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# Integration of photovoltaic panels in the habitat

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## ملخص

نقدم في هذا العمل معلومات عامة عن دراسة تحجيم المنشآت الكهروضوئية. لهذا نقوم بدراسة الواجهة التي تميز النظام الكهروضوئي وفقا لبيانات ومعلومات الموقع والمكان. لذلك نعمل على إختيار النوع سواءا كان مستقل أو متصل بالشبكة عن طريق القيام بتحجيم يدوي ثم آلي بإستخدام برنامج PVSyst والحصول على مختلف النتائج ودراستها على أن تكون معقولة.



**الكلمات المفتاحية:** نظام كهروضوئي، تحجيم، شبكة، PVSyst.



## Résumé

Dans ce travail, nous présentons des informations et des généralités sur le dimensionnement d'installation PV. Pour cela nous proposons une méthode pour choisie l'interface qui caractérise le système PV suivant les différentes données du site et d'endroit. Après le traitement des différents information on va choisie le type d'installation soit autonome ou raccordé au réseau, on veut faire un dimensionnement manuel puis automatique avec le logiciel PVSyst pour prendre les différentes résultats.



**Mots clé :** Système Photovoltaïques, Dimensionnement, réseau, PVSyst.



## Abstract

In this work, we present information and generalities on the dimensioning of PV installation. For this we propose a method for choosing the interface that characterizes the PV system according to the different site and location data. After processing the different information, we will choose the type of installation, either stand-alone or connected to the network, we want to do manual and then automatic sizing with the PVSyst software to take the different results.



**Key words:** Photovoltaic system, sizing, network, PVSyst.

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**List of symbols:**

J: Day number of the year (J)

TSV : Temps universel (h)

TL : Temps légal (h)

λ: Longitude of the place (°)

δ: Solar declination (°)

H : hour angle of the sun (°)

a : Azimuth(°)

h : Height (°)

φ: Latitude(°)

β : Angle of inclination (°)

λ : Wave length (μm)

p: Atmospheric pressure (Bar)

$V_D$: Diffusion voltage on a junction (V).

$N_D$: Donor Concentration (cm 3).

$N_A$: Hole concentration (cm 3)

k: 1.380662.10 23C. Boltzmann constant.

q: 1.602. 10 19C. elemental load.

T: absolute crystal temperature (K).

$n_i$: Intrinsic concentration.

$P_m$: Peak power of the module (W)

$V_m$: Voltage at maximum power point (V)

$I_m$: Current at maximum power point (A)

$V_{oc}$: Open circuit voltage (V)

$I_{cc}$: Circuit Breaker Current (A)

## Nomenclature

$n_s$ : Number of cells in series

$\eta_{ond}$: Inverter efficiency

$n_s$ : Number of cells in parallel

ff : Form factor.

$E_{AC}$: Daily energy requirement (Wh/d)

$E_T$ : Total daily electrical energy (Wh/d)

$N_t$ : Number of total modules

$N_p$ : Number of modules in parallel

$N_s$ : Number of modules in series

$S_p$ : Solar panel area ($m^2$)

# General introduction

Energy needs of all kinds are growing all over the world. Coal, oil and natural gas are known as non-renewable sources of energy because they exist in limited quantities in nature. In other words, they are generated from finite resources or they take an extremely long time to regenerate. These resources are found in nature, but they disappear as they are used. According to a recent study published in the scientific journal Nature, oil reserves will be depleted by 2043**.** The same applies to coal and natural gas - the date when we will no longer have these fossil fuels is fast approaching. But the reason why we must urgently seek new sources of energy is not because these resources are running out, but because of the serious environmental impact of non-renewable energies on our planet.

Algeria, as far as it is concerned, is facing the impacts of climate change, which aggravate the phenomenon of desertification from which it suffers. It has integrated the dimension of sustainable development into its development plans, including with a view to reducing its greenhouse gas emissions. It also adopted measures to improve energy efficiency and a policy to promote renewable energies.

The energy-intensive building sector is at the forefront of this trend. On a global scale, the building sector represents 30 to 40% of total energy consumption and a large share of environmental impacts. In Algeria, buildings are no exception to this rule. The national energy balance shows that the building sector represents a large part of the country's energy consumption. Indeed, the latest statistics give a rate higher than 45% compared to national consumption and it is growing significantly for several reasons, example: Substantial increase in the housing stock, Low price of conventional energies, Increase in the number of electrical equipment within each household, Use of uneconomical electrical equipment such as low-end and cheaper incandescent lamps and air conditioners, Lack of awareness and lack of culture on energy management, Growing desire of residents to comfort.

To meet these energy and environmental challenges, several elements of solutions can be implemented in a complementary way. From an environmental point of view, there are many solutions, including the rationalization of the use of raw materials, the reduction of polluting emissions and waste and the recycling of materials. From the energy point of view, the measures will be targeted in priority on reducing the energy consumption of buildings, improving the energy efficiency (EE) of equipment and in the development, even modest, of renewable energies (ER) in particular photovoltaic solar energy.

It is in this perspective that the bioclimatic approach is adopted. This approach makes it possible to reduce the energy consumption of the habitat by using passive and active solar techniques.

The modeling and especially the construction of a single house that would produce only a part of the energy it consumes is the best way to apply all the concepts decrease consumption and local production of energy. Thus, the present thesis aims to study the contribution of photovoltaic solar energy in the energy performance of high-quality energy housing in Algeria. The solar photovoltaic system is a system connected to the electricity grid and does not use electrochemical storage. During sunny periods, the power is supplied by the photovoltaic system and during the absence of the sun, the power is drawn from the electricity grid.

Our work is divided into four chapters. After a brief introduction, the first chapter globally presents the renewable and non-renewable energy systems.

The second chapter is about solar energy in general.

The purpose of the following chapter is to provide as much information as possible concerning photovoltaic systems connected to the electricity grid and to cover the different possible structures of these systems.

Finally, the fourth chapter will be the subject of Integrating photovoltaic panels in the habitat

## Introduction

The world's reserves of minerals and fossil fuels are limited, and the exploitation of coal, oil, gas and uranium is not sustainable in the long term. Fortunately, renewable energies from nature's regenerative streams are inexhaustible and have no long-term negative impact on the environment. Also, these natural sources could become in the future the basis of energy supply, and probably the only way to produce electricity. The next few years look promising for clean energy. The fight against climate change, the development of decentralized electricity production and technical progress should give a tremendous boost to these young sectors. In the first chapter we are going to know about renewable and non-renewable energy and the difference between the two. (Solar energy in the chapter II)

## I.1 Non-renewable energy

A non-renewable energy is a source of energy which is renewed more slowly than it is consumed and in a negligible way on a human scale, as opposed to renewable energies.

The main sources of non-renewable energy are products with intrinsic nuclear (such as fissile materials) or chemical (such as hydrocarbons, formed from fossil biomass that time has transformed into coal, oil or gas) energy properties.

### I.1.1 fossil fuels

Fossils are the remains of creatures that lived long ago. So, fossils include organic matter buried beneath layers of rocks. A fuel is a source of energy. Without fossil fuels, most people could not drive their cars. They could not turn on their lights or heat their homes. This is because most of the energy needed to do these things comes from fossil fuels.

#### a- Coal

Coal is a chemically and physically heterogeneous, "combustible," sedimentary rock consisting of both organic and inorganic material. Organically, coal consists primarily of carbon, hydrogen, and oxygen, with lesser amounts of sulfur and nitrogen. Inorganically, coal consists of a diverse range of ash-forming compounds distributed throughout the coal. The inorganic constituents can vary in concentration from several percentage points down to parts per billion of the coal. Coal is the most abundant fossil fuel in the world [1].

- **Origin of Coal**

Coal is found in deposits called seams that originated through the accumulation of vegetation that has undergone physical and chemical changes. These changes include decaying of the vegetation, deposition and burying by sedimentation, compaction, and transformation of the plant remains into the organic rock found today. Coals differ throughout the world in the kinds of plant materials deposited (type of coal), in the degree of metamorphism or coalification (rank of coal), and in the range of impurities included (grade of coal) [1].

- **Coal Energy Systems**

The following figure I.1 summarizes the coalification process.

| Materials | Partial Processes | Main Chemical Reactions |
|---|---|---|
| Decaying Vegetation | Peatification | Bacterial and fungal life cycles |
| *Peat* | Lignitification | Air oxidation, followed by decarboxylation and dehydration |
| *Lignite* | Bituminization | Decarboxylation and hydrogen disproportioning |
| *Bituminous coal* | Preanthracitization | Condensation to small aromatic ring systems |
| *Semianthracite* | Anthracitization | Condensation of small aromatic ring systems to larger ones; dehydrogenation |
| *Anthracite* | Graphitization | Complete carbonification |

**Figure I.1 :** The coalification process [1].

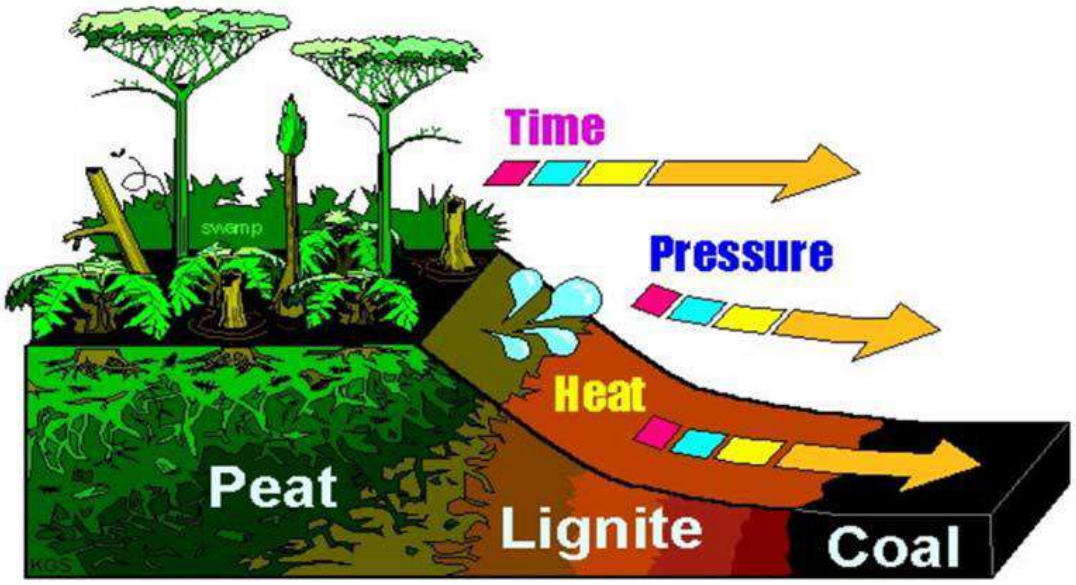



**Figure I.2:** Diagram showing the steps in the formation of coal. [10]

## b- oil and natural gas resource:

For the purposes of this resource inventory, conventional oil and gas resources are hydrocarbons that will flow to extraction wells without first having to make dramatic changes to either the reservoir rock or the reservoir fluids. This distinguishes them from various unconventional oil and gas resources, which may require massive reservoir stimulation to create permeable conduits (tight gas sands, shale oil, and shale gas), thermal or chemical treatments to reduce oil viscosity (heavy oil and tar sands), or dewatering to promote the relative permeability of gas (coalbed methane). The formation of conventional hydrocarbon accumulations hinges on a series of crucial geologic processes unfolding in the proper sequence over millions or, in some cases, hundreds of millions of years. When all the necessary components are present, effective, and have had the proper interactions, they are said to make up a conventional petroleum system (Magoon and Dow, 1994). [10]

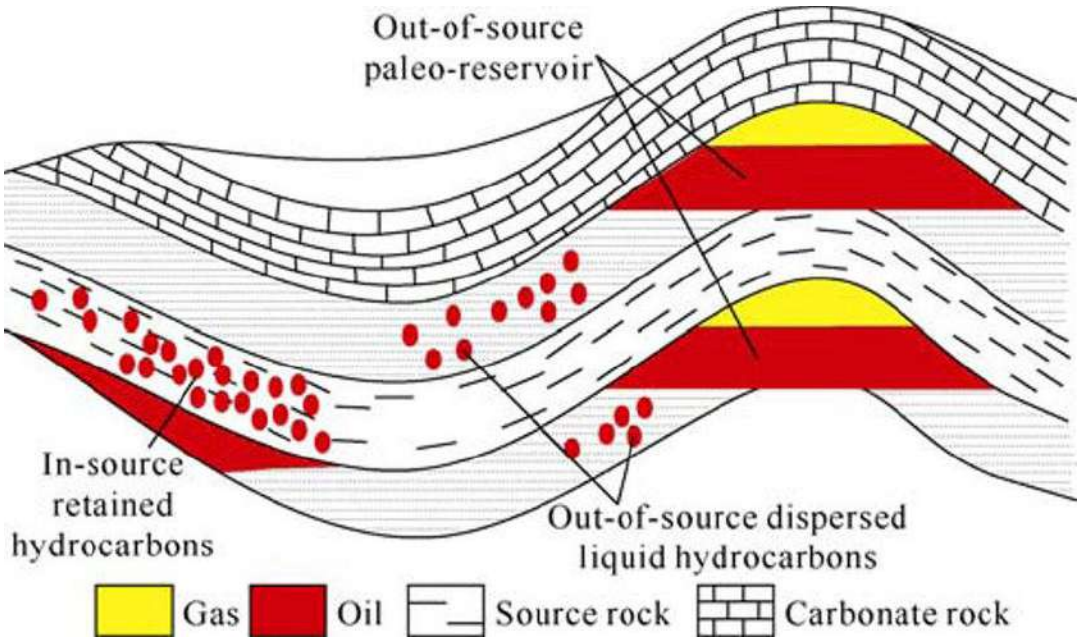



**Figure I.3 :** Sources of natural gas [11].

Oil source rocks (usually black shales or limestones) contain elevated levels of organic molecules rich in carbon and hydrogen that, when heated slowly to the right temperature (typically greater than about 212 degrees Fahrenheit [212°F; >100 degrees Celsius, 100°C]), react to form the mix of chainlike hydrocarbon molecules we call crude oil. The part of a basin that is buried deeply enough to cause this thermal conversion is called 'the kitchen.' With continued burial and increased heating of 'the kitchen' (above about 300°F [150°C]), these same rocks generate less oil but expel increasing amounts of the lighter, smaller hydrocarbon molecules (mainly methane) that make up natural gas. Source rocks that start out rich in carbon but leaner in hydrogen (including coals as well as many shales and limestones) can generate natural gas but not the more hydrogen-rich liquid hydrocarbons. [10]

## I.1.2 Advantages of non-renewable energy

- Non-renewable resources are high in energy. Resources such as coal and oil tend to provide us more energy in comparison to renewable energy like solar or wind energy.
- Huge profits can be generated in the mining of coal, selling of oil or the construction of natural gas pipelines.

- Non-renewable energy is easily found anywhere and everywhere. This implies that they can be conveniently moved across the world. People living in areas that are not easily approachable can make use of non-renewable energy as well.

- Most importantly, non-renewable recourses are job-creating. Extracting, transporting and refining are the parts of non-renewable sources that provide employment

### I.1.3 Disadvantages of non-renewable energy

- One of the major disadvantages of non-renewable energy is that it is time-consuming. Mining of coal, searching for oil, installing oil drills, building oil rigs, inserting pipes to extract and transporting natural gases are very time-consuming processes. It also takes a lot of effort.

- Since non-renewable energy takes billions of years to form, they are slowly but gradually vanishing from the earth. Using non-renewable resources indiscriminately without thinking for our future generations could be selfish.

- Non-renewable energy can be dangerous and can cause respiratory problems in humans because sources like fossil fuels emit gases such as carbon monoxide.

- To keep the power station working, every time we need to keep a huge amount of fuel in reserve. This can be expensive and occupy a lot of space.

## I.2 Renewable energy

According to Algerian law, renewable energies qualified as such are: Forms of electrical, mechanical, thermal or gaseous energy are obtained from the transformation of solar radiation, wind energy, geothermal, organic waste, hydropower and biomass techniques [1]. However, many experts believe that the share of renewable energy, even if it increases in the coming years, will remain low overall. On the one hand, because fossil energy resources are still considerable: 40 years of proven oil reserves, 62 years for gas, 400 years for coal. On the other hand, because renewable energy will probably always be more expensive than conventional energy. [2]

This solar source provides radiation on average, intercepted by the earth's surface, equivalent to 8,000 times greater than primary energy consumption. With the current world population, this rate rises to an incredible average of 20 MW per person (20 million W). Therefore, the energy flow can be obtained directly using thermal or photovoltaic technology, or indirectly, through wind, waves, river

dams and biofuels. Most renewable energies are easily convertible into electricity. But solar, geothermal or biomass energy can also be used to provide heat. They can provide all the services provided by conventional sources: heating, refrigeration, electricity, and whatever with difficulty and additional cost for transport. For a natural source, it is an added benefit to be able to provide energy to remote areas without the need for a costly transportation network. It is important to note that it is not always necessary to convert renewable energy into electricity. Solar hot water or a wind turbine operating a water pump are examples of systems that canoperate without any electrical circuit. However, to meet more and more the needs of consumers, renewable energy will be mainly used in electric form. [3]

No energy source is neutral [4] to nature and everything is a matter of compromise. The objective which is gradually emerging is that of sustainable development which means that it must continue over time without depleting scarce resources, that it must be economically viable and that it will allow a harmonious development of the world economy, especially for the poorest countries, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [5]. An overview of the different types of renewable energy in general is needed:

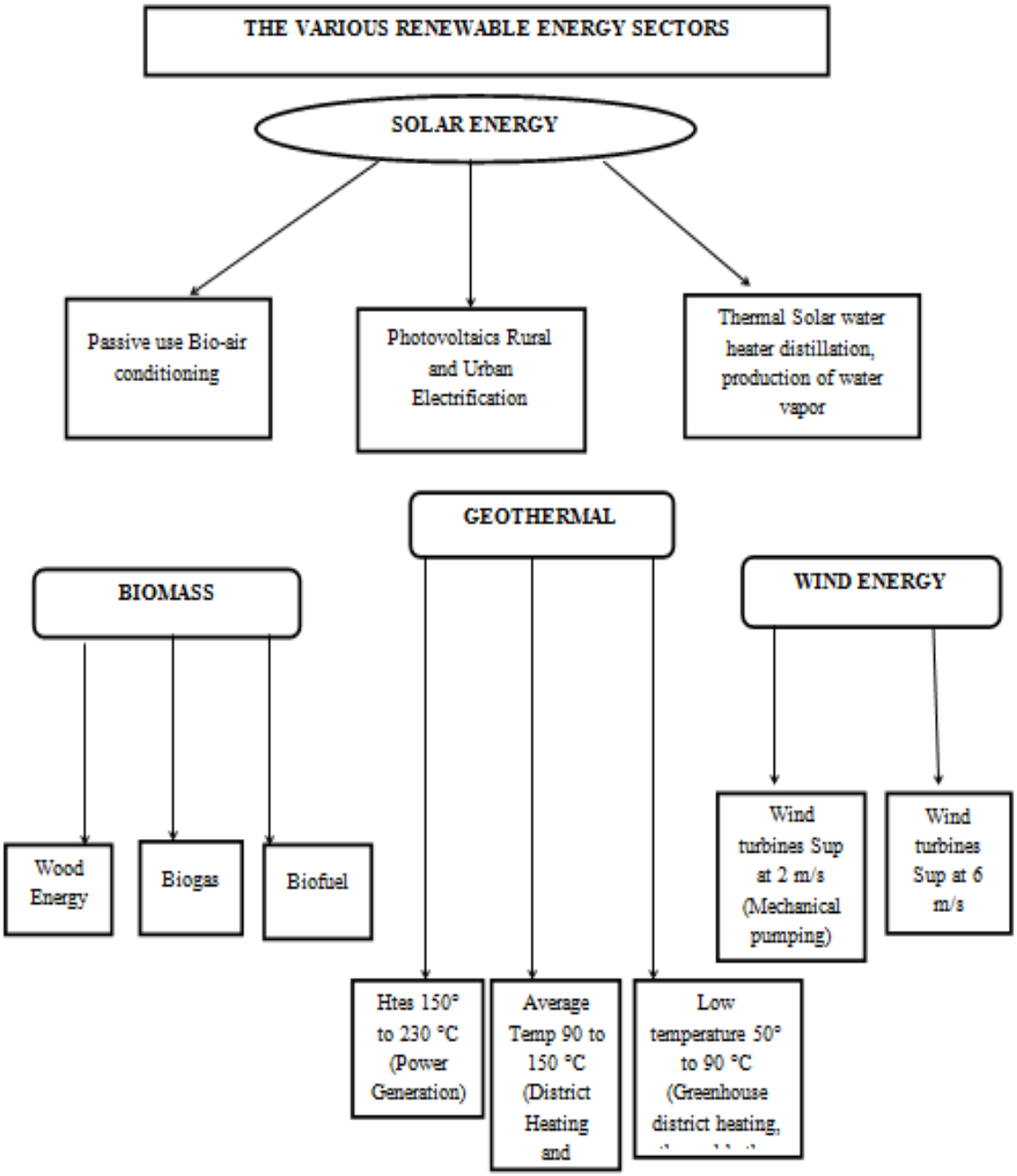



**Figure I.4:** The various renewable energy sectors [2].

## I.2.1 Biomass

Biomass is a Greek word where bio means life and maza means mass. Biomass refers to non fossilized biological material derived from living/recently living organisms and biodegradable organic or carbon-based material originating from plants, animals, vegetable-derived materials, and

microorganisms. Biomass is the world's fourth largest energy source, following coal, oil, and natural gas. Biomass includes products, by-products, residues, and waste generated during processing or operation from agriculture; wood from forests; agricultural residues such as straw, Stover, and cane trash; green agricultural wastes, forestry; and biodegradable organic fractions of industrial/ municipal solid wastes (sewage, human, and animal wastes), such as black liquor from paper manufacturing, sugarcane bagasse, and rice husk. Animal wastes include manures, slurries, animal bedding such as poultry litter, and grass silage. It also includes gases and liquids recovered from the decomposition of non fossilized and biodegradable organic materials and food wastes from many food materials during processing stage to remove components that are inedible or not required such as peel/skin, shells, husks, cores, pips/stones, fish heads, pulp from juice, and oil extraction [1,2]. The most probable source of biomass is displayed in Figure I.5. [6]

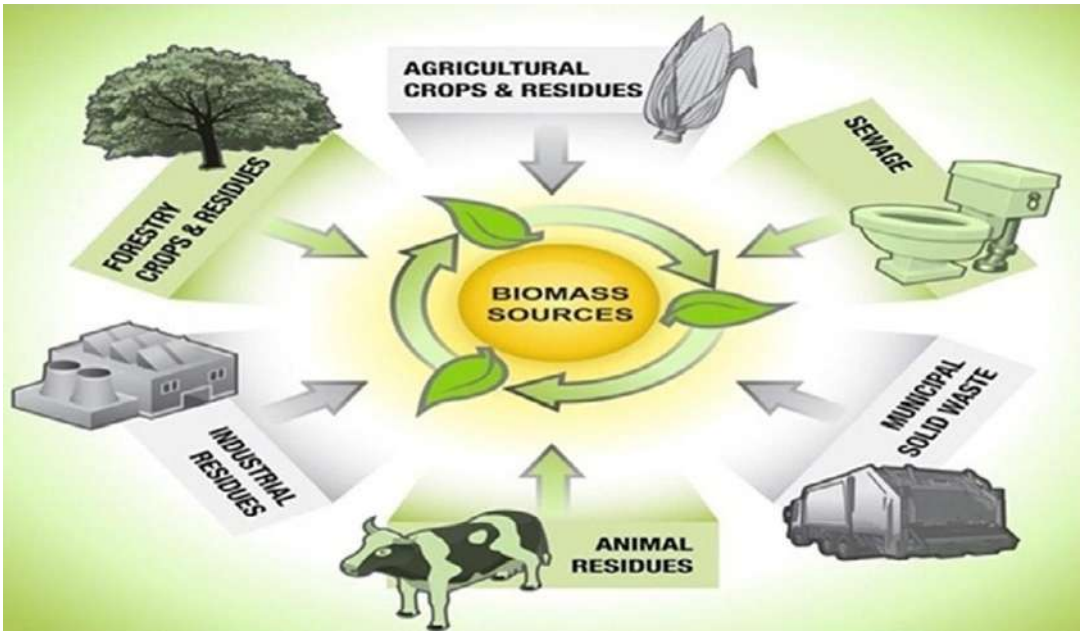



**Figure I.5:** Most probable sources of biomass [6]

### a- Wood energy

Wood is probably the most interesting source of energy in the field of renewable energy. Everyone has in mind the damage caused by deforestation in tropical regions. Wood is therefore a renewable and relatively clean source of energy. Without getting into a debate of specialists, a small reminder is necessary; by burning (or rotting on the ground), a tree releases into the atmosphere the

carbon dioxide it had absorbed as it grew, no more and no less. In a country that practices forestry and replants at least as many trees as it cuts, the ecological balance is therefore neutral. [3]

**b- Biofuel**

The other thing about biomass is the ability to make biofuels. There are two types of biofuels : ethanol and biodiesel. Ethanol, which is used in gasoline engines, is used in a variety of plants such as wheat, corn, beet and sugar cane. The process involves extracting the sugar from the plant to obtain ethanol after fermentation. As for biodiesels, they are extracted from oilseeds (rapeseed, sunflower, soya etc.). The oil esters obtained can then be mixed with diesel oil. Typically, these biofuels are blended with conventional fuels, gasoline and diesel. They then lead to a small reduction in the emissions of carbon monoxide and carbon dioxide, which are responsible for the greenhouse effect. But these biofuels have a huge disadvantage; they occupy agricultural land to the detriment of food crops. [3]



**Figure I.6 :** Different types of biomass, source: CDER.

**c- Biogas**

Biogas is essentially a mixture of methane (CH4) and carbon dioxide ($CO_2$). Depending on its origin, 6, it also contains variable amounts of water, nitrogen, hydrogen sulphide (H2S), oxygen, aromatics, organo-halogenated compounds (chlorine and fluorine) and heavy metals, the last three chemical families being present in trace amounts. Biogas is produced by an anaerobic fermentation process of animal or plant organic matter, which takes place in three stages (hydrolysis, acidogenes and methanogenes) under the action of certain bacteria. It takes place spontaneously in the landfills of

municipal waste, but can be artificially caused in enclosures called "digesters" where both solid and liquid organic waste and bacterial cultures are introduced. This voluntary methanation technique can be applied:

- raw household waste or its fermentable fraction,
- sludge from urban or industrial wastewater treatment plants,
- Industrial organic waste (hides and skins, chemicals, parachemistry, etc.),
- As well as agricultural and livestock waste (manure, manure, etc.).

Biogas's upgrading routes are: heat alone, electricity alone, cogeneration, automotive fuel and injection into the natural gas network. [3]

### I.2.2 Utilization of biomass in different sectors

Responding to the increasing awareness and concern among the world population to ward new environmental regulations, growing socio-ecological issues, high rate of depletion of petroleum and mineral resources has promoted an intensive use of biomass wastes. Biomass residues from agricultural wastes are exploring the potential of using cheaper, nontoxic, and renewable reinforcing fillers in polymer composites such as sisal, jute, pineapple leaves, banana stem, oil palm, rice hulls, and sugar palm [4].Interestingly, considerable amounts of organic waste and residues from the industrial and agricultural processes are still underutilized as low-value energy sources. Organic materials are commonly disposed of or subjected to the traditional waste management [6].

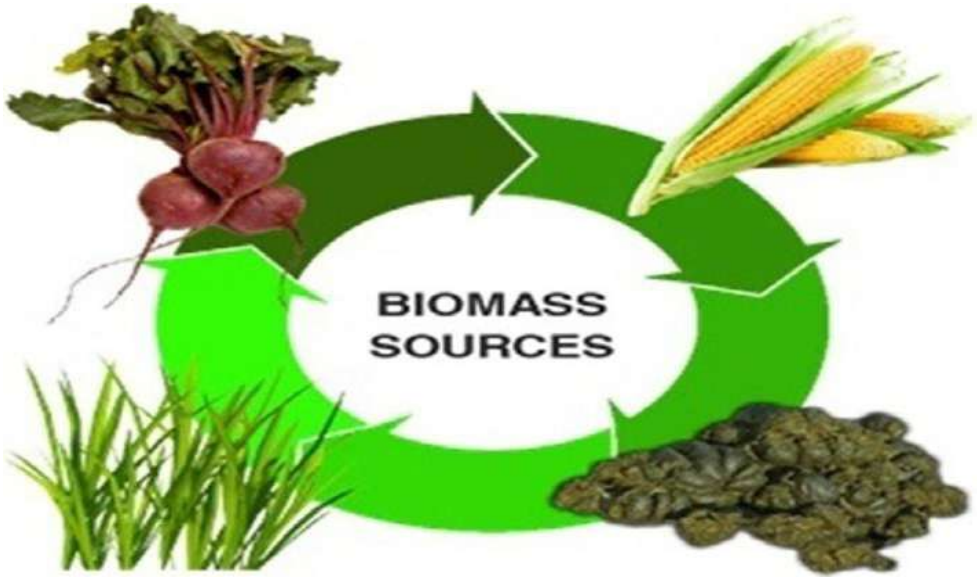



**Figure I.6:** Biomass sources for biogas plant [6]

### I.2.3 Wind Energy

A propeller driven in rotation by the force of the wind allows the production of mechanical or electrical energy in any place sufficiently windy. The applications of energy wind turbines are varied but the most important is to provide electricity. These are wind farms. They use medium- and high-power machines (200 to 2000 kW). Autonomous systems, from 500 W to a few tens of kW, are interesting for electrifying isolated sites of the electricity network (islands, villages...), and recently in ultra-modern buildings, citing here the twin-towers of Bahrain. [3]

#### a- The production of mechanical energy through wind

Mechanical wind turbines are most often used to pump water. The propeller drives a piston, which lifts the water from the ground. This technique is well adapted to meet the water needs (agriculture, food, hygiene) of isolated villages.

#### b- Power generation by wind generators

The figure below shows the main components that make up the machine. The wind energy captured on the blades drives the rotor, coupled to the generator, which converts mechanical energy into electrical energy. It is then distributed to the standards on the network, via a transformer. [3]

#### c- Wind turbine concepts

Wind turbines can either be designed to operate at fixed speed (actually within a speed range about 1%) or at variable speed. Many low-power wind turbines built to-date were constructed according to the so-called “Danish concept” that was very popular in the eighties, in which wind energy is transformed into electrical energy using a simple squirrel cage induction machine directly connected to a three-phase power grid (Qiao et al., 2007). The rotor of the wind turbine is coupled to the generator shaft with a fixed-ratio gearbox. At any given operating point, this turbine has to be operated basically at constant speed. On the other hand, modern high-power wind turbines in the 2-10 MW range are mainly based on variable speed operation with blade pitch angle control obtained mainly by means of power electronic equipment, although variable generator rotor resistance can also be used. These wind turbines can be mostly developed using either a direct-in-line system built with a direct-driven (without gearbox) PMSG grid-connected via a full-scale power converter, or a doubly-fed induction generator (DFIG) system that consists of a DFIG with a partial-scale power converter

connected to the rotor windings. Based on these concepts, the most commonly applied wind turbine designs can be classified into four wind turbine concepts, as described below. [7]

- **Type A – Fixed speed wind turbine**

This topology corresponds to the constant or fixed speed controlled wind turbine, with a synchronous squirrel cage induction generator (SCIG) directly connected to the electric grid using a step up power transformer, as depicted in Figure I.7 [7]

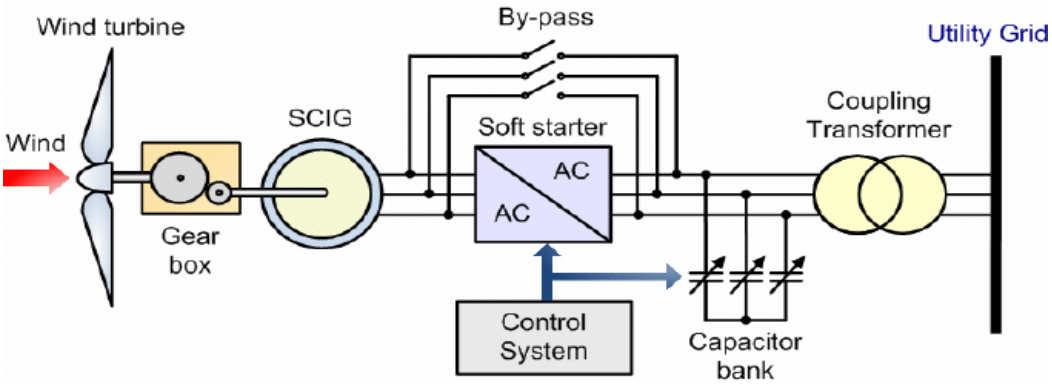



**Figure I.7:** Type A wind turbine [7].

- **Type B – Partial variable speed wind turbine with variable rotor resistance**

This topology corresponds to the partial variable speed controlled wind turbine with variable generator rotor resistance, aka OptiSlip by the Danish manufacturer Vestas™ Wind Systems (Krüger & Andresen, 2001), as presented in Figure I.8. [7]

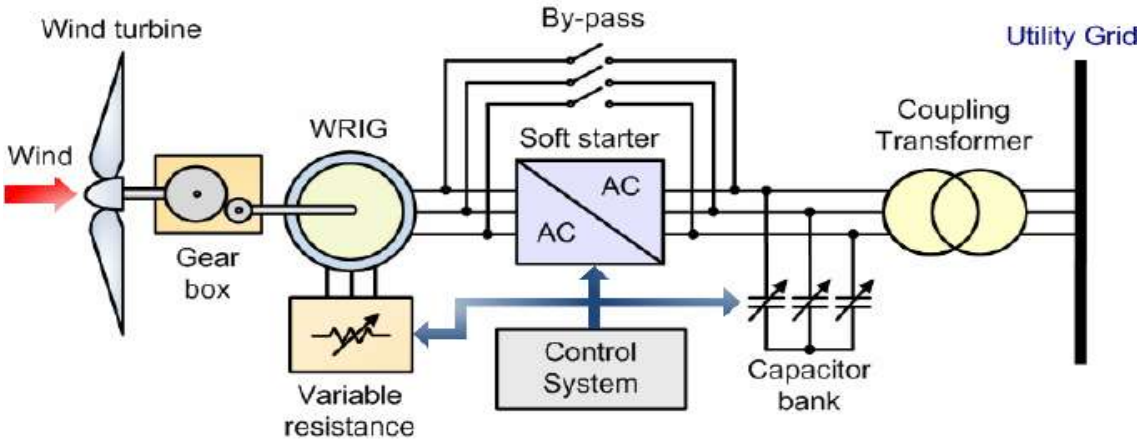



**Figure I.8:** Type B wind turbine [7]

- **Type C – Variable speed wind turbine with partial-scale power converter**

This configuration corresponds to the direct-in-line full variable speed controlled wind turbine, with the generator connected to the electric grid through a full-scale power converter. A synchronous generator is used to produce variable frequency AC power. Then power converter connected in series (or in-line) with the wind turbine generator transforms this variable frequency AC power into fixed-frequency AC power. [7]

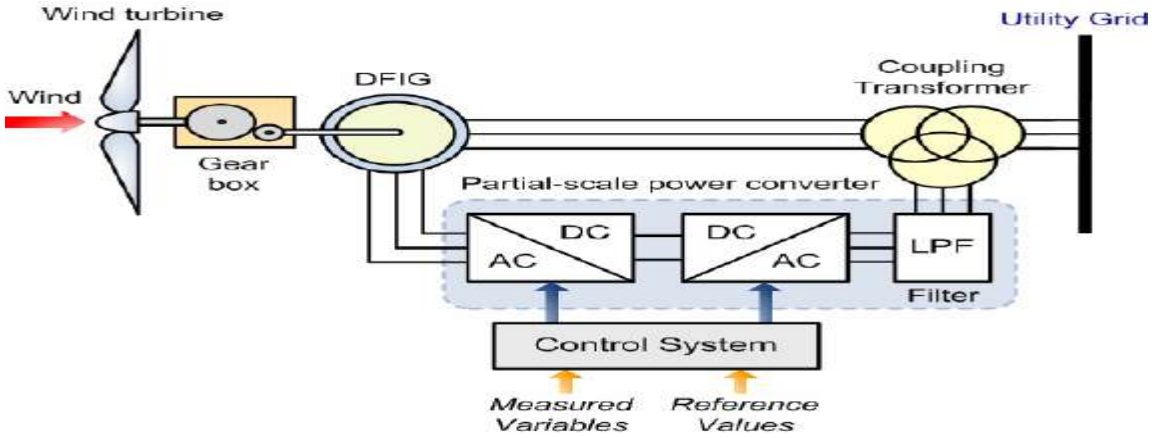



**Figure I.9 :** Type C wind turbine [7].

- **Type D – Direct-in-line variable speed wind turbine with full-scale power converter**

This configuration corresponds to the direct-in-line full variable speed controlled wind turbine, with the generator connected to the electric grid through a full-scale power converter. A synchronous generator is used to produce variable frequency AC power. The power converter connected in series (or in-line) with the wind turbine generator transforms this variable frequency AC power into fixed-frequency AC power.

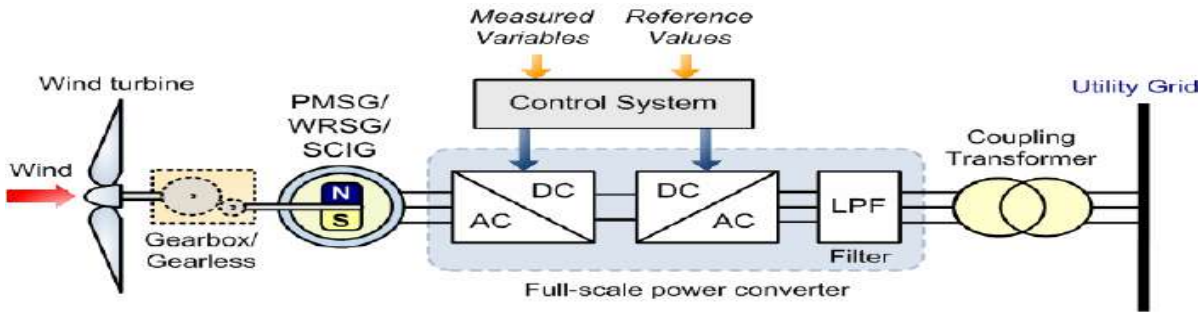



**Figure I.10:** Type D wind turbine. [7]

## I.2.4 Geothermal energy

The principle of geothermal energy is to extract the energy contained in the soil and use it in the form of heating or electricity. Everywhere, the temperature grows from the surface to the inside of the Earth. Depending on the region, the increase in temperature with depth is more or less strong, and varies from 3°C per 100 m on average to 15°C or even 30°C. This heat is mainly produced by the natural radioactivity of the rocks that make up the Earth's crust. It also comes, for a small part, from thermal exchanges with the internal zones of the Earth whose temperatures range from 1000°C to 4300°C. However, the extraction of this heat is only possible when the geological formations that constitute the sub-soil is porous or permeable and contains aquifers (groundwater containing water or water vapor). There are four types of geothermal: high, medium, low and very low energy. [3]

### a- High-energy and medium-energy geothermal energy

Geothermal resources of high energy (> 180°C) and medium energy (temperature between 100°C and 180°C) are heated as electricity.

### b- Low-energy geothermal energy

Low-energy geothermal energy (temperatures between 30°C and 100°C) can cover a wide range of uses: district heating, greenhouse heating, use of heat in industrial processes, thermalism.... Compared to other renewable energies, geothermal energy has the advantage of not depending on atmospheric conditions (sun, rain, wind), or even on the availability of a substrate, as is the case with biomass. It is therefore a reliable and stable energy over time. However, it is not a question of an inexhaustible energy in the sense that a well will one day see its calorific reservoir diminish. If geothermal facilities are technologically advanced and the energy they take is free, the cost of geothermal facilities remains, in some cases, very high. [3]

### c- Very low energy geothermal energy: heat pumps:

The principle of heat pumps (PAC) which use the heat contained in the ground to feed a heating floor has been known for about twenty years, it has undergone notable technical developments that allow it to compete today with the means of heating "Traditional". However, a significant part of the energy supplied by a PAC is of electrical origin. The technique of using ACCs is based on buried

sensors consisting of a network of tubes in which circulates a coolant: HCFC-type refrigerant derived from Freon, or glycol water.

To restore this heat in the heating floor of the house several solutions exist. The most common is to use a «transfer module» including the compressor, one or two exchangers... The recommended catchment area varies between 1.5 and 3.5 the heated surface of the house. A PAC can be reversible and allow the floor to become refreshing in summer. For every 1 kWh of electricity consumed, a heat pump produces an average of 2 to 4 kWh of heat. A PAC is therefore a softened form of electric heating. The two main qualities of this heating mode are related to the mode of heat diffusion by low temperature heating floor, and to the share of free energy used (qualities found in Direct Solar Floors). On the other hand, early frost problems can occur on certain types of terrain for buried sensors at shallow depths, as well as summer drying if the refresh function is used. In addition, refrigerants are harmful to the ozone layer (some of them are prohibited). [3]

### I.2.5 Hydroelectric power

Photo of water spilling at dam hydroelectric power, or hydroelectricity, is generated by the force of falling water. (Hydro comes from the Greek word for water.) It's one of the cleanest sources of energy, and it's also the most reliable and costs the least.

#### a- The work of hydropower

The hydrologic cycle–water constantly moves through a vast global cycle, in which it evaporates from lakes and oceans, forms clouds, precipitates as rain or snow, then flows back to the ocean. The energy of this water cycle, which is driven by the sun, is tapped most efficiently with hydropower [8].

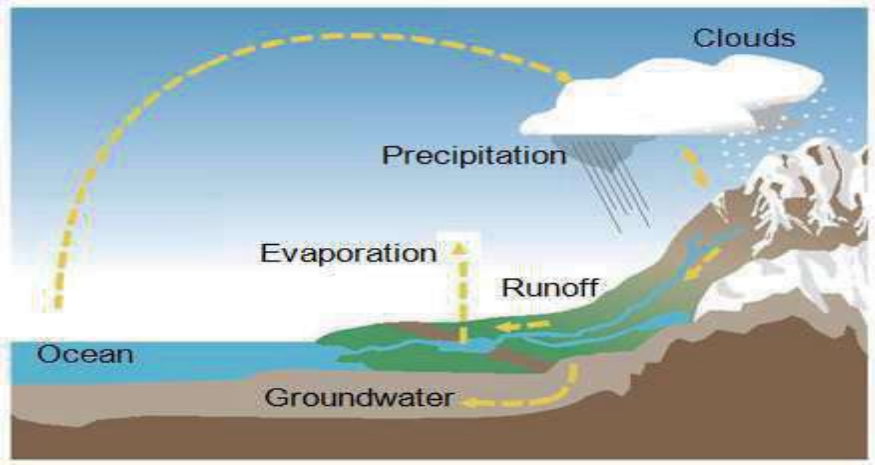



**Figure I. 11:** Water Cycle [9].

**b- Types of Hydropower Facilities**

- **Impoundment hydropower**

Use a dam to store water. Water may be released either to meet changing electricity needs or to maintain a constant reservoir level. Pumped storage–pumps water from a lower reservoir to an upper reservoir at times when demand for electricity is low [8]. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

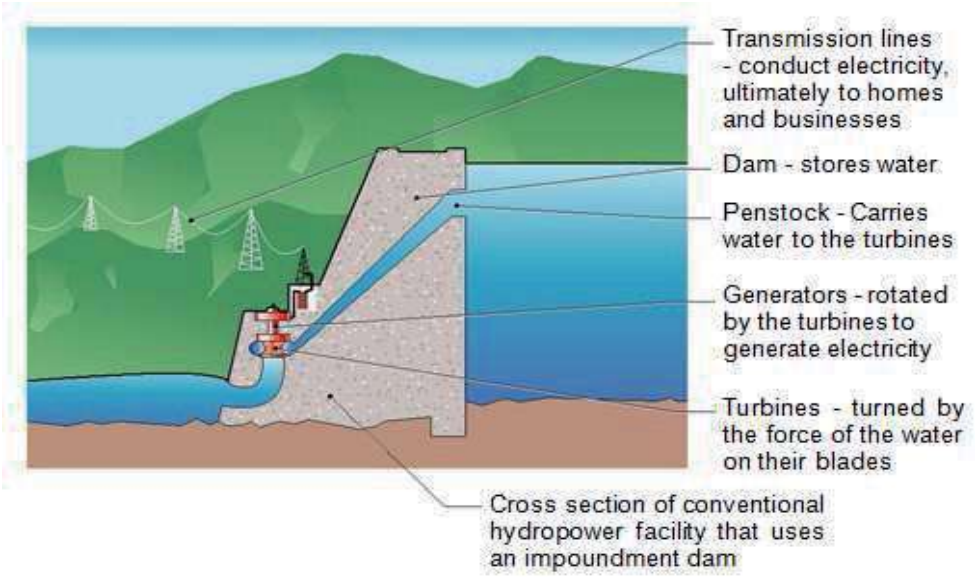



**Figure I.12:** Tidal Power [9].

## I.3 Differences between Renewable and Non-renewable Resources

Form what we sow from renewable and non-renewable energies and what I've read and study this are some of the differences between renewable and non-renewable resources:

**Table I.1:** Differences between Renewable and Non-renewable Resources.

| Renewable Resources | Non-renewable Resources |
|---|---|
| Depletion | |
| Renewable resource cannot be depleted over time | Non-renewable resources deplete over time |
| Sources | |
| Renewable resources include sunlight, water,wind and also geothermal sources such as hot springs and fumaroles | Non-renewable energy includes fossil fuels such as coal and oil and naturel gas |

| Environmental Impact | |
|---|---|
| Most renewable resources have low carbon emissions and low carbon footprint | emissions and low carbon footprint Non-renewable energy has a comparatively higher carbon footprint and carbon emissions |
| Cost | |
| The upfront cost of renewable energy is high, for instance, Generating electricity using technologies running on renewable energy is costlier than generating it with fossil fuels | Non-renewable energy has a comparatively lower upfront cost. |
| Infrastructure Requirements | |
| Infrastructure for harvesting renewable energy is prohibitively expensive and not easily accessible in most countries. | Cost-effective and accessible infrastructure is available for non-renewable energy across most countries |
| Area Requirements | |
| Requires a large land/ offshore area, especially for wind farms and solar farm | Comparatively lower area requirements |

## Conclusion:

From this chapter we sow renewable energy and non-renewable energy we conclude non-renewable energy sources run out upon consumption and additional resources are required for their regeneration. Accordingly, they have an important environmental impact and contribute to pollution. In fact, the production of non-renewable energy releases waste consisting of carbon dioxide and toxic gases into the atmosphere, and not all energy produced from renewable sources is sustainable: in fact, not all of them are produced with zero impact. By way of example, producing energy from biomass might require burning wood or pellets, thus producing gaseous particles that disperse into the environment and contribute to pollution. And we sow in the table I.1 some of the differences of the both energies.

## Introduction

Generating solar electricity has long since been a utopia. From solar roofs with a power of a few kilowatts to power stations of a few megawatts, all these installations contribute to an environmentally friendly energy supply and, thanks to their flexibility, have enormous potential for the energy sector. Also with solar thermal power plants, it is possible to use the energy of the sun on an industrial scale for the production of electricity (thanks to the transformation of solar radiation into heat).

In this second chapter, we will first approach some essential notions on the solar field. Namely the equatorial and terrestrial coordinates. We will then describe solar radiation and its composition.

## II.1 the main source the Sun

The sun is the only star of our solar system located at its center. The earth and other planets orbit the sun. Energy from the sun in the form of solar radiation supports almost all life on earth via photosynthesis and drives the earth's climate and weather. The sun is a pseudo-spherical star with a diameter of 1391000 km. The sun is composed of gaseous matter, essentially hydrogen and helium [12]

This table presents the main characteristics of the sun:

**Table II.1:** The main characteristics of the sun [12]

| | |
|---|---|
| **Diameter (km)** | 1392000 |
| **Mass (kg)** | $10^{30}$ |
| **Surface ($km^2$)** | $6.09*10^2$ |
| **Volume ($km^3$)** | $1.41*10^{18}$ |
| **Average density ($kg/m^3$)** | 1408 |
| **Speed (km/s)** | 217 |
| **Distance from the center of the Milky Way (km)** | $2.5*10^{18}$ |

## II.2 The orbital motion of the Earth

The earth moves around the sun on a plane called the eclipse plane. The axis of the poles, around which the Earth rotates, is not perpendicular to the plane of the ecliptic. The earth's center of gravity describes an ellipse where the sun occupies one of the focal points (figure II.1).

The earth rotates on itself about the axis of the poles and the equatorial plane, perpendicular to this axis. Thus, the rotation and inclination of the earth also means that the energy available at a given point varies with latitude, time and season. It rotates around the sun in 365 days 5h 48 min 40s ≈ 365.25 days. [13]

The earth rotates at an average speed of 29.77 Km/s (maximum speed in winter 30.27 Km/s and minimum speed in summer 29.77 Km/s). This movement takes place in the trigonometric direction and causes the cycle of the seasons. [13]

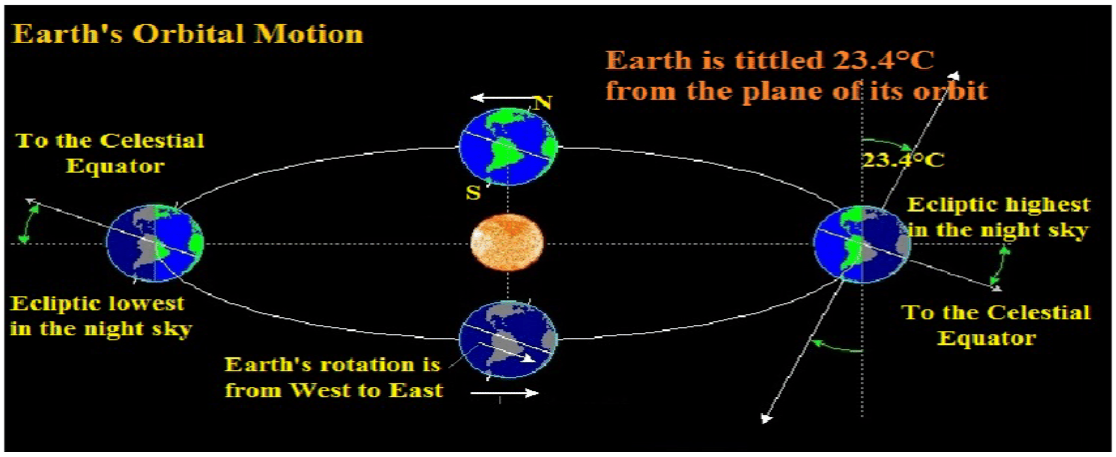



**Figure II.1:** The orbital motion of the Earth. [22]

## II.3 Apparent trajectory of the sun

For an observer located on the surface of the earth, the sun describes an apparent trajectory that depends on the latitude and longitude of its location, see figure II.2.

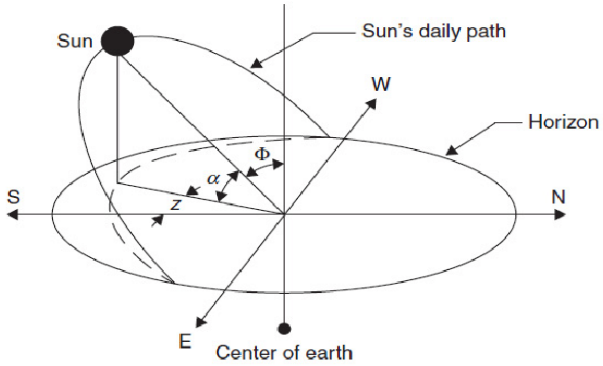



**Figure II.2:** Apparent daily path of the sun across the sky [17].

## II.4 Sun coordinates

For a given place, the position of the sun is spotted at every moment of the day and the year by two different coordinate systems. [13]

- Relative to the equatorial plane of the earth (equatorial reference).
- Relation to the horizontal plane of the location (horizontal reference).

## II.4.1 Equatorial coordinates

The movement of the sun is marked with two angles with respect to the equatorial plane of the earth.

**a- Solar declination (δ)**

It is the angle that the direction of the sun makes with its projection on the equatorial plane. The declination of the sun varies daily according to the relationship: [13]

$$\delta = 23{,}45 \times \sin\left[\frac{360}{365}(J - 80)\right] \qquad \text{(II.1)}$$

Or more precisely:

$$\delta = ArcSin\left[0.389 \times Sin\left[\frac{360}{365}(J - 82) + 2 \times Sin\frac{360}{365}(J - 2)\right]\right] \qquad \text{(II.2)}$$

With:

J: the number of the day of the year counted from January 1, that is to say, varies from 1 to 365 or 366 depending on the year.

The variation of the declination of the sun during the year is represented by figure II.3.

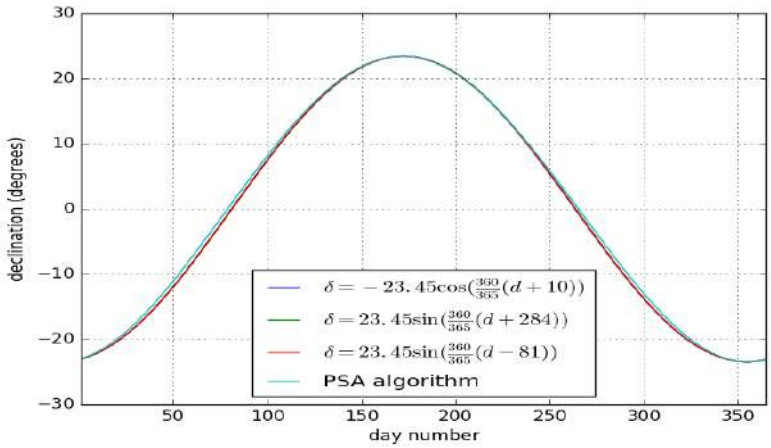



**Figure II.3**: Declination of the sun according to the number of the day of the year. [16]

δ: varies between two extreme values: $-\delta_0 < \delta < +\delta_0$ with $\delta_0$ =23.45°.

The equinoxes represent the two dates of the year when the sun crosses the equatorial plane, the fall equinox on September 23, marking the beginning of the fall in the duration of the day, and the spring equinox on March 21, marking the beginning of the increase in the duration of the day. [13]

δ=23.45°: at the Summer Solstice (S.S) (on June 21), we observe that the sun is at its highest point in the sky. It marks the beginning of summer in the northern hemisphere.

δ=-23.45°: at the Winter Solstice (W.S) (on December 21).

**b- Hourly Sun Angle H**

It is the angle made by the projection of the direction of the sun with the direction of the meridian of the place, the hour angle of the sun varies at each moment of the day according to the relationship: [13]

$$H = 15\,(TSV - 12) \qquad \text{(II.3)}$$

with:

$$TSV = TL - TU + \left(\frac{\Delta t + \Delta\lambda}{60}\right) TL - \left(TU - \frac{\lambda}{15}\right) + \frac{\Delta t}{60} \qquad \text{(II.4)}$$

$$\Delta t = 9{,}8 \times Sin2\left(\frac{360}{365}(J - 81) - 7{,}35\ Cos\left(\frac{360}{365}(J - 81)\right) - 1{,}5 \times Sin\left(\frac{360}{365}(J - 81)\right)\right)$$

TU: Universal Time: is the time difference from the Greenwich meridian. For Algeria: TU= +1.

TL: Legal time: time given by a watch.

Δt: correction of the equation of time.

λ: Longitude of the place.

H>0: afternoon.

H<0: in the morning.

H=0: noon TSV.

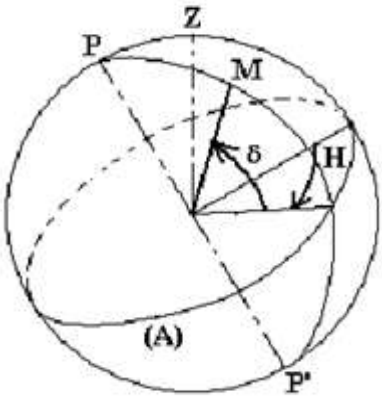



**Figure II.4:** Modifies the hour angle according to the true solar time. [20]

**c- Horizontal coordinates of the sun:**

The position of the sun at a considered moment is given by the azimuth of the sun a and its elevation h.

- **Azimuth (a):**

It is the angle between the projection of the direction of the sun on the horizontal plane and the direction of the South. The azimuth of the sun varies at each moment of the day according to the relation: [13]

$$\text{Sin } \alpha = \frac{\text{Cos } \delta \times \text{Sin H}}{\text{Cos h}} \qquad \text{(II.5)}$$

a: varies between -180° and 180°

We take:

- a > 0 : to the west.
- a< 0: to the east.
- a = 0:direction to the south.

- **Height (h):**

It is the angle formed by the direction of the sun and its projection on the horizontal plane. The height of the sun varies at every moment of the day and year according to the following relation: [13]

$$Sin\text{h} = Cos\delta \times Cos\varphi \times CosH + Sin\varphi \times \quad \text{(II.6)}$$

The height of the sun varies between -90° and +90°.

- h = 0 at sunrise and sunset.
- h > 0 during the day.
- h< 0 at night.

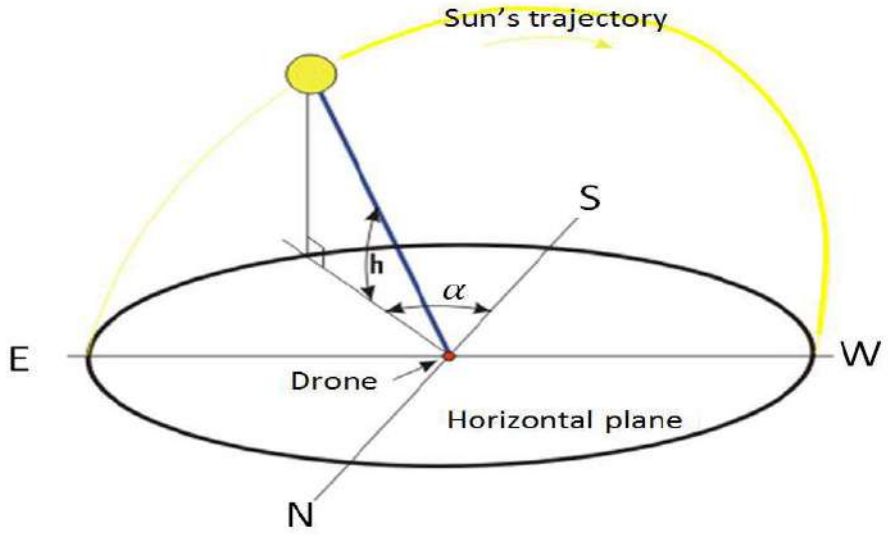



**Figure II.5:** Horizontal coordinates of the sun: azimuth (α) and elevation (h) [24].

## II.5 Earth coordinates

Any point on the Earth's surface can be identified by its geographical coordinates: longitude, latitude, and altitude, see figure II.6.

### II.6.1 Longitude

The longitude (λ) of a place corresponds to the angle formed by two meridian planes (passing through the axis of the poles), one being taken as the origin (Greenwich meridian 0°) and the other determined by the intended place.

The longitude of a place can be between -180 and 180°. Any deviation of 1° in longitude corresponds to a deviation of 4 minutes in time. [13]

The sign (+) is assigned to the meridians located to the east of this meridian, and the sign (-) to the meridians located to the west.

### II.5.2 Altitude

The altitude of a point is the vertical distance in meters from that point to a theoretical reference surface (mean sea level). [13]

### II.5.3 Latitude

The angle (φ) of latitude is the angle between a line drawn from a point on the surface of the earth to the center of the latter, and the equatorial circle of the earth. The intersection of the equatorial circle with the surface of the earth forms the equator and is indicated as latitude 0°, the North Pole as latitude +90° and the South Pole as latitude -90°.

By convention, the sign (-) is assigned to all places in the northern hemisphere and the sign (-) to all places in the southern hemisphere. The latitude of a location Can be between -90° and +90°.

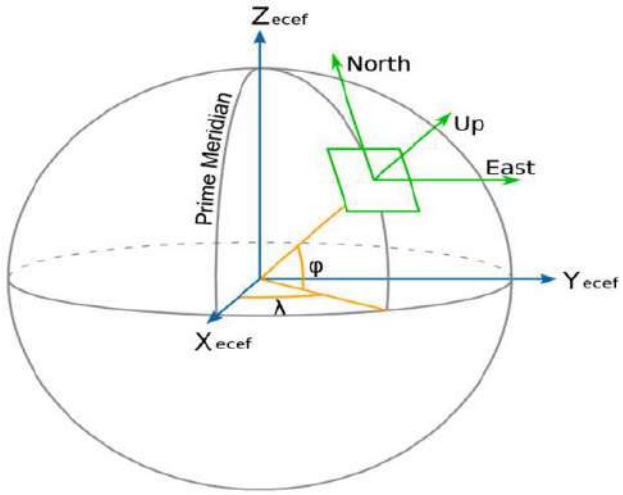



**Figure II.6:** Earth coordinates [18].

## II.6 Orientation and tilt of a surface

### II.6.1 Azimuth α:

This is the angle made by the projection of the sun on the horizontal plane with the direction of the South and it designates the orientation of the surface in such a way that:

α = -90° for an East orientation.

α = 0 for a South orientation.

α = 90° for a West orientation.

α = 180° for a North orientation.

### II.6.2 Angle of inclination β:

This is the angle that the surface makes with the horizontal plane. The inclination of the surface is designated by variable b, chosen in such a way that:

β = 0 for a horizontal surface

β = 90° for a vertical plane

β = 180° for a horizontal plane facing downwards.

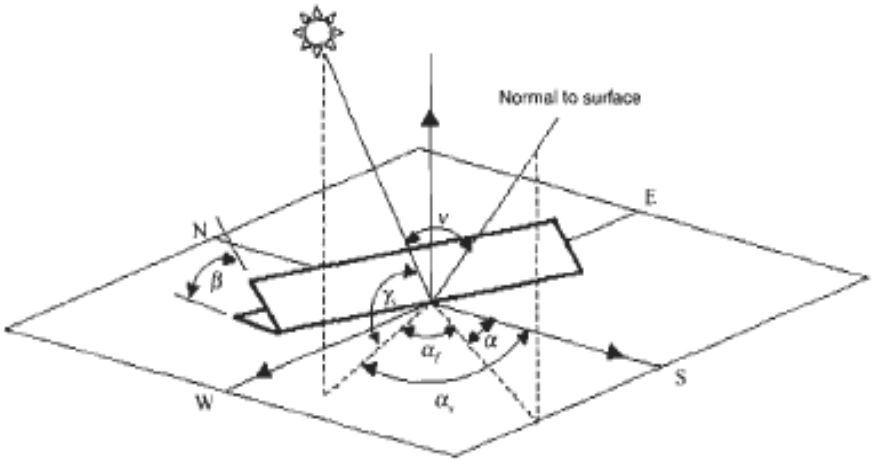



**Figure II.7:** Orientation and tilt of a surface [13]

## II.7 solar radiation

### II.7.1 Spectral distribution of solar radiation

Solar radiation consists of photons with wavelengths ranging from ultraviolet (0.2 μm) to far infrared (2.5 μm).The energy associated with this solar radiation breaks down approximately:

– 9% in the ultraviolet band (<0.4 μm),

– 47% in the visible band (0.4 to 0.8 μm),

– 44% in infrared band (>0.8 μm).

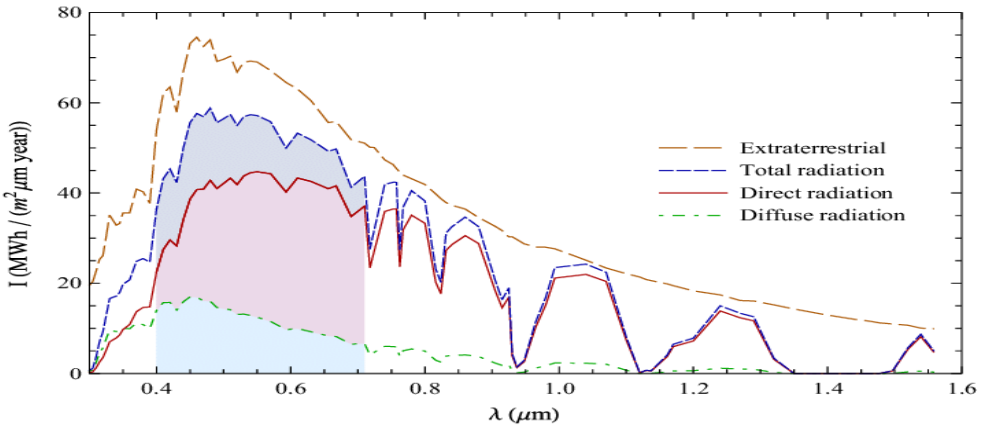



**Figure II.8:** General characteristics of solar radiation outside the atmosphere and at the earth's surface [23].

Table II.2 shows the characteristic energy values of the photographs for various wavelengths, as well as the zones corresponding to the light spectrum [14].

**Table II.2:** Energy values of solar spectrum photos. [14]

| $\lambda\ (\mu m)$ | $E_{ph}$ | zone |
|---|---|---|
| 0.2 | 6.2 | Ultraviolet |
| 0.4 | 3.1 | Visible blue |
| 0.5 | 2.48 | Visible yellow-green |
| 0.78 | 1.59 | Visible red |
| 1 | 1.24 | Infrared |
| 2 | 0.62 | Infrared |
| 4 | 0.31 | Infrared |

Solar energy collectors must therefore be compatible with these wavelengths in order to be able to trap the photos and return them in the form of heat or electrons.

For solar radiation to produce an electric current in a given material, then acting as a sensor, the photons must first be absorbed by one or more materials sensitive to the wavelength of the photons, which are then collected in order to constitute a global electrical current. [16]

### II.7.2 solar constant

The solar energy received per unit time at the upper limit of the atmosphere on a unit surface perpendicular to the solar rays and for an Earth-Solar distance equal to its average value, is called the solar constant. The solar constant was estimated at 1367 W/m$^2$ by Claus Fröhlich and Christoph Wehrli of the World Radiometric Center in Davos (Switzerland).

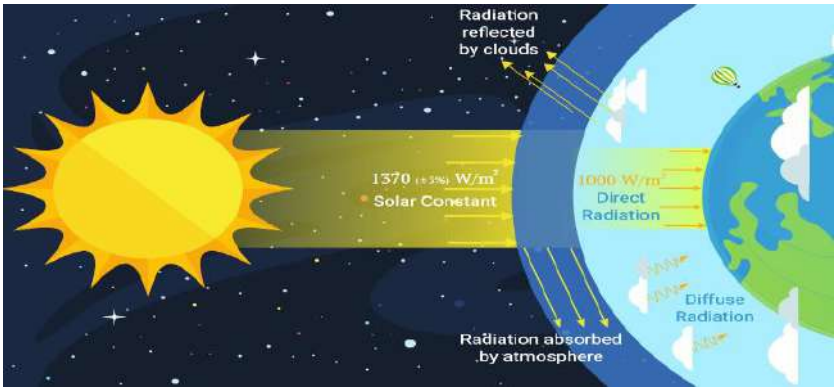



**Figure II.9:** Solar constant [25].

### II.7.3 air mass

We call air mass, the ratio between the thickness of the atmosphere crossed by the direct radiation to reach the ground and the thickness crossed vertically of the place.

Using points O, A and M and angle h, the length of the path of the sun through the atmosphere:

$$OM = \frac{OA}{\sin h} \quad \text{(II.7)}$$

So, air mass:

$$\frac{OM}{OA} = \frac{1}{\sin h} \quad \text{(II.8)}$$

For any site:

$$AMX = \frac{1}{\sin(h)} \times \frac{p}{1013} \quad \text{(II.9)}$$

p: atmospheric pressure of the site under consideration (mb)

And we say that we have AM1 conditions when the sun is at its zenith, AM2 when we have an inclination of 30°.

Out of the atmosphere at high altitude, we're in AM0.

The curves below figure II.11 represent the solar spectrum for various Air Mass values, noted AM. The index after AM represents the number of atmosphere crossed, AM0 therefore is the solar spectrum outside the atmosphere, and AM2 is the solar spectrum having crossed 2 layers of atmosphere (height of 30° of the sun above the horizon).

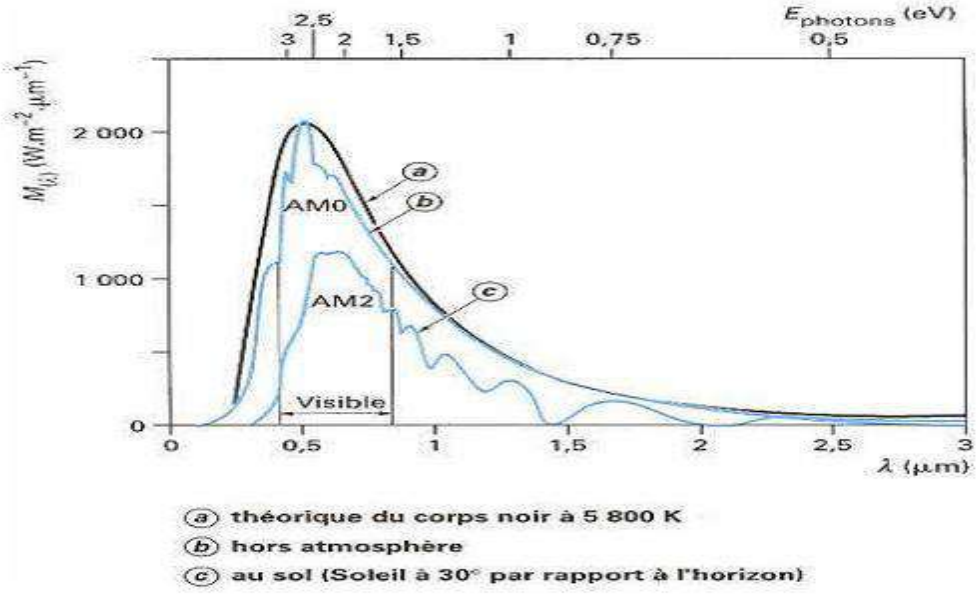



**Figure II.10:** Solar spectrum according to different values, Air Mass. [15]

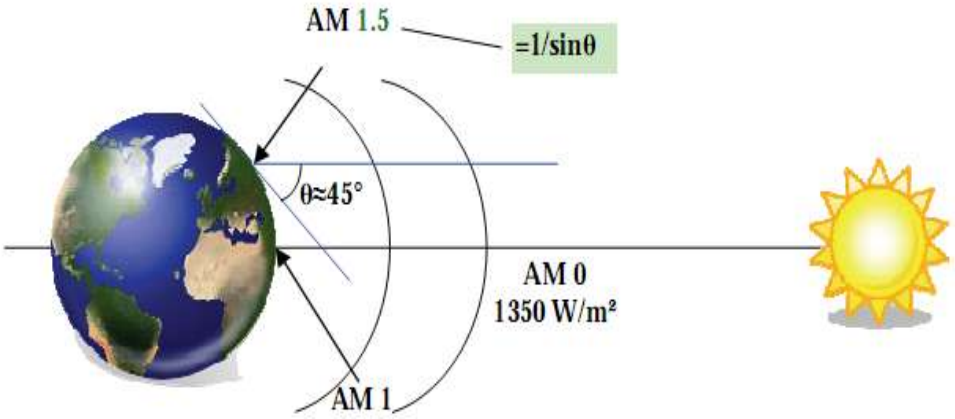



**Figure II.11:** Standards for measuring the spectrum of light energy emitted by the sun, concept of the AM convention. [23]

It is important to understand the two aspects covered by the concept of air mass number. On the one hand, it characterizes the power transported by solar radiation (1367 /m$^2$) for AM0, 833 W/m$^2$ for

AM1, 5) and on the other hand, it is used to define a reference spectrum to calibrate the standard cells intended to qualify the performance of photovoltaic devices. Thus the standard qualification conditions for the cells are an AM1.5 spectrum, an incident power of 1000 W/m$^2$ and a temperature of 25°C.

Unless otherwise stated, it is for such conditions that the performance and specifications of a given photovoltaic device must be provided.

### II.7.4 Sunshine duration

The duration of sunshine corresponds to the number of hours during the day, between sunrise and sunset, when it is clearly visible. The survey is made using the Campbell-Stokes heliograph in which a crystal sphere concentrates the sun's rays on a paper which it burns as it moves. Thus, only the moments when the sun is clearly visible are recorded; we then speak of real or effective sunshine duration and depend on whether the rising sun is visible from the observation point or hidden by clouds.

In the absence of the heliograph, it is possible from the calculation of the relative astronomical movement of the sun and the earth to evaluate the theoretical duration of the day; that is to say, the one that there would be if the clouds did not hide the sun. This duration is calculated according to the latitude of the site and the apparent declination which itself depends on the period of the year considered. [26]

### II.7.5 Composition of solar radiation

Following the attenuation of the solar radiation by the various atmospheric phenomena, the solar radiation on a surface on the ground is composed as follows:

**a- Direct radiation**

It is the fraction of solar radiation that arrives directly at the ground, whose path is "linear" (there are, in fact, slight deviations) and unique at a given moment. If it is direct radiation. [21]

In the case of a horizontal plane, the radiation is written:

$$I_h = I \times Sin\text{h} \qquad \text{(II.10)}$$

With: h the height of the sun.

**b- Diffuse radiation**

Diffuse radiation is radiation from the entire celestial vault. This radiation is due to the absorption and diffusion of part of the solar radiation by the atmosphere and its reflection by the clouds. Thus, in a

serene sky, it constitutes 20% of the total energy. In an overcast sky, it corresponds to the totality of the energy received on the ground. [13]

**c- Reflected radiation (Albedo)**

Reflected solar radiation is radiation that is reflected from the ground or objects on its surface. This radiation depends on the albedo of the soil and can be important when the soil is particularly reflective (water, snow).

$$Albedo\ ALB = \frac{reflected\ energy}{received\ energy} \quad \text{(II.11)}$$

There are some albedo values according to the soil surface.

**Table II.3:** Some albedo values [13].

| Soil surface | Albedo |
|---|---|
| Water surface | 0.01 to 0.1 |
| Forest | 0.05 to 0.2 |
| cultivated soil | 0.07 to 0.14 |
| stones and rocks | 0.15 to 0.25 |
| Fields and meadows | 0.1 à to.3 |
| Zero soil | 0.15 to 0.4 |
| old snow | 0.5 to 0.7 |
| fresh snow | 0.8 to 0.95 |

**d- Global radiation**

- **Horizontal surface**

It is the whole of the solar radiation that reaches a horizontal surface on the Earth's globe. It therefore includes the vertical component of direct solar radiation and diffuse solar radiation. [21]

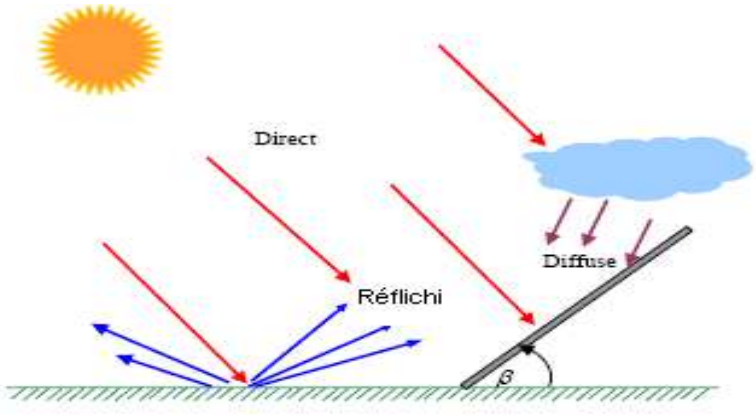



**Figure II.12:** The three components of global solar radiation on an inclined plane. [13]

- **An inclined surface:**

Global radiation on an inclined surface is the sum of the radiation: Direct, Diffuse and Reflected

### II.8 Nomenclature of the various radiation measuring instruments:

**e- Pyrradiometer**

Instrument for measuring total radiation reaching a surface from a 2π steriadian solid angle; it is mainly used for measuring total descending radiation, the sum of solar and atmospheric radiation directed towards the ground.

**f- Pyranometer**

An instrument for measuring global G radiation reaching a flat surface from a solid 2π steriadian angle; when equipped with a sun visor, it can measure diffuse D radiation.

**g- Pyrheliometer**

Instrument measuring direct solar radiation I, the device can be oriented so that its receiving surface is normal to the sun's rays**.**

**h- Differential pyrradiometer or bilanmeter**

Measures the total radiation balance, the difference between the total downward radiation and the total upward radiation (solar and atmospheric radiation reflected back to space).

**i- Heliograph**

Instrument for measuring and recording the duration of insolation.

## Conclusion

In this chapter, we have presented the main source of solar energy and the orbital motion the we described the important concepts on solar irradiation such as terrestrial and hourly coordinates, and finally, the composition of solar radiation.The advantage of a rigorous exploitation of the solar field lies in the precise orientation of any sensor on earth.

## Introduction

At the global level, the market for photovoltaic systems has been experiencing for more than 10 years, a very high growth rate, of the order of 30 to 40% per year. [27] This exceptional growth, mainly due to photovoltaic systems connected to the electricity distribution network, Of course, this is reflected in technological innovations and lower costs for photovoltaic modules, but also in major research and development efforts in the field of power electronics. This chapter focuses on the study of photovoltaic systems connected to the grid. First, the operating principle of the latter and the PV systems for habitat will be discussed. Then, the main components of a PV system connected to the network will be detailed. Then, the study of the main photovoltaic systems connected to the network will show the presence of two classes of systems: direct-connected systems and intermediate continuous bus systems. These systems operate with one or more power converters. These converters allow the connection to the network and extract the maximum power from the photovoltaic panels thanks to the MPPT (Maximum Power Point Tracking) algorithm. Finally, the photovoltaic energy produced by the PV generator will be injected totally or only the surplus on the network.

## III.1 Principle of operation of a photovoltaic installation

A photovoltaic installation consists of solar modules, themselves made up of photovoltaic cells, usually based on silicon.

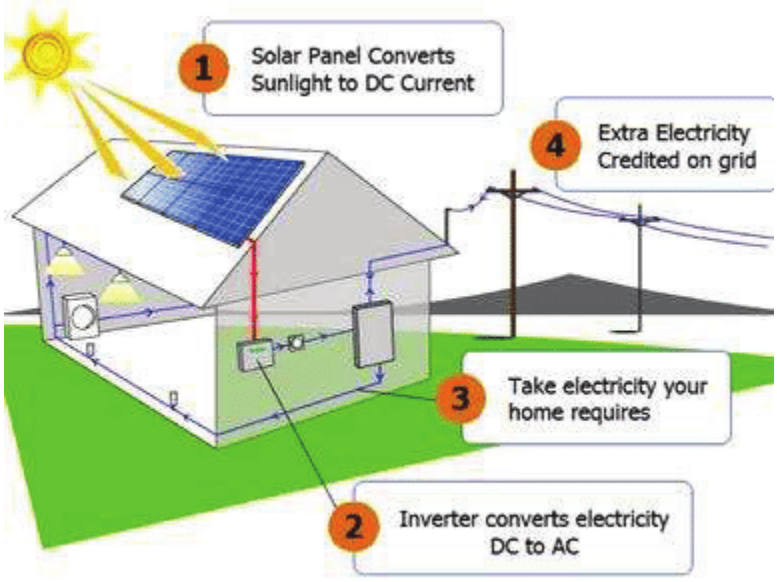



**Figure III.1:** Grid-connected PV system. [29]

These generators convert solar energy directly into electricity (direct current). The power is expressed in Watt-peak (Wc), the unit that defines the electrical power available at the terminals of the generator in the optimal sunlight conditions. One or more inverters convert the direct current produced into alternating current at 50 Hz and 220 V. Depending on the choice chosen, all or part of the production is injected into the public network, and the rest is consumed by the producer. Where photovoltaic production is insufficient, the grid provides the necessary electricity, see Figure III.1.

## III.2 Photovoltaic systems for housing

PV systems are classified into two broad categories depending on how the energy is used. [30]

### III.2.1 stand-alone

The role of stand-alone systems is to power one or more consumers located in an isolated area of the electricity grid. As noted in figure III.2, an example of a stand-alone PV system, a storage system is associated with the PV generator to provide power at each time and for several days despite intermittent production.

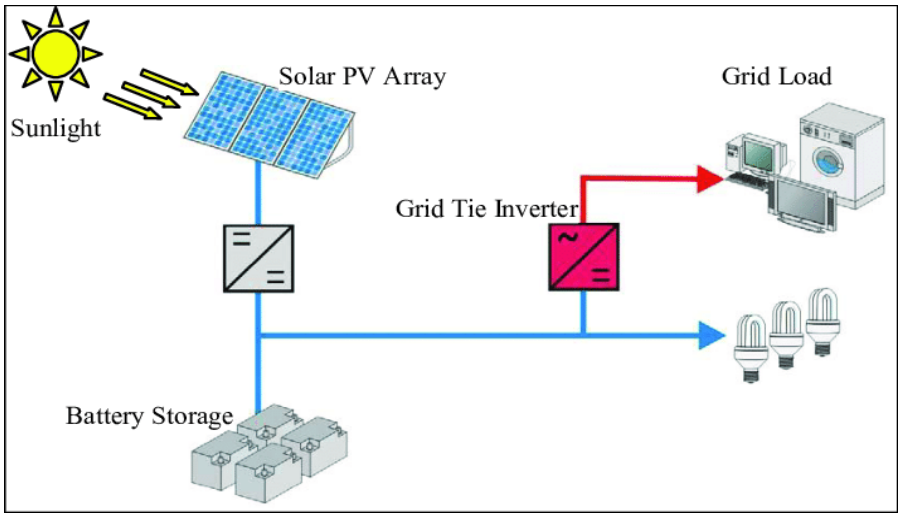



**Figure III.2:** Stand-alone PV system. [31]

### III.2.2 Grid-connected

Such a system is installed on a site connected to the network (Sonelgaz in Algeria). Generally on homes or businesses that wish to use a form of renewable energy and that benefit from good sunlight, see figure III.1.

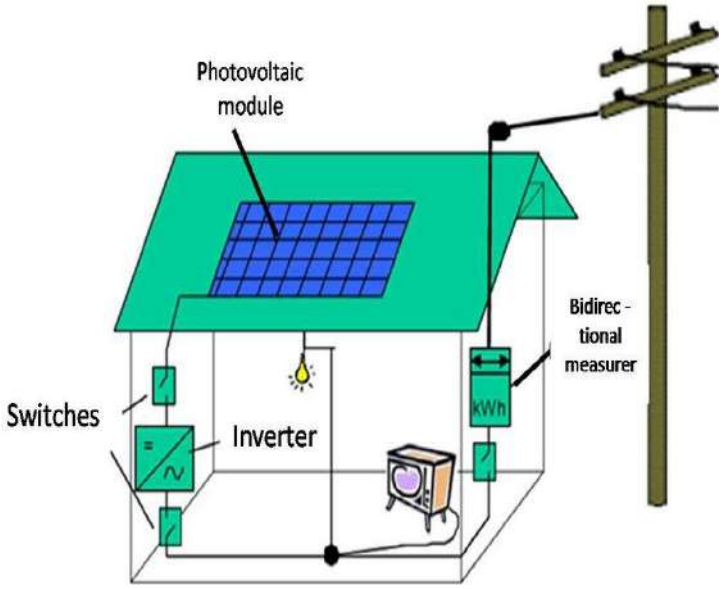



**Figure III.3:** PV system. [32]

The huge benefit of this system is that, we don't have a battery. We don't store it any more. We put it directly into the local or national grid. And this without quantitative limit, so all the energy is recovered. There is a meter that runs in one direction for consumption, and another in the other direction for production. However, it is still necessary to convert the direct current of the panels into AC through an inverter and it must be approved by the electricity company that will receive this current. Because it must meet standards on its «sinusoidal» quality. These systems are not backup power supplies in the event of a power outage, as there is no energy reserve. In some cases, a backup battery is added to the system for short-term outage.

- **Advantages**

Compared to a stand-alone system, we gain on the following points:

- ❖ Exploitation of all photovoltaic energy from panels (storage is «infinite»).
- ❖ Savings of around 40% on investments (less batteries).
- ❖ Almost non-existent maintenance (it is the batteries that require the most attention).
- ❖ Better life of the system.

This solution is more cost-effective than purely independent photovoltaic power supply, but unfortunately still very expensive compared to 100% grid power supply. The energy produced by the modules is directly consumed on site by the loads. Any surplus of production in relation to consumption is injected into the network.

- **Disadvantage**

However, grid-coupled photovoltaic installations have two major disadvantages:

- ❖ The intermittency of solar energy production does not allow the control of injection periods.
- ❖ The shift between consumption and production reduces the notion of personal energy autonomy.

## III.3 Study of the components of a grid-connected photovoltaic system

A photovoltaic (PV) system connected to the grid is made up of one:

- ❖ Photovoltaic generator.
- ❖ Converter (DC/AC) to supply alternative loads.

### III.3.1 Photovoltaic generator

The photovoltaic cell or solar cell is the constituent element of photovoltaic modules. A photovoltaic panel is made up of several modules, the latter being made up of several cells in series in order to obtain a desired voltage.The operating principle of a photovoltaic cell consists in the conversion of light energy (solar) into electrical energy: it is the photovoltaic effect, one of the electrical properties of semiconductors. [33]

**a- Photovoltaic principle**

- **P-N junction**

A P-N junction is created by the contact of an N-doped semiconductor (electron donor) and a P-doped semiconductor (hole compound). The interface between these two regions is called a junction.

To make photovoltaic cells, there are three configurations of junctions:

- ❖ A PN junction (homo-junction, i.e. the two regions are made of the same semiconductor material, silicon in most cases).
- ❖ A heterojunction (junction between two different semiconductors).
- ❖ A semiconductor metal junction.

In these three configurations, the physical phenomena involved in the operationPhotovoltaic cells are similar.[33]

The electrons of the junction move towards the P region and the holes towards the N region. Only fixed ionized atoms remain. This area (called depletion) of free carriers is called the "space load area" creating an electrical field. Outside, the electric field sucks.

In a homojunction at the thermodynamic equilibrium, at the boundary of the two regions, a potential barrier (VD) (diffusion voltage) was formed during the depletion process.

$$VD = \frac{kT}{q} \ln\left(\frac{N_D N_A}{n_i^2}\right) \quad \text{(III.1)}$$

With:

$V_D$: Diffusion voltage on a junction [V].

$N_D$: Donor Concentration [cm 3]

$N_A$: Hole concentration [cm 3]

k: 1.380662.10 23C. Boltzmann constant.

q: 1.602. 10 19C. elemental load.

T: absolute crystal temperature [K].

$n_i$: Intrinsic concentration.

$VT = \frac{KT}{q} = 26\ mV$ at room temperature.

Photovoltaic solar cells are often asymmetric junctions, i.e. one doping is stronger than the other. In this case, the space charge region is practically in the most weakly doped region.

- **Electricity production**

The solar cell is where the conversion of light energy into electrical energy occurs. The electrical power resulting from this conversion depends on the flux and the spectral distribution of the spectral energy.

In a photovoltaic cell based on a PN junction a light excitation creates, around the junction, electron-hole pairs that move under the influence of the electrical field of the junction.

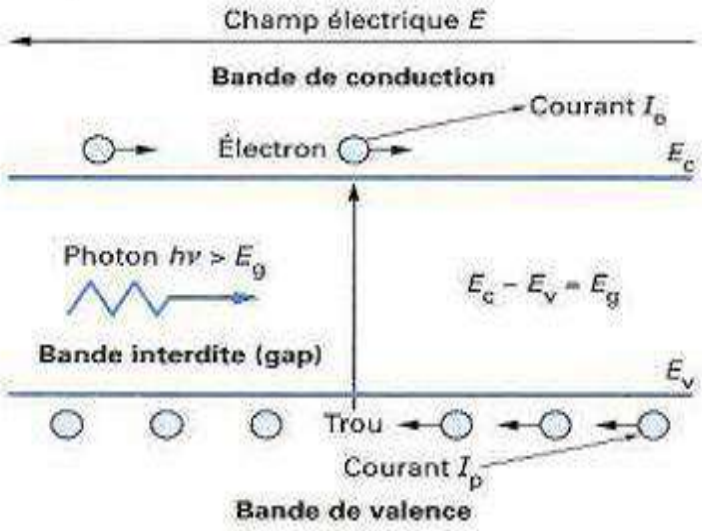



**Figure III.4:** Principle of photon-electron conversion in a system with two energy levels. [33]

- **Principle of operation of a photovoltaic cell**

The birth of a potential difference when the load carriers are created in the vicinity of the light excitation junction, allows the cell to function as an electrical generator when both sides of the cell are electrically connected to a charge, such as an R resistor.

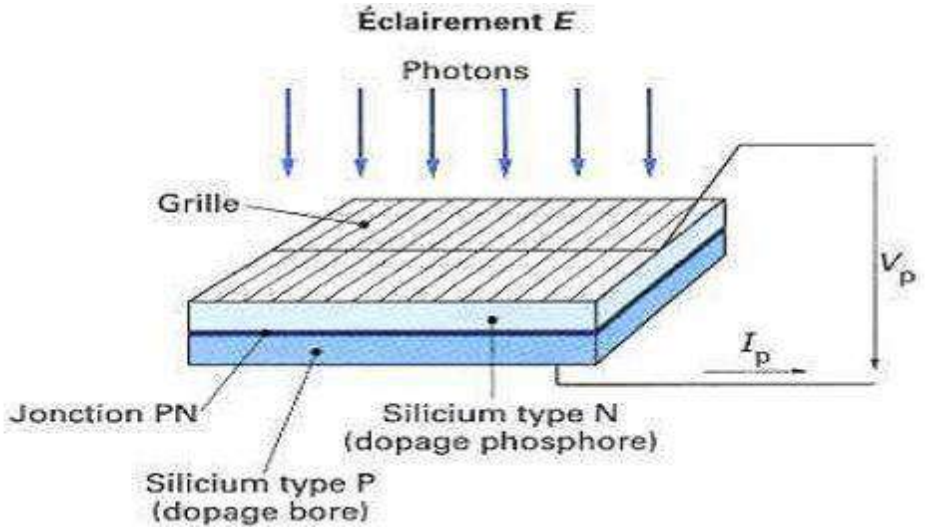



**Figure III.5:** Generation of electricity by electron-hole separation. [33]

The contacts on the illuminated side of the cell have the structure of a grid in order to obscure only a small part of the surface (5 to 10%). The back side can be entirely metallized. In order to reduce

the losses by reflection of the incident radiation, an antireflection layer uniformly covers the entire front face.

### b- Parameters of photovoltaic cells

The main parameters of photovoltaic cells are:

- **The I-V characteristic**

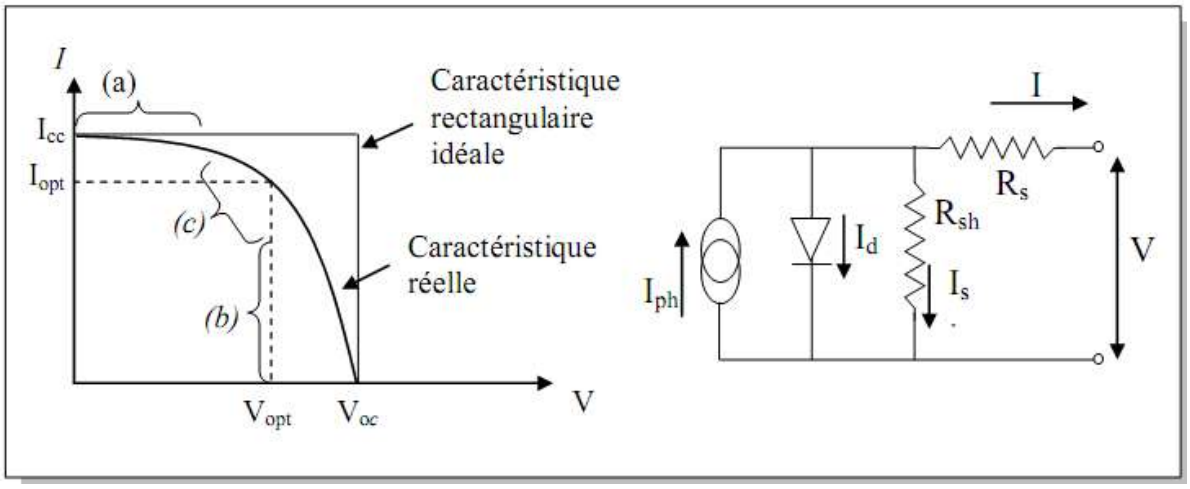



**Figure III.6:** Characteristic and equivalent diagram of a real photovoltaic cell. [33]

The feature is divided into three parts:

- ❖ The area (a) where the cell behaves as an Icc current generator proportional to the illumination,
- ❖ The area (b) where the cell behaves as a Voc voltage generator,
- ❖ The area (c) where the internal impedance of the generator varies rapidly. [34]

- **Open circuit voltage, Voc**

The open circuit voltage is obtained when the current passing through the cell is zero. It depends on the energy barrier and the shunt resistance. It decreases with temperature and varies little with light intensity. [35]

$$V_{oc} = \frac{kT}{e} \ln\left(\frac{I_{CC}}{I_S} + 1\right) \qquad \text{(III.2)}$$

- **Short circuit current, Icc**

This is the current obtained by short-circuiting the terminals of the cell (taking V=0 in the equivalent diagram). It increases linearly with the intensity of illumination of the cell and depends on the illuminated cell, the wavelength of the radiation, the mobility of the carriers and the temperature.

- **Point de fonctionnement optimum, (Vm, Im)**

When the peak power is maximum in "full sun"

$$P_m = V_m \times I_m \quad \text{(III.3)}$$

- **Conversion yield**

The efficiency η, of the PV cells designates the power conversion efficiency. It is defined as being the ratio between the ratio between the maximum power delivered by the cell and the incident light power.

$$\eta = \frac{P_m}{P_{in}} = \frac{ff \times V_{oc} \times I_{CC}}{P_{in}} \quad \text{(III.4)}$$

Pin: Incident power = P solar = 100 W/cm$^2$ [6]

The incident power density equal to Pin/A.

A: Section of the cell

This efficiency can be improved by increasing the form factor, the circuit current and the open circuit voltage.

- **Form factor, ff**

The form factor is the ratio between the optimum power Pm and the maximum power that the cell can have; it is defined by the following relationship:

$$ff = \frac{P_m}{V_{oc} \times I_{cc}} = \frac{V_m \times I_m}{V_{oc} \times I_{cc}} \quad \text{(III.5)}$$

**c- Different types of solar cells**

There are three main types of cells.

- **Monocrystalline cells**

The monocrystalline cell closest to the theoretical model: this cell is actually composed of a single crystal divided into two layers. [36]

However, there are disadvantages to these cells:

- ❖ First generation of photobatteries.
- ❖ Excellent yield of 15% and up to 24% in the lab.
- ❖ Laborious and difficult method of production, and therefore, very expensive
- ❖ It takes a lot of energy to get a pure crystal.

- **Polycrystalline cells**

Polycrystalline cells are composed of crystals. They also come from the sawing of blocks of crystals, but these blocks are cast and are therefore heterogeneous. [36]

Polycrystalline cells are characterized by:

- ❖ Lower cost of production.
- ❖ Less energy intensive process.
- ❖ Yield of 13% and up to 20% in the lab.

- **Amorphous cells**

Amorphous silicon appeared in 1976. Its atomic structure is disordered, not crystallized, but it has a coefficient of absorption higher than that of crystalline silicon.

However, what it gains in absorption power, it loses in mobility of electric charges (low conversion efficiency) [36]

- ❖ Much lower production cost.
- ❖ Yield only 6% per module and 14% in the lab.
- ❖ Works in very low light.

Thanks to the technology of new materials, cadmium telluride (CdTe), gallium arsenide (GaAs) and copper diselenide (CIS) have made it possible to obtain solar cells with yields of 38% in the laboratory.

**d- Association of photovoltaic cells**

Under standard sunlight conditions (1000 W/m$^2$; 25°C; AM 1.5), the maximum power delivered by a 150 cm2 silicon cell is approximately 2.3 Wp at a voltage of 0.5 V An elementary photovoltaic cell therefore constitutes a photovoltaic generator of low power insufficient as such for most domestic or industrial applications. The photovoltaic generators are, therefore, made by association, in series and / or in parallel, of a large number of elementary cells. [37]

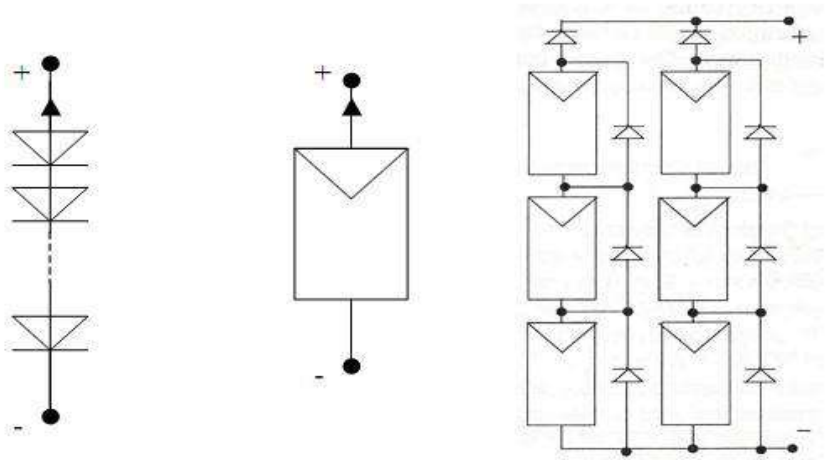


**Figure III.7:** Cell, module and photovoltaic panel (bypass diode protection). [35]

- **Serial Association**

An association of ns cells in series makes it possible to increase the voltage of the photovoltaic generator (GPV). The cells are then crossed by the same current and the resulting characteristic of the series grouping is obtained by adding the elementary voltages of each cell, figure III.8. Equation (III.6) summarizes the electrical characteristics of a series association of $n_s$cells.

$$Voc_{n_s} = n_s \times Vco \text{ And } \quad Icc = Icc_{n_s} \qquad \text{(III.6)}$$

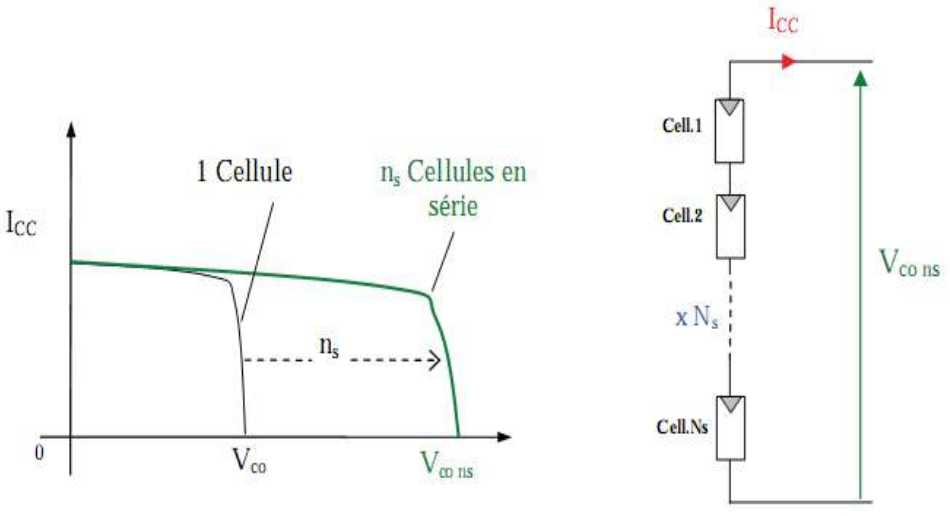



**Figure III.8:** Resulting characteristics of an array of ns cells in series. [37]

The expressions for the voltage (Tmod) and the current (Imod) of the module are:

$$V_{mod} = \sum V_{cel} \quad \text{(III.7)}$$

$$I_{mod} = \sum I_{cel} \quad \text{(III.8)}$$

Where: Vcel and Icel are respectively the voltage and current of a PV cell.

- **Parallel Association**

A parallel association of np cells is possible and increases the output current of the generator thus created.

In a group of identical cells connected in parallel, the cells are subjected to the same voltage and the resulting characteristic of the group is obtained by addition of the currents, figure (III.9). Equation (III.9) in turn summarizes the electrical characteristics of a parallel association of $n_p$ cells.

With: $Isc_{n_p} = n_p \times Isc$ and $Voc_{n_p} = Voc$ (III.9)

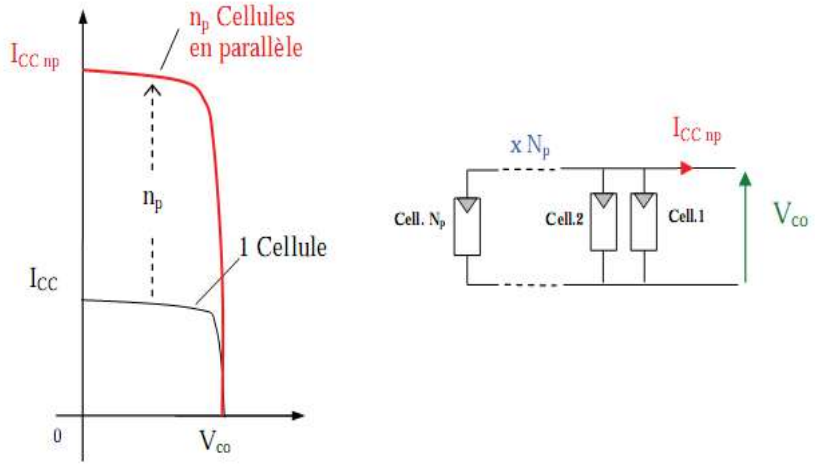



**Figure III.9:** Resulting characteristic of parallel grouping np identical cells. [37]

- **Hybrid association (series-parallel)**

According to the series and/or parallel association of these cells, see figure III.10, the values of the total short-circuit current and the total open-circuit voltage are given by the relations (III.10) and (III.11): [38].

$$I_{cc}^{t} = n_p \times I_{CC} \quad \text{(III.10)}$$

$$V_{oc}^{t} = n_s \times V_{oc} \quad \text{(III.11)}$$

The transition from a module to a panel is done by adding protective diodes, in a series to avoid inverted currents and in parallel, diode by-pass, which intervenes only in case of imbalance of a set of cells to limit the inverse voltage to the terminals of this set and minimize the associated loss of protection.

Theby-pass diode, when it starts to operate, then short-circuits part of the panel as shown in figure (III.10.b), thus avoiding the circulation of reverse currents within the defective cells. The degradation of a single cell therefore condemns the group of cells associated with the defective cell and protected by the by-pass diode to not produce power. This partial power loss phenomenon is to be compared to the total loss of an entire panel in case of a problem on a cell with a panel operating without protection. [37]

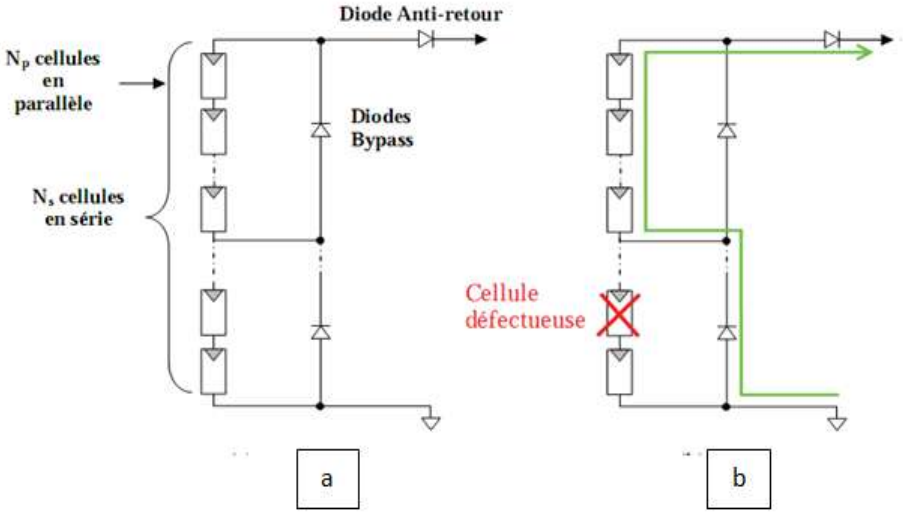



**Figure III.10:** a) - Classical architecture of a photovoltaic solar panel with protective diodes. b)- Failure of one of the PV module cells and activation of the by-pass diode and highlighting of the IPV circulation current. [37]

### III.3.2 Converter

#### a- Definition

Converters are devices used to transform the DC voltage supplied by the panels or batteries to adapt it to receivers operating either at a different DC voltage, or at an AC voltage. [39]

**b- Direct-to-direct (DC/DC) converters**

This type of component is used to transform the battery voltage into a different DC voltage to power a special device such as a mobile phone charger, radio, and laptop…..

Two types of DC/DC converters are possible: "up" converters to increase voltage and "down" converters to lower voltage.

- **Up converters (voltage step-up)**

Figure III.11 shows the typical components of an up converter. When the switch is closed, the inductor stores the current coming from the battery; when the switch opens, the interruption of the current in the inductor causes an overvoltage which is shunted into the capacitor and the receiver; the diode prevents any current return.

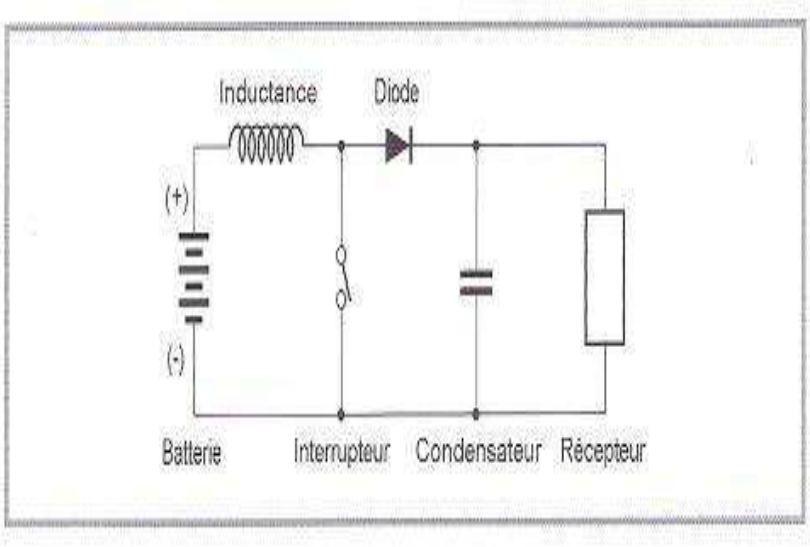



**Figure III.11:** Example of DC/DC converter upwards. [39]

The capacitor is used to smooth the output voltage and the switch is controlled by control electronics which constantly measures the output voltage and current to adjust the frequency and width of the switch drive and limits the current to a safe bet for components. Typical efficiency generally exceeds 70% and can reach 85 to 90% for the best converters. [39]

- **Down converters (step-down)**

Figure III.12 shows the typical components of a down converter. When the switch is closed, current flows from the battery to the receiver through the inductor and when the switch opens, the

voltage across the inductor reverses causing the diode to conduct which protects the switch. The control electronics control the frequency and duration of operation of the switch according to the desired voltage and the maximum possible current. The typical efficiency here is slightly higher than the previous model and generally 80 to 90% for modern devices. [39]

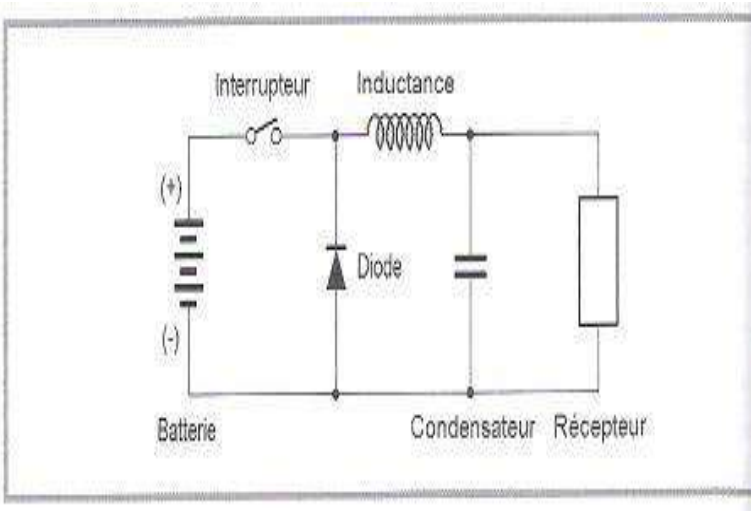



**Figure III.12:** Typical DC/DC down converter. [39]

### c- DC/AC inverters

- **Principle of operation**

An inverter is a DC/AC converter. It is used to convert photovoltaic electrical energy into alternative electrical energy either to operate loads or to deliver energy to the grid. Generally based on thyristors, depending on the operation of this inverter can be single-phase or three-phase. [27]

The figure presents an example of a simple circuit composed of a bridge of transistors controlled by PWM; the voltage inverter (single-phase or three-phase) imposes at its output a system ofvoltage in the form of pulse-width modulated slots (PWM). The alternating signal obtained is then filtered by the inductance Ld located before the transformer in order to obtain a sinusoidal alternating signal at the network frequency. This last signal is then adjusted to the network voltage by a 50Hz transformer which at the same time provides galvanic isolation to the assembly.

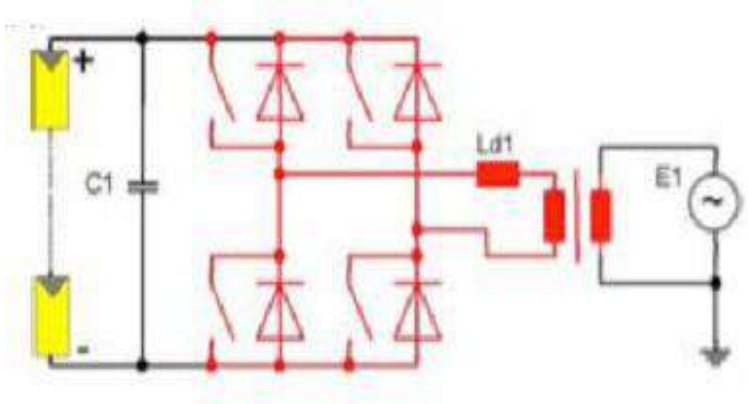



**Figure III.13:** Simple circuit using a transistor bridge. [27]

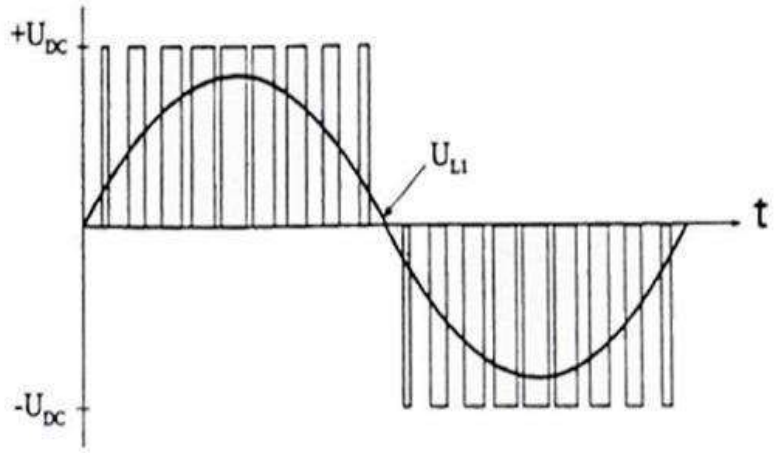



**Figure III.14:** Filtering the voltage by the output choke. [27]

- **Selection criteria for inverters**

Historically, inverters can be classified as generators producing a sine wave, a square wave or even a so-called pseudo-sine wave. The choice of the inverter will depend on the devices it will have to operate, this choice being based on criteria valid for any wave.

- **Output Voltage Accuracy**

This number is given as a percentage in relation to 230 VAC. Useful in certain uses when powering delicate electronic devices. The inverter must be stable regardless of its load and regardless of its input voltage.

- **Resistance to overloads and reactive current:**

To be able to start certain loads, the inverter must often produce several times its maximum power for a fairly short time.

- **Harmonic distortion**

In certain sensitive uses, the presence of harmonics is an audible nuisance (hi-fi) or it disturbs the operation of the load (motors). Non-sinusoidal inverters not only disturb the electromagnetic environment but the harmonics are also a loss of energy in the case of motor supply for example.

- **Yield**

This is undoubtedly the main selection criterion. We want to lose as little energy as possible between the batteries and the 230 VAC load.

We are interested in the efficiency curve according to the load of the inverter; modern high-performance devices achieve an efficiency of over 90% as soon as the load is 5 to 10% of their nominal power.

- **Consumption in standby mode**

This is very important data for inverters that work occasionally and remain permanently connected. Often in these cases the energy used by the off-load consumption is greater than that used by the receivers. To save power, modern devices use user sensing techniques to start full power as soon as a receiver is plugged into the network.

- **Input voltage**

In the case of a stand-alone system, the input voltage corresponds to the voltage of the system in place. The following method may also be used to select this voltage, depending on the demand for electricity (D):

- If D < 2 kW then Ue = 12 VCC
- if D between 2 and 5 kW then Ue = 24 or 48 VDC
- if D > 5 kW then Ue = 48 VDC and more

In the case of a grid-connected system, the input DC voltage must be higher (eg 120 VDC and more), respecting the series connection of the PV modules. [40]

### d- Grid-connected inverters

The most valuable photovoltaic applications at present are PV installations designed to power the public electricity grid.

There are different management topologies for these facilities. Nevertheless, all these approaches are based on a grid-connected GPV through inverters that transfer and shape solar electric energy. The progress made in recent years in the development of photovoltaic inverters has made it possible to greatly evolve these management systems. Inverters are no longer just about transforming continuous power (DC) generated by the solar panels in alternative power in the form of a sine voltage of desired frequency but they also exploit the power delivered by the GPV by forcing it to operate at its maximum power point. In addition, they provide reliable network monitoring to protect the network from outages and shut down power in the event of network or installation problems. Currently, there are mainly three architectures inverters giving good technical solutions: the central inverter, the string inverters (chains) and the inverters integrated in the panels (module).

- **Central inverter**

In the case of an inverter, the various solar panels for a large installation (>10kW) are mounted in rows to form a chain, itself coupled in parallel with non-return diodes to several others, figure III.15. The structured high power PV generator is connected on the DC side to a single inverter. This central inverter has high energy efficiency at reduced costs. The main function of this unit is to create an AC voltage from a DC voltage that is most compatible with the network and to continuously examine the presence or absence of the network to allow the injection of current. The conventional structure of the inverter is often a bridge circuit to connect each of the two input poles to each of the two output poles through power interceptors.

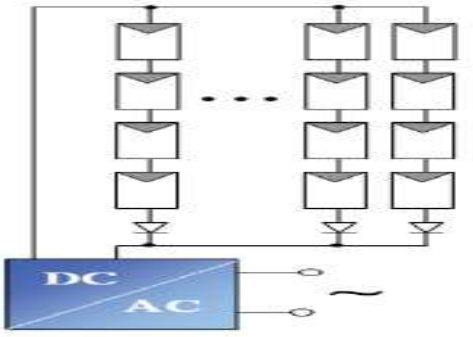



**Figure III.15:** Typology of Centralized Inverter systems. [27]

Direct coupling of PV installations with inverters without transformers is becoming more important. Indeed, they are inexpensive and offer unbeatable energy efficiency (between 95% and 97% for high power). In order to power the network, the input voltage must always exceed the peak voltage of the rectified network voltage. Either, for an effective network value of 250V, a minimum voltage source of 354V is required for be able to inject a sine current into the network. Consequently, a poorly adapted panel or partial shading damages the optimal operation of each PV chain and leads to a reduction in energy efficiency. The central inverter most often has at least one MPPT control system allowing it to operate at its maximum power point. This works perfectly as long as the panels are identical and operate under homogeneous sunlight. But when the electrical characteristics between the panels differ, due to shading, dirt, aging or stress, the MPPT control becomes uncertain and the photovoltaic field does not produce as much as it could. In addition, the reliability of the installation is limited because it depends on a single UPS. Thus, when a failure of the central inverter occurs, it causes the complete shutdown of the installation and therefore of the production.

- **Chain inverter**

As with the central inverter, the PV array here also consists of strings. Each string is however connected to an inverter, Figure III.16.

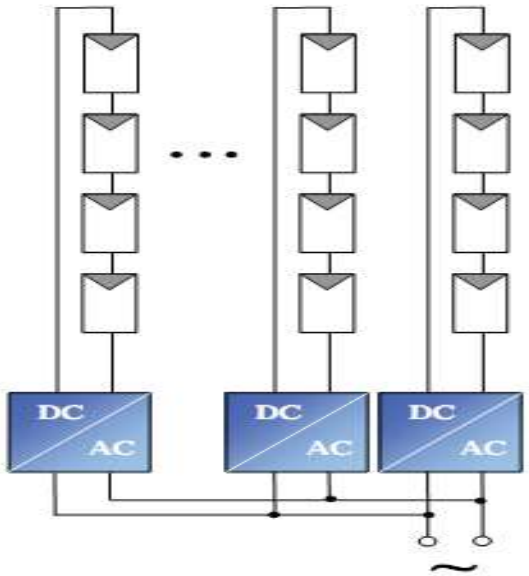



**Figure III.16:** Typology of systems Inverter String. [27]

Each string can thus operate at its maximum power point. This technology significantly reduces the risk of adaptation problems as well as losses due to shading effects, while eliminating those caused by non-return diodes and extended wiring to the DC generator. These advantageous properties increase the reliability of the facility as well as its energy production. But we must take into accountthe increase in the number of medium-power inverters with efficiency between 92% and 96% needed to calculate the additional cost of such an architecture compared to the previous one.

- **module inverter:**

Each panel here has its own inverter (figure 2.18), which theoretically makes it possible to avoid any losses linked to the difference in power between each module, whatever the origin of the fault. However, the efficiency of the inverters integrated into the panels remains below that of the string inverter due to the large voltage difference between the GPV and the load. In addition, the inverters integrated into the panels induce additional wiring costs on the AC side, since each panel of the installation must be connected to the 230V network. The much higher number of inverters integrated into the panels required in this architecture leads to a much greater coupling work. This concept therefore generally only applies to PV installations with a modest power ranging from 50 W to 400 W.

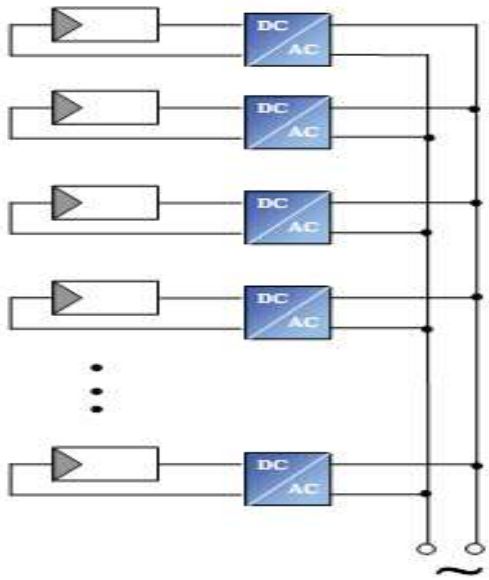



**Figure III.17:** Typology of systems inverter AC module. [27]

Usually, the strings and integrated inverters are known for their best response to variations in sunlight and light inhomogeneities but also for their ease of installation. On the other hand, the central inverter is often cheaper in terms of electronic equipment which is, after all, very modest, has a better efficiency and is, in addition, more reliable, Table III.1.

**Table III.1:** Technical characteristics of the different configuration systems. [27]

| | Central inverter | String inverter | Integrated inverter |
|---|---|---|---|
| PV Voltage | 340-800V | 150-800V | 17-90V |
| DC Loss (ohmic) | ˜1-5% Depending on voltage and distance | ˜1% Depending on voltage and distance | Negligible |
| $\eta_{CONV}$ | 95-97% | 92-96% | 87-93% |
| Maintenance and dispatch | Simple | Difficult research dysfunction | Difficult research dysfunction |

## III.4 General Structure of a photovoltaic system connected to the network

There are two types of photovoltaic system structures. [41]

- Direct-to-grid systems. This installation consists of a photovoltaic generator which is connected using an inverter to the electrical network.
- The intermediate DC bus system. The photovoltaic generator is connected to a DC bus via a DC-DC bus. An inverter delivers a modulated voltage. This is filtered to reduce the harmonic rate (THD). A usable voltage that can be injected into the network is then obtained at the output of this device.

### III.4.1 PV System connected directly to the grid

The structure shown in Figure III.18 is the simplest because it has the least number of components possible. In this case, several photovoltaic modules are combined in series to obtain a sufficiently large DC voltage. This solution is an alternative to a voltage-enhancing chopper. A conventional photovoltaic inverter (DC/AC converter) is placed at the output of the modules. Its role is to operate the modules at their maximum power points and convert the photovoltaic direct current into alternating current synchronized with the network. The energy produced by the photovoltaic modules must be able to feed the loads; the surplus is injected into the grid.

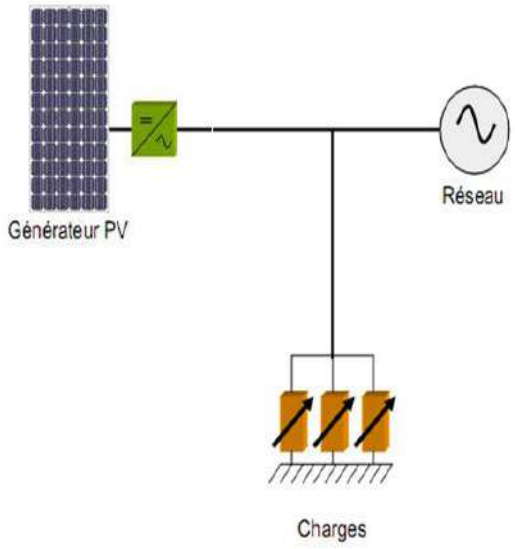



**Figure III.18: A**rchitecture of the PV system with an alternating current (ac) bus. [42]

It might be advantageous to insert a transformer to isolate the PV system from the grid. The major drawback of this architecture is the total and immediate shutdown of energy production when a problem occurs upstream of the inverter. In addition, the control of the maximum operating point is approximate because all the cells do not deliver the same current due to their differences in internal structure and insolation.

### III.4.2 Intermediate DC bus systems

In this case, the system has two conversion elements, figure III.19. A DC/DC converter (chopper) placed at the output of the photovoltaic modules which controls the maximum operating point of the photovoltaic generator and raises its output voltage delivered AC bus on the DC bus. With the chopper, it is difficult to raise the output voltage of the modules more than 4 or 5 times to obtain a large enough DC voltage, due to the resistance of the inductor. A central inverter is added to have a sinusoidal output. The advantage of this system is that batteries can be easily connected to the DC bus to obtain an autonomous system.

The major disadvantages of this type of assembly are:

- The capacity must be relatively large, because of the current ripples at the output of the module,
- The high voltage passing through the continuous bus reduces the safety of maintenance personnel.

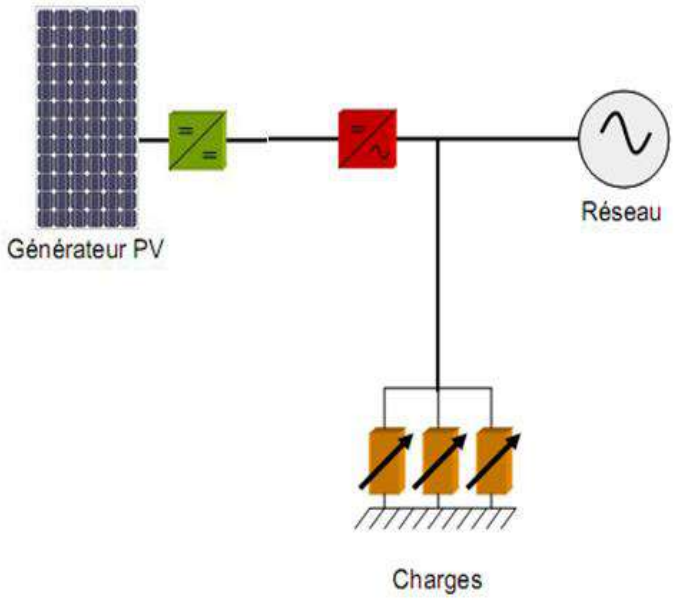



**Figure III.19:** PV System Architecture with DC Bus. [42]

## Conclusion

This chapter has highlighted the main components of a grid-coupled photovoltaic generator to be taken into account for its study and modeling. The bibliographical study of these generators made it possible to classify them in two categories: structures with direct connection and structures with intermediate DC bus.

## Introduction

After having described in the previous chapter grid-connected Photovoltaic system, in this last chapter we will study the energy performance of a house located in the Wilaya of Medea. In This chapter we first briefly present the site of Medea and the dwelling studied. Then we define the daily electricity consumption and finally the sizing of the PV system that must meet the energy needs of our home.

## IV.1 Geographical characteristics of the site

Medea Located in the north-central region of Algeria, 89 km from the capital Algiers, at a latitude 36.27°, a longitude of 2.76° and an altitude of 981m, Medea extend over an area of 8 866 Km2and shows great geographical interest.

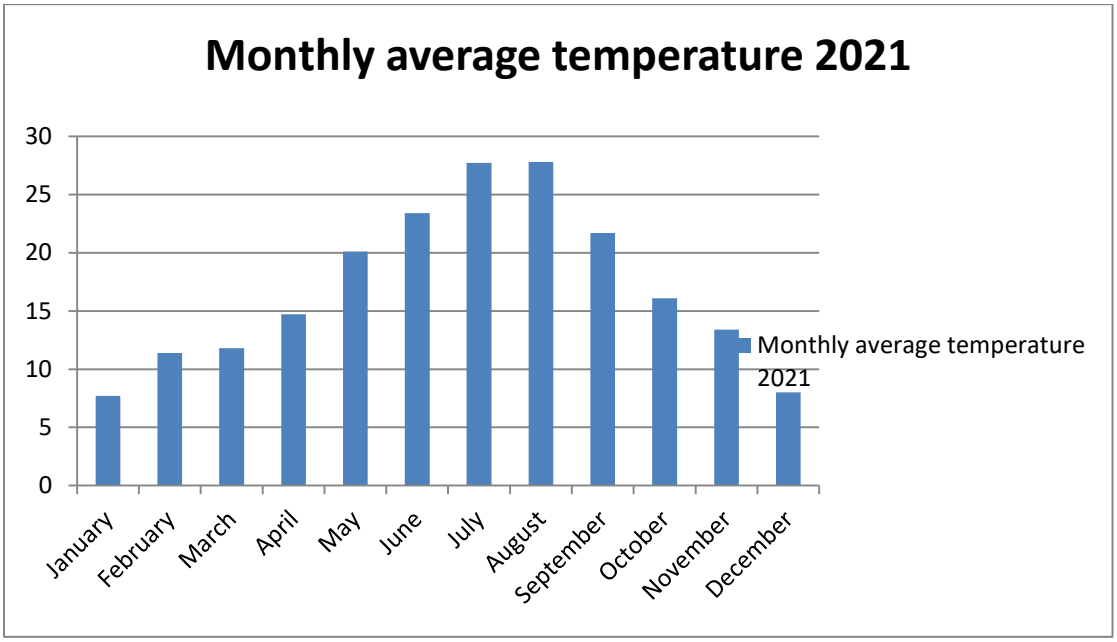



**Figure IV.1:** Monthly average temperature in Medea 2021

Located in the center of the country in the heart of the Tellien Atlas in the tittery region, it is a transit zone and a link between the Tell and the Sahara, and between the Eastern Highlands and those of the West. Medea characterized by its moderate climate.

Figure IV.1 shows the changes in mean temperature of the Medea site over time.

## IV.2 Description of the habitation studied

The habitation chosen to be the subject of our study is an individual dwelling of a city located in the Wilaya of Medea.

Currently occupied by a family made up of a couple and a daughter, the housing studied is representative of an average Algerian family, both by its type and by its level of equipment, in particular electrical equipment. This aspect greatly contributed to the choice that we made.

## IV.3 Home energy consumption

The house is connected to the electricity, water and gas networks. Annual consumption is calculated on the basis of electricity and gas readings invoiced by the national electricity and Gas Company. For this dwelling, the cumulative electrical energy consumption for the year 2008 was 1360 kWh. Figure IV.2 shows the quarterly distributions of electricity consumption respectively for the year 2021.

**Table IV.1**: Balance sheet for energy consumption of the studied dwelling, 2021

| Period | January-March | April-June | July-September | October-December |
|---|---|---|---|---|
| Electricity (kWh) | 283 | 320 | 395 | 290 |

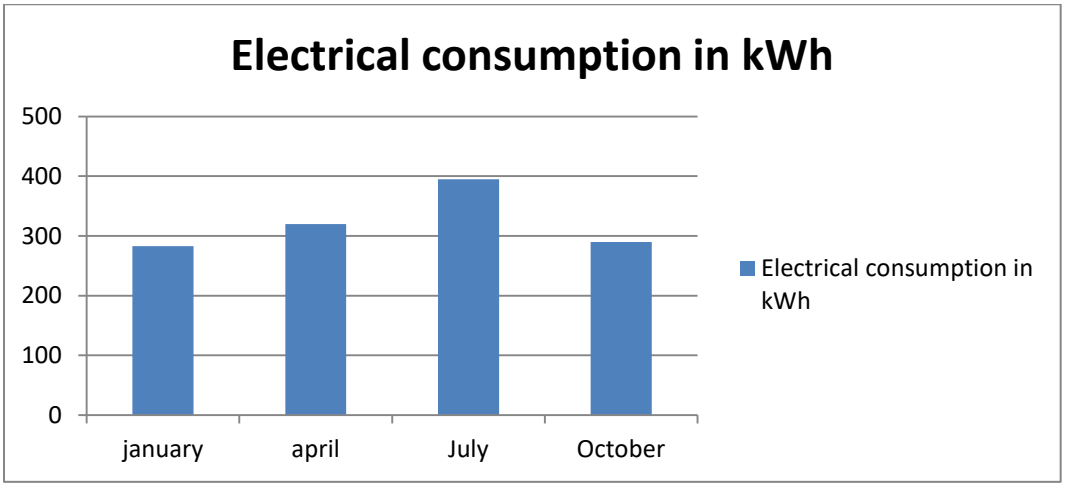



**Figure IV.2:** Electricity consumption report (kWh) of the habitat studied in 2021

For the conditioning periods from April to June and from July to September, the electricity consumption is high. While for the winter, it is a little lower compared to the summer period.

## IV.4 Energy sizing of the photovoltaic system

The sizing study is always confronted by two essential criteria which are solar deposit and energy demand. This energy management is based on the intelligence of the regulation and control devices used.

### IV.4.1 Sunshine

The energy source of our system is solar, it is important to take care of specific to the sunlight profile.

Table IV.2 represents the average sunshine duration in Medea. These data are provided by the Medea weather station.

**Table IV.2:** Duration of sunshine in Medea.

| Month | January | February | March | April | May | Jun |
|---|---|---|---|---|---|---|
| Duration (h/d) | 5.2 | 6.2 | 7.3 | 9.2 | 10.8 | 12.3 |
| Month | July | August | September | October | November | December |
| Duration (h/d) | 12.5 | 11.4 | 9.1 | 6.4 | 5.0 | 5.2 |

### VI.4.2 Study of the electricity consumption profile

We propose to estimate the daily electricity consumption of a dwelling of $m^2$ in area, located in the wilaya of Medea. This house consists of three bedrooms, a living room, a kitchen, a hallway, a bathroom and a toilet and is inhabited by a family of 3 people.

Table IV.3 shows the number and type of loads and their electrical consumption (1st case).

**Table IV.3:** Electrical consumption of the dwelling by type of load.

| Elements | Equipment | Power (w) | Number | Hours of operation | Electric energy consumption |
|---|---|---|---|---|---|
| Living | Lamp | 75 | 1 | 4 | 300 |

| | | | | | |
|---|---|---|---|---|---|
| room | Television | 75 | 1 | 2 | 150 |
| | Demo sat | 40 | 1 | 2 | 80 |
| | Fan | 45 | 1 | 4 | 180 |
| Lobby | Lamp | 75 | 1 | 5 | 375 |
| | Television | 75 | 1 | 4 | 300 |
| | Demo sat | 40 | 1 | 4 | 160 |
| Room 1 | Lamp | 75 | 1 | 5 | 375 |
| | Fan | 45 | 1 | 3 | 135 |
| Room 2 | Lamp | 75 | 1 | 3 | 225 |
| | Fan | 45 | 1 | 4 | 180 |
| Room 3 | Lamp | 75 | 1 | 5 | 375 |
| | Computer | 200 | 1 | 2 | 400 |
| Kitchen | Lamp | 75 | 1 | 5 | 375 |
| | Fridge | 100 | 1 | 13 | 1300 |
| Bathroom | Lamp | 75 | 1 | 2 | 150 |
| | Washing machine | 1500 | 1 | 1/2 | 750 |
| Toilet | Lamp | 75 | 1 | 1 | 75 |
| Corridor | Lamp | 75 | 1 | 4 | 300 |
| | | | | Total | 6185 Wh/d |

We find that the daily electricity consumption of this house is very high, about 6.185KWh/d. To reduce electricity consumption, the following solutions are proposed:

- Replace traditional 75W incandescent electric lamps with 15W energy-saving lamps (which consume 5 times less energy and last 10 times longer).
- The fridge among the most electricity-intensive household appliances.
  Replace the classic 100W fridge with an efficient 40W fridge (ex: condor RMC 350).
- Replace the 75W television with a 55W television (ex: condor Lcd Series V68).

### IV.4.3 Proposal of an energy consumption profile

Table IV.4 presents the number and type of loads and their new electrical consumption (2nd case).

**Table IV.4:** New household electrical consumption by type of charges.

| Elements | Equipment | Power (w) | Number | Hours of operation | Electric energy consumption |
|---|---|---|---|---|---|
| Living room | Lamp | 15 | 1 | 4 | 60 |
| | Television | 55 | 1 | 2 | 110 |
| | Demo sat | 40 | 1 | 2 | 80 |
| | Fan | 45 | 1 | 4 | 180 |
| Lobby | Lamp | 15 | 1 | 5 | 75 |
| | Television | 55 | 1 | 4 | 220 |
| | Demo sat | 40 | 1 | 4 | 160 |
| Room 1 | Lamp | 15 | 1 | 5 | 75 |
| | Fan | 45 | 1 | 3 | 135 |
| Room 2 | Lamp | 15 | 1 | 3 | 45 |
| | Fan | 45 | 1 | 4 | 180 |
| Room 3 | Lamp | 15 | 1 | 5 | 75 |
| | Computer | 200 | 1 | 2 | 400 |
| Kitchen | Lamp | 15 | 1 | 5 | 75 |
| | Fridge | 40 | 1 | 13 | 520 |
| Bathroom | Lamp | 15 | 1 | 2 | 30 |
| | Washing machine | 1000 | 1 | 1/2 | 500 |
| Toilet | Lamp | 15 | 1 | 1 | 15 |
| Corridor | Lamp | 15 | 1 | 4 | 60 |
| | | | | Total | 2995 Wh/d |

We find that the proposed solutions are effective, they make it possible to reduce the daily consumption of the dwelling up to 2.995 KWh/d with an energy saving of 3 KWh/d.

Consumption can also be reduced by changing the behavior of family members. We can therefore save energy by adopting the right actions without reducing comfort and quality of life.

- Cut the standbys of all devices and use power strips equipped with a switch, do not leave your devices plugged in all day!
- Unplug your camera charger, laptops... as soon as they are charged.
- Place your cold equipment away from heat sources.
- Avoid washing your clothes at very high temperatures, choose economical washing programs and air dry them.

### IV.4.4 Distribution of electricity consumption in the household

The distribution of the electricity consumption of the studied house is represented by table IV.5 and figures IV.3 and IV.4.

**Table IV.5:** Distribution of electricity consumption.

| Type | Consumption | |
|---|---|---|
| | 1st case | 2nd case |
| Lighting | 2550 | 510 |
| Washing machine | 750 | 500 |
| Television | 450 | 330 |
| Fridge | 1300 | 520 |
| Air-conditioning | 495 | 495 |
| Audio-visual | 400 | 400 |
| Others | 240 | 240 |

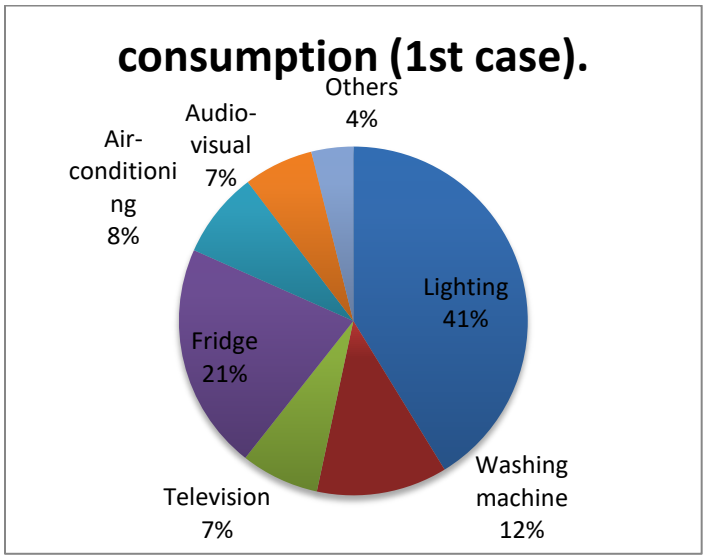



**Figure IV.3:** Distribution of electricity consumption (1st case).

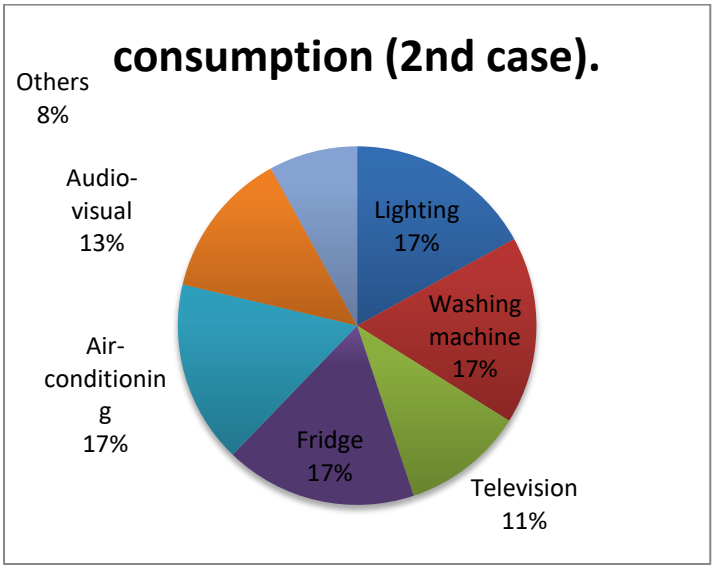



**Figure. IV.4:** Distribution of electricity consumption (2nd case).

We can notice that in the first case, the lighting constitutes more than 40% of the electricity consumption. While in the second case represents only 17% of the household power consumption. Therefore, the use of energy-saving lamps plays a very important role in saving electrical energy.

Also, the choice of high-performance household appliances can considerably reduce the household's electrical energy consumption.

### IV.4.5 Features of Grid Connected PV System

We made the choice of the PV module and the type of the inverter of the system to meet the needs for ours. See appendix (I, II) and the electrical energy requirements in the previous paragraph, as agreed we have chosen to impose the voltage of the continuous bus at a value of 127V. Table VI.6 summarizes the characteristics of our photovoltaic system.

**Table IV.6:** Characteristics of the PV system.

| Setting | Value |
|---|---|
| Daily energy requirements, $E_C$ [Wh/d] | 2995 |
| The lowest daily sunshine duration of the months [h] | 5.0 |
| DC bus voltage [V] | 127 |
| Electrical efficiency of the converter [%] | 97 |
| Optimal peak power of the pv module [W] | 280 |

### IV.4.5 Sizing of the photovoltaic field

- **Calculation of total daily electrical energy**

The system has been sized to meet daily power consumption needs, estimated at 2930 Wh. The total daily electrical energy, $E_T$ is given by the following equation IV.1:

$$E_T = \frac{E_C}{\eta_{ond}} \qquad \text{(IV.1)}$$

Using the EAC value from Table IV.6 and the inverter efficiency value (Appendix 2), the total daily electrical energy is equal to 3.087 kWh/d.

- **Calculation of the peak power of the photovoltaic generator required**

The sizing of the PV generator is done according to the following formula:

$$P_c = \frac{E_T}{sunshine\ duration \times 0.77} \qquad \text{(IV.2)}$$

According to Table IV.6, The lowest daily sunshine duration of the months is: the month of November where the sunshine duration is: 5.0 hours.

So, this equipment requires a power of 801.81W and a consumption of 3087 Wh/d.

- **The choose of the operating voltage of the photovoltaic field**

The operating voltage is chosen according to the peak power of the box photovoltaic field in general [41]:

- Less than 500 peak watts: it is 12V.
- From 501 to 2000 peak watts: it is 24V.
- From 2001 to 10000 peak watts: it is 48V.
- More than 10.000 peak watts: it is greater than 48V.

- **Required number of solar modules constituting the photovoltaic field**

-**Total number of modules**

$$N_t = \frac{P_C}{P_M} \quad \text{(IV.3)}$$

The number of modules needed to meet the housing demand is: 3 modules

-**Number of modules in series**

To have sufficient voltage to power the inverter, we need 3 modules in series. ($Ns$=3 modules)

-**Number of modules in parallel**

$$N_p = \frac{N_T}{N_s} \quad \text{(IV.4)}$$

The number of modules in parallel is 1module.

- **Calculation of the surface occupied by the PV array**

The PV generator is installed on the roof of the house. It has a constant area. It is therefore necessary to determine the total area of the modules that make up our PV panel.

Figure IV.5 shows the dimensions of a PV generator. That is a generator of length L and width l, installed with an angle slope θp with the horizontal. Its footprint on the ground (in other words, the surface that the generator occupies on the ground) will determine the dimensions occupied by the PV generator, as shown in Figure IV.6. The length and width of the PV generator are calculated respectively by the formulas IV.5 and IV.6:

$$L = Lm \times Ns \quad \text{(IV.5)}$$

$$l = lm \times Np \quad \text{(IV.6)}$$

With: ($Lm$ = 1.640 m) and ($lm$ = 0.995 m) are respectively the length and width of the

Module PV. (See Appendix I)

Figure IV.6 shows the layout of the PV panel on the roof of the house, Lp corresponding to the width of the inclined field.

Lpis calculated based on the tilt angle of the panel.

$$Lp = L \times cos\theta p \quad \text{(IV.7)}$$

Choosing the orientation, we use the table IV.7, which indicates the relationship between the latitude and inclination of the solar panels [39].

**Table IV.7:** Latitude and inclination of the solar panels [39].

| Latitude | Inclination |
|---|---|
| φ<10° | $\alpha = 10°$ |
| 10°<φ <30° | α=φ |
| 30°<φ<40° | α=φ+10° |
| φ>40° | α=φ+15° |

In our case, the tilt angle is 45°, the height of the tilted generator for a module with a length of 1.640 m is 3.47 m wide.

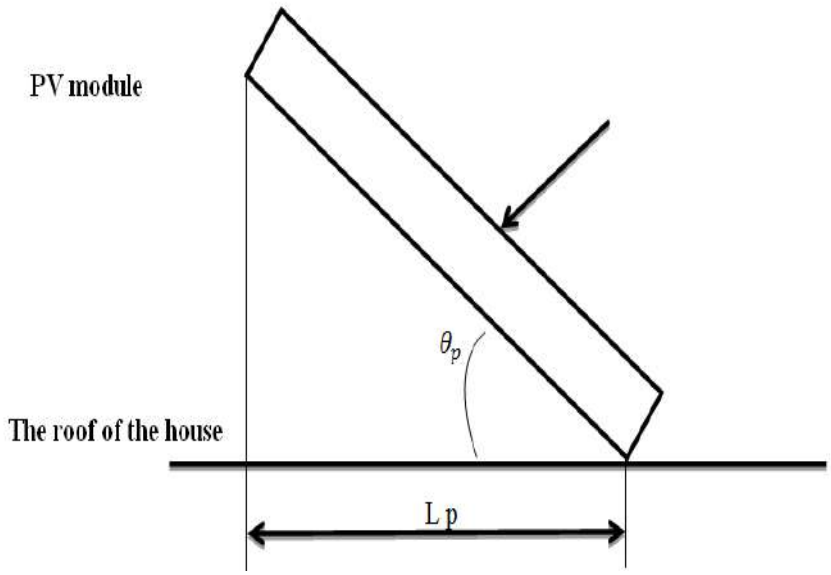



**Figure IV.5:** Layout diagram of a PV generator on the roof

The total area $S_p$ occupied by the photovoltaic field is calculated according to the width of the PV panel:

$$Sp = l \,.\, Lp \quad \text{(IV.8)}$$

So the area occupied by the solar generator PV feeding the house is 5 m². The surface occupied by the solar panel can be exploited as a shelter from the sun in summer. The 8 modules are divided into 2 parallel rows of 2 modules in series figure IV.6.

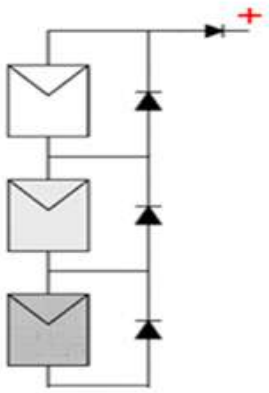


**Figure IV.6:** Solar photovoltaic generator of the house studied.

So we have for a bench of 8 modules, the current, voltage and power delivered by the generator PV are given respectively by the equations:

$$I = 1 \times Imodule \quad \text{(IV.9)}$$

$$V = 3 \times Vmodule \quad \text{(IV.10)}$$

$$P = 3 \times I \times V \quad \text{(IV.11)}$$

## IV.5 Simulation of sizing by using PVsyst software

### IV.5.1 Presentation of PVsyst software

PVsyst is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone, pumping and DC-grid (public transportation) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools. This software is geared to the needs of architects, engineers, researchers. It is also very helpful for educational training.

**IV.5.2 the steps to make the calculations in PVsyst**

- **First step:**

- **Naming the project:**

Choosing the name of the project, it is the first thing before start sizing by choosing the name of your project.

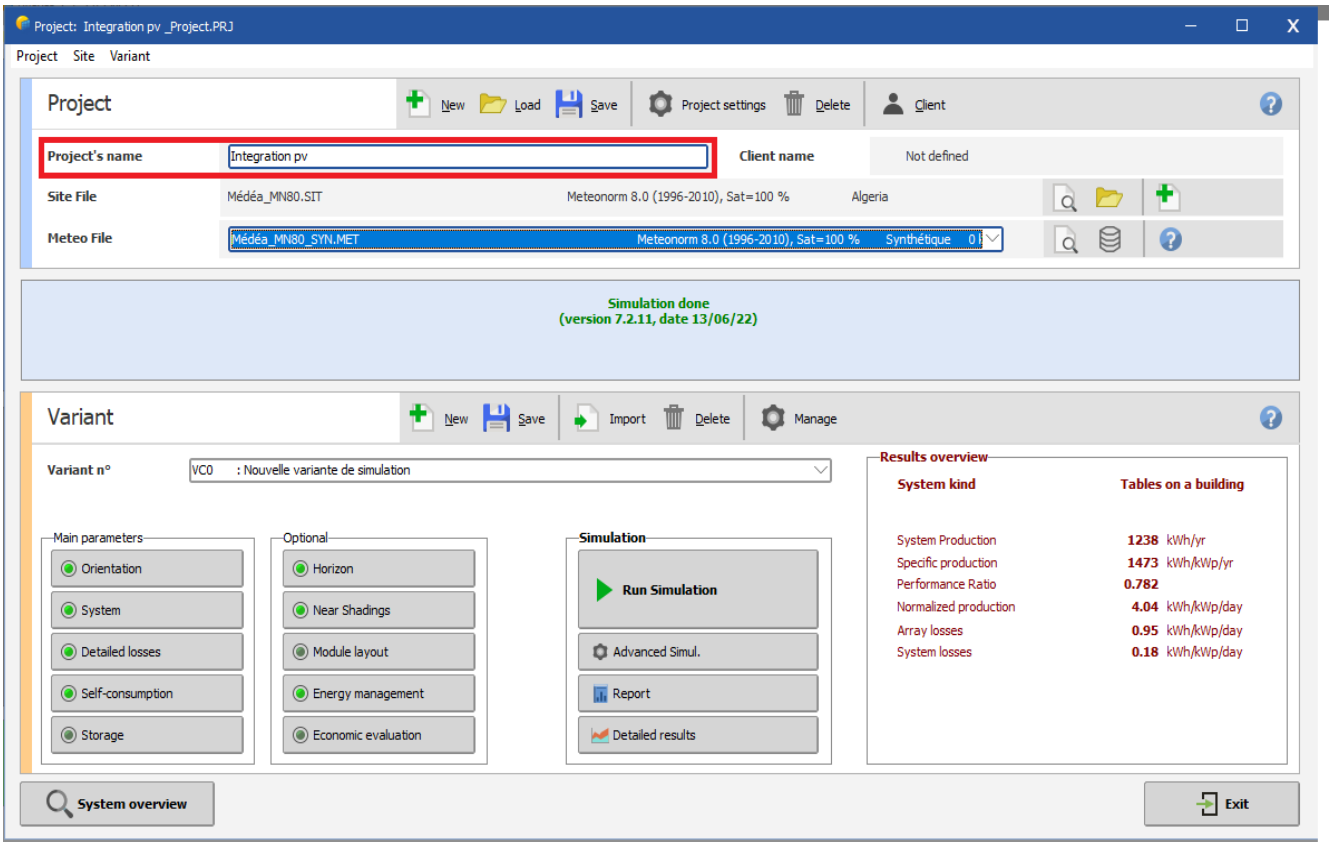



**Figure IV.7:** PVsyst interface.

- **Second Step**

Determining the geographical location, According to the figure IV.8 the house located exactly in Baziwech neighborhood in the Wilaya of Medea and it is in an opened place, that's make it a good place to install solar panel, as you can see in the figure IV.8, the geographical coordinates of this place are: Latitude (°): 36.2771, longitude (°):2.761, altitude (m):991

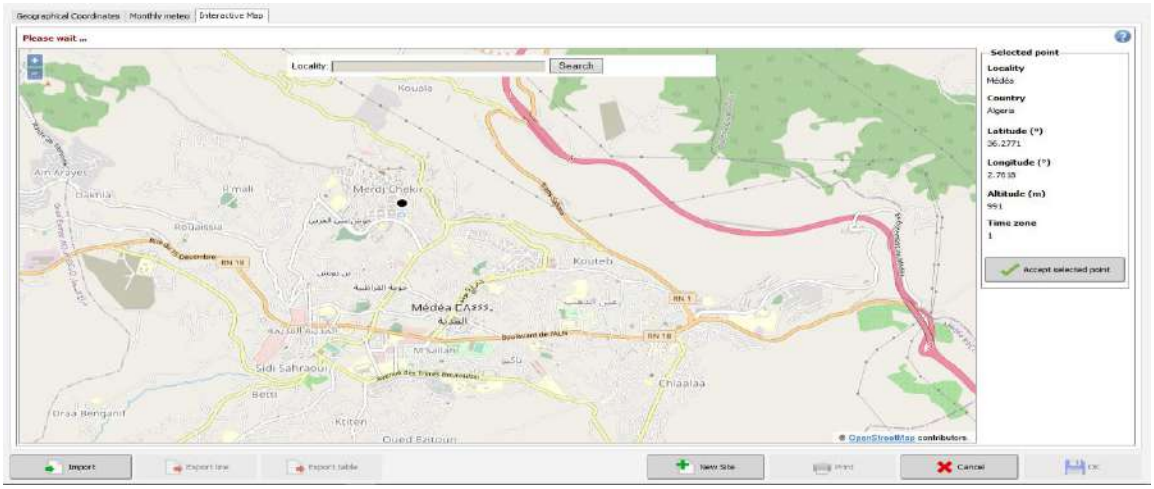



**Figure IV.8:** The geographical site of the house.

- **Monthly meteo**

When determining the geographical site of the area the PVsyst defines the monthly meteo of the whole year data, all the information about the site we choose which includes (global horizontal irradiation, horizontal diffuse irradiation, temperature, wind velocity, linke turbidity and relative humidity) as it is shown in the figure IV.9.

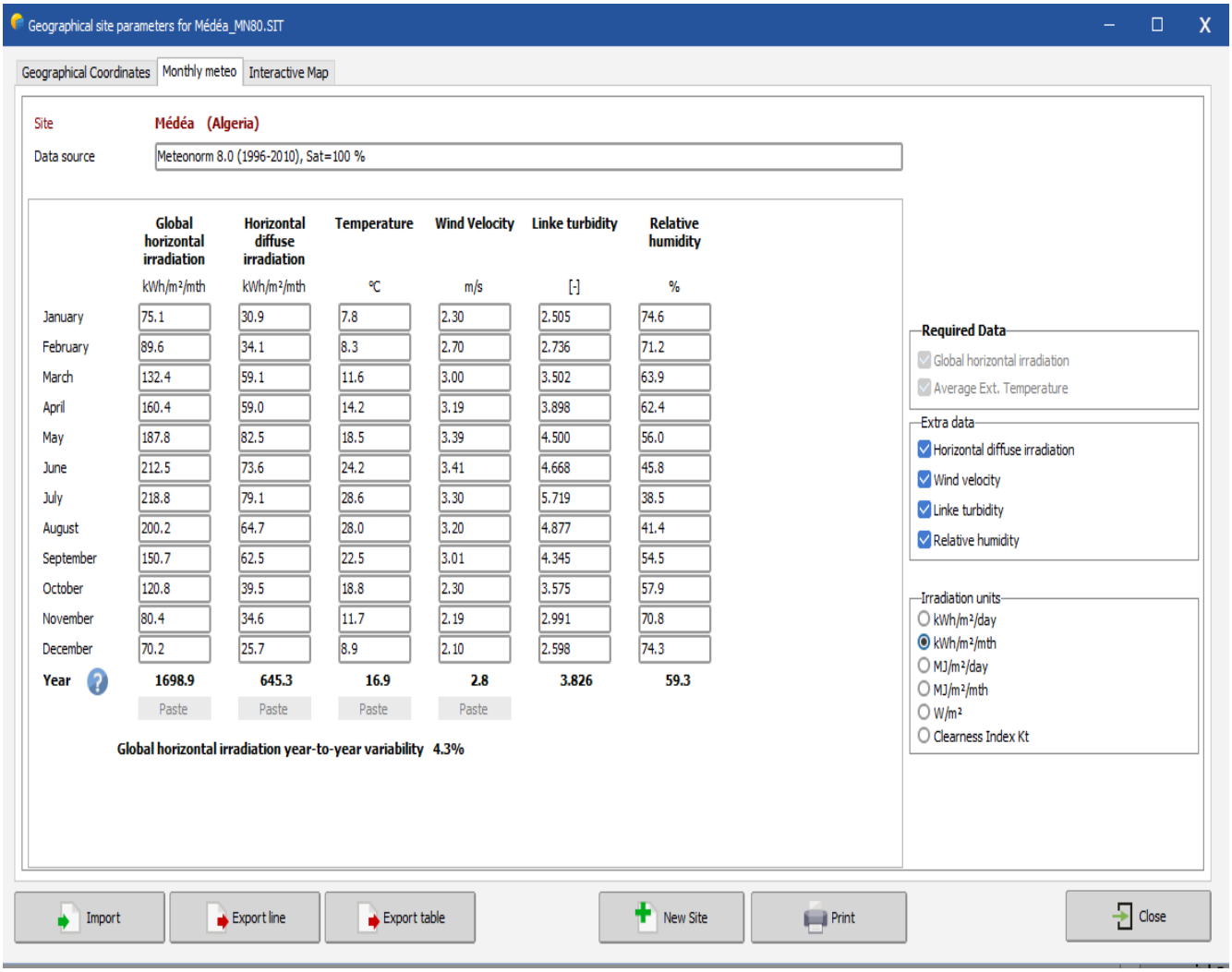



**Figure IV.9:** Monthly meteo interface in PVsyst.

➢ **Third step**

Determining the orientation (the tilt and the azimuth).

- **Orientation:**

In the step we choose the orientation of our PV panelsaccording to our site, the figure IV.10 shows:

❖ The tilt 45°

❖ Azimuth 0°

This means our PV panels headed directly to the south with an angle of 45°

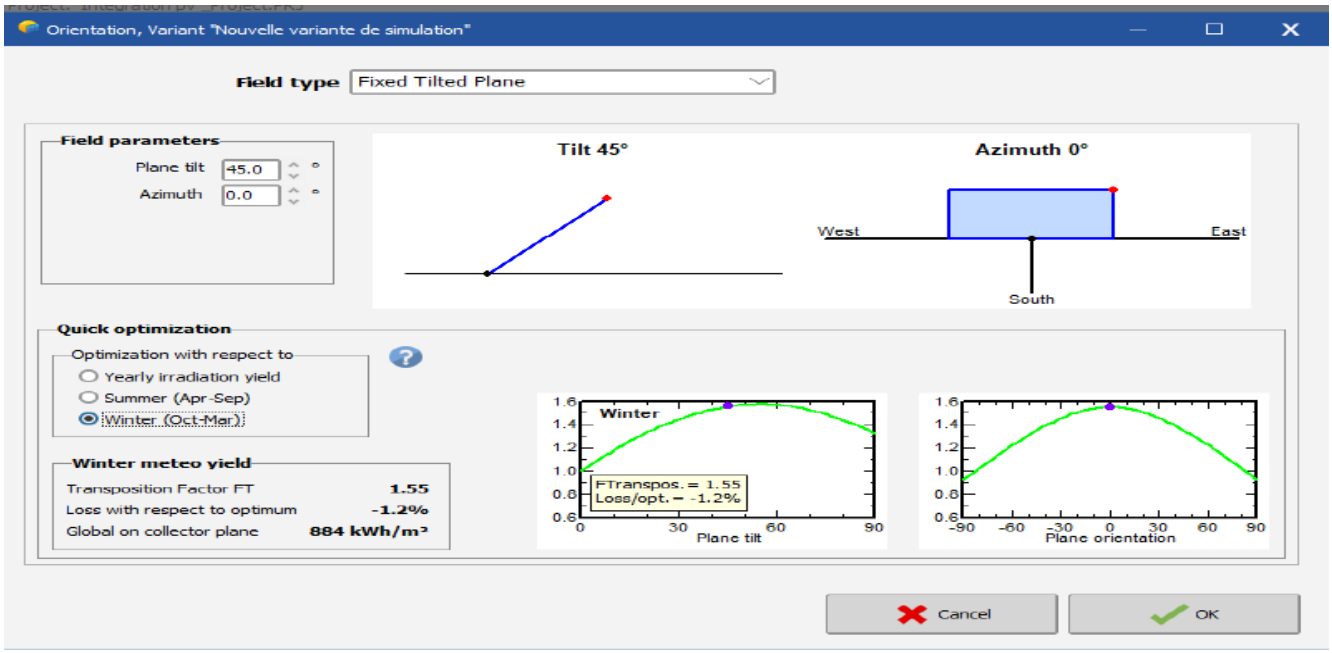



**Figure IV.10:** The position of PV panel systems.

➢ **4 th step**

Sizing of the photovoltaic system with PVsyst software, the detailed simulation of a PV system includes:

❖ The choice of components (PV panel, load regulator…..)

❖ The detail layout of the PV field (orientation, mounting mode……..)

❖ The estimation of the energy produced $P_c = 801.30\ watts$

- **PV module characteristics**

The figure IV.11 shows our panel characteristics, includes the length, width, thickness, weight…) everything about our PV module that we choose, and it is also shown in appendix 1

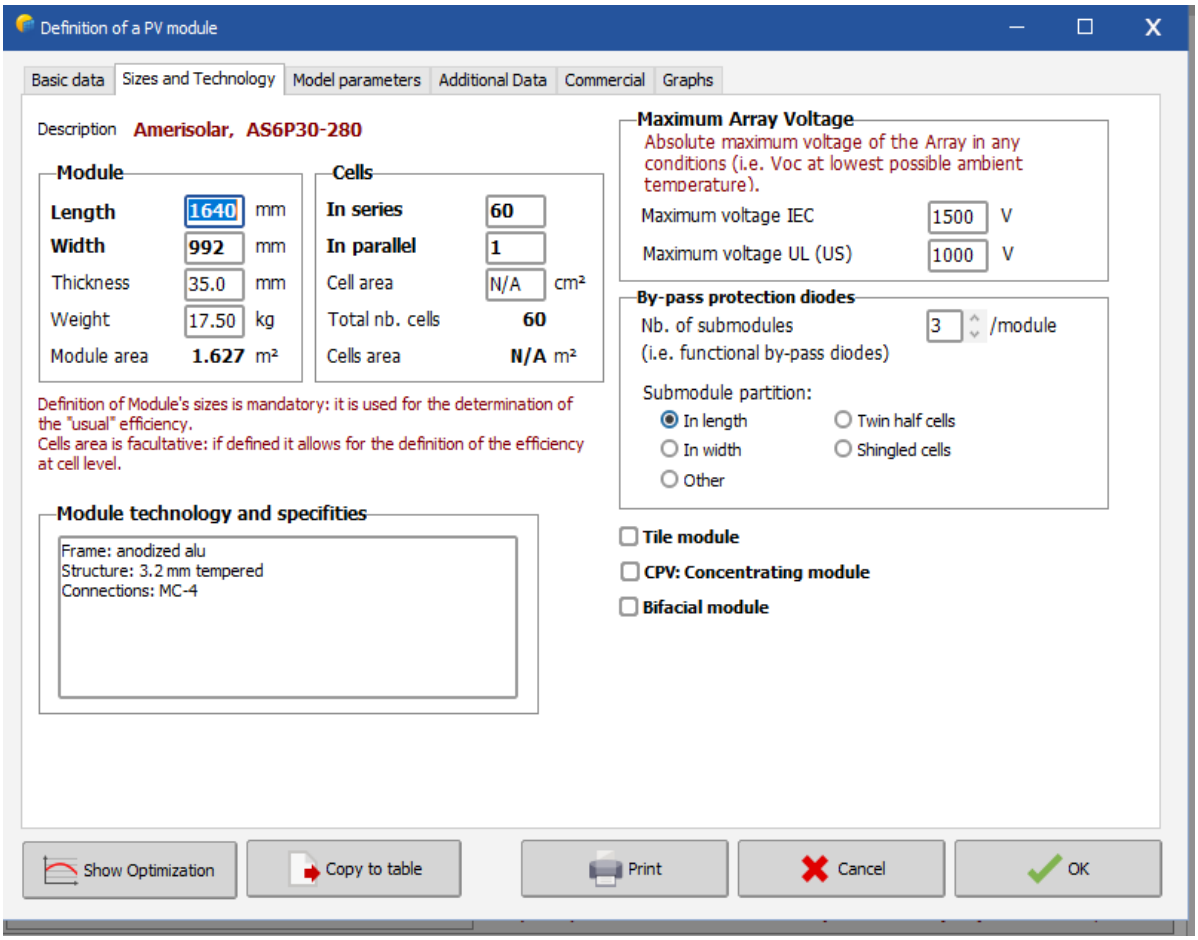



**Figure IV.11:** PV module characteristics.

- **The isolated system configuration in PVsyst**

In this step we have to:

- ❖ Enter the planned power in our case it is 0.8 kwp (number 1 in figure IV.12) then PVsyst will determining automatically the available area of our modules which is 5m² (number 2 in the figure IV.12) and defines the number of the module in series (number 8in the figure IV.12)
- ❖ Select the PV Module (number 3and 4 in the figure IV.12) in our case we select amerisolar – AS6P 30-280
- ❖ Select the inverter ( number 6 and 7 in the figure IV.12)in our case it is AEG Industrial Solar Gmbh – AS-IR01-750(750w)
- ❖ When something is wrong or the system won't work good will write the issue down (number 9in the figure IV.12) like the inverter is strongly oversized in our case there is nothing written so everything work well.

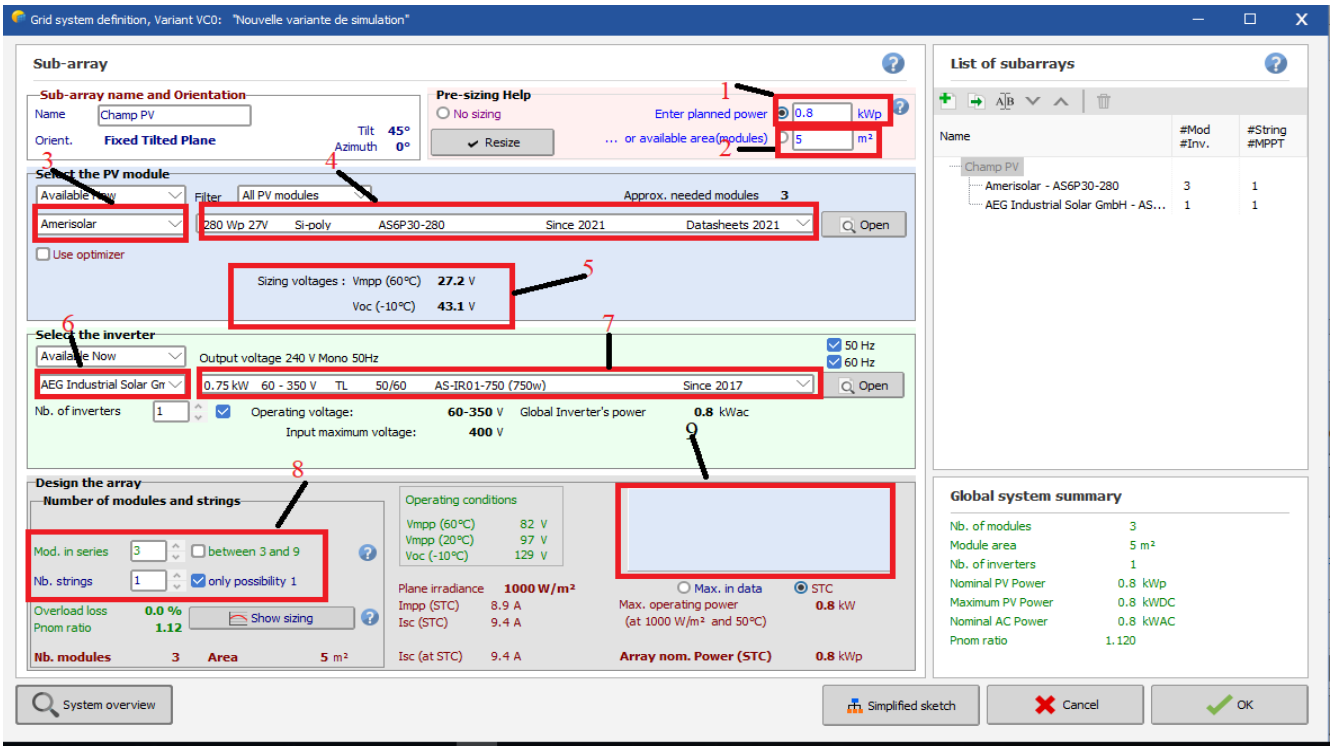



**Figure IV.12:** The isolated system configuration in PVsyst.

- **Trajectory of the sun**

The knowledge of the apparent movement of the sun for a given point on the earth's surface is necessary for all solar applications; the numbers from 1 to 7 shows the highest of the sun over the year as it is shown in the figure IV.13.

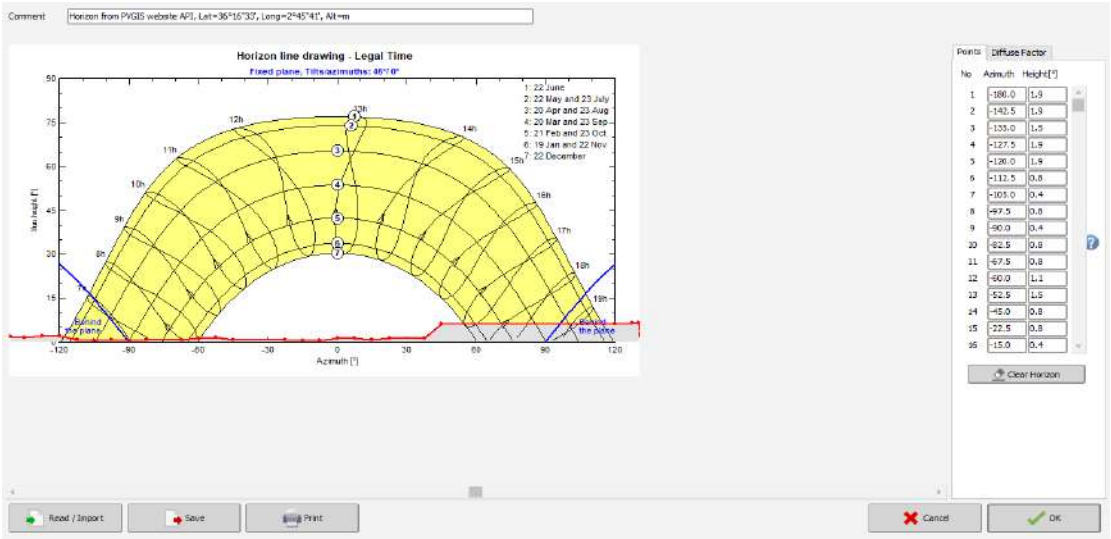



**Figure IV.13:** The trajectory of the sun in Medea.

- **Near shading definition**

Simplified designed for the house that we studied and its surroundings in PVsyst.as you can see in this the house in an opened place a good place to install solar panels

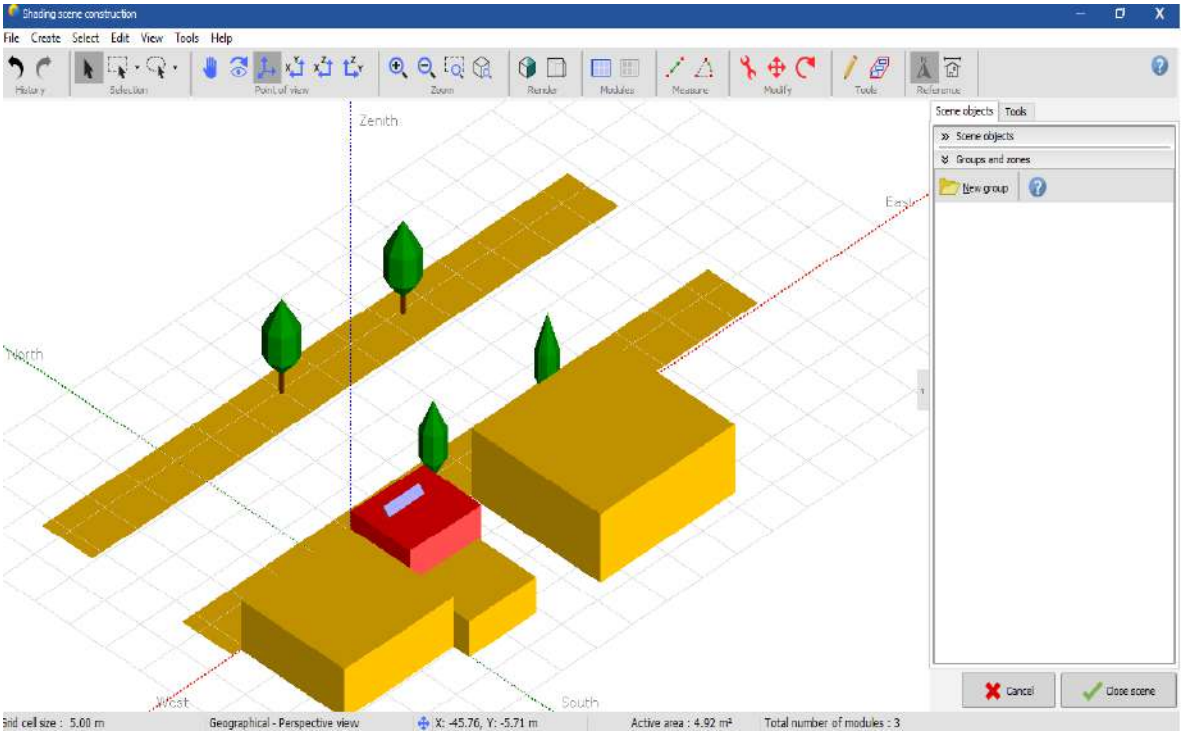



**Figure IV.14:** Simplified designed for the house in PV syst.

➢ **Final step**

Running the simulation

- **Simulation results**

The simulation results of our PV installation for limited power are summarized in the above report (table IV.8), so this is the system production shown in the figure IV.15.

**Table IV.8:** Simulation results

| | System production |
|---|---|
| Produced energy | 1238 kWh/year |
| Used energy | 7008 kWh/year |
| Specific production | 1473 kWh/kWp/year |
| Performance Ratio PR | 78.21 % |
| Solar fraction | 17.66 % |

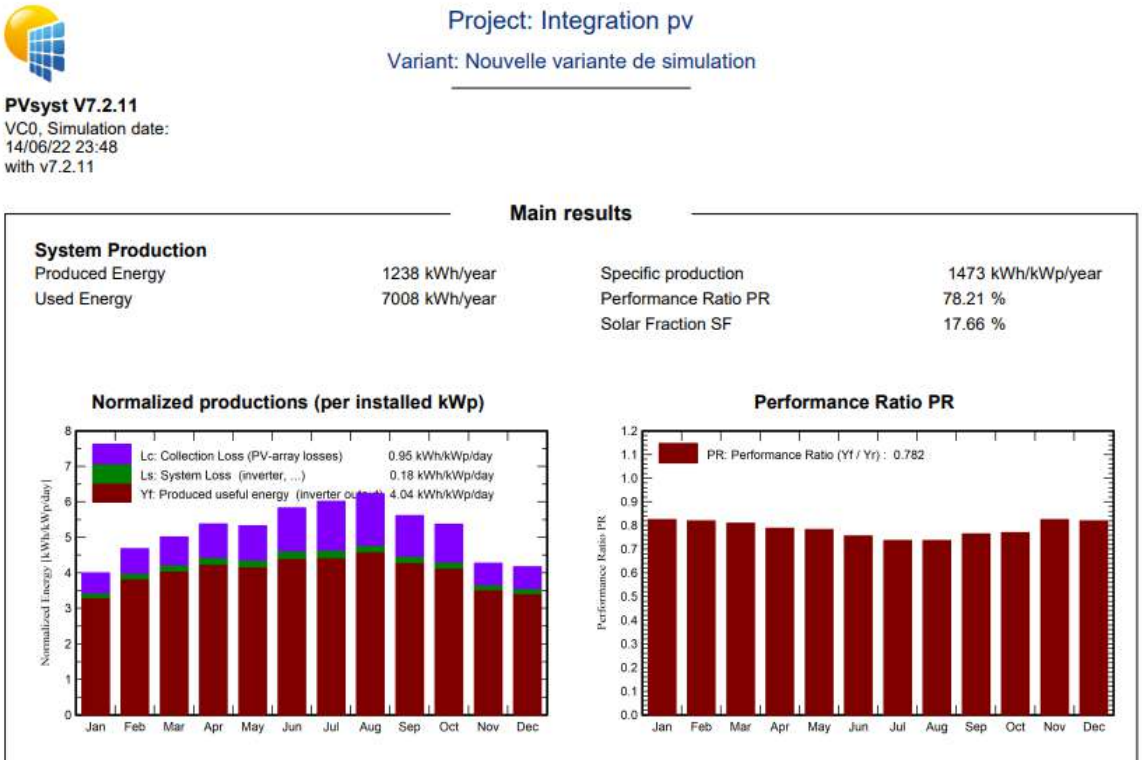



**Figure IV.15:** The main result of our PV installation.

## Conclusion

In this chapter we have taken a view of the sizing of photovoltaic systems and installations grid-connected in the first part of this chapter we have shown the methodology a photovoltaic installation in a house located in the wilaya of Medea and after that we have shown the steps for sizing of a photovoltaic system connected to the network by PVsyst software.

**General conclusion:**

To conclude, we can say that the results obtained in this study have highlighted the aspects that have an impact on the energy needs of the house located in the Medea region. From a practical point of view, the results presented in this work shows in the first phase, by acting only on the lighting, it is possible to achieve substantial savings in electrical energy by agreeing to a very low investment which can be amortized very quickly. Indeed, the lighting in the premises for residential use being provided almost exclusively by incandescent lamps which consume a lot of electrical energy, the replacement of these lamps by low-consumption electronic lamps should make it possible to achieve significant savings. Of electrical energy. In addition to lighting, the use of high-performance household appliances has also ensured other electrical energy savings.

Furthermore, the work carried out within the framework of this thesis made it possible to study and optimizes a photovoltaic system connected to the network. This system plays a very important role in improving the energy performance of the house by producing only part of the electrical needs of the house. To do this, we paid particular attention to the choice of the various components constituting the PV system, by apprehending the problem of operation at an optimal point.

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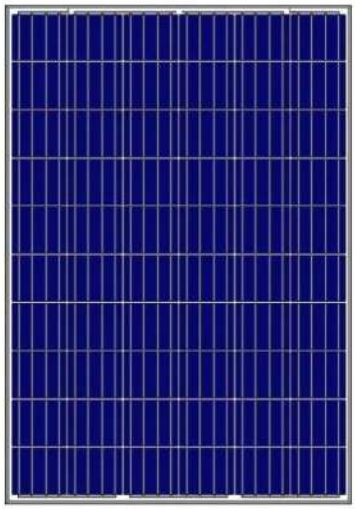
# Appendix 1:

## Module photovoltaic Amerisolar - As-6P30-280:

Amerisolar | New Energy New World®

# AS-6P30

## POLYCRYSTALLINE MODULE



### ADVANCED PERFORMANCE & PROVEN ADVANTAGES

- High module conversion efficiency up to 17.52% by using high efficient solar cells and advanced manufacturing technology.
- Low degradation and excellent performance under high temperature and low light conditions.
- Robust aluminum frame ensures the modules to withstand wind loads up to 2400Pa and snow loads up to 5400Pa.
- High reliability against extreme environmental conditions (passing salt mist, ammonia and hail tests).
- Potential induced degradation (PID) resistance.
- Positive power tolerance of 0 ~ +3 %.

### CERTIFICATIONS

- IEC61215, IEC61730, IEC62716, IEC61701, CE, CQC, CGC, ETL(USA), JET(Japan), J-PEC(Japan), Kemco(South Korea), KS(South Korea), MCS(UK), CEC(Australia), FSEC(FL-USA), CSI Eligible(CA-USA), Israel Electric(Israel), InMetro(Brazil), TSE(Turkey)
- ISO9001:2008: Quality management system
- ISO14001:2004: Environmental management system
- OHSAS18001:2007: Occupational health and safety management system

**Passionately committed to delivering innovative energy solution**

### SPECIAL WARRANTY

- 12 years limited product warranty.
- Limited linear power warranty: 12 years 91.2% of the nominal power output, 30 years 80.6% of the nominal power output.




Worldwide Energy and Manufacturing USA Co., Ltd.
www.weamerisolar.com, sales@weamerisolar.com

EN-V1.0-2017

| ELECTRICAL CHARACTERISTICS AT STC | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal Power ($P_{max}$) | 250W | 255W | 260W | 265W | 270W | 275W | 280W | 285W |
| Open Circuit Voltage ($V_{OC}$) | 38.0V | 38.1V | 38.2V | 38.3V | 38.4V | 38.5V | 38.6V | 38.7V |
| Short Circuit Current ($I_{SC}$) | 8.75A | 8.83A | 8.90A | 8.98A | 9.09A | 9.20A | 9.31A | 9.42A |
| Voltage at Nominal Power ($V_{mp}$) | 30.3V | 30.5V | 30.7V | 30.9V | 31.1V | 31.3V | 31.5V | 31.7V |
| Current at Nominal Power ($I_{mp}$) | 8.26A | 8.37A | 8.47A | 8.58A | 8.69A | 8.79A | 8.89A | 9.00A |
| Module Efficiency (%) | 15.37 | 15.67 | 15.98 | 16.29 | 16.60 | 16.90 | 17.21 | 17.52 |
| Operating Temperature | -40°C to +85°C | | | | | | | |
| Maximum System Voltage | 1000V DC | | | | | | | |
| Fire Resistance Rating | Type 1(in accordance with UL1703)/Class C(IEC61730) | | | | | | | |
| Maximum Series Fuse Rating | 15A | | | | | | | |

STC: Irradiance 1000W/m², Cell temperature 25°C, AM1.5

| ELECTRICAL CHARACTERISTICS AT NOCT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal Power ($P_{max}$) | 184W | 188W | 191W | 195W | 199W | 202W | 206W | 210W |
| Open Circuit Voltage ($V_{OC}$) | 35.0V | 35.1V | 35.2V | 35.3V | 35.4V | 35.5V | 35.6V | 35.7V |
| Short Circuit Current ($I_{SC}$) | 7.09A | 7.15A | 7.21A | 7.27A | 7.36A | 7.45A | 7.54A | 7.63A |
| Voltage at Nominal Power ($V_{mp}$) | 27.6V | 27.8V | 27.9V | 28.1V | 28.3V | 28.5V | 28.7V | 28.9V |
| Current at Nominal Power ($I_{mp}$) | 6.67A | 6.77A | 6.85A | 6.94A | 7.04A | 7.09A | 7.18A | 7.27A |

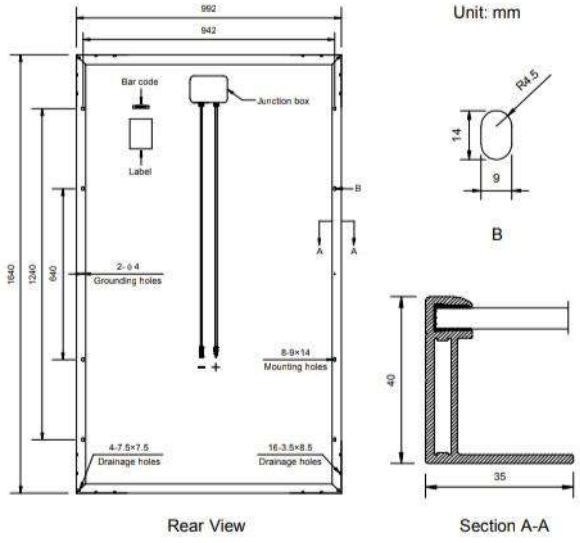
NOCT: Irradiance 800W/m², Ambient temperature 20°C, Wind Speed 1 m/s

| MECHANICAL CHARACTERISTICS | |
|---|---|
| Cell type | Polycrystalline 156x156mm (6x6inches) |
| Number of cells | 60 (6x10) |
| Module dimensions | 1640x992x40mm (64.57x39.06x1.57inches) |
| Weight | 18.5kg (40.8lbs) |
| Front cover | 3.2mm (0.13inches) tempered glass with AR coating |
| Frame | Anodized aluminum alloy |
| Junction box | IP67, 3 diodes |
| Cable | 4mm² (0.006inches²), 900mm (35.43inches) |
| Connector | MC4 or MC4 compatible |

| TEMPERATURE CHARACTERISTICS | |
|---|---|
| Nominal Operating Cell Temperature (NOCT) | 45°C±2°C |
| Temperature Coefficients of $P_{max}$ | -0.41%/°C |
| Temperature Coefficients of $V_{OC}$ | -0.31%/°C |
| Temperature Coefficients of $I_{SC}$ | 0.05%/°C |

| PACKAGING | |
|---|---|
| Standard packaging | 26pcs/pallet |
| Module quantity per 20' container | 312pcs |
| Module quantity per 40' container | 728pcs(GP)/784pcs(HQ) |

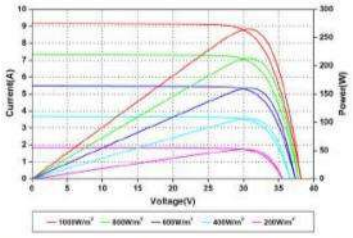
## ENGINEERING DRAWINGS



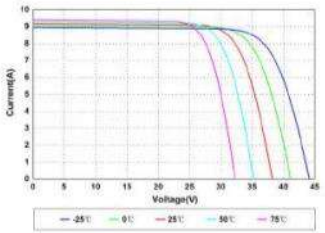

Rear View

Section A-A

## IV CURVES




Current-Voltage and Power-Voltage Curves at Different Irradiances




Current-Voltage Curves at Different Temperatures

Specifications in this datasheet are subject to change without prior notice.

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# Appendix 2:

## Inverter AS-IR01 Series (750W):



## INPUT (DC)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal DC Input Power (W) | 750 | 1000 | 1500 | 2000 | 3000 | 4000 | 4600 | 5000 |
| Max. DC Input Power (W) | 900 | 1200 | 1700 | 2200 | 3300 | 4800 | 5520 | 6000 |
| Max. DC Input Voltage (V) | 400 | 450 | 450 | 450 | 500 | 600 | 600 | 600 |
| Starting Voltage / Min. Operation Voltage (V) | 60/50 | 80/60 | 80/60 | 80/60 | 80/60 | 120/100 | 120/100 | 120/100 |
| MPPT Operating Voltage Range (V) | 50-400 | 60-400 | 80-410 | 100-410 | 120-450 | 120-550 | 120-550 | 120-550 |
| Number of MPPT / String per MPPT | 1/1 | 1/1 | 1/1 | 1/1 | 1/2 | 1/2 | 1/2 | 1/2 |
| Max. DC Current (A) per MPPT x Nr. of MPPT | 8 x 1 | 9 x 1 | 10 x 1 | 12 x 1 | 15 x 1 | 16 x 1 | 18 x 1 | 20 x 1 |
| DC Switch | Integrated | | | | | | | |

## OUTPUT (AC)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rated Output Power (W) | 750 | 1000 | 1500 | 2000 | 3000 | 3680 | 4200 | 4600 |
| Max. Apparent Power $SE_{max}$ (VA) | 776 | 1013 | 1517 | 2042 | 3028 | 3899 | 4450 | 4599 |
| Max. AC Output Current (A) | 3.6 | 4.5 | 6.5 | 9 | 13 | 16 | 18.3 | 20 |
| Grid Voltage Range | 230 / 180-277V | | | | | | | |
| Grid Frequency Range | 50 Hz (44-55 Hz) | | | | | | | |
| Power Factor | ≥0.99 (adjustable) | | | | | | | |
| THDi | <3% (at rated power) | | | | | | | |
| AC Output | Single-phase (L, N, PE) | | | | | | | |

## SYSTEM

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cooling | Natural cooling | | | | | | | |
| Max. Efficiency (%) | 96.80 | 96.90 | 97.20 | 97.20 | 97.30 | 97.70 | 97.70 | 97.80 |
| Euro-Efficiency (%) | 95.95 | 96.00 | 96.10 | 96.10 | 96.50 | 96.50 | 96.70 | 96.80 |
| MPPT Efficiency (%) | 99.90 | | | | | | | |
| Protection Rating | IP65 | | | | | | | |
| Self-Consumption at Night (W) | <1 | | | | | | | |
| Topology | Transformerless | | | | | | | |
| Operating Temperature | -25°C ~ +60°C (derate after 45°C) | | | | | | | |
| Relative Humidity | 0~+95%, no condensation | | | | | | | |
| Protection | PV array insulation protection, PV array leakage current protection, Ground fault monitoring, Grid monitoring, Island protection, DC monitoring, Short current protection | | | | | | | |

## MECHANICAL PARAMETERS

| | | |
|---|---|---|
| Dimensions (H x W x D, mm) | 290 × 300 × 138 | 405 × 360 × 150 |
| Weight (kg) | 9.5 | 16 |
| DC Terminal | BC03A, BC03B (PV-CF-S2, 5-6 [+]...; PV-Cm-S2, 5-6 [-] ..., Helios H4 2.5 $mm^2$ | |
| Installation | Wall mounting | |
| Safety certificates / EMC category / Grid Standards | IEC 62109-1 (ed.1) , IEC 62109-2 (ed1) , EN 62109-1:2010, EN 62109-2:2011, EN 61000-6-3:2007+A1:2011, EN 61000-6-2:2005, VDE-AR-N 4105:2018, DIN VDE V 0124-100:20, C10/11:2019 | |

## DISPLAY AND COMMUNICATION

| | |
|---|---|
| Display | LED (Standard); LCD (Optional) |
| System Language | English, German, Dutch |
| Communication | RS485 + WiFi (Standard), Ethernet (Optional) |

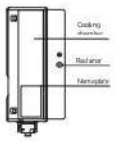
## WARRANTY

Product Warranty 5+5* years (optional: 15/20 years)

*Product warranty of 5+5 years (5 years basic warranty + 5 years additional warranty) available for: Netherlands, Belgium and Luxembourg. For the full Warranty Terms please visit www.aeg-industrialsolar.de. © Solar Solutions GmbH. Specifications in this datasheet are subject to change without notice.
Code: AS-IR01-(750-5000) version 202108V1EN-EU
AEG is a registered trademark used under license from AB Electrolux (publ)

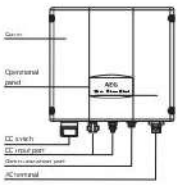


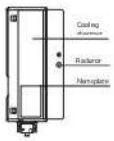




AS-IR01-(750-3000)







AS-IR01-(4000-5000)