Task 2

Preparation of the scheme for a pilot mini-grid in Randa

This section contains:

- ☐ Introduction to Task 2
- ☐ Ability and willingness to pay assessment in Randa
- ☐ Technical design and costing for a minigrid in Randa
- ☐ Sizing and technical specifications for SHS and pico lighting
- ☐ Subsidy requirements
- ☐ Institutional arrangements
- ☐ Regulatory procedures
- ☐ Draft tender procedure and documents

1 Introduction

1.1 Randa as part of a broader electrification programme

Following a workshop in Djibouti to discuss the recommendations of the Task 1 Report, Randa was selected by ADDSas the village to become the pilot for the minigrid. However, at the same time it was expected that Randa would be part of a broader programme to develop solar-diesel mini- and microgrids in Djibouti and that some of the other minigrids and microgrids might be supplied with other technologies such as wind. The Consultant was therefore requested, without changing the scope of work, to design the pilot in such a way that it would ultimately be as useful as possible for the broader programme to roll-out of minigrids and microgrids.

1.2 Description of Randa

Randa is an affluent village located in the mountains around 25 km north of Tadjoura. There are around 2,600 inhabitants (450 households) of which 1,700 are nomadic. The village consists mainly of solid brick houses, which are built close to each other along a dried out river bed in a narrow valley. The village currently has an electricity grid which is supplied by a diesel generator.

The village has a few general stores, a barber and one international phone operator. Additionally a small hotel on the outskirts of the village provides employment and income. Randa traditionally depended on agriculture, selling its produce to Djibouti-ville and Tadjoura. Agriculture has however declined over the past decade due to drought. The mainstay activity remains pastoral farming. Additional sources of income are provided from remittances of family members living in Djibouti-ville.

Public institutions in the village include one school, one large health centre and two mosques. As a result of the relatively high degree of commercial activity the average income levels are high by rural Djiboutian standards and are estimated at between 40,000 and 45,000 DJF per month.

The new road from Tadjourahto Ethiopia (currently under construction) is expected to bring development to Randa, creating business opportunities to support the transportation industry.

Figure 1Overview of Randa

2 Ability and willingness-to-pay

Randa currently has an electricity distribution network reaching two thirds of the population and a water network with piped connections to one third of the households. The remaining households collect water from public taps. Water and electricity is managed by a village committee. Households with piped water connections are expected to pay 1,000 DJF/month *(5.6 US$/month)* for these services while the rest of households pay 500 DJF/month *(2.8 US$/month)*.

Electricity and water supply are said to be unreliable and only half the population pays these fees regularly. Alternative sources of energy used in the village include kerosene, dry-cell batteries and candles. This section estimates ability to pay for improved electricity supply based on the current levels of expenditure in energy (current electricity fees as well as other energy goods).

Household surveys as well as interviews with business and public institutions were conducted in Randa with the objective of determining ability and willingness of the population to pay for improved energy services. The detailed findings of this survey can be found in Annex **Erreur ! Source du renvoi introuvable.**.

2.1 Determination of ability to pay

Ability to pay for energy has been estimated on the basis of the current levels of expenditure on electricity as well as other basic energy goods such as kerosene, dry cell batteries and candles. The approach followed includes:

- Calculation of current energy demand based on existing electrical appliances and consumption of other energy services
- Estimation of increased energy demand if access to electricity is consistent and available 12 hours a day**(determination of energy demand in kWh/month)**
- Calculation of current level of expenditure on energy goods and the portion of this that could realistically be offset with access to improved electricity supply**(offset expenditure in US$/month)**
- Based on the previous two figures, the amount people could afford to pay per unit of energy is calculated **(ability to pay in US$/kWh)**

Surveys were conducted for households currently connected to the grid as well as for households without a grid connection. Given that their levels of expenditure and energy consumption vary significantly, they are presented separately.

The following sections present the results of the survey as well the estimation of ability to pay for grid-connected households and off-grid households.

There are a total of 300 households currently connected to the grid. Households have been grouped according to the self-perceived level of expenditure of the house leader (high, medium and low). The survey collected information about existing electrical appliances in each household, which was used to determine current power and energy consumption based on availability of power supply during 4 hours per day. Table 1 summarizes the findings.

Table 1 Energy demand of grid-connected households

	Category of expenditure and number of HHs per category		
	High	*Medium*	*Low*
Appliances:	*39 HH*	*235 HH*	*26 HH*
Lights (18W)	6.3	2.9	2.0
CDMA phone charging (10W)	1.3	1.1	1.0
Radio (20W)	1.0	0.5	0.5
Fans (40W)	2.0	0.3	0.3
TV (80W)	1.0	0.7	0.7
Fridge (120W)	1.0		
Power consumption (W)	**427**	**141**	**124**
Energy consumption (kWh/day)	**1.71**	**0.56**	**0.50**

Based on Table 1, electricity consumption at present averages 21 kWh per household per month. In addition to electricity (and due to the lack reliability of electrical power supply) the population also consumes other basic energy goods, predominantly dry cell batteries for torches and kerosene for lighting. A few households also own car batteries or small solar energy systems to power other appliances while the grid is not operating.

The level of expenditure in energy goods is shown in Table 2. This includes the monthly fees paid to the water and energy committee as well as the expenditure in other energy goods. As evidenced by the Table, the largest part of the monthly energy expenditure is in kerosene and dry-cell batteries, not the electricity fees. The detailed calculations supporting Table 2 can be found in **Erreur ! Source du renvoi introuvable.** in Annex **Erreur ! Source du renvoi introuvable.**.

Table 2 Average energy expenditure per household (grid-connected)

Energy good	Average expenditure per HH (DJF/month)
Water and electricity fees	815
Kerosene	5,126
Dry cell batteries	972
Candles	130
Total	**7,043**

Average energy expenditure per household is 7,000 DJF/month (**39US$/month**). The surveys show a wide range in expenditure levels, with the high end in 18,700 DJF/month and the low end in 1,250 DJF/month *(*104 US$/month to 7US$/month*)*.

Based on the existing electrical appliances and assuming consistent the availability of power from the minigrid, the total energy demand of an average household is assumed to increase. Annex **Erreur ! Source du renvoi introuvable.**presents all assumptions regarding energy demand for different uses. High income HH are assumed to consume 76 kWh/month and medium and low income HH 25 kWh/month and 23 kWh/month respectively. The weighted average energy consumption per HH results in 32 kWh/month (see Table 3).

One important assumption behind the estimation of increased household energy consumption is that electricity would, at least initially, not be available 24 hours per day but rather 12 hours per day. This is meant to avoid households getting into the habit of consuming electricity excessively (e.g. leaving lights on all night) which is a common practice in rural minigrids (e.g. in Mali, operating hours are agreed between the utility and the community members, see Annex**Erreur ! Source du renvoi introuvable.**).

If the grid is available during 12 hours per day, expenditure in dry cell batteries (used for torches and radios), candles (used for lighting) and the portion of kerosene that is used for lighting (as opposed to cooking) is expected to come down significantly. A conservative estimate is that consistent electricity supply over 12 hours per day would offset at least 50% of the above mentioned expenditure. The relevant portion of expenditure in the calculation of ability to pay is therefore of 22 US$/month. Based on the relevant energy expenditure of 22 US$/month, the average ability to pay for the improved energy services can be calculated at **0.68US$/kWh**. Table 3 presents more details of this calculation.

Table 3 Electrical energy consumption per HH and ability to pay

Level of expenditure	**High**	**Medium**	**Low**	***Average***
% of HH in category	13%	78%	9%	
Energy consumption (kWh/month)	76	26	23	*32*
Current energy expenditure (US$/month)	104	32	7	*39*
Offset energy expenditure (current electricity fees + 50%of expenditure in other energy goods)	55	18	3	*22*
Estimated ability to pay (US$/kWh)	**0.72**	**0.71**	**0.12**	***0.68***

Households not connected to the grid

There are a total of 150 households in the immediate proximity of the grid that do not currently have an electricity connection (see Annex**Erreur ! Source du renvoi introuvable.** for geographical layout of Randa). ADDS requested that these households should be included in the assessment. Based on the type of construction---all permanent or semi-permanent and 81% made of bricks with corrugated iron roofs---it is assumed that all 150 households can be connected with associated connection costs (MV line extension, LV distribution line extension, circuit breakers, earthing, etc.). The technical requirements of grid connection are summarised in Section 3.5.

Income and expenditure levels of off-grid households are in average lower than those of grid connected households. Off-grid households are in the medium income (75%) and low income (25%) categories.

Households not connected to the grid do not have electrical appliances and their potential energy consumption is estimated on the basis of their current level of expenditure in energy goods which is shown in Table4.

Table4 Average energy expenditure per household (off-grid)

Energy good	Average expenditure per HH (DJF/month)
Kerosene	1,950
Dry cell batteries (torches)	588
Candles	313
Total	**2,850**

Average energy expenditure for off-grid households is 2,850 DJF/month (**16 US$/month**).

It can be assumed that given a grid connection, households will invest in a similar set of appliances as the grid-connected households of a comparable level of income (see Table 1, medium and low income HH). This has been confirmed during interviews with the local cooperative, who indicated that eitherpeople in Randa or their wealthier relatives in Tadjourahor Djibouti city would purchase electrical appliances.

The total electricity demand of an average household is assumed to increase to 25 kWh/month. Based on the current average energy expenditure of 16 US$/month and the assumption that only 50% of this will be offset by electricity, then the average ability to pay for the improved energy services can be calculated at **0.32US$/kWh**. Table5 presents more details of this calculation.

Table5 Electrical energy consumption per HH and ability to pay

Level of expenditure	**Medium**	**Low**	*Average*
% of HH in category	75%	25%	
Energy consumption (kWh/month)	26	23	*25*
Current energy expenditure (US$/month)	18	10	*16*
Offset energy expenditure (50%of expenditure in energy goods)	9	5	*8*
Estimated ability to pay (US$/kWh)	**0.35**	**0.21**	***0.32***

Summary of ability to pay

Table6 summarises the results on ability to pay based on current expenditure levels and projected levels of energy demand.

Table6 Estimated ability to pay (US$/kWh)

Level of expenditure	High	Medium	Low	*Average*
Grid-connected HH	0.72	0.71	0.12	*0.68*
Off-grid HH	-	0.35	0.21	*0.32*
Average (US$/kWh)	***0.72***	***0.60***	***0.18***	***0.58***
Energy consumption (kWh/month)	***76***	***26***	***23***	***30***
Total (US$/month)	***55***	***15***	***4***	***17***

For an average level of energy consumption per household of **30 kWh/month** and **ability to pay of 17 US$/month**, average ability to pay per unit of energy is **0.58 US$/kWh**.

2.2 Willingness to pay

The previous section estimated ability to pay at 0.58US$/kWh or US$17 per household per month in average. When setting tariffs however, significant downward pressure can be expected from the population and the local authorities. The main reasons indicating that people would be willing to pay less than what they are able to include:

- The comparison with electricity rates from the national utility is inevitable. The price of electricity in neighbouring Tadjourahis 40 DJF/kWh (0.22 US$/kWh)[1].The effects of this comparison can be mitigated by setting fixed fees to access a certain level of capacity limited by load limiters (e.g. 200W, 100W, 50W). The discussion on load limiters versus energy meters is resumed in Section3.5.

- The current level of payment for water and electricity is low. According to the Randa's water and energy committee only 50% of households pay their dues regularly. The main reason for non-payment is the inconsistent supply of energy and water. Even though all respondents claimed they would be willing to pay regularly for improved and consistent electricity supply, there is a high precedent of people not paying for this service.

- Linked to the previous point, several respondents are under the impression that electricity is provided for free. The fees paid to the village committee are normally associated with water services alone. Non-payment does not cause the interruption of electricity supply from the committee.

Section **Erreur ! Source du renvoi introuvable.** presents a simplified financial model for the minigrid aimed at determining financial sustainability of the project and required level of subsidies. Two tariff scenarios are discussed in that section:

[1] Social tariff below 200 kWh/month.

- **Rate of 0.58 US$/kWh**(average ability to pay) and the corresponding monthly fees of Table6. Rates of non-payment assumed to be high (30-40%, non-payment from low income and some middle income HH) at least initially.

- The social tariff of EDD of **0.22 US$/kWh**. This is also the rate negotiated with the community of Ali Adde for the ADDS/KOICA minigrid project. With this rate, non-payment rates would decrease to 10-20% (non-payment from low income HH).

The final tariff should be expected to vary between these two.

3 Technical design and costing

The technical design for the solar energy system for Randa has been prepared on the basis of the total energy demand in the village. The following section presents a summary of the results of the energy demand assessment. The details of can be found in Annex **Erreur ! Source du renvoi introuvable.**.

3.1 Energy demand and solar PV system sizing

Energy demand

Total energy demand has been calculated based on the information collected for each type of consumer and is summarised in the table below:

Table7 Total energy demand per type of consumer

Type of consumer	Details	Energy consumption (kWh/month)	Special remarks/ assumptions
Residential	Including grid connected households and houses currently off-grid that could be integrated	13,280 (61%)	30 kWh/HH/month (Table6 and Annex**Erreur ! Source du renvoi introuvable.**) for 450 HH.
Commercial	Includes existing shops, hotel and the upcoming Djibouti Telecom BTS	2,470 (11%)	Djibouti Telecom could be offered the possibility of connecting their BTS to the minigrid. The tower could be equipped with back batteries or genset to increase reliability of supply.
Public uses	Includes school, clinic, public lighting, water supply and other public buildings	6,000 (28%)	Energy for water supply considers that existing wells are powered by the existing solar power system (28.8 kWp) that is separate from the minigrid. The minigrid is however assumed to power the pump for the borehole currently under construction. Public lighting has added as a potential public use of electricity.
Total		**21,750**	

Energy demand for different users is broken down in Figure 2. The largest energy consumers are households with high and medium expenditure levels. The energy consumption for water supply is significant. This is due to the construction of a new borehole (deeper than the existing ones) that is to provide a more consistent source of water for Randa.

Public lights and telecom BTS have been highlighted in Figure 2 given that they are optional. Villagers need to be asked whether they are willing to pay for public lighting and Djibouti

Telecom might not be willing to buy power from the minigrid due to power reliability concerns.

Figure 2Energy consumption per user (kWh/month)

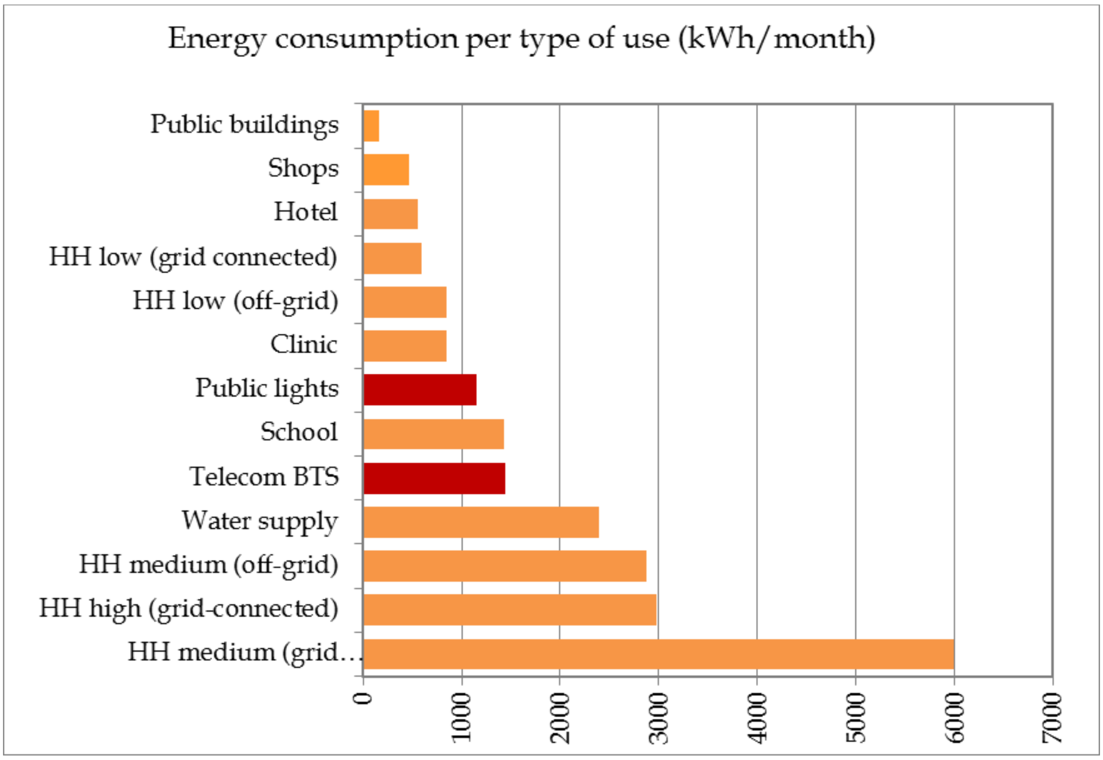


Figure 3 presents a modelled load profile for Randa. The different colours represent different types of use of energy. Cooling (fans), lighting and entertainment (TVs, radios) represent the largest loads.

Regarding the time distribution of the different loads:

- The peak of energy consumption is assumed to occur in the evening hours, mainly due to lighting.
- Water pumping has been assumed to occur during daylight hours to favour direct consumption of solar energy (thus avoiding the use of the batteries or generator)
- The loads during night hours (23:00 to 07:00) are related to interior lighting, fans, power for the telecom BTS and public lighting. Due to the limited budget of the population, it is possible that grid power will not be available during those hours for residential users.

The loads shown in Figure 3 are an average. Short-duration power peaks are not shown in the graph but are expected to reach 100 kW.

Figure 3Modelled load profile for Randa (kW)

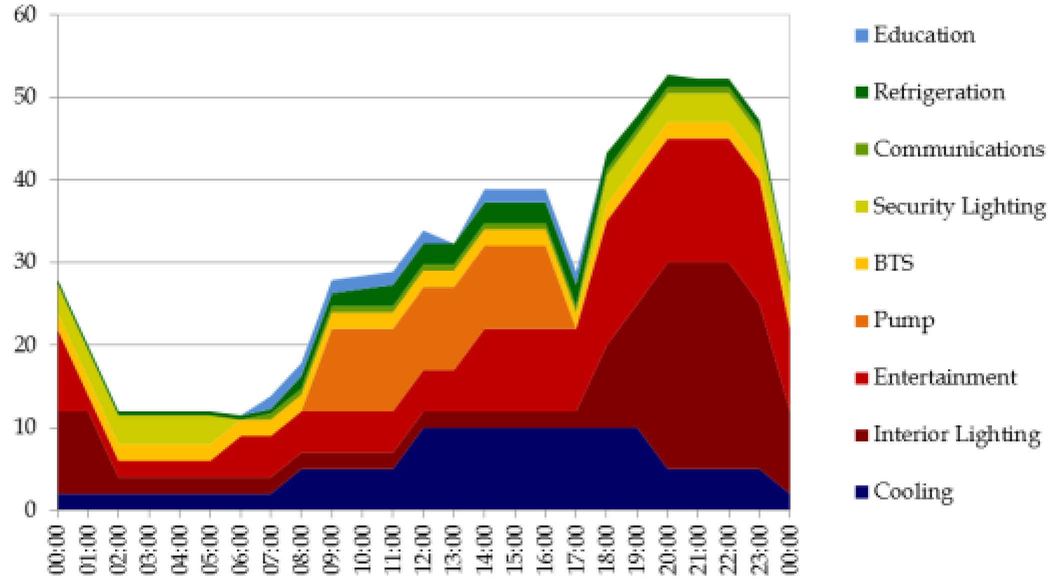
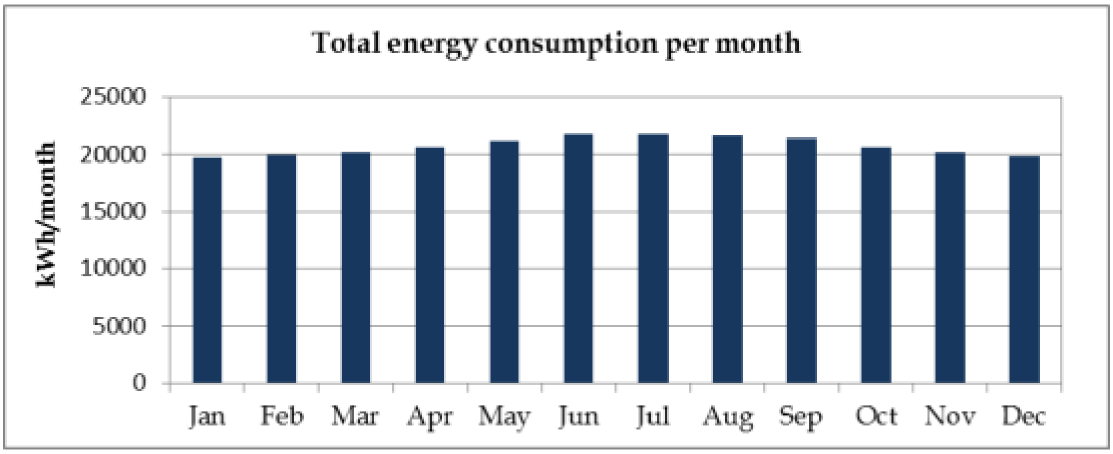


Figure 4 presents the total energy demand throughout a year. Energy demand has been assumed to be relatively constant. Main variations are due to cooling loads (fans) in relation to temperature.

Figure 4Total energy consumption per month



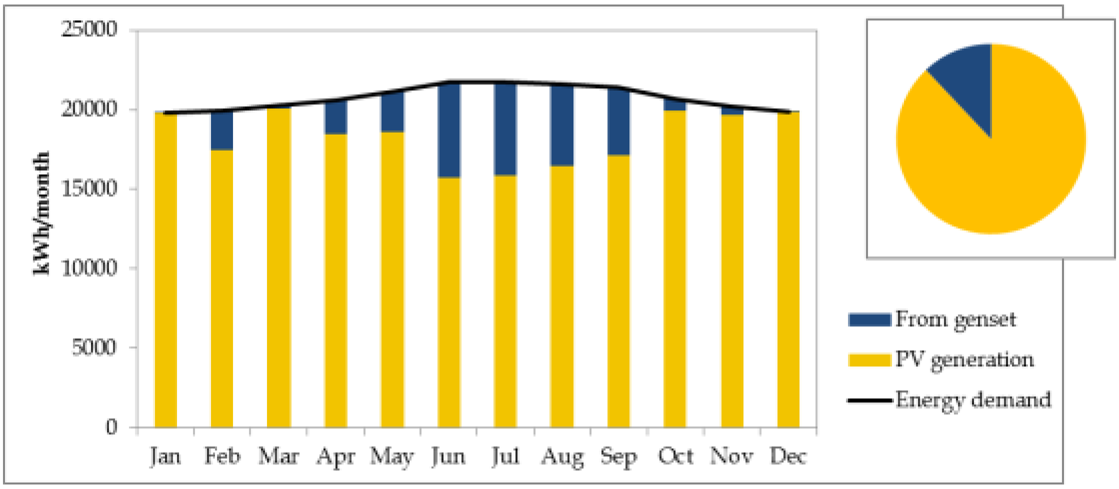
Demand growth projections

The previous information regarding energy demand is used as the basis to size the solar energy system for Randa. Randa's energy consumption can be expected to grow (especially in the residential and commercial categories) as the road from the Tadjourahport to Ethiopia develops. Growth forecasts are however uncertain and have not been used in system sizing. As explained in the system sizing section, the power system will however have flexibility to expand and cater for increased energy consumption.

System sizing

The system sizing methodology used in this study is explained in Annex**Erreur ! Source du renvoi introuvable.**. Based on the modelled energy demand, available insolation data[2] and system losses (in energy conversion, system cooling and T&D), the solar array is proposed at **136 kWp**. As shown in Figure 5 solar energy production will cover 100% of the demand of the cooler months of January and December and the generator will have to be used when energy demand is in excess of solar PV output during the rest of the year. It is estimated that under the current demand scenario the generator will contribute no more than 12% of the total energy generation.

Figure 5Energy production and energy demand model



The most important sizing parameters are summarized in Table8. The detailed calculations behind these parameters are to be found in Annex**Erreur ! Source du renvoi introuvable.**.

Table8System sizing parameters

Power system component	Size	Comments
Solar PV capacity	136kWp	Based on the modelled energy demand (20-22 MWh/month), available insolation data (6.3 kWh/m²/day in average) and system losses (30% in average for energy conversion, cooling and T&D).
Diesel generator capacity	130 kVA	It is proposed that the existing generator is used.
Battery inverter capacity	114 kW	Sized based on estimated peak load
Battery capacity	1,900 kWh (e.g. 40,000 Ah@48V)	Sized based on the assumption that 30% of the solar energy is consumed directly and 70% stored, 2 days of autonomy, 50% DoD and 20% conversion losses.

[2] Latitude tilt irradiance from NREL (medium resolution) and NASA (low resolution) were used for Randa (11.85, 42.66).

Power system component	Size	Comments
Required solar PV surface	1,360 m^2	Approx. 900m^2 of solar PV surface + 50% for spacing in between rows

System expansion

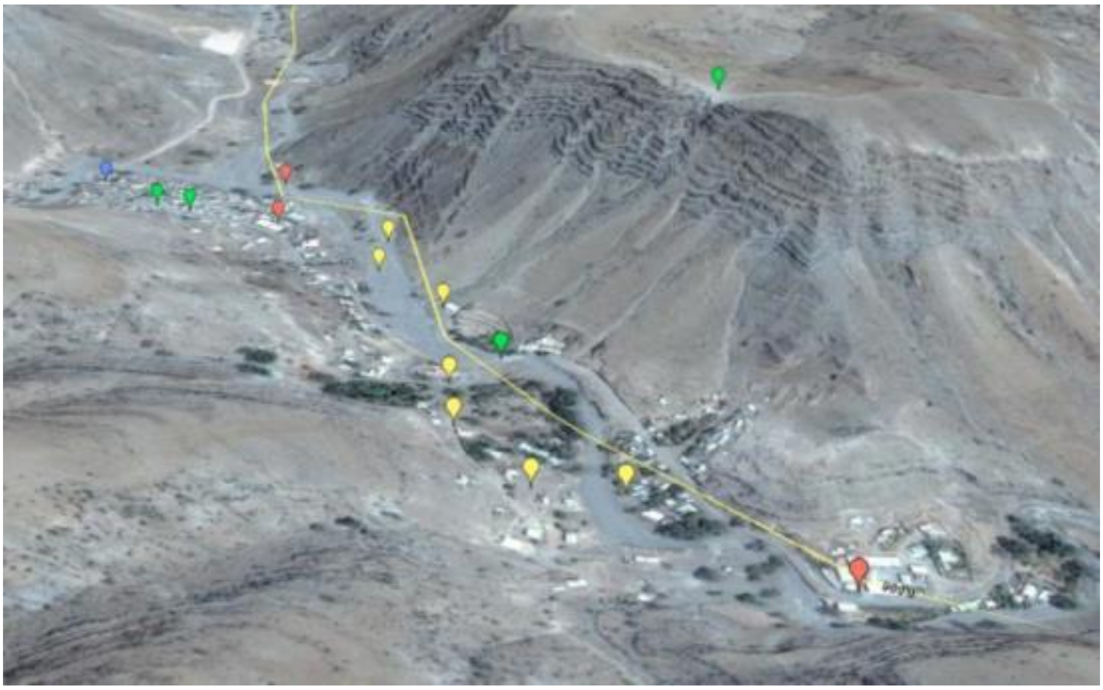
The solar energy system is sized based on existing energy demand (including the connection of an additional 150 households) and planned/potential power uses such as for water supply, public lighting and the BTS. The solar energy system is not oversized to accommodate significant growth in the coming years. The system will however be flexible and easily expandable:

- The system is designed so that fuel consumption is minimal under the current energy demand scenario. The generator can be used to accommodate short to medium term growth (e.g. if energy demand doubles the hybrid power system can provide energy with a 50% solar/50% diesel mix).
- The existing solar energy system used to power water pumps (28.8 kWp) can be integrated into the minigrid to make better use of its output.
- The solar energy system is modular. New modules of solar arrays, inverters and batteries can be added at a later stage.

3.2 Placement of solar PV system

Randa is located in a narrow valley. Shading can be considered a major concern for the placement of the solar energy array. Simulations of shading from the mountains will be required. It will be required that tendering companies incorporate suggestions regarding placement in their proposal. *GoogleEarth* provides a very good representation of the town and its topography as shown in Figure 6.

Figure 6GoogleEarth image of Randa



Some of the options for placement of the PV system can be:

- **Next to power station (preferred location)**, same as the existing 28.8 kWp system powering the pumps. The power station is however at the foot of a hill which could project a shadow on the array.
- Decentralised PV system feeding energy into different points of the MV or LV grid, e.g. in each of the current 4 zones of Randa.
- On the top of the hill, where the Djibouti Telecoms base station will be located. In this case shade would not be a concern but the system would be approximately 200m away from the power station (high losses with LV cabling) and the isolated location could bring security concerns.

The preferred location of the PV system is shown in Figure 7. The advantages of the proposed location are:

- Proximity to the existing generator and LV/MV transformer
- The surface on the slope of the hill is not currently in use and does not interfere with the road upgrade project.

The main challenges associated to this location are:

- Civil works for ground-mounted PV array and technical room on the slope of the hill. Access paths will also need to be constructed.
- The location of the array needs to avoid shade from the hill located north of the proposed placement.

Figure 7 Proposed location for PV array and technical room

Due to the above mentioned challenges regarding location, EPC contractors will be requested to take these into consideration in the technical specifications.

3.3 Technical specifications of PV system

Functional specifications for the PV system will be produced together with draft tender procedures and draft contracts after the first revision of this draft. Technical specifications will be produced for EPC contractors or PV system integrators capable of providing a detailed design based on the general specifications provided. The specifications will be based on the above system sizing and will include the following conditions:

- The solar plant will connect to a three phase (230V/400V) mini-grid
- The solar plant will be based on a modular design which enables straightforward system expansion and allows for simple repair by replacement of faulty module
- For sizing purposes, the solar plant is designed to operate almost exclusively on solar power (under current energy demand scenario). The system is to allow functioning as a hybrid system incorporating the existing generator (genset technical specifications will be provided).
- The PV system will preferably be AC coupled.
- Due to limited surface, mono-/poly-crystalline Si modules are preferred.
- The battery storage is expected to last 10 years. VLA (flooded) tubular plate batteries (OPzS) or VRLA (sealed) tubular plate batteries (OPzV) preferred.

- Communication equipment for remote monitoring, remote diagnosis, data storage, configuration and visualization needs to be provided. Note: there currently is no mobile telephone network in Randa. This is however expected in the short term. Alternatives to communication need to be explored.

- The system needs to command the diesel genset when the battery state of charge is low or the load is higher than the capacity of the battery inverters (configurable parameters). Alternatively, a visible indicator outside the technical room (e.g. blinking lights) will instruct the operator to manually turn on the genset.

- A technical room will be constructed to house batteries, inverters and other control and communication equipment. The construction of the battery/technical room will house energy efficient air conditioning equipment to keep air temperature at the optimal functioning range for batteries and inverters.

- The PV array will be ground mounted. The preferred location (coordinates: 11.850047, 42.657464) is on a slope of approx. 30° inclination in the proximity of the existing powerhouse. The EPC contractor is to consider and critically assess the proposed location with regards to potential shading from surrounding hills as well as terrain challenges for the construction of concrete slabs for the solar PV array. Ground levelling work will be necessary.

- Whether the contract is to include works to upgrade/expand the distribution network and end-user connections (including safety devices, metering equipment and/or load limiters) is to be determined (see Section3.5).

3.4 System costing

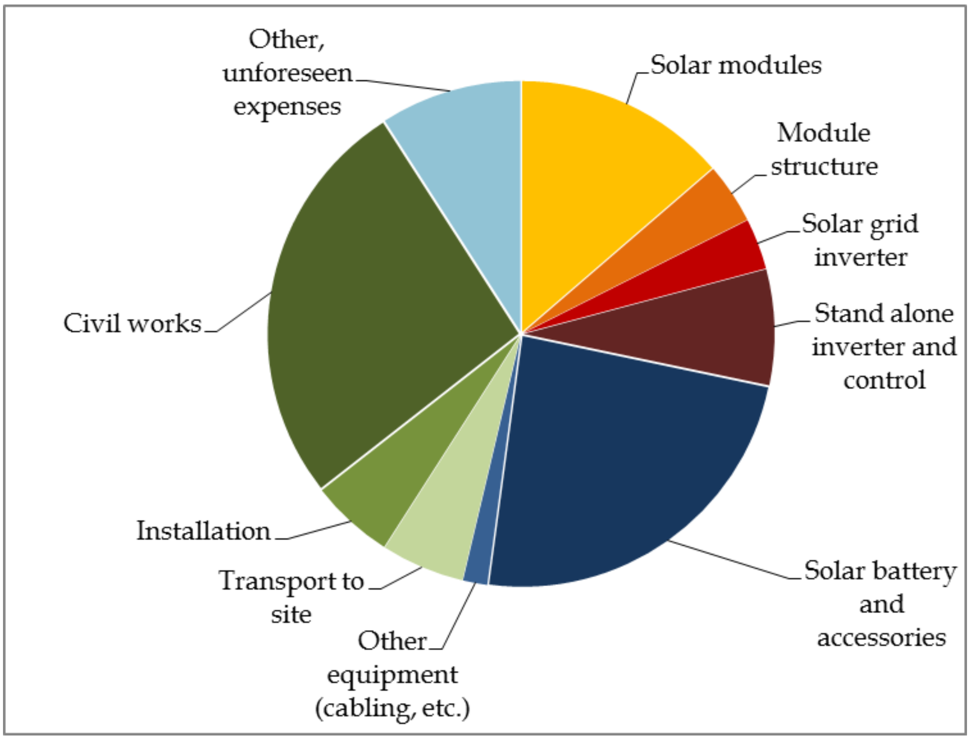
Based on the system's size and standard costs for solar PV, the budget for the solar energy system is estimated at approximately US$ 1 million. Table9provides a breakdown of the investment cost and Figure 8 presents a graphical breakdown of the cost components.

Table9 Estimated budget for the Randa solar energy system

Components	Details	Unit	Qty	Cost per unit (US$)	Subtotal (US$)
Solar modules	Mono-/poly- crystalline Si	kWp	136	1,300	176,800
Module structure	Ground-mounted, concrete slabs	kWp	136	371	50,388
Solar grid inverter	Grid-tie, 3-phase	kW	136	312	42,432
Stand alone inverter and control	AC coupled system	kW	114	845	96,313

Components	Details	Unit	Qty	Cost per unit (US$)	Subtotal (US$)
Solar battery and accessories	LA (flooded) tubular plate batteries (OPzS) or VRLA (sealed) tubular plate batteries (OPzV), 10 years lifetime.	kWh	1,898	163	308,439
Other equipment (cabling, etc.)	All required for connection of PV system to existing grid	%	3%		20,231
Transport to site	To Tadjourahport and road transport to Randa	%	10%		69,460
Installation	Includes travel of international expert + local team	%	10%		69,460
Civil works	Includes ground levelling work and construction of technical room and access paths, estimated by ADDS, see Annex**Erreur ! Source du renvoi introuvable.**	-	-		342,500
Local taxes	Donor supported project assumed exempt of tax	%	0%		0
Other, unforeseen expenses		%	10%		117,602
Total (US$)					**1,293,626**
Total per kWp (US$/kWp)					***9,512***

Figure 8Cost components for the Randa solar energy system



This estimated budget is for the solar energy system to be installed, connected to the existing minigrid and commissioned. The budget does not include:

- ☐ Upgrades to the electricity distribution system
- ☐ Upgrades to the end-user connections, including safety devices, metering equipment and/or load limiters.
- ☐ Programme management costs (cost of tendering, evaluation, contracting, monitoring, etc.)

The next sub-section discusses the first two points, where additional investment could be necessary. The budget also assumes that the solar energy components are not liable to tax or import duties given that they will be procured with grant funding.

3.5 Additional investments in power infrastructure

In addition to the investment in the solar energy system, upgrades in the energy distribution network as well as the end-user connections might be required:

- ☐ The MV and LV distribution lines will need extension if power is to reach the entire population of Randa. There are currently 150 households close to the grid (seeFigure 9) that do not have a grid connection. In order to reach them the MV line will need extension of approximately 300m. One MV/LV transformer and LV distributionlines will be needed as well.

- ☐ End-user connections might require upgrades to meet safety standards (circuit breakers, earthing, etc.)
- ☐ Load limiters and/or electricity consumption meters will be necessary given the large difference in energy consumption patterns of different users.

Distribution network and end-user connections

There are currently 150 HH in the immediate proximity of the existing grid (within 200m) that have been considered in the PV system sizing. Connecting these households would require the extension of the MV line (approx. 300m), a MV/LV transformer, the LV distribution and the end-user connections. A rough cost estimate based on an international benchmark is US$150/connection for the LV lines plus connections, US$5,000 for the MV/LV transformer and US$ 15,000 per km for the MV line.

Figure 9 MV distribution line in Randa

In addition to the new connections, maintenance works are required in the existing grid. The distribution infrastructure was installed in 1980 and last rehabilitated in 1995. A certain number of poles in the MV need replacement. Regarding the end-user connections, no assessment of existing connections has been conducted to determine whether they conform to safety standards. A rough estimation for budgeting purposes is that 50% of grid-connected need their grid connections upgraded.

Table 11 presents a rough estimate of the cost of grid connections and required grid upgrades. A more detailed assessment of the grid is required in case this work is to be included in the minigrid EPC contract.

Load limiters / energy metering

Based on the chosen tariff scheme---metered energy-based tariffs or fixed tariffs based on expected power consumption---investment in either energy meters or load limiters is necessary.Table 10 briefly summarizes the implications of using load limiters or energy meters.

Table 10 Tariff schemes and corresponding technology

Tariff scheme	Recommended technology	Advantages	Disadvantages
Energy based	Energy meters / Pre-paid meters	Accurate record of consumption, useful to incentivize energy conservation/ efficiency. Useful for families that are semi-nomadic and should not pay for the time they are away.	Higher cost. Hard to read for uneducated rural people. Running costs: control of meters and billing procedures in the case of post-paid and a well-organized local sales and support services for pre-paid. If used without additional load-limiting components they do not prevent system overload
Expected power consumption	Load limiters or no specific technology (e.g. fixed charge based on existing appliances)	Load limiters prevent system overloading and ensure that all consumers have access to some electricity Reliable load limiters are cheaper than meters. Payment is also made easier for both the collector and the consumer, as the amount to be paid on a regular basis is known in advance.	Abuse is difficult to contain, no incentives for energy efficiency. Consumer fraud and theft. Tampering with load limiters is not rare in developing countries and it can endanger the whole system. Requires education of the consumer on the technical aspects of the system and on the electric appliances they can use.

It is common that minigrid tariff schemes include both energy metering for large consumers, such as businesses or cottage industry and load limiters for smaller consumers such as households.

At present, the energy and water cooperative uses neither technology for their tariff scheme. Households and businesses are charged a fixed amount regardless of their consumption. The cooperative could continue using a similar approach (although with differentiated tariffs according to energy consumption) without the need for additional technology. Investing in load limiters and/or energy meters should however significantly improve the management of the minigrid and fee collection.

A rough estimate of the investment in load limiters or energy meters is provided in Table 11.

Summary of additional investments

Table 11 provides a rough estimate of the cost of grid connections and required grid upgrades. A more detailed assessment of the grid is required in case this work is to be included in the minigrid EPC contract.

Table 11Additional investments in grid infrastructure

Components	Details	Subtotal (US$)
Distribution grid upgrades and new connections	MV line extension (300m at US$ 15,000 per km) and one additional MV/LV transformer (US$ 5,000)	10,000
	Rehabilitation of existing MV line (1 km)	10,000
	150 connections at US$ 150/HH for the LV lines plus connections	22,500
	Upgrade of 150 existing connections at US$ 150/HH for the LV lines plus connections	22,500
Energy meters and/or load limiters	Load limiters and/or pre-paid meters for 450 connections at 60 US$/connection	27,000
		92,000