 | 7 | x |
| A12-15 | Youth Centre D1 | 13.400 | 2.000 | 3 | x |
| A12-16 | Youth Centre D2 | 13.400 | 2.000 | 3 | x |
| **Summary** |  |  |  | **142** |  | **142** |

Table 73: Maarandhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **School** | **Council Office** | **Health Centre** | **Youth Centre** |
| --- | --- | --- | --- | --- |
| Owner | Ministry of Education | Council | Ministry of Health | Ministry of Youth |
| Available Roof Area (L x W) in meters | A: 33m x 5.65m x 2nos  B: 27m x 5.75m x 2nos | 15.5m x 4.75m 2nos | 12m x 8.5m x 2nos | 8m x 4.9m x 2nos  8m x 7.4m x 2nos  13.4m x 4.9m x 2nos  13.4m x 2m |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to site layout |
| Height of building | A-5.6m  B-5.9m | 4.4m | 5.5m | 4.2m |
| Age of the building | 15 years | 13 years | 12 years | 7 years |
| Type of Roof | Gable | Gable | Gable | Gable |
| Direction of Gable | A-91°  B-13° | 102° | 33° | 109° |
| Direction of Roof(s) (Azimut) | A-181°/ 1°  B-283°/ 103° | 192°  12° | 123°  303° | 199°  19° |
| Roof Material | Lysaght | Lysaght | Lysaght | Lysaght |
| Roof profile (make a detailed sketch) | lysaght | | | |
| Slope | A-31.5°  B-26.6° | 12.2° | 20° | 9° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 90m from A1  6°51'07.84" N 72°58'58.93" E | 35m from A1  6°51'07.84" N 72°58'58.93" E | 10m from B4  6°51'00.51" N 72°59'05.35" E | 95m from A3  6°51'13.30" N 72°59'01.06" E |
| Size of next grid connection point, space available, cable dimensions | 4Cx35sqmmm | 4Cx35sqmmm | 4Cx35sqmmm | 4Cx35sqmmm |
| Distance to Power House | 145m | 100m | 340m | 330m |
| GPS coordinates | 6°51'09.97" N 72°58'57.79" E | 6°51'08.92" N 72°58'59.02" E | 6°51'00.82" N 72°59'04.81" E | 6°51'15.04" N 72°59'02.88" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 2 | 1 | 3 |
| Support Structure of Roof (take pictures of support) | Concrete Columns and Cement Block Walls | Concrete Columns and Cement Block Walls | Concrete Columns and Cement Block Walls | Concrete Columns and Cement Block Walls |
| Layer Structure of Roof | - | - | - | - |
| Bearing Capacity | - | - | - | - |
| Type of near shading obstacles | Coconut palm trees on east side | No major obstacles | Some trees on North side |  |
| Access to the Roof | Portable Ladder | Portable Ladder | Portable Ladder | Portable Ladder |
| Describe existing lightning protection equipment | N/A | N/A | N/A | N/A |
|  |  |  |  |  |

Table 74: Maarandhoo Island possible Buildings for PV installation

## A13 Thakandhoo Island

### General

#### The Thakandhoo is one of the inhabited islands of Haa Alif Atoll and is geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Thakandhoo Island Council. It stretches over 1,220 meters in length at a width of 460 meters. The island is 299 km away from Male. The central western part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 35 minutes by speed boat from Hanimaadhoo Airport.



Figure 37: Thakandhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°50′44″N 72°59′38″E |
| Inhabitants (approx.) | 1020 |
| Harbour type | Harbour size 90 x 60 meter |
| Airport | Domestic Hanimaadhoo airport |

Table 75: Thakandhoo Island identification and general data

### Grid Infrastructure

#### The power house in Thakandhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 743 kWh/day, which is equivalent to an average power consumption of 31 kW. Maximum registered load value of 56 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years’ data recorded show little seasonality. Expected load increase per year is 3%.

#### The following load profiles shall be considered for sizing.

Figure 38: Thakandhoo Island typical daily load profile

### Diesel generators

#### Four Diesel generators of different sizes are installed on the island.

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Deutz  BF1012EC | Cummins 6CTA8.3G2 | Parkins  AG1041 | Perkins  1006TG |
| Engine power rating (continuous) | 58kW | 150kW | 32kW | 68kW |
| Alternator power rating | 72.5kVA | 187.5kVA | 40kVA | 85kVA |
| Hours of operation / date of installation | 38000hrs | 9800hrs | Exact data not available | Exact data not available |
| General maintenance performed | 11000hrs after last overhaul | No | Exact data not available | Exact data not available |
| Required upgrade / replacement |  |  |  |  |

Table 76: Thakandhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 58 kW, 150 kW and 32 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

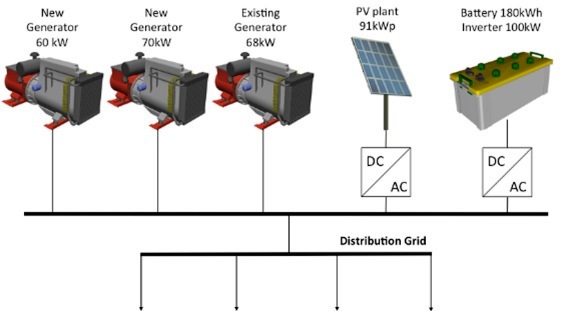


Figure 39: Thakandhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Thakandhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 60, new 70kW and existing 68kW
* Roof-mounted PV: 91kWp
* Li-Ion based battery storage system: 180kWh and 100kW (1C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 39% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

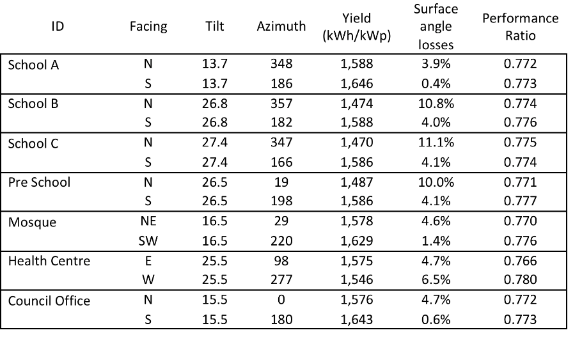


Table 77: Thakandhoo Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 91 | 1595.25 |

Table 78 Thakandhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 163,669 | 68,741 | 94,928 | 42 | 5.04 |

Table 79: Thakandhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A13-1 | School A1 | 20,500 | 11,000 | 23 | x | 60 |
| A13-2 | School B1 | 20,000 | 11,000 | 22 | x |  |
| A13-3 | School C1 | 14,000 | 11,000 | 15 | x |  |
| A13-4 | Health Centre A1 | 15,600 | 12,200 | 19 | x | 19 |
| A13-5 | Mosque | 7,500 | 11,800 | 9 | x | 9 |
| A13-6 | Pre-School A1 | 18,000 | 10,800 | 19 | x | 25 |
| A13-7 | Pre-School A2 | 8,000 | 7,500 | 6 | x |  |
| A13-8 | Council Office A1 | 11,500 | 6,000 | 7 | x | 16 |
| A13-9 | Council Office A2 | 15,700 | 6,000 | 9 | x |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Summary** |  |  |  | **130** |  | **130** |

Table 70: Thakandhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **School** | **Health centre** | **Mosque** | **Pre-school** | **Council Office** |
| --- | --- | --- | --- | --- | --- |
| Owner | Ministry of Education | Ministry of Health | Ministry of Islamic Affairs | Island Council | Island Council |
| Available Roof Area (L x W) in meters | A: 20.5x11m  B: 20x11m  C: 14x11m | 15.6x12.2m | 7.5x11.8m | 18x10.8m  8x7.5m | 11.5x6m  15.7x6m |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout | Refer to site layout | Refer to site layout |
| Height of building | A – 4.2 m  B – 5.9 m  C – 6.0 m | 5.5 m | 5.1 m | 5.6 m | - |
| Age of the building | - | - | - | - | - |
| Type of Roof | Gable | Gable | Gable | Gable | Gable |
| Direction of Gable | A – 960 E  B – 870 E  C – 760 E | 1870 S | 1200 SE | 1110 E | 900 E |
| Direction of Roof(s) (Azimut) | A – 1860S  3480N  B – 1820S  3570N  C – 3470 N  1660 S | 2770W  980 E | 290 NE  2200 SW | 1980 S  190 N | 00 N  1800 S |
| Roof Material | Lysaght corrugated metal sheet | Lysaght corrugated metal sheet | Lysaght corrugated metal sheet | Lysaght corrugated metal sheet | Lysaght corrugated metal sheet |
| Roof profile (make a detailed sketch) | lysaght | | | | |
| Slope | A – 13.70  B – 26.80  C – 27.40 | 25.50 | 16.50 | 26.50 | 15.50 |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 15m from A4X2  6°50'32.84" N 72°59'44.31" E | 15m from A2  6°50'36.02" N 72°59'41.80" E | 30m from A2  6°50'36.02" N 72°59'41.80" E | 35m from B2  6°50'39.40" N 72°59'39.52" E | 50m from B1X1-2  6°50'38.49" N 72°59'43.07" E |
| Size of next grid connection point, space available, cable dimensions | Refer to DB network | Refer to DB network | Refer to DB network | Refer to DB network | Refer to DB network |
| Distance to Power House | 310m | 135m | 160m | 65m | 210m |
| GPS coordinates | 6°50'31.93" N 72°59'43.85" E | 6°50'36.01" N 72°59'42.30" E | 6°50'35.29" N 72°59'42.03" E | 6°50'38.69" N 72°59'38.97" E | 6°50'39.32" N 72°59'42.45" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Refer to pictures | Refer to pictures | Refer to pictures | Refer to pictures | Refer to pictures |
| Layer Structure of Roof | - | - | - | - | - |
| Bearing Capacity | - | - | - | - | - |
| Type of near shading obstacles | No major obstacle small plants | No major obstacle small plants | No major obstacle small plants | No major obstacle small plants | No major obstacle small plants |
| Access to the Roof | Potable ladder | Potable ladder | Potable ladder | Potable ladder | Potable ladder |
| Describe existing lightning protection equipment | N/A | N/A | N/A | N/A | N/A |

Table 80: Maarandhoo Island possible Buildings for PV installation

## A14 Utheemu Island

### General

#### The Utheemu is one of the inhabited islands of Haa Alif Atoll and is geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Utheemu Island Council. It stretches over 900 meters in length at a width of 730 meters. The island is 296 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 35 minutes by speed boat from Hanimaadhoo Airport.



Figure 40: Utheemu Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°50'06.16" N 73°06'45.92" E |
| Inhabitants (approx.) | 916 |
| Harbour type | Harbour size 150 (L) x 76 (W) x 3.3 (D) meter |
| Airport | Domestic Hanimaadhoo airport |

Table 81: Utheemu Island identification and general data

### Grid Infrastructure

#### The power house in Utheemu Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1405 kWh/day, which is equivalent to an average power consumption of 59 kW. Maximum registered load value of 115 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years’ data recorded show little seasonality. Expected load increase per year is 3%.

#### The following load profiles shall be considered for sizing.

Figure 41: Utheemu Island typical daily load profile

### Diesel generators

#### Three Diesel generators of different sizes are installed on the island.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Cummins  6CTAA8.3G2 | Deutz  1013EC | Cummins  NT-855G6 |  |
| Engine power rating (continuous) | 160kW | 80kW | 200kW |  |
| Alternator power rating | 200kVA | 100kVA | 250kVA |  |
| Hours of operation / date of installation | 2014 | 2009 | Installed July 2016 |  |
| General maintenance performed | No | Yes |  |  |
| Required upgrade / replacement |  |  |  |  |

Table 82: Utheemu Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated 200 kW (oversized).

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

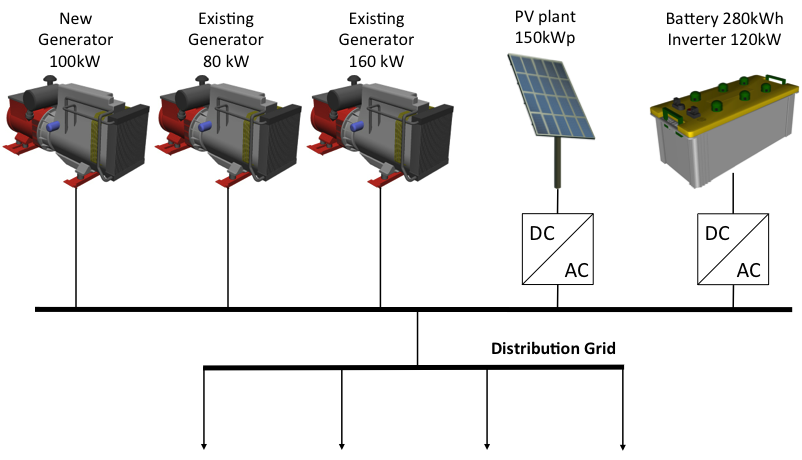


Figure 42: Utheemu Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Filladhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 100kW, Existing 80kW and 160kW
* Roof-mounted PV: 150kWp
* Li-Ion based battery storage system: 280kWh and 120kW (1C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 38% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

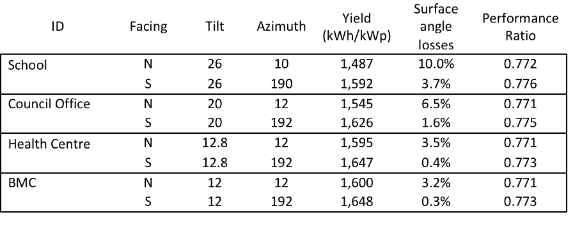


Table 83: Utheemu Island characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 91 | 1616.07 |

Table 84 Utheemu Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 183,552 | 108,571 | 74,981 | 40.8 | 5.17 |

Table 85: Utheemu Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A14-1 | School A1 | 39,000 | 5,400 | 21 | x | 104 |
| A14-2 | School A2 | 39,000 | 5,400 | 21 | x |
| A14-3 | School B1 | 26,000 | 4,400 | 11 | x |
| A14-4 | School B2 | 26,000 | 4,400 | 11 | x |
| A14-5 | School C1 | 45,000 | 4,300 | 19 | x |
| A14-6 | School C2 | 45,000 | 4,300 | 19 | x |
| A14-8 | Council Office A1 | 10,000 | 6,000 | 6 | x | 15 |
| A14-9 | Council Office A2 | 6,000 | 6,000 | 4 | x |
| A14-10 | Council Office A3 | 7,000 | 7,000 | 5 | x |
| A14-11 | Health Centre A1 | 16,500 | 6,000 | 10 | x | 20 |
| A14-12 | Health Centre A2 | 16,500 | 6,000 | 10 | x |
| A14-13 | BMC A1 | 21,000 | 5,300 | 11 | x | 85 |
| A14-14 | BMC A2 | 21,000 | 5,300 | 11 | x |
| A14-15 | BMC B1 | 9,500 | 5,000 | 5 | x |
| A14-16 | BMC B2 | 9,500 | 5,000 | 5 | x |
| A14-17 | BMC C1 | 39,000 | 6,800 | 27 | x |
| A14-18 | BMC C2 | 39,000 | 6,800 | 27 | x |
| **Summary** |  |  |  | **223** |  | **223** |

Table 86: Utheemu Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **School** | **Council Office** | **Health Centre** | **BMC** |
| --- | --- | --- | --- | --- |
| Owner | Ministry of Education | Island Council | Ministry of Health | Heritage |
| Available Roof Area (L x W) in meters | 39mx5.4m x 2  26mx4.4m x 2  45mx4.3m x 2 | Refer to layout | 16.5mx6m x 2 | 21mx5.3m x 2  9.5mx5m x 2  39mx6.8m x 2 |
| Available surrounding areas | Refer to site Layout | Refer to site Layout | Refer to site Layout | Refer to site Layout |
| Height of building | 6m | 6m | 5.5m |  |
| Age of the building | 5 years | 10 years | 10 years |  |
| Type of Roof | Gable | Gable | Gable | Gable + Bonnet |
| Direction of Gable | 100°E | 112°E | 112°E | 112°E |
| Direction of Roof(s) (Azimut) | 10°N, 190°S | 12°N, 192°S | 12°N, 192°S | 12°N, 192°S |
| Roof Material | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets | Lysaght Trapezoidal Steel Sheets |
| Roof profile (make a detailed sketch) | lysaght | | | |
| Slope | 26° | 20° | 12.8° | 12° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 20m from DB-D1 | 25m from 5.5 DB-A5 | 70m from DB-C3X1 | 20m from A2 |
| Size of next grid connection point, space available, cable dimensions | 50sqmm cable, space available | 16sqmm cable, there is no space for additional connection | 16sqmm cable, there is no space for additional connection | 25sqmm cable, DB shall be replaced |
| Distance to Power House | 250m | 350m | 345m | 220m |
| GPS coordinates | 6°50'01.39" N 73°06'45.78" E | 6°50'14.36" N 73°06'45.53" E | 6°50'06.32" N 73°06'42.12" E | 6°50'09.79" N 73°06'46.24" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 2 |
| Support Structure of Roof (take pictures of support) | Concrete Columns and Cement Block walls | Concrete Columns and Cement Block walls | Concrete Columns and Cement Block walls | Concrete Columns and Cement Block walls |
| Layer Structure of Roof | 8”x2” Wooden Truss @ 3.3m  4”x2” battens @ 750mm | 4”x2” rafters @ 750mm  2”x1.5” battens @ 600mm | 4”x2” rafters @ 750mm  2”x1.5” battens @ 600mm | 4”x2” rafters @ 750mm  2”x1.5” battens @ 600mm |
| Bearing Capacity |  |  |  |  |
| Type of near shading obstacles | Trees on east side of Site 20m away from building | No major shading obstacles | No major shading obstacles | No obstacles |
| Access to the Roof | Portable ladder | Portable ladder | Portable ladder | Portable ladder |
| Describe existing lightning protection equipment | - | - | - | - |

Table 87: Utheemu Island possible Buildings for PV installation

## A15 Muraidhoo Island

### General

#### The Muraidhoo is one of the inhabited islands of Haa Alif Atoll administrative division and is geographically part of Thiladhummathi Atoll in the north of the Maldives. It is an island-level administrative constituency governed by the Muraidhoo Island Council. It is one of the intra-atoll islands (i.e. not forming the atoll border). It stretches over 1,050 meters in length at a width of 680 meters. The island is 296 km away from Male. The central part of the island is mostly urbanized. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 35 minutes by speed boat from Hanimaadhoo Airport.



Figure 43: Muraidhoo Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°50′23″N 73°09′54″E |
| Inhabitants (approx.) | 896 |
| Harbour type | Harbour size 45x90 meter, Depth 4 metre |
| Airport | Domestic Hanimaadhoo airport |

Table 88: Muraidhoo Island identification and general data

### Grid Infrastructure

#### The power house in Muraidhoo Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 1053 kWh/day, which is equivalent to an average power consumption of 44 kW. Maximum registered load value of 75 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years’ data recorded show little seasonality.

#### School new class room construction is in progress and will be completed at the end of January. Sewerage system to be completed 2016, Desalination Plant and Waste Manage system to be completed 2017. A 30 Rooms Guest house Project is due to complete 2018. Expected load increase per year is 3%.

#### The following load profiles shall be considered for sizing.

Figure 44: Muraidhoo Island typical daily load profile

### Diesel generators

#### Two Diesel generators of different sizes are installed on the island. Diesel Geerators 1 shall be integrated in the hybrid PV system.

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | CUMMINS  6CTA8-3G2 | CUMMINS  6CTA8-3G2 |  |  |
| Engine power rating (continuous) | 120 kW | 150 kW |  |  |
| Alternator power rating | 150kVA | 182kVA |  |  |
| Hours of operation / date of installation | 2926hrs  07/02/2015 | 6717hrs  21/05/2014 |  |  |
| General maintenance performed | YES | No |  |  |
| Required upgrade / replacement |  |  |  |  |

Table 89: Muraidhoo Island Diesel generators currently installed

#### New synchronizing panel with generator controller for three generators shall be installed as part of this grid upgrade project.

#### The discarded Diesel genset due to lifetime, poor efficiency or to be transferred to other islands is the gensets rated at 120 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

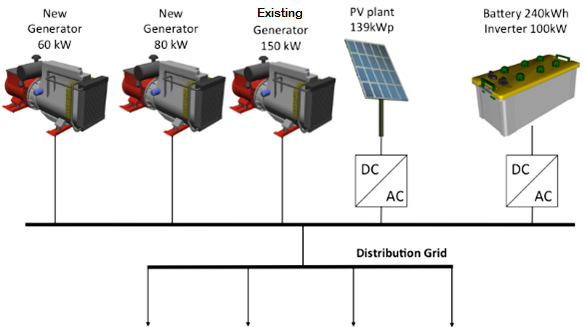


Figure 45: Muraidhoo Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Muraiddhoo Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type C system design (Grid forming battery)
* Diesel Generators: New 60 kW, new 80kW existing 150 kW
* Roof-mounted PV: 139kWp
* Li-Ion based battery storage system: 240kWh and 100kW (1C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 44% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

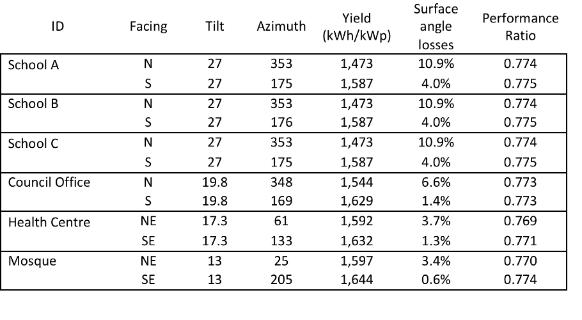


Table 90: Muraidhoo Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 139 | 1558.79 |

Table 91 Muraidhoo Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 147,371 | 72,790 | 74,581 | 50.6 | 5.65 |

Table 92: Muraidhoo Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A15-1 | School A1 | 49.600 | 5.000 | 25 | x | 88 |
| A15-2 | School A2 | 49.600 | 5.000 | 25 | x |
| A15-3 | School B1 | 26.200 | 3.840 | 10 | x |
| A15-4 | School B2 | 26.200 | 3.840 | 10 | x |
| A15-5 | School C1 | 22.550 | 3.840 | 9 | x |
| A15-6 | School C2 | 22.550 | 4.450 | 10 | x |
| A15-7 | Council Office A1 | 17.100 | 4.450 | 8 | x | 15 |
| A15-8 | Council Office A2 | 17.100 | 4.450 | 8 | x |
| A15-10 | Health Centre A1 | 15.240 | 5.360 | 8 | x | 16 |
| A15-11 | Health Centre A2 | 15.240 | 5.360 | 8 | x |
| A15-12 | Mosque A1 | 11.000 | 8.500 | 9 | x | 19 |
| A15-13 | Mosque A2 | 11.000 | 8.500 | 9 | x |
| **Summary** |  |  |  | **139** |  | **139** |

Table 93: Muraidhoo Island available roofs and maximum PV power installable

#### Buildings and roofs

| **Item** | **School** | **Council** | **Health Centre** | **Mosque** |
| --- | --- | --- | --- | --- |
| Owner | Ministry of Education | Local Government Authority | Ministry of Health | Islamic Ministry |
| Available Roof Area (L x W) in meters | 2 x Roof 49.6x5  2 x Roof 26.2x3.84  2 x Roof 22.55x4.45 | 2 x Roof 17.1x4.45 | 2 x Roof 15.24x5.36 | 2 x Roof 11x8.5 |
| Available surrounding areas | Refer to site Layout | Refer to site Layout | Refer to site Layout | Refer to site Layout |
| Height of building | A - 5.6m  B - 8m  C – 5.6m | 5m | 6.4m | 5.1m |
| Age of the building | 8-10 years | 10-15 years | 10 years | 12 years |
| Type of Roof | Gable Roof | Gable Roof | Gable Roof | Gable Roof |
| Direction of Gable | A - 83°E  B - 88°E  C - 83°E | 77°E | 176°S | 128°S |
| Direction of Roof(s) (Azimut) | A - 353°N / 175°S  B - 355°N / 176°S  C - 353°N / 175°S | 169°S / 348°N | 133°SE / 61°NE | 25°NE / 205°SE |
| Roof Material | Lysaght roofing | Lysaght roofing | Lysaght roofing | Lysaght roofing |
| Roof profile (make a detailed sketch) | Attached | Attached | Attached | Attached |
| Slope | A - 26.5°  B – 27.9° | 19.8° | 17.3° | 13.7° (Main Roof)  12.2° (Lower Roof) |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | 98m | 98m | 107m | 61m |
| Size of next grid connection point, space available, cable dimensions | Main incoming cable 16sqmm  DB needed to be replaced. | Main incoming cable 16sqmm  DB needed to be replaced. | Main incoming cable 16sqmm  DB needed to be replaced. | Main incoming cable 16sqmm  DB needed to be replaced. |
| Distance to Power House | 560m | 485m | 606m | 490m |
| GPS coordinates | 6°50’18”N  73°9’59”E | 6°50’19”N  73°10’3”E | 6°50’18”N  73°9’58”E | 6°50’26”N  73°9’44”E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Wooden Structure | Wooden Structure | Wooden Structure | Wooden Structure |
| Layer Structure of Roof | Roofing Sheets  Timber battens  Timber Rafters | Roofing Sheets  Timber battens  Timber Rafters | Roofing Sheets  Timber battens  Timber Rafters | Roofing Sheets  Timber battens  Timber Rafters |
| Bearing Capacity |  |  |  |  |
| Type of near shading obstacles | Refer to site layout for possible obstacles | Refer to site layout for possible obstacles | Refer to site layout for possible obstacles | Refer to site layout for possible obstacles |
| Access to the Roof | Requires a portable ladder | Requires a portable ladder | Requires a portable ladder | Requires a portable ladder |
| Describe existing lightning protection equipment | - | Mast 1: 20m high  Mast 2: 16m high  Two lightning rods. | - | - |
|  |  |  |  |  |
|  |  |  |  |  |

Table 94: Muraidhoo Island possible Buildings for PV installation

#### Possible areas for ground mount PV installation

| **Item** | **Area 1** | **Area 2** | **Area 3** | **Area 4** |
| --- | --- | --- | --- | --- |
| Owner | Shading Roof in Playground area |  |  |  |
| Size of area(L x I) | 30x117m |  |  |  |
| Possible site for car port/ shading roof in public area like harbour, school, etc. | Vehicle Parking / Shading Roof |  |  |  |
| Distance to next grid connection point | - |  |  |  |
| Size of next grid connection point, space available, cable dimensions | - |  |  |  |
| Distance to Power House | 150m |  |  |  |
| GPS coordinates | 6°50’6”N  73°10’1”E |  |  |  |
| Area borders for ground mounted PV installation | Refer to Site Layout |  |  |  |
| Borders of area according to plans | 30x117m |  |  |  |
| Surface soil composition | Soft soil layer |  |  |  |
| Ground composition | 300mm soft layer followed by a rocky sand layer of 300 mm again followed by a soft sand bed. |  |  |  |
| Slope of area | Flat land |  |  |  |
| Distance to Obstacles (shading) | No high trees were in sun line except for one tree which is in the installation area, which will be any way removed. The place was cleaned and trees were removed a year ago. |  |  |  |
| Size of Obstacles (if any) | - |  |  |  |
| Site Protection Measures (if required) | This is a public area and will be open for everyone. The inverters and other equipment shall be kept in a closed room. |  |  |  |
| Describe existing lightning protection equipment | No lightning protection in this area. |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Table 95: Muraidhoo Island Possible ground for PV installation

## A-16 Baarah Island

### General

#### The island of Baarah is located in the Haa Alif Atoll. It stretches over 2,400 meters in length at a width of 1,500 meters. The island is 379 km away from Male and the shaped like the letter 'C'. It is 1,565 m in length by 720 m in width. and a large part of the shores are covered by mangroves. The urbanized area is in the middle part of the island. The nearest international port is in Kulhudhuffushi where cargo ships can unload the goods. From kulhudhuffushi small boats or landing crafts can deliver goods to these islands. Distance from closest airport 20 minutes by speed boat from Hanimaadhoo Airport. 296 km



Figure 46: Baarah Island buildings with available roofs and the powerhouse

| Atoll name | Haa Alif Atol. |
| --- | --- |
| Utility | FENAKA |
| GPS coordinates | 6°49′8″N 73°12′30″E |
| Inhabitants (approx.) | 1983 |
| Harbour type | Harbour |
| Airport | Domestic Hanimaadhoo airport |

Table 96: Baarah Island identification and general data

### Grid Infrastructure

#### The power house in Baarah Island has three diesel generators that supply the load requirements of the island.

#### Generators are connected to a single bus bar at low voltage (230/400V). There exist synchronizers for generation connection and “manual” rudimentary load following operation strategy defined by the power house operators. Distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, as the customers‟ meters are generally accurate. For this island the distribution losses are estimated to be 5-15% of the total generated energy. Some feeders are close to saturation and power grid upgrade is part of this project.

### Load profile

#### The island has a fluctuating energy consumption, which is shown in below. Currently, this island has an average electricity demand of 2,480 kWh/day, which is equivalent to an average power consumption of 103 kW. Maximum registered load value of 157 kW. The profile has an absolute maximum around the midday due to the work activity and air conditioner, and a local maximum peak in the early hours of the night, coinciding with the highest consumption in lighting. The last few years data recorded show little seasonality, in addition to an annual growth of 7.7%.

#### The following load profiles shall be considered for sizing.

Figure 47: Baarah Island typical daily load profile

### Diesel generators

#### : Three Diesel generators of different sizes are installed on the island..

#### The following table shows the existing Diesel Generators with specifications.

| Item | Diesel Gen. 1 | Diesel Gen. 2 | Diesel Gen. 3 | Diesel Gen. 4 |
| --- | --- | --- | --- | --- |
| Engine manufacturer & motor references | Parkins 1006TG | Cummins NTAA855G7 | 6CTA8.3G2 |  |
| Engine power rating (continuous) | 68kW | 300kW | 120kW |  |
| Alternator power rating | 85Kva | 403.8Kva | 150Kva |  |
| Hours of operation / date of installation | 10hrs/day  44,659  June 2008 | 14hrs/day  5,034  November 2014 | 10hrs/day  32,575  Feb 2012 |  |
| General maintenance performed | Yes | Yes | Yes |  |
| Required upgrade / replacement | Yes | - | - |  |

Table 97: Baarah Island Diesel generators currently installed

#### The existing Deep Sea controllers could be reused depending on the solution of the EPC. However for a harmonized architecture of all islands of Phase 2a, it might be necessary to replace these controllers..

#### The discarded Diesel gensets due to lifetime, poor efficiency or to be transferred to other islands are the gensets rated at 68 kW and 300 kW

### Conceptual Design

#### The Bidder shall develop the Hybrid Plant´s basic and detail engineering design in compliance with the specifications mentioned section 6.1. The Bidder shall prepare the project documentation that shall include, among others, the engineering, preparation and delivery program of the engineering, guaranteed data, essential diagrams, general arrangements, design criteria and main equipment specifications.

#### The design of the equipment and systems of the Plant shall be based on achieving the performance of the PV plant as described in Yield and Fuel Savings Summary chapter below for each island and its corresponding test procedures in the Tender document section 6.1 chapter 16. The Hybrid Plant system design, diagrams and main equipment shall require the approval by the Project Management Team prior to the commencement of any installation.

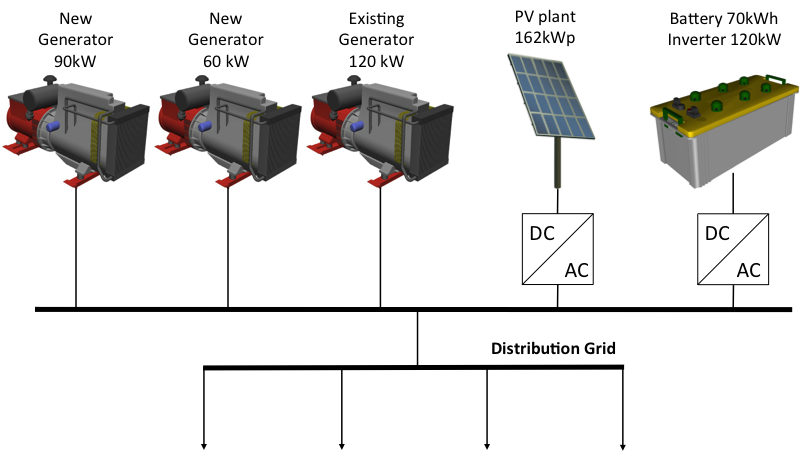


Figure 48: Baarah Island Conceptual design of the hybrid PV system

#### A feasibility study was conducted with detailed analysis of the current electrical energy system of Baarah Island (generation, demand and current condition). Collected information was analysed and a HOMER simulation was conducted with different variables for optimum PV power generation using different combination of PV, inverter, storage battery and genset. Following the simulation and data analysis, conceptual design was presented which is to improve the system by means of efficiency increase measures in the conventional generation gensets, hybridization with electricity production technologies based on PV energies, and introduction of energy storage systems.

#### The proposal focuses on the feasibility study, HOMER and PVSyst simulation and on a sensitivity analysis with respect to diesel cost projections and estimations of an eventual energy demand increase after the installation of the proposed systems and technologies.

#### The main results of this feasibility study in terms of optimal electricity generation mix (and storage) is as follows:

* Type B system design (Grid support battery)
* Diesel Generators: New 90kW, new 60 kW and existing 120 kW
* Roof-mounted PV: 162kWp
* Li-Ion based battery storage system: 70kWh and 120kW (2C)

#### The optimization process gives a hybrid grid for a maximum Renewable Energy Consumption Penetration of 25% penetration (energy obtained from PV). The main technical characteristics of the optimized hybrid PV power plant are summarized on the following table:

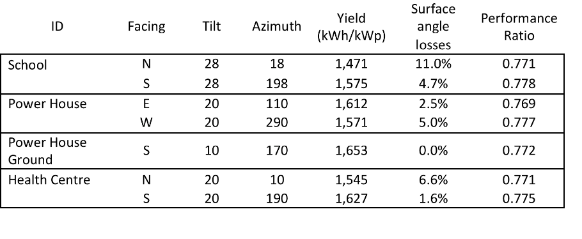


Table 98: Baarah Island Technical characteristic of optimized PV plant

The specific yield (Yield) normalizes the energy produced with respect to the system size and can be calculated theoretically as

Yield =

This net value already considers conversion, wiring and efficiency losses.

The performance ratio (PR) is defined as the energy output injected into the grid divided by the nameplate DC energy obtained under STC of the PV array and is calculated as.

PR =

These results are obtained using the PVSyst software simulation.

#### Yield and Fuel Savings Summary

|  |  |  |
| --- | --- | --- |
|  | **Power**  **kWp** | **Average Yield**  **(KWh/kWp)** |
| **PV Plants** | 139 | 1581.12 |

Table 99 Baarah Island PV plant Yield summary

Since there are several locations for PV installation, a weighted average yield was calculated for the hybrid power plant of the island as follows

Average Yield =

Several fuel consumptions figures are also provided:

* The fuel consumption for the base case (L/year) is the total consumed diesel liters in a year for a power plant consisting of only diesel gensets and optimally dispatched
* The fuel consumption for the hybrid system (L/year) is the total consumed diesel liters in a year for the PV/Diesel/Battery plant optimally dispatching the generation mix. for minimum cost of energy
* The total energy production - PV and Gensets –per fuel consumption (kWh/L).

The figures on the table below were obtained for simulated irradiance levels and load conditions using the software Homer. Real figures will depend on actual operating conditions like the irradiance level and load conditions. The bidder shall provide a fuel saving matrix, *i.e.,* fuel savings for each combination of irradiation and load levels. Values in steps of 100 W/m2 for the irradiance and 20 kVA of load at the grid connection point are suggested.

| Fuel consumption Base Case  - Only Diesel - (L/year) | Fuel consumption Proposed Hybrid System (L/year) | Fuel savings (L/year) | Fuel reduction (%) | Total energy production - PV and Gensets –per fuel consumption (kWh/L) |
| --- | --- | --- | --- | --- |
| 364,043 | 206,429 | 157,614 | 43.3 | 4.34 |

Table 100: Baarah Island PV plant Fuel Savings summary

#### **Overview of possible installation locations:** The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation. The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Roof number** | **Building and name** | **Roof size X (mm)** | **Roof size Y (mm)** | **Max PV on selected roofs [kWp]** | **Useable roofs** | **Total Max PV on selected roofs [kWp]** |
| A16-1 | Health center Roof A 1 | 18,000 | 8,000 | 14 | x | 28 |
| A16-2 | Health center Roof A 2 | 18,000 | 8,000 | 14 | x |
| A16-3 | Powerhouse Roof B 1 | 24,500 | 5,250 | 13 | x | 126 |
| A16-4 | Powerhouse Roof B 2 | 14,500 | 3,250 | 5 | x |
| A16-5 | Power House Ground | 43,000 | 25,000 | 108 | x |
| A16-6 | School Roof C 1 | 15,000 | 5,500 | 8 | x | 63 |
| A16-7 | School Roof C 2 | 15,000 | 5,500 | 9 | x |
| A16-8 | School Roof D1 | 43,000 | 5,250 | 23 | x |
| A16-9 | School Roof D2 | 43,000 | 5,250 | 23 | x |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Summary** |  |  |  | **217** |  | **217** |

Table 101: Baarah Island available roofs/ground and maximum PV power installable

#### Buildings and roofs

| **Item** | **Powerhouse** | **Health Centre** | **School** |
| --- | --- | --- | --- |
| Owner | Fenaka | Ministry of Health | Ministry of Education |
| Available Roof Area (L x W) in meters | 24.5mx11.5m | 18mx16m | 15mx11m  43mx10.5m |
| Available surrounding areas | Refer to site layout | Refer to site layout | Refer to site layout |
| Height of building | 5.5m | 5m | 5m |
| Age of the building | 12 | 15 | 20 |
| Type of Roof | Gable | Gable | Gable |
| Direction of Gable | 100° | 20° | 108° |
| Direction of Roof(s) (Azimut) | 10°/190° | 110°/290° | 18°/198° |
| Roof Material | Lysaght corrugated metal sheet | Lysaght corrugated metal sheet | Lysaght corrugated metal sheet |
| Roof profile (make a detailed sketch) | lysaght | | |
| Slope | 20° | 20° | 28° |
| Distance to next grid connection point and GPS coordinates, or mark in map “Cable Network” | Refer to DB network | 115m from D2  6°49'04.24" N  73°12'44.26" E | 75m from D1  6°49'03.18" N  73°12'43.16" E |
| Size of next grid connection point, space available, cable dimensions | Direct connection to Powerhouse | 4Cx95sqmm | 4Cx95sqmm |
| Distance to Power House | Direct connection to Powerhouse | 310m | 290m |
| GPS coordinates | 6°48'58.23" N  73°12'44.82" E | 6°49'03.62" N  73°12'45.47" E | 6°49'00.48" N  73°12'42.99" E |
| Soiling of roof (1=clean, 5=very dirty) | 1 | 1 | 1 |
| Support Structure of Roof (take pictures of support) | Concrete columns and Cement block walls | Concrete columns and Cement block walls | Concrete columns and Cement block walls |
| Layer Structure of Roof | Steel truss  C profile | Wooden Rafters and battens | Wooden Truss and Rafters |
| Bearing Capacity | - | - | - |
| Type of near shading obstacles | - | - | Refer to Site Layout |
| Access to the Roof | Potable ladder | Potable ladder | Potable ladder |
| Describe existing lightning protection equipment | A single lightning rod is fixed  11 m above the ground | N/A | N/A |
|  |  |  |  |
|  |  |  |  |

Table 102: Baarah Island Possible Buildings for PV installation

### Possible areas for ground mount PV installation

| **Item** | **Powerhouse Site** | **Area 2** | **Area 3** | **Area 4** |
| --- | --- | --- | --- | --- |
| Owner | Fenaka |  |  |  |
| Size of area(L x I) | 40mx25m |  |  |  |
| Possible site for car port/ shading roof in public area like harbour, school, etc. | Storage Area / Open Air Work Shop |  |  |  |
| Distance to next grid connection point | Direct connection to Powerhouse |  |  |  |
| Size of next grid connection point, space available, cable dimensions | - |  |  |  |
| Distance to Power House | - |  |  |  |
| GPS coordinates | 6°48'58.26" N 73°12'45.52" E |  |  |  |
| Area borders for ground mounted PV installation |  |  |  |  |
| Borders of area according to plans |  |  |  |  |
| Surface soil composition | Soft soil |  |  |  |
| Ground composition |  |  |  |  |
| Slope of area | flat |  |  |  |
| Distance to Obstacles (shading) | - |  |  |  |
| Size of Obstacles (if any) | - |  |  |  |
| Site Protection Measures (if required) | - |  |  |  |
| Describe existing lightning protection equipment | . |  |  |  |

Table 103: Baarah Island Possible GroGround for PV installation

# Drawings

The following list of drawings are provided in attachment to the present Volume 6.

|  |  |  |
| --- | --- | --- |
| **S No.** | **Drawing Number** | **Title** |
| ***General Design*** | | |
| 1 | G409-HA ALIF-GEN-GRID-001 | SINGLE LINE DIAGRAM OF DISTRIBUTION BOX: INDICATIVE (COMMON) |
| 2 | G409-HA ALIF-GEN-GRID-002 | DISTRIBUTION BOX LAYOUT: INDICATIVE (COMMON) |
| 3 | G409-HA ALIF-GEN-GRID-003 | CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON) |
| 4 | G409-HA ALIF-GEN-GRID-004 | Front View Control and protection panel: INDICATIVE (COMMON) |

| **S No.** | **Drawing Number** | **Title** |
| --- | --- | --- |
| ***Tender Design*** | | |
| 1. 1 | G409-HA ALIF-A01-SLD-1 | A-1 Thuraaku Grid SLD Proposed |
| 1. 2 | G409-HA ALIF-A01-SLD-2 | A1-Thuraaku PH Single LIne Panel |
| 1. 3 | G409-HA ALIF-A02-SLD-1 | A-2 Uligam Grid SLD Proposed |
| 1. 4 | G409-HA ALIF-A02-SLD-2 | A2-Uligam PH Single LIne Panel |
| 1. 5 | G409-HA ALIF-A05-SLD-1 | A-5 Mulhadho Grid SLD Proposed |
| 1. 6 | G409-HA ALIF-A05-SLD-2 | A-5 Mulhadho PH Singel Line Panel |
| 1. 7 | G409-HA ALIF-A06-SLD-1 | A-6 Hoarafushi Grid SLD Proposed |
| 1. 8 | G409-HA ALIF-A06-SLD-2 | A-6 Hoarafushi PH SIngle Line Panel |
| 1. 9 | G409-HA ALIF-A07-SLD-1 | A-7 Ihavandh Grid SLD Proposed |
| 1. 10 | G409-HA ALIF-A07-SLD-2 | A-7 Ihavandh PH Single Line Panel |
| 1. 11 | G409-HA ALIF-A08-SLD-1 | A-8 Kela Grid SLD Proposed |
| 1. 12 | G409-HA ALIF-A08-SLD-2 | A-8 Kelaa PH Single Line Panel |
| 1. 13 | G409-HA ALIF-A09-SLD-1 | A-9 Vashafaru Grid SLD Proposed |
| 1. 14 | G409-HA ALIF-A09-SLD-2 | A-9 Vashafar PH Single Line Panel |
| 1. 15 | G409-HA ALIF-A10-SLD-1 | A-10 DhidhdhOO Grid SLD Existing |
| 1. 16 | G409-HA ALIF-A10-SLD-2 | A-10 Dhidhdh PH Single Line Panel |
|  | G409-HA ALIF-A10-SLD-3 | A-10 Dhidhdh SUB1 Single Line Panel |
|  | G409-HA ALIF-A10-SLD-4 | A-10 Dhidhdh SUB2 Single Line Panel |
| 1. 17 | G409-HA ALIF-A11-SLD-1 | A-11 Filladh Grid SLD Proposed |
| 1. 18 | G409-HA ALIF-A11-SLD-2 | A-11 Filladh PH Single Line Panel |
| 1. 19 | G409-HA ALIF-A12-SLD-1 | A-12 Maarand Grid SLD Proposed |
| 1. 20 | G409-HA ALIF-A12-SLD-2 | A-12 Maarandhoo PH SIngel LIne Panel |
| 1. 21 | G409-HA ALIF-A13-SLD-1 | A-13 Thakand Grid SLD Proposed |
| 1. 22 | G409-HA ALIF-A13-SLD-2 | A-13 Thakanddhoo PH Single Line Panel |
| 1. 23 | G409-HA ALIF-A14-SLD-1 | A-14 Utheem Grid SLD Proposed |
| 1. 24 | G409-HA ALIF-A14-SLD-2 | A-14 Utheem PH Single Line Panel |
| 1. 25 | G409-HA ALIF-A15-SLD-1 | A-15 Muraidh Grid SLD Proposed |
| 1. 26 | G409-HA ALIF-A15-SLD-2 | A-15 Muraidh PH Single Line Panel |
| 1. 27 | G409-HA ALIF-A16-SLD-1 | A-16 Baarah Grid SLD Proposed |
| 1. 28 | G409-HA ALIF-A16-SLD-2 | A-16 Barrah Single Line Panel |

# Supplementary Information

The following lists of supplementary information’s are provided in attachment to the present Volume 6.

|  |  |
| --- | --- |
| **S No.** | **Title** |
| 1 | List of Signals required for centralized SCADA System |
| 2 | Ha Alif Atoll Islands Available Roof size |

# Certificates

## Form of Completion Certificate

Contract: [. . . . .*insert name of contract and contract identification details*. . . . . ]

Date:

Certificate No.:

To: [. . . . .*insert name and address of contractor*. . . . . ]

Dear Ladies and/or Gentlemen,

Pursuant to GCC Clause 24 (Completion of the Facilities) of the General Conditions of the Contract entered into between yourselves and the Employer dated [. . . . .*insert date*. . . . . ], relating to the [. . . .*brief description of the Facilities* . . . .], we hereby notify you that the following part(s) of the Facilities was (were) complete on the date specified below, and that, in accordance with the terms of the Contract, the Employer hereby takes over the said part(s) of the Facilities, together with the responsibility for care and custody and the risk of loss thereof on the date mentioned below.

1. Description of the Facilities or part thereof: [. . . .*description* . . . .]
2. Date of Completion: [. . . .*date* . . . .]

However, you are required to complete the outstanding items listed in the attachment hereto as soon as practicable.

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

[. . . .*Signature* . . . .]

Project Manager

## Form of Operational Acceptance Certificate

Contract: [. . . . .*insert name of contract and contract identification details*. . . . . ]

Date:

Certificate No.:

To: [. . . . .*insert name and address of contractor*. . . . . ]

Pursuant to GCC Sub clause 25.3 (Operational Acceptance) of the General Conditions of the Contract entered into between yourselves and the Employer dated [. . .*date. . .*], relating to the [. . .*brief description of the facilities*. . .], we hereby notify you that the Functional Guarantees of the following part(s) of the Facilities were satisfactorily attained on the date specified below.

1. Description of the Facilities or part thereof: [. . . *description . . .*]
2. Date of Operational Acceptance: [. . . *date* . . .]

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

[. . . .*Signature* . . . .]

Project Manager

# Change Orders

## Change order procedure

### General

This section provides samples of procedures and forms for implementing changes in the Facilities during the performance of the Contract in accordance with GCC Clause 39 (Change in the Facilities) of the General Conditions.

### Change Order Log

The Contractor shall keep an up-to-date Change Order Log to show the current status of Requests for Change and Changes authorized or pending. Entries of the Changes in the Change Order Log shall be made to ensure that the log is up-to-date. The Contractor shall attach a copy of the current Change Order Log in the monthly progress report to be submitted to the Employer.

### References for Changes

(1) Request for Change as referred to in GCC Clause 39 shall be serially numbered CR-X-nnn.

(2 )Estimate for Change Proposal as referred to in GCC Clause 39 shall be serially numbered CN-X-nnn.

(3) Acceptance of Estimate as referred to in GCC Clause 39 shall be serially numbered CA-X-nnn.

(4) Change Proposal as referred to in GCC Clause 39 shall be serially numbered CP-X-nnn.

(5) Change Order as referred to in GCC Clause 39 shall be serially numbered CO-X-nnn.

Note:

(a) Requests for Change issued from the Employer’s Home Office and the Site representatives of the Employer shall have the following respective references:

Home Office CR-H-nnn

Site CR-S-nnn

(b) The above number “nnn” is the same for Request for Change, Estimate for Change Proposal, Acceptance of Estimate, Change Proposal and Change Order.

## Change Order Forms

### Request for Change Proposal Form

[ *Employer’s letterhead*]

To: [ *Contractor’s name and address* ] Date:

Attention: [ *Name and title* ]

Contract Name: [ *Contract name* ]

Contract Number: [ *Contract number* ]

Dear Ladies and/or Gentlemen:

With reference to the captioned Contract, you are requested to prepare and submit a Change Proposal for the Change noted below in accordance with the following instructions within [ *number* ] days of the date of this letter [or on or before ( *date* )].

1. Title of Change: [ *Title* ]

2. Change Request No./Rev.: [ *Number* ]

3. Originator of Change:

*Employer: [Name]*

*Contractor (by Application for Change Proposal No. [Number Refer to Annex 6.2.7])*

4. Brief Description of Change: [ *Description* ]

5. Facilities and/or Item No. of equipment related to the requested Change: [ *Description* ]

6. Reference drawings and/or technical documents for the request of Change:

*Drawing No./Document No. Description*

7. Detailed conditions or special requirements on the requested Change: [ *Description* ]

8. General Terms and Conditions:

(a) Please submit your estimate showing what effect the requested Change will have on the Contract Price.

(b) Your estimate shall include your claim for the additional time, if any, for completing the requested Change.

(c) If you have any opinion that is critical to the adoption of the requested Change in connection with the conformability to the other provisions of the Contract or the safety of the Plant or Facilities, please inform us in your proposal of revised provisions.

(d) Any increase or decrease in the work of the Contractor relating to the services of its personnel shall be calculated.

(e) You shall not proceed with the execution of the work for the requested Change until we have accepted and confirmed the amount and nature in writing.

[ *Employer’s name* ]

[ *Signature* ]

[ *Name of signatory* ]

[ *Title of signatory* ]

### Estimate for Change Proposal Form

[ *Contractor’s letterhead* ]

To: [ *Employer's name and address* ] Date:

Attention: [ *Name and title* ]

Contract Name: [ *Contract name* ]

Contract Number: [ *Contract number* ]

Dear Ladies and/or Gentlemen:

With reference to your Request for Change Proposal, we are pleased to notify you of the approximate cost to prepare the below-referenced Change Proposal in accordance with GCC Sub clause 39.2.1 of the General Conditions. We acknowledge that your agreement to the cost of preparing the Change Proposal, in accordance with GCC Sub clause 39.2.2, is required before estimating the cost for change work.

1. Title of Change: [ *Title* ]

2. Change Request No./Rev.: [ *Number* ]

3. Brief Description of Change: [ *Description* ]

4. Scheduled Impact of Change: [ *Description* ]

5. Cost for Preparation of Change Proposal: [ *insert costs, which shall be in the currencies of the contract* ]

(a) Engineering (Amount)

(i) Engineer hours (hrs) x rate/hr =

(ii) Draftsperson hrs x rate/hr =

Sub-total hrs

Total Engineering Cost

(b) Other Cost

Total Cost (a) + (b)

[ *Contractor's name* ]

[ *Signature* ]

[ *Name of signatory* ]

[ *Title of signatory* ]

### Acceptance of Estimate Form

[ *Employer’s letterhead* ]

To: [  *Contractor’s name and address*] Date:

Attention: *[ Name and title ]*

Contract Name: *[ Contract name ]*

Contract Number: *[ Contract number ]*

Dear Ladies and/or Gentlemen:

We hereby accept your Estimate for Change Proposal and agree that you should proceed with the preparation of the Change Proposal.

1. Title of Change: [ *Title*]

2. Change Request No./Rev.: [ *Request number/revision*]

3. Estimate for Change Proposal No./Rev.: [ *Proposal number/revision*]

4. Acceptance of Estimate No./Rev.: [ *Estimate number/revision*]

5. Brief Description of Change: [ *Description*]

6. Other Terms and Conditions: In the event that we decide not to order the Change accepted, you shall be entitled to compensation for the cost of preparing the Change Proposal described in your Estimate for Change Proposal mentioned in para. 3 above in accordance with GCC Clause 39 of the General Conditions.

[ *Employer’s name* ]

[ *Signature* ]

[ *Name of signatory* ]

[ *Title of signatory*]

### Change Proposal Form

[ *Contractor’s letterhead*]

To: [ *Employer's name and address*] Date:

Attention: [ *Name and title*]

Contract Name: [ *Contract name*]

Contract Number: [ *Contract number*]

Dear Ladies and/or Gentlemen:

In response to your Request for Change Proposal No. [Number], we hereby submit our proposal as follows:

1. Title of Change: [ *Name* ]

2. Change Proposal No./Rev.: [ *Proposal number / revision* ]

3. Originator of Change: Employer: [ *Name*] / Contractor: [ *Name*  ]

4. Brief Description of Change: [ *Description* ]

5. Reasons for Change: [ *Reason* ]

6. Facilities and/or Item No. of Equipment related to the requested Change: [ *Facilities* ]

7. Reference drawings and/or technical documents for the requested Change:

[ *Drawing/Document No./Description* ]

8. Estimate of increase/decrease to the Contract Price resulting from the Change Proposal:

Amount

[ *insert amounts in the currencies of the Contract* ]

(a) Direct material

(b) Major construction equipment

(c) Direct field labor (Total hrs)

(d) Subcontracts

(e) Indirect material and labor

(f) Site supervision

(g) Head office technical staff salaries

Process engineer hrs @ rate/hr

Project engineer hrs @ rate/hr

Equipment engineer hrs @ rate/hr

Procurement hrs @ rate/hr

Draftsperson hrs @ rate/hr

Total hrs

(h) Extraordinary costs (computer, travel, etc.)

(i) Fee for general administration, % of Items

(j) Taxes and customs duties

Total lump sum cost of Change Proposal [ *Sum of items (a) to (j)* ]

Cost to prepare Estimate for Change Proposal [ *Amount payable if Change is not accepted* ]

9. Additional time for Completion required due to Change Proposal

10. Effect on the Functional Guarantees

11. Effect on the other terms and conditions of the Contract

12. Validity of this Proposal: within [Number] days after receipt of this Proposal by the Employer

13. Other terms and conditions of this Change Proposal:

(a) You are requested to notify us of your acceptance, comments or rejection of this detailed Change Proposal within [Number] days from your receipt of this Proposal.

(b) The amount of any increase and/or decrease shall be taken into account in the adjustment of the Contract Price.

(c) Contractor’s cost for preparation of this Change Proposal: [*. . . .insert amount. This cost shall be reimbursed by the employer in case of employer’s withdrawal or rejection of this Change Proposal without default of the contractor in accordance with GCC Clause 39 of the General Conditions . . . .*]

[ *Contractor's name* ]

[ *Signature* ]

[ *Name of signatory* ]

[ *Title of signatory*]

### Change Order Form

[ *Employer’s letterhead* ]

To: *[ Contractor’s name and address**]* Date:

Attention: *[ Name and title**]*

Contract Name: *[ Contract name**]*

Contract Number: *[ Contract number**]*

Dear Ladies and/or Gentlemen:

We approve the Change Order for the work specified in the Change Proposal (No. [ *number*]), and agree to adjust the Contract Price, Time for Completion, and/or other conditions of the Contract in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: [ *Name*]

2. Change Request No./Rev.: [ *Request number / revision*]

3. Change Order No./Rev.: [ *Order number / revision*]

4. Originator of Change: Employer: [*Name*] / Contractor: [ *Name*]

5. Authorized Price:

Ref. No.: [ *Number*] Date: [ *Date*]

Foreign currency portion [ *Amount* ] plus Local currency portion [ *Amount*]

6. Adjustment of Time for Completion

None Increase [ *Number*] days Decrease [ *Number*] days

7. Other effects, if any

Authorized by: Date:

Employer

Accepted by: Date:

Contractor

### Pending Agreement Change Order Form

[ *Employer’s letterhead* ]

To: *[ Contractor’s name and address**]* Date:

Attention: *[ Name and title**]*

Contract Name: *[ Contract name**]*

Contract Number: *[ Contract number**]*

Dear Ladies and/or Gentlemen:

We instruct you to carry out the work in the Change Order detailed below in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: [ *Name* ]

2. Employer’s Request for Change Proposal No./Rev.: [ *number/revision* ] dated: [ *date* ]

3. Contractor’s Change Proposal No./Rev.: [ *number / revision* ] dated: [ *date* ]

4. Brief Description of Change: [ *Description* ]

5. Facilities and/or Item No. of equipment related to the requested Change: [ *Facilities* ]

6. Reference Drawings and/or technical documents for the requested Change:

[ *Drawing / Document No. / Description* ]

7. Adjustment of Time for Completion:

8. Other change in the Contract terms:

9. Other terms and conditions:

[ *Employer’s name* ]

[ *Signature* ]

[ *Name of signatory* ]

[ *Title of signatory*]

### Application for Change Proposal Form

[ *Contractor’s letterhead*]

To: [ *Employer's name and address*] Date:

Attention: [ *Name and title*]

Contract Name: [ *Contract name*]

Contract Number: [ *Contract number*]

Dear Ladies and/or Gentlemen:

We hereby propose that the work mentioned below be treated as a Change in the Facilities.

1. Title of Change: [ *Name* ]

2. Application for Change Proposal No./Rev.: [ *Number / revision* ] dated: [ *Date* ]

3. Brief Description of Change: [ *Description* ]

4. Reasons for Change:

5. Order of Magnitude Estimation (amount in the currencies of the Contract): [ *Amount* ]

6. Scheduled Impact of Change:

7. Effect on Functional Guarantees, if any:

8. Appendix:

[ *Contractor's name* ]

[ *Signature* ]

[ *Name of signatory* ]

[ *Title of signatory*]

# Personnel Requirements

Using Form PER-1 and PER-2 in Section 4 (Bidding Forms), the Bidder must demonstrate that it has personnel who meet the following requirements:

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Position** | **Total Work Experience [years]** | **Experience In Similar Work [years]** |
| 1 | Project Manager (PV/electrical engineer) | 5 | 3 |
| 2 | PV engineer | 5 | 3 |
| 3 | Battery specialist | 5 | 3 |
| 4 | Civil engineer | 5 | 3 |
| 5 | Electrical engineer | 5 | 3 |
| 6 | Electro-mechanical engineer (Diesel) | 5 | 3 |
| 7 | Site supervision manager | 5 | 3 |

All staff must be fluent in English

# Equipment Requirements

Using Form EQU in Section 4 (Bidding Forms), the Bidder must demonstrate that it has the key equipment listed below:

|  |  |  |
| --- | --- | --- |
| No. | Equipment Type and Characteristics | Minimum Number Required |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |