TOOLKIT

SOLARISATION

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About the Climate Action Accelerator

The Climate Action Accelerator is a Geneva-based not-for-profit initiative created in 2020 with the aim of leveraging a critical mass of high human impact organisations in order to scale up climate solutions, contribute to greater resilience, and ultimately limit global warming to well below 2°C in order to avoid adverse impacts on communities around the world. Its overall goal is to help shift the aid, health and higher education sectors towards a radical transformation of their practices, halving greenhouse gas (GHG) emissions by 2030 on a 'net zero' trajectory in line with the Paris Agreement, and transitioning to low-carbon, resilient, sustainable models.

Acknowledgements

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It was edited by Macarena Castro (Communications Officer) and translated into English by Noa Jay (Solutions Intern).

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MINISTÈRE DE L'EUROPE ET DES AFFAIRES ÉTRANGÈRES
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RÉPUBLIQUE ET CANTON DE GENÈVE

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INTRODUCTION

Why solarise a structure?

The primary driver of climate change are carbon dioxide (CO_2) emissions, with the main source of CO_2 emissions being the use of fossil fuels. International aid organisations and health facilities in low- and middle income countries often rely on large diesel generators, which not only produce significant greenhouse gas emissions but also incur high costs. This also creates a reliance on fuel, whose supply can be complex, or even impossible, in certain circumstances. Transitioning to renewable energy, particularly photovoltaic solar power, helps to reduce emissions and costs, while enhancing the organisation's energy independence.

Purpose of this toolkit

The purpose of this Climate Action Accelerator toolkit is to provide organisations with a set of introductory resources and information on photovoltaic power generation systems, including equipment sizing and selection, installation and maintenance. It is not intended to replace formal training on these issues.

Target audience and users

This toolkit is designed to help environmental coordinators, logisticians and technicians responsible for planning and monitoring solar photovoltaic energy production projects.

Feedback

This toolkit is a living document and will continuously be updated to reflect evolving good practice. Partners and other organisations are invited to share suggestions, challenges, and success stories. Additionally, organisations are welcome to contribute in-house tools for potential inclusion.

Please contact us at contact@climateactionaccelerator.org with your comments and contributions.

OVERVIEW

PART I : PREPARATION

Step 1 : Define the resources and key elements

- Define the requirements
- Define the budget

Step 2: Size the installation

- Evaluate the total maximum instantaneous power
- Estimate the electrical energy to be produced
- Calculate the daily consumption
- Define the total power of the solar panels to be installed

PART II : IMPLEMENTATION

Step 3 : Choose the equipment

- Choose photovoltaic panels
- Select the batteries
- Determine the charge controller
- Select the inverter

Step 4: Install the equipment

- Points of attention

Step 5 : Maintain the equipement

- Maintenance Checklist

PART III : ADDITIONAL RESOURCES

PART I : PREPARATION

STEP 1 : DEFINE THE RESOURCES AND KEY ELEMENTS

Objective

Defining the needs and objectives is a key step in preparing a solar energy system. It allows for the precise adaptation of the system and its various components (panels, batteries, etc.) to the user's needs. The production of photovoltaic electricity can have several objectives – energy self-suffciency, reduction in operating costs, reduction in CO2 emissions – which must be considered as they will impact the chosen technical solution.

1. Define the requirements

The right questions must be asked from the outset regarding the equipment to be installed, the areas to be solarised, and consider a hybrid solution if necessary (complementary use of a generator and a photovoltaic system). The photovoltaic installation will vary depending on the type and size of structure to be equipped:

Types of installation

- For the needs of small basic health centres with limited power requirements, or even centres with maternity wards in rural areas isolated from the grid, a stand-alone photovoltaic installation with energy storage as the sole power source may be suitable.
- For hospitals and facilities with more demanding needs, or where interruption of the power supply is not an option (operating theatres, energy-intensive equipment, air conditioning, etc.), hybridisation of solar energy with a more stable energy source is often essential for safety reasons:

- Either with the grid, if available. This is referred to as a grid-connected solar installation, or “on-grid”.
- Or with a back-up generator.

Without this hybridisation the battery parc will often be too large and expensive.

Checklist for defining requirements

- What equipment will be connected to the photovoltaic system, and what is their power consumption ?
- What are the average monthly fuel consumption rates for the generators and in kWh of electricity if there is a local supplier?
- What is the desired battery autonomy without sunlight (e.g. 1 day, 2 days)?
- What is the proportion of ‘green’ energy?
  - Requested by the donor
  - Desired by the client
- What are the geographical access conditions to the site?
- What is the site’s orientation relative to the sun, and are there any shaded areas?
- Does the available surface area (on the ground or in the roof) allow for the installation of the PV field ?

2. Define the budget

Allow for a sufficient budget for the initial photovoltaic installation, including panels, batteries, equipment and assembly. Future operating costs, maintenance, and equipment replacement as it ages should also be taken into account.

Budget checklit

- How are the initial investment costs financed? Have the necessary and sufficient funds been allocated? Be cautious, as the cost of solarisation is often underestimated and poorly anticipated (e.g. solarisation of warehouses, energy-intensive uses such as air conditioning).
- How are renewal costs financed (replacement of batteries, photovoltaic panels or the generator?
- How are current operating costs financed (fuel for the generator, preventive and corrective maintenance). When calculating operating costs, it is important to consider the actual longevity of the equipment (especially electronic equipment).
- Does national regulation allow injecting the energy produced into the national grid? What are the conditions for selling electrical energy, if applicable?

Definitions of the various components of a photovoltaic electricity generation system are provided in Annex I, at the end of this toolkit.

STEP 2 : SIZE THE INSTALLATION

Objective

Precisely size the planned system to ensure optimal operation. Sizing begins with a thorough assessment of requirements, which then allows for determining the number of panels and batteries required.

1. Evaluate the total maximum instantaneous power

Knowing the total maximum instantaneous power involves conducting an inventory of the equipment to be powered and their usage schedules (number of hours of use, during the day or at night).

The total maximum instantaneous power will correspond to the cumulative maximum power of the equipment that will be used simultaneously. It is necessary to distinguish between daytime uses (sun-driven), powered solely by solar panels, and nighttime uses, which require a dedicated circuit connected to batteries.

Given the investment cost of photovoltaic installations (panels, but especially batteries), the following points should be considered from the design stage:

- Control of energy consumption and energy efficiency through the systematic selection of high-efficiency devices designed for photovoltaic use.
- Identification of devices that consume too much power to be reasonably supplied by the installation.

2. Estimate the electrical energy to be produced

The energy to be produced is determined by the total sum of the unitary consumption of the devices associated with the previously defined installation.

The assessment of energy needs in terms of electrical energy is a crucial element of the photovoltaic installation for :

- Sizing the PV panel array.
- Sizing the battery parc.

If the actual consumption differs from the evaluation, this will result in :

- An installation that is more expensive than necessary in the event of under-consumption.
- Premature wear of equipment in the event of over-consumption, and therefore a limited lifespan.

One should not hesitate to question certain devices or their power supply by the system, particularly thermal devices (heating and cooling systems, excluding refrigerators), in order to minimise the size and cost of the photovoltaic installation.

The connection of energy-intensive air conditioning equipment should be avoided, or even prohibited. Such equipment, which consumes a lot of energy, should be powered either by the national or local electricity grid, or by a dedicated generator.

For example : Air conditioning can be replaced by ventilation system with a misting system, which consumes less energy. This is a solution that can meet certain comfort needs, especially when the premises are well ventilated.

3. Calculate the daily consumption

Daily consumption is expressed in Watt-hours/day or Wh/d. Knowing the daily consumption is important in oder to propely size the photovoltaic system to be installed.

To do this, take the number of hours of use per day of each equipment, and multiply it by the power of that device. Then, sum up all the daily consumptions to determine the total daily consumption.

For example : A device with a power of 50W used 5 hours per day will have a daily consumption of 250 Wh/d.

Power consumption of some typical health facility equipment:

- Vaccine fridge : 50 to 80 W continuous (recommendation → on stand-alone battery)
- Sterilizer : 600 W
- Fan : 50 W per unit
- Ultrasound machine : 300 W

It is also important to determine which equipment can be :

- Supplied by a solar-powered circuit (consumption at the same time as solar energy production),
- Temporarily interrupted in the event of under-production or over-consumption,
- Under no circumstance run out of power.

The number of consuming devices must be limited exclusively to those initially planned in order to ensure the longevity of the installation. If additional equipment is connected, the installation is put at risk.

Consumption management can be ensured by a device that monitors consumption, with cut-off according to programmed criteria, or by triggering alarms or load shedding for non-priority loads. Example: Michaud managers.

The link below provides more information on automatic energy management devices (in French): [Michaud Export | Gestionnaire d'énergie]

The following table offers an exemplary list of equipment to be powered, along with their power and daily operating time. The sum of the results gives the total daily energy to be produced.

Equipment	Unit power	Operation	Number of units	Daily energy
Room light bulbs	7 W	5 h	= 2 x 5 = 10	350 Wh
Corridor light bulbs	7 W	5 h	= 3 x 1 = 3	105 Wh
Refrigerator	300 W	8 h	1	2400 Wh
Fan	60 W	8 h	= 1 x 5 = 5	2400 Wh
Medical equipment	250 W	4 h	2	2000 Wh
Laptop	50 W	6 h	1	300 Wh
Printer	50 W	2 h	1	100 Wh
Phone chargers	10 W	2 h	5	100 Wh
	Total power			**Total energy**
Total	**1341 W**			**7755 Wh**

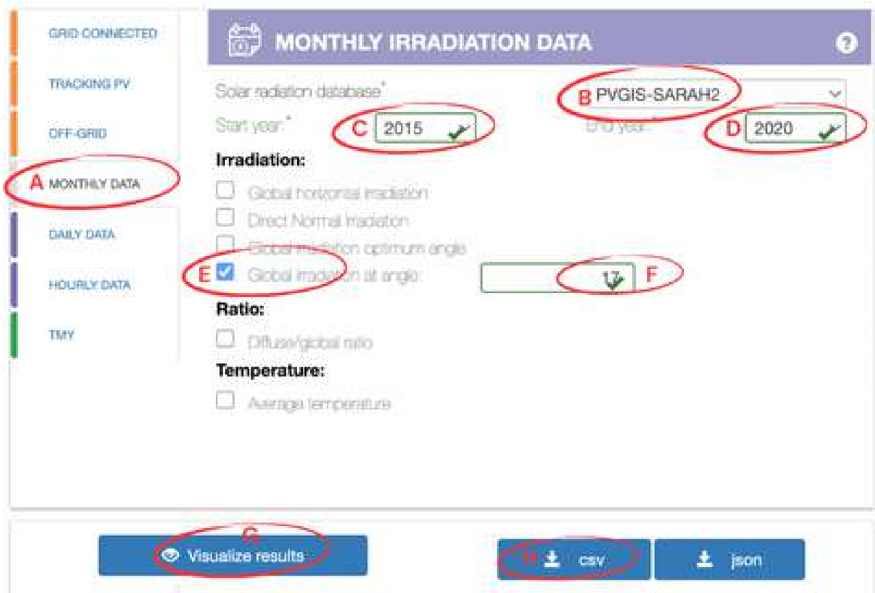
4. Define the total power of the solar panels to be installed

Solar sizing (panel): the peak power of the panels depends on the **consumption**, the **solar radiation** and a loss coefficient at the panel level (efficiency). The power is expressed in Watt peak or Wp.

To determine the total power of the solar panels to be installed, it is necessary to know the average daily sunshine value in the geographical area. This value is available on several websites.

The most commonly used is the PVGIS (Photovoltaic Geographical Information System) website, developed by the Research Centre of the European Commission's Institute for Environment and Sustainable Development.

The screenshot below shows the page of the PVGIS website where the monthly solar irradiation data are provided. The procedure for using this website is detailed in Annex II at the end of this toolkit.



Another website providing solar irridation data: GAISMA (website using NASA data).

Caution : A study should not be based on the reference of a single year. It should be conducted using an average of several years (at least 5 years) to smooth out extreme values and potential specificities.

Example of the difference in solar irradiation between France and an African country near the equator

Number of hours of sunshine per year

France	1600 to 2800 (4,4 to 7,6 h/d)
Africa	3100 to 3700 (8,5 to 10,1 h/d)

PART II : IMPLEMENTATION

STEP 3 : CHOOSE THE EQUIPEMENT

Objective

Choose quality equipment that will last longer, and that is suited to its intended use, i.e. selected and sized precisely according to the appliances to be powered.

1.Choose photovoltaic panels

Technology used for silicium cells

There are two main types of silicon photovoltaic cells: monocrystalline and polycristalline. Their difference lies in their manufacturing process.

To date, the performance gap between these two technologies has been significantly reduced. Polycristalline technology has almost disappeared in favour of monocrystalline technology (now cheaper and more efficient).

Power

Called Watt peak (Wp), it is characterised according to Standard Test Conditions (STC), which correspond to irradiation under natural sunlight standardised at 1000 W/m² and a temperature of 25°C. Panels producing 400 W of power (with irradiation of 1000 W/m2 and a temperature of 25°C) for a surface area of around 1,7 m2 are available.

Influence of temperature

Temperature is an important parameter in the electrical production of panels. All suppliers or manufacturers of photovoltaic panels provide correction factors for power, voltage, and current. A panel can lose 5% of its power with just a 15°C increase in temperature.

Degradation

The ageing of the photovoltaic panel results in a loss of power, although this loss is relatively small. It ranges from 15 to 20 % after 25 years of operation. These power losses are generally linear over time.

2. Select the batteries

The battery plays a role in storing electrical energy. Storage is necessary whenever there is a mismatch between production and consumption (either in time or in consumed power). Batteries are required whenever there are nighttime consumptions or power demand peaks.

Battery sizing (capacity)

Sizing depends on daily consumption, the number of days of autonomy required (= days without sunlight), the voltage and type of battery used. It is expressed in Ampere hours or Ah.

Caution: batteries are the most expensive part of the installation, financially and environmentally: they have a relatively short lifespan compared to panels, involve the rare earth extraction for production, and require management at the end of life.

To size the batteries, it is necessary to define the desired number of days of autonomy (usually 3 for a health center, for example), as well as the technology used in the batteries.

There are several types of batteries:

A/ lead acid

Starter battery (e.g., for a car)
Withstands high currents for a very short time and only accepts a low depth of discharge ‹ 30%.

- Thin plate batteries

Deep-cycle battery (or solar)
Withstands current (low or medium) for several hours and accepts depths of discharge of 70% or more.

- Thick plate or tubular batteries

Factors influencing the lifespan of a lead-acid battery

- The number of cycles and depth of discharge per cycle
- Temperature

B/ lithium

A technology that has become more widespread and affordable recently, lithium batteries, in comparison with lead-acid batteries, are considered more efficient, lighter, and resistant to high temperatures. However, they are more expensive to purchase and sometimes less readily available locally.

The table below compares the two technologies:

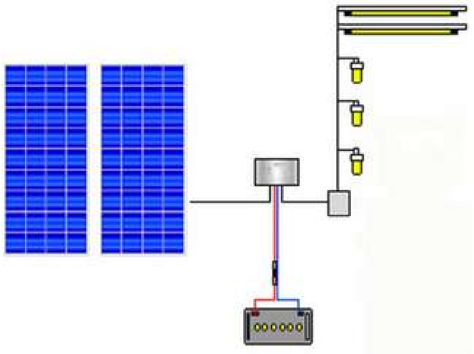
	Lead acid	Lithium LiFeO04
Self-discharge	5 %	2-3 %
Max capacity	50 % of load	100 % of load
Charging time	8-10h	2-3h
Lifespan	300-500 cycles	› 3000 cycles

Electriciens sans frontières recommends using **Lithium batteries or OPzV type tubular anode lead-acid batteries.**

Photos : Electriciens sans frontières

Component	Lifespan	Comments
PV Modules*	25 years	Polycristalline modules: 1 % loss of producibility/year
Regulators	10 years	
Inverters	10 years	
OPzV battery (sealed lead-acid battery)	8 to 10 years	
Li-ION battery	12 years	

3. Determine the charge controller



Functions

- Adjusts the voltage and current for optimal battery charging (disconnects or limits the current from the solar panel depending on the battery's charge state)
- Includes (depending on the model) functional indicators, alarms, and a communication port for remote management.
- Disconnects usage in the event of low battery voltage on smaller models.

Charge controller sizing is based mainly on 3 criteria:

- The voltage of the battery parc (12, 24 or 48 V),
- The maximum charging current accepted by the regulator, which must be compatible with the power of the panels and the battery bank voltage.
- The technology : PWM (for lower power) ou MPPT (for better efficiency).

Note: Many manufacturers of charge controllers specify the maximum power in peak watts (Wp) that the controller can handle.

4. Select the inverter

It converts the **direct current** generated by the PV system into **alternating current**. Most electrical devices operate on **230 volts alternating** current (some countries have a 110-volt grid). The inverter should be selected based on the total power of the system, with an additional safety margin of 1500 or 2000 watts.

The inverter will be selected based on the total power of the system, with an additional safety margin of 1500 or 2000 watts. In the market, inverters are available in capacities of 1200, 1600, or 2000 watts. It is recommended to choose an inverter with a higher capacity than the system's power to compensate for losses due to the ageing of electronic components.

Photo : Electriciens sans frontières

STEP 4 : INSTALL THE EQUIPMENT

Objective

Avoid errors that could occur during the installation of the system by considering key factors such as safety, maintenance and accessibility.

Type of solar power installation	Advantages	Disadvantages
On the ground	• Accessibility (installation and maintenance) • Ease of considering the best orientation	• Risk of degradation (stones, balls...) • Need for fencing • Groundwork and masonry work • Risk of shading (trees, buildings)
On roofs	• Lower risk of theft • Shorter electrical connection	• Difficult maintenance (ladder) • Load-bearing capacity of the roof structure • Increased risk of strong winds

Special attention must be paid to the following points when installing a photovoltaic system:

- The orientation of the panels depends on the hemisphere in which the photovoltaic system will be installed. Panels are installed facing south in the northern hemisphere and north in the southern hemisphere.
- Shading (external elements and panels blocking each other).
- The metal structures or supports must be able to withstand wind gusts.
- Distances between equipment (sources of additional losses), especially for low-voltage lines.
- Accessibility for maintenance.
- Inaccessibility for unauthorised individuals.
- For electronic equipment (charger, inverter, and batteries), minimise the impact of heat (a source of efficiency losses) – it is recommended to install them inside a dedicated technical room.

- When creating a technical room, it must be sufficiently large to accommodate the electronic equipment, electrical panels, and batteries. It should allow for maintenance and/or replacement of components without any electrical risks. The room should be secure, well-ventilated, and protected from heat and dust. it must be equipped with a light source and a power outlet.
- Careful attention should be paid to cable sizes, the quality of cable gland sealing, and the choice of electrical components, particularly circuit breakers, disconnectors, etc.
- It is recommended to put in place a remote monitoring and surveillance system.

STEP 5 : MAINTAIN THE EQUIPEMENT

Objective

Maintaining a photovoltaic installation is essential to ensure its smooth operation. If no maintenance is carried out, particularly if the panels are not cleaned, the system's efficiency can drop considerably. PV systems require relatively little maintenance. The main tasks to be implemented are listed in the checklist below.

Maintenance Checklist

- Clean panels as soon as dust is detected; use a soft brush; a non-abrasive sponge or a cloth (avoid corrosive or abrasive products and hard tools); do not use pressurised water. Be mindful of the need for cleaning after sandstorms.
- To access rooftop panels, use a ladder in good condition, positioned stably and secured to the ground by a second operator.
- When cleaning, avoid spraying the solar modules with cold water when the sun is too strong to prevent damage to the panels.
- Do not step on the solar modules.
- Check the tightness of screws on the structures (annually) and the seals on cable glands.
- Inspect the condition of electrical connections (mechanical damage, corrosion) and the sealing of cable passages (annually).
- Ensure that the electronic boxes (chargers and inverters) do not show excessive temperature rise (measure input and output temperatures).
- If necessary, check the battery electrolysis (level and acidity).
- In general, check the cleanliness of all equipment.
- Monitor and record information displayed on the various screens.
- Record electrical production.
- Perform continuous monitoring and ensure the correct transfer of information.

Non-exhaustive list of various causes of efficiency loss

- Panel ageing.
- Effect of panel orientation.
- Effect of panel cleanliness.
- Thermal losses in the wiring.
- Regulator/charger efficiency
- Inverter efficiency
- Effect of battery charge capacity and its possible discharge.
- Inclusion or non-inclusion of the possibility of load shedding for certain equipment.

Photo : Electriciens sans frontières

PART III: ADDITIONAL RESOURCES

Further reading

- The Oscaro Power guide provides extensive information information on choosing the various components of a PV system (panels, storage, inverter, monitoring, and wiring), as well as its installation, including very detailed technical implementation specifics (in French). https://guide.oscaro-power.com/fr-FR/comparatif-des-panneaux-solaires-869019

- This document, entitled « Power source sizing tool » and produced by Médecins Sans Frontières, is a table designed to estimate a facility's energy requirements, based on the inventory of electrical devices to be powered. https://logistic.ocg.msf.org/#./KBD/u=c&_f_uid=5d94da2675a74c0382618eaff93648b8&custom_order=title&src_lang=en

- The document « Power consumption log tool » created by Médecins Sans Frontières, provides a method for recording and tracking energy consumption in the field. https://logistic.ocg.msf.org/#./KBD/u=c&_f_uid=e6a97fbf5a234ae8b8af598a3a6c422d&custom_order=title&src_lang=en

- This « Best practice guide » created par Electriciens sans frontières with the support of the Groupe URD, provides a framework based on 12 criteria to improve project setup and implement sustainable solutions tailored to the needs of populations. https://www.urd.org/wp-content/uploads/2018/09/Guide_bonnes_pratiques_ESF_bd.pdf

- The logistics teams of Médecins Sans Frontières tested an innovative photovoltaic installation solution that can be deployed quickly and in the most challenging contexts. It is a container that supports 150m2 of solar panels that can produce up to 60 kWh. https://www.msf.ch/nos-actualites/articles/energie-solaire-mobile-solution-reside-t-elle-ce-conteneur

- Specific recommendations on the sizing of solarisation systems for health centres in Madagascar, produced by SEforALL: www.seforall.org/publications/powering-healthcare-in-madagascar-market-assessment-and-roadmap-for-health-facility

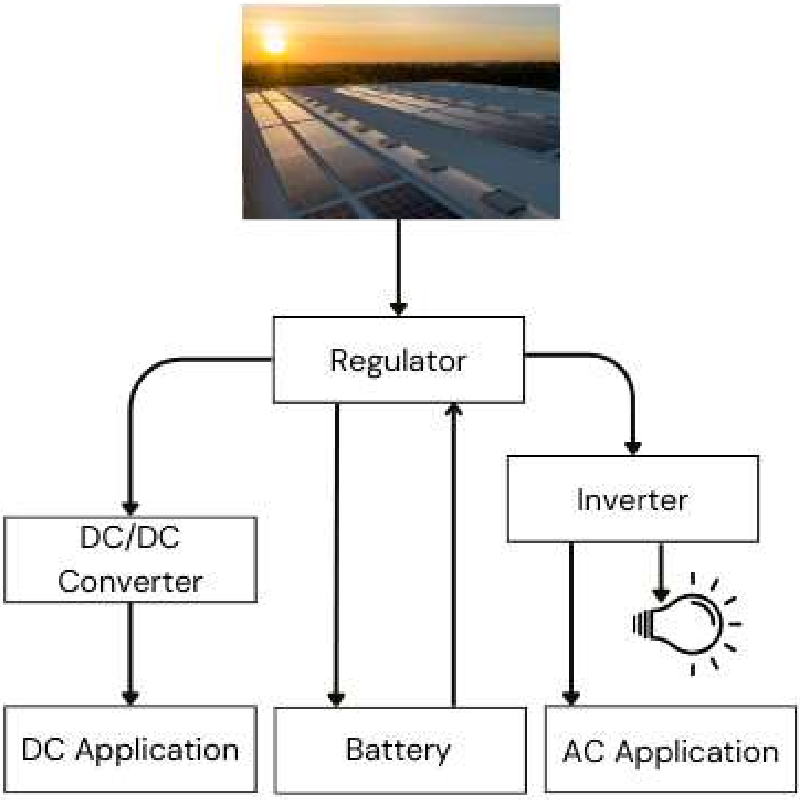
- Specific recommendations on the sizing of solarisation systems for health centres in Burkina Faso, produced by IRENA and the Indian SELCO foundation: https://www.irena.org/Publications/2022/Oct/Electrification-with-renewables-Enhancing-healthcare-delivery-in-Burkina-Faso

- The training module below on reducing the carbon footprint of NGOs, developed by Coordination Sud, gives a concrete example of the solarisation of buildings in Lebanon in the "Examples of action and feedback" section: https://www.coordinationsud.org/formation/reco-module-3-prioriser-et-mettre-en-oeuvre-des-actions-de-reduction-de-lempreinte-carbone-des-activites-dune-ong/

- In addition to the steps involved in solarising a structure, the International Medical Corps guide includes a section on evaluating and comparing costs between generators and solar solutions, not included in the Accelerator toolkit. https://internationalmedicalcorps.org/wp-content/uploads/2024/11/Solarization-Guidance-International-Medical-Corps.pdf

Definitions

Definitions of different parts of a photovoltaic installation



- **Photovoltaic panel or field**: converts solar energy into electrical current
- **Regulator**: controls battery charging and discharging
- **DC/DC Converter** : transforms 12 V DC into 24 V DC, for example
- **Battery**: stores and releases energy
- **DC Application**: devices operating on direct current
- **Inverter**: converts direct current into alternating current
- **AC Application** : devices operating on alternating current

Electrical Units

- **Voltage in Volts (V)** : potential difference between 2 terminals of the same circuit.
- **Current in Amperes (A)** : amount of electricity flowing through a dipole or wire.
- **Power in Watts (W or kW)** : electrical power is defined as the electrical energy transferred in a circuit per unit of time.

- **Energy in Watt-hours (Wh or kWh) or Joules (1 Wh = 3600 J)** : electrical energy is the energy associated with the movement of electrons through a conductor or dipole : E (J) = P(W) x t(s)
- **Battery capacity in Watt-hours**: capacity (Ah) x voltage (V)
  - It is often expressed in Ah with the voltage implied (e.g., 12V)
- **Efficiency (in %)**: η = Useful output power (P_out) / Provided input power (P_in) x 100.

Photo : Electriciens sans frontières

Example of a photovoltaic projet in Niger

Type of structure : Health center

Location : Agadez in Niger

List of equipment to be supplied

- 2 LED light bulbs of 7 W for each of the 5 rooms operating 5 hours per day.
- 3 LED light bulbs for the corridor, operating 5 hours per day.
- 1 refrigerator of 200 L, consuming 300 W, with an average operation of 8 hours per day.
- 1 fan of 60 W for each of the 5 rooms, operating 8 hours per day.
- 2 medical devices of 250 W each, with an average operation of 4 hours per day.
- 1 laptop of 50 W, operating 6 hours per day.
- 1 printer of 50 W, operating 2 hours per day.
- 5 mobile phone chargers of 10 W each, operating 2 hours per day.

1. Assessment of requirements

Equipment	Unit power	Operation	Number of units	Daily energy
Room light bulbs	7 W	5 h	= 2 x 5 = 10	350 Wh
Corridor light bubls	7 W	5 h	= 3 x 1 = 3	105 Wh
Refridgerator	300 W	8 h	1	2400 Wh
Fan	60 W	8 h	= 1 x 5 = 5	2400 Wh
Medical equipment	250 W	4 h	2	2000 Wh
Laptop	50 W	6 h	1	300 Wh
Printer	50 W	2 h	1	100 Wh
Phone chargers	10 W	2 h	5	100 Wh
	Total power			**Total energy**
Total	**1341 W**			**7755 Wh**

2. Determination of solar irradiation

To determine solar irradiation, the PVGIS tool can be used by following the link below: https://re.jrc.ec.europa.eu/pvg_tools/en/

Caution: updates are made to the website, which may result in changes to the values provided.

Once on the website, select the location for the study. In our case, the installation to be studies is located in Agadez, Niger.

There are 3 ways to select the location :

- Using GPS coordinates: at the bottom right of the map (letter A, fig. 1),
- Clicking directly on the map with the mouse (letter B, fig. 1),
- Or by entering the location's address directly, if possible (letter C, fig. 1),
- The map can be moved by right-clicking the mouse.

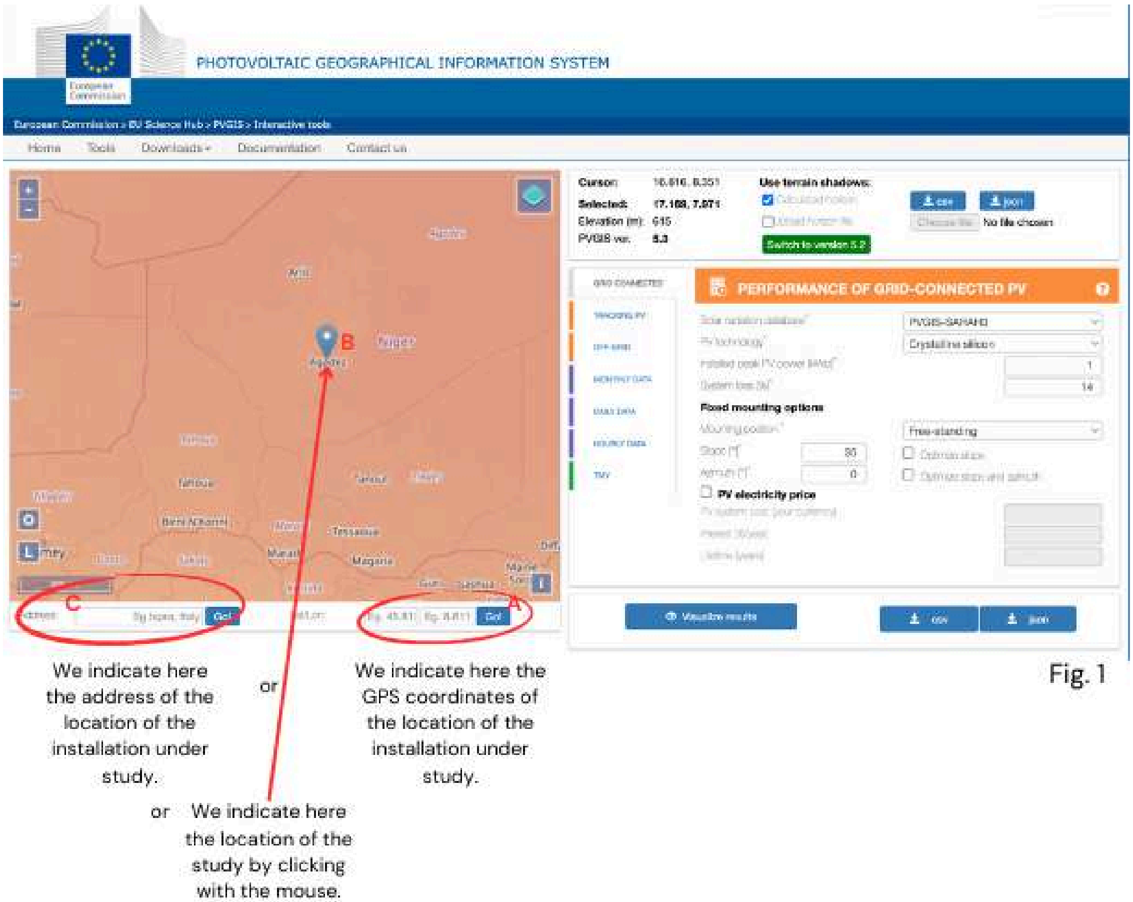


Fig. 1

Now the 'Monthly data" tab (letter A, fig. 2) should be selected, and the chosen solar radiation database (letter B, fig. 2) should indicate: 'PVGIS-SARAH2'.

To ensure the study is as realistic as possible, it must be conducted over a period of at least 5 years (to smooth out extremes). The start year (letter C, fig. 2) and the end year (letter D, fig. 2) for the study period should be specified. In this case, 2015 to 2020, covering 6 years, will be selected.

Fig. 2

The study requires global irradiation with a panel positioning angle (letter E, fig. 2) relative to the horizontal of 17° (letter F, fig. 2). This value of 17° corresponds to the latitude of the site. The calculation is performed by clicking on the "View Results" button (letter G, fig. 2).

To export the values into an Excel table, after viewing the results, click the "csv" button (letter H, fig. 2).

Photo : Electriciens sans frontières

The resulting Excel table has the following CSV format:

Latitude (decimal degrees):16.976
Longitude (decimal degrees):7.987
Radiaton database:PVGIS-SARAH2
yearmonthH(h)_mH(i)_m
2015Jan218.88
2015Feb203.32
2015Mar218.32
2015Apr229.81
2015May219.74
2015Jun197.29
2015Jul203.42
2015Aug197.38
2015Sep203.52
2015Oct222.99
2015Nov214.09
2015Dec216.39
2016Jan210.02
2016Feb213.24
2016Mar215.17
2016Apr217.46
2016May216.39
2016Jun185.96
2016Jul202.05
2016Aug199.42
2016Sep205.46
2016Oct211.56
2016Nov209.79
2016Dec205.76
2017Jan214.26

This is the date. Year, followed by month. In our case, year: 2017 and the month is January

This the value of the global solar irradiation in kWh/m²/month, which in this case is 194.08 for the month of January 2017.

The data in this format need to be reformatted so that the information can be used. The values obtained in CSV format will be placed in a table (see below), which will allow for the calculation of the average monthly and daily irradiation.

		2015	2016	2017	2018	2019	2020	Monthly average	Daily average
Jan	31	218,88	210,02	214,26	218,11	214,45	217,18	215,48	7.0 kWh/m2/d
Feb	28	203,32	213,24	201,72	203,48	205,15	214,27	206,86	7.4 kWh/m2/d
Mar	31	218,32	215,17	240,52	236,04	229,58	236,72	229,39	7.4 kWh/m2/d
Apr	30	228,81	217,46	216,38	231,68	218,49	226,91	223,29	7.4 kWh/m2/d
May	31	219,74	216,39	214,28	219,3	216,16	218,96	217,47	7.0 kWh/m2/d
Jun	30	197,29	185,96	183,85	192,23	191,29	199,3	191,65	6.4 kWh/m2/d
Jul	31	203,42	202,05	197,85	203,4	203,28	203,07	202,18	6.5 kWh/m2/d
Aug	31	197,38	199,42	201,1	200,94	194,57	192,29	197,62	6.4 kWh/m2/d
Sep	30	203,52	205,46	214,42	200,96	210,18	208,49	207,17	6.9 kWh/m2/d
Oct	31	222,99	211,56	229,98	218,5	209,47	218,77	218,55	7.0 kWh/m2/d
Nov	30	214,09	209,79	210,68	207,69	207,54	214,7	210,92	7.0 kWh/m2/d
Dec	31	216,39	205,76	197,02	211,17	215,2	211,63	209,53	6.8 kWh/m2/d
							Min:	191,65 kWh/m2/m	6.4 kWh/m2/d
							Max:	229,39 kWh/m2/m	

Fig. 3

From this table, the value to retain is the minimum daily irradiation, which in our example is 6.4 kWh/m2/day.

It is calculated as follows:

Min (Average monthly irradiation) / Number of days in the considered month
= 191,65 kWh/m2/month / 30 days = 6,4 kWh/m2/d

› The theoretical average daily irradiation is 6,4 kWh/m2/d.

3. Determine the power of the photovoltaic panels

The value above corresponds to the theoretical average daily irradiation. It is necessary to account for losses due to various effects:

- **Thermal effect on electricity production (-5%)**
- **Cleanliness of the panels (-2%)**
- **Ageing over 10 years (-10%)**
- **Orientation (-2%)**

Calculation of losses

Thermal effect x Dirt effect x Ageing effect x Orientation effect = Panel efficiency (excluding photovoltaic conversion)
(1-5%) x (1-2%) x (1-10%) x (1-2%) = 0,95 x 0,98 x 0,9 x 0,98 = 0,82.

This value of 0,82 or 82% corresponds to the efficiency of the panel production chain (excluding photovoltaic conversion).

The total losses are equal to 1 - 0,82 = 0,18 or 18%

In our case, assuming a reduction coefficient of 18%, the average useful solar irradiation (output from panels) is :

6,4 x (1 – 0,18) = 5,2 kWh/m2/d

The various electrical efficiencies must also be taken into account:

- **Charger (-5%)**
- **Inverter (-5%)**
- **Joule effect (-10%)**
- **Batteries (-10%)**

Calculations of losses due to various efficiencies

Charger efficiency x Inverter efficiency x Wires efficiency x Battery efficiency = Conversion efficiency

(1-5%) x (1-5%) x (1-10%) x (1-10%) = 0,95 x 0,95 x 0,9 x 0,9 = 0,73

The total losses are equal to 1 - 0,73 = 0,27 or 27%

The reduction coefficient retained is 27%. The average useful electrical irradiation (at the output of the inverter) becomes :

5,2 x (1 – 0,27) = 3,8 kWh/m2/d

It is now possible to determine the power of the photovoltaic panels to be installed:

$$\textbf{Panel Power} = \frac{\text{Energy consumed (Wh/d)} \times \text{k(W/m2)}}{\text{Average useful electrical irradiance (Wh/m2/d)}} = \frac{7755 \times 1000}{3830} = 2025 \text{ Wp}$$

The coefficient k correspond to the electrical output for an **average solar irradiation of 1000 W/m2**.

> The installed power of the photovoltaic panels must be at least equal **to 2025 Wp**.

Therefore, it will be necessary to install: **either 4 PV panels with a power of 500 W each, or 6 PV panels with a power of 330 W.**

To accelerate the battery charging, the power of the photovoltaic panels can be increased by 10 to 20 %.

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4. Determine the capacity of the battery bank

To find out the capacity of the batteries, perform the following calculation:

Battery capacity
=

$$\frac{\text{Energy consumed x Autonomy x Coefficient of safety}}{\text{Permissible degree of discharge of batteries x Battery voltage}}$$

=

$$\frac{7755 \times 2 \times (1 + 25\%)}{50\% \times 48}$$

- Energy consumed : 7755 Wh (see energy requirements table)
- Autonomy (in days) : 2
- Permissible degree of discharge for batteries : 50%
- Battery voltage : 48 V
- Coefficient of safety : 25%

→ The capacity of the 48 V battery bank must be **808 Ah.**

It will therefore be necessary to install 4 batteries of 200 Ah

N.B. : The various percentages (%) related to losses and surcharges are for information purposes only. In the case of a real project, they will have to be defined or calculated based on the actual equipment installed.

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