The basics of electricity and photovoltaic systems

Electricity is a form of energy that results from the movement of electrical charges. It plays an essential role in our daily lives. A photovoltaic system consists of the components that capture, store and use solar energy. It powers various electrical devices by converting sunlight into electricity.

By Eric Chimeshula

Course Objectives

1

Technical skills

Master the basics of electricity. Understanding solar technologies. Identify and analyze system components.

2

Practical know-how

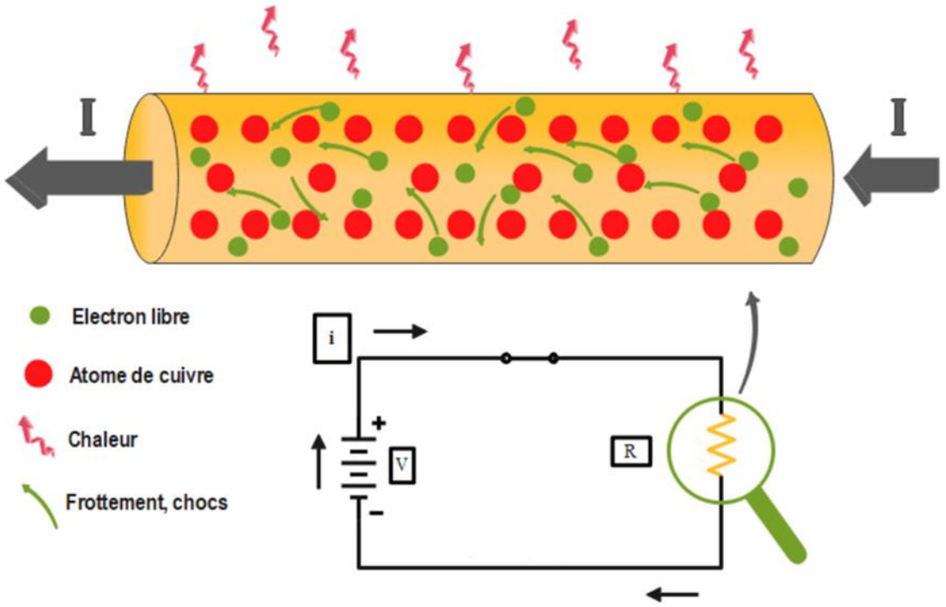
Calculate the electrical quantities. Choosing the components. Ensure the electrical safety of equipment and people.

3

Transversal skills

Compare different energy solutions. Keep up with technological innovations in the field.

Introduction to Electricity



1 **Omnipresence**

Electricity is everywhere in our modern lives.

2 **Form of energy**

It results from the organized movement of electric charges.

3 **Importance**

Understanding its basics allows you to use it better on a daily basis.

The electric charge

Negative Charges

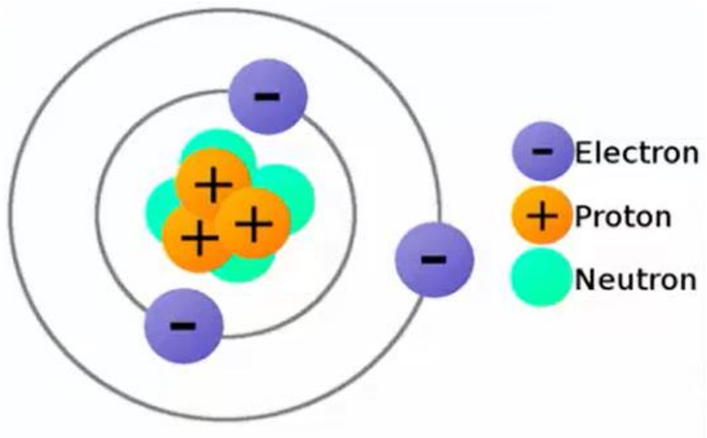
Electrons carry negative charges. They move easily in the conductors.

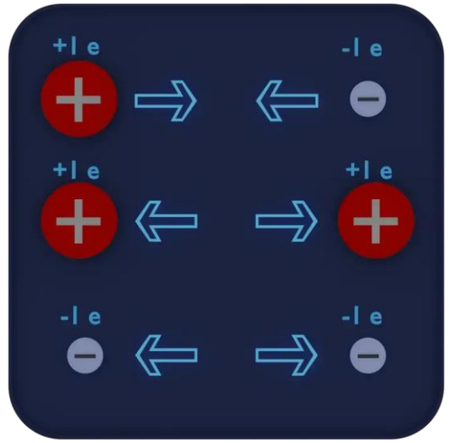
Positive Charges

Protons carry positive charges. They usually remain in the atomic nucleus.

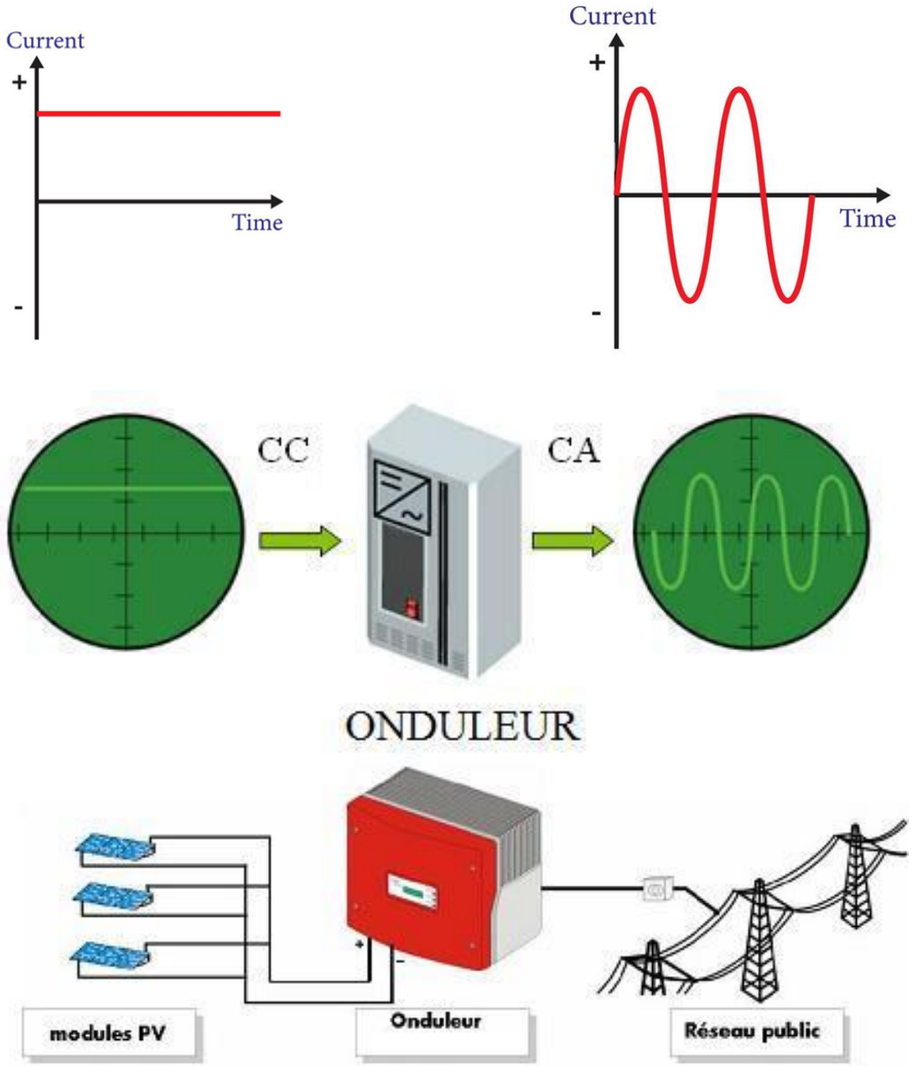
Interaction

Opposing charges attract. Identical charges repel each other.





Electric current



Definition

Electric current is a displacement of charges in a conductive material. It circulates under the effect of a potential difference.

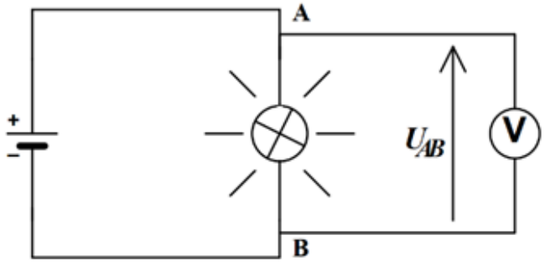
Direct Courant (DC)

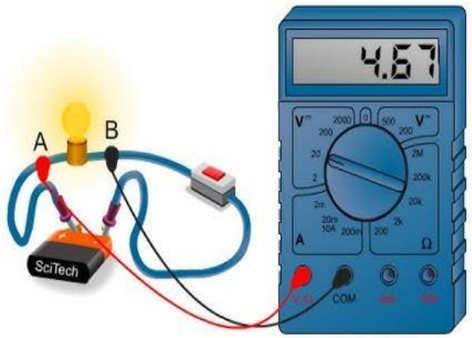
It always travels in the same direction, and is found in batteries and solar panels.

Alternative Courant (AC)

It periodically changes direction. This is the type provided by our domestic plugs.

Voltage and resistance





Electrical Voltage

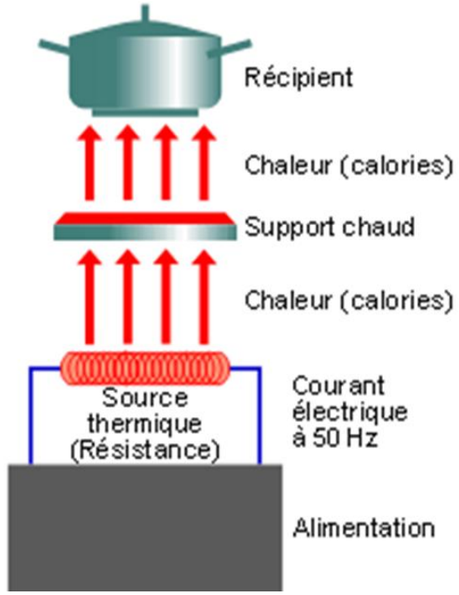
Expressed in volts (V). Represents the potential difference between two points. One AA battery: 1.5V. A domestic socket: 230V.

Electrical Resistance

Expressed in ohms (Ω). Limits the passage of current. The filament of a light bulb is a resistor.

Application

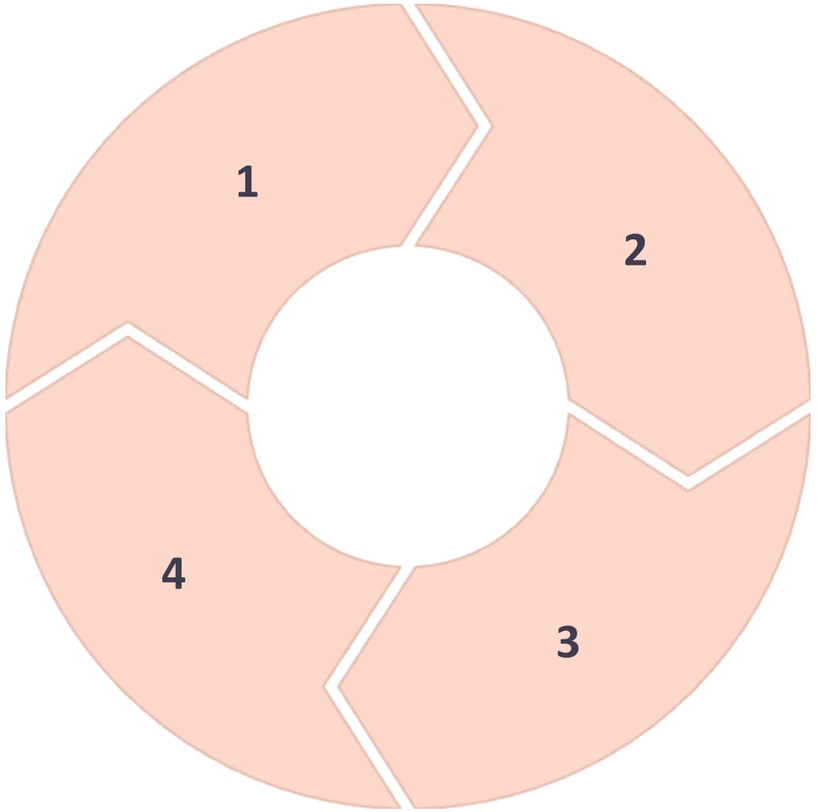
The resistor transforms electrical energy into heat or light.



Ohm's Law

Formula

U = R × I



Voltage (U)

Mesurée en volts (V)

Courant (I)

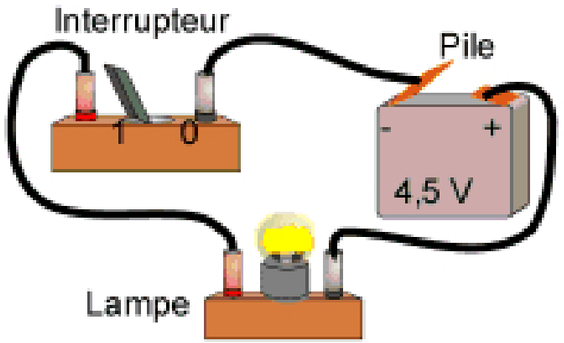
Mesuré en ampères (A)

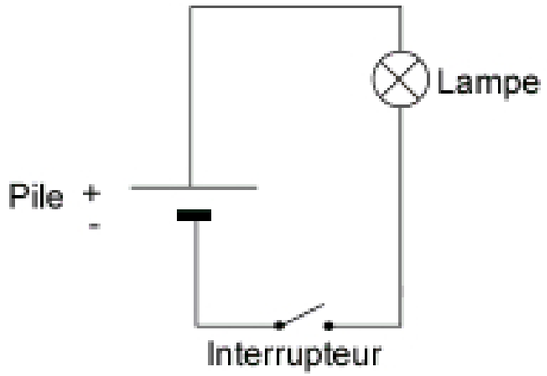
Resistance (R)

Mesurée en ohms (Ω)

Real example: A 100Ω bulb under 230V allows a current of 2.3A to pass through.

Electrical circuits





1

Power Source

Battery, battery or electrical outlet. Provides the necessary voltage to the circuit.

2

Conductors

Copper or aluminum wires. Allows current to flow.

3

Loads

Light bulbs, motors, resistors. Transform electrical energy.

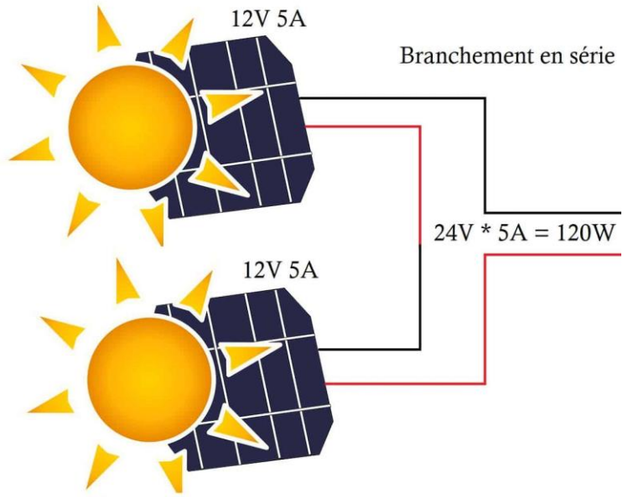
4

Switches

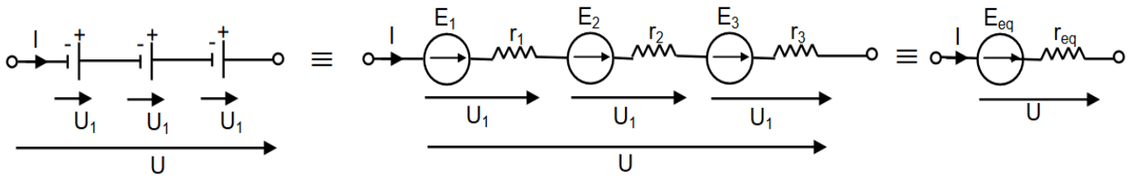
Open or close the circuit. Control the flow of current.

Serial circuit

The components are connected one after the other. The current is the same everywhere. The tension spreads.



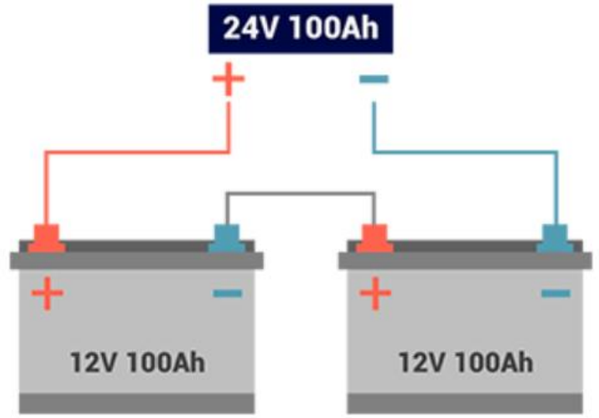
Example: Batteries in Series to Increase Output Voltage



En effet : $U = U_1 + U_2 + U_3 = (E_1 - r_1.I) + (E_1 - r_1.I) + (E_1 - r_1.I) = (E_1 + E_2 + E_3) - (r_1 + r_2 + r_3) = E_{eq} - r_e.I$

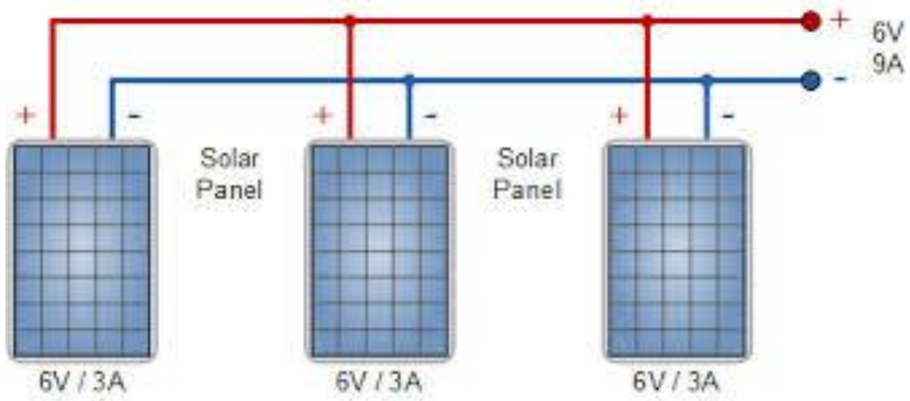
$$E_{eq} = E_1 + E_2 + E_3 + \ldots\ldots\ldots\ldots + E_n$$

$$r_e = r_1 + r_2 + r_3 + \ldots\ldots\ldots\ldots\ldots\ldots + r_n$$

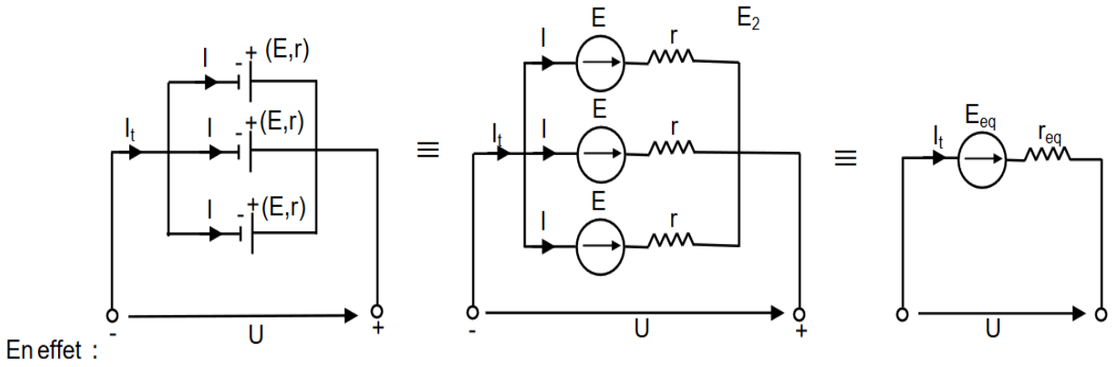


Parallel Circuit

The components are connected in branch after each other. The tension is the same everywhere. The current is divided.

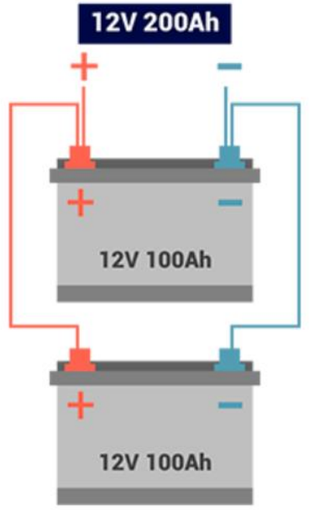


Example: Solar panel in parallel to increase the power produced

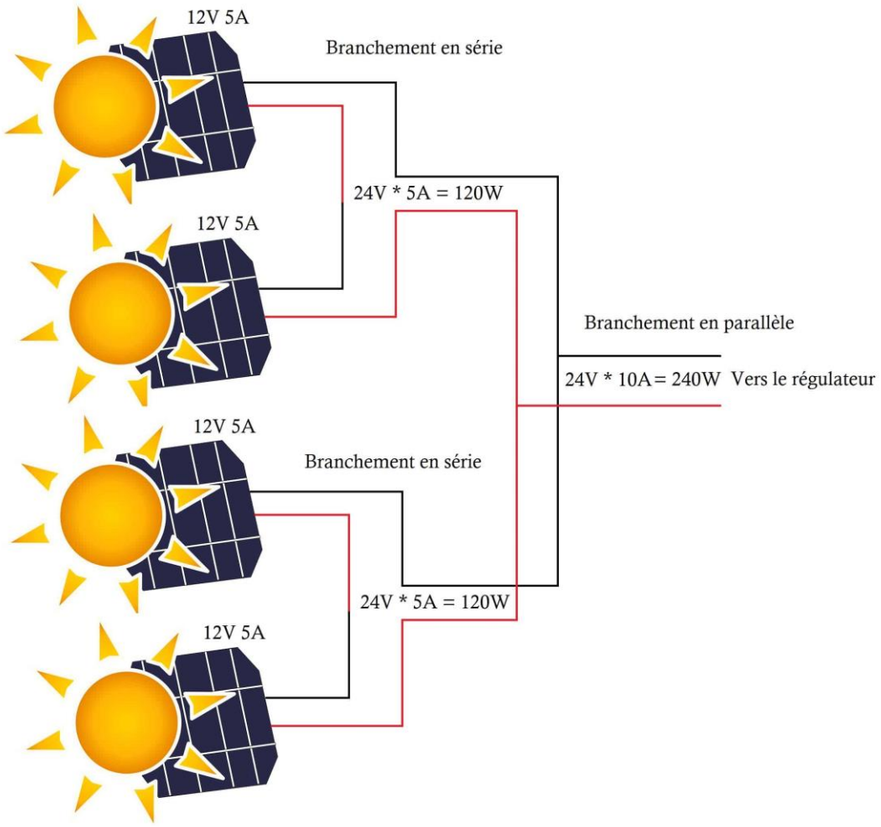


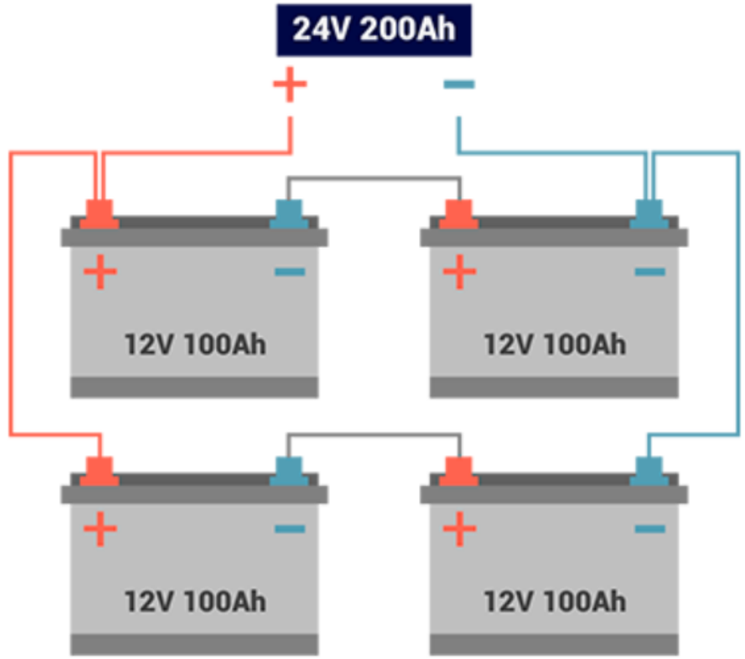
En effet :

$$\left.\begin{array}{l} I_t = 3.I \\ U = E - r.I = E_{eq} = r_e.I = E_{eq} - 3.r_e.I \end{array}\right\} \Rightarrow \boxed{\begin{array}{l} E_{eq} = E \\ r_e = \dfrac{r}{n} \end{array}}$$

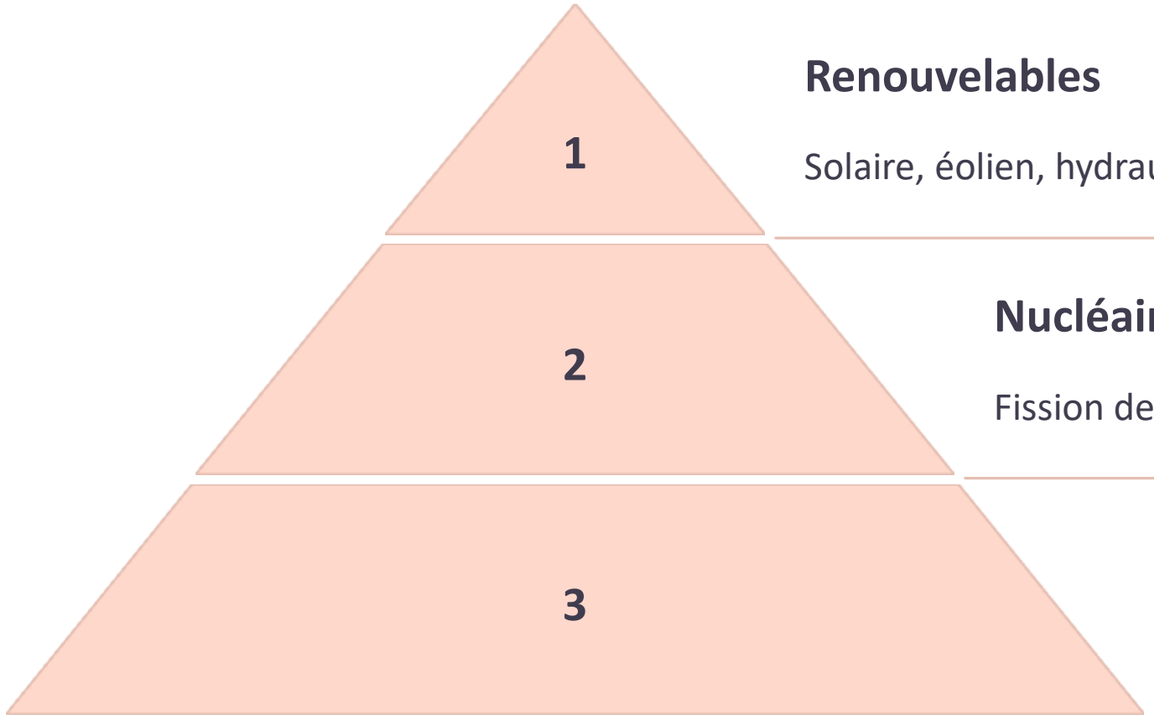


Mixed circuit





Power Generation



Renouvelables

Solaire, éolien, hydraulique

Nucléaire

Fission de l'uranium

Fossiles

Charbon, gaz, pétrole

Real-life example: The Three Gorges Dam in China produces about 22,500 MW of electricity. It is the largest hydroelectric power plant in the world.

Solar radiation

1 Definition

All the electromagnetic waves emitted by the Sun. Some of them reach the earth's surface.

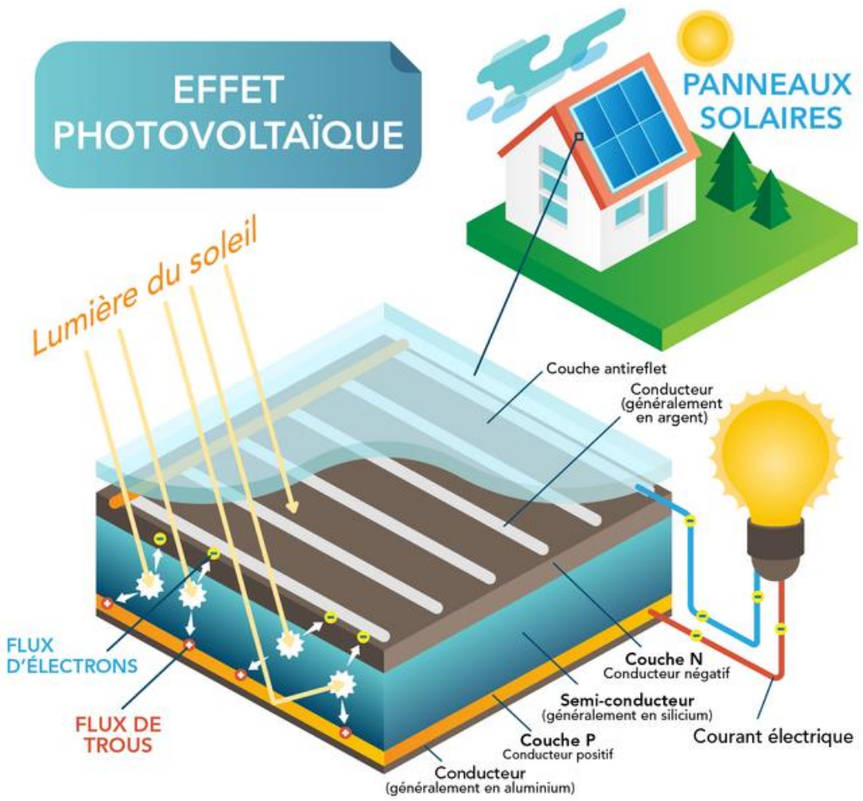
2 Intensity Factors

Latitude, time of day, seasons, and weather conditions influence intensity.

3 Conversion possible

This radiation can be converted into heat or electricity using different technologies.

Photovoltaic Solar Energy



1

Silicon cells

The panels are made up of semiconductor cells that capture light.

2

Photovoltaic effect

The photons hit the cell and release electrons from the material.

3

Electric current

The movement of electrons creates a usable electric current.

Centrale solaire de Rwamagana

1

Largest complex

Located 60 km east of the capital, Kigali, it is one of the largest solar complexes in Africa.

8,5

Megawatts

It generates a few megawatts of clean electricity.

28360

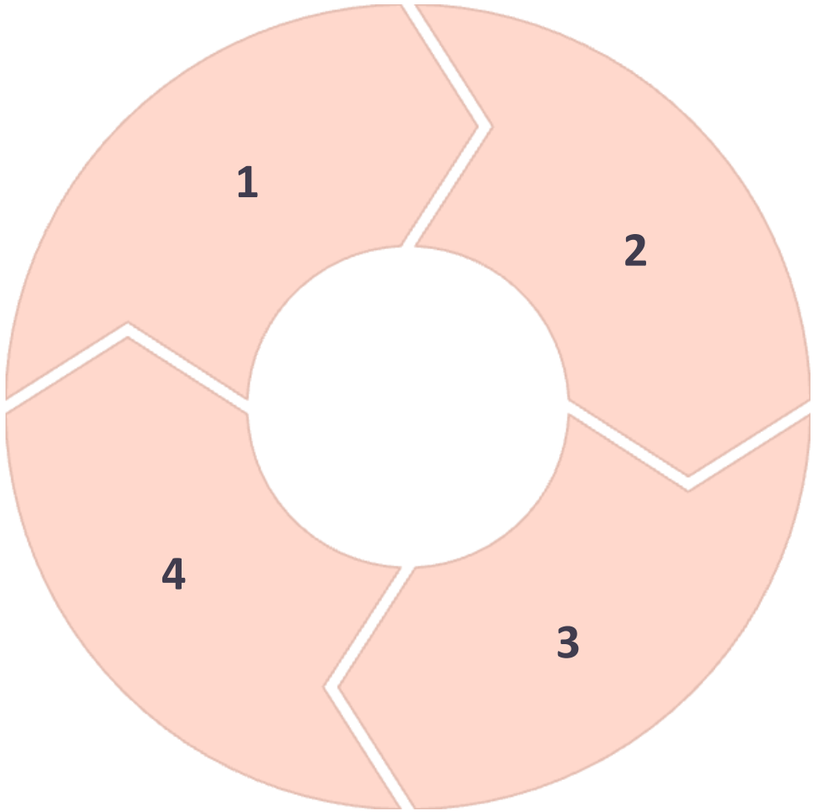
Solar pannels

Thousands of photovoltaic panels capture solar energy.

Solar thermal energy

Captation

Sensors absorb the Sun's heat.



Transfert

The heat is transferred to a heat transfer fluid.

Production

Turbines drive generators that produce electricity.

Generation

The heated fluid produces steam that drives turbines.

Ivanpah Solar Power Plant

Advanced Technology

Uses hundreds of thousands of mirrors to focus sunlight.

Power Towers

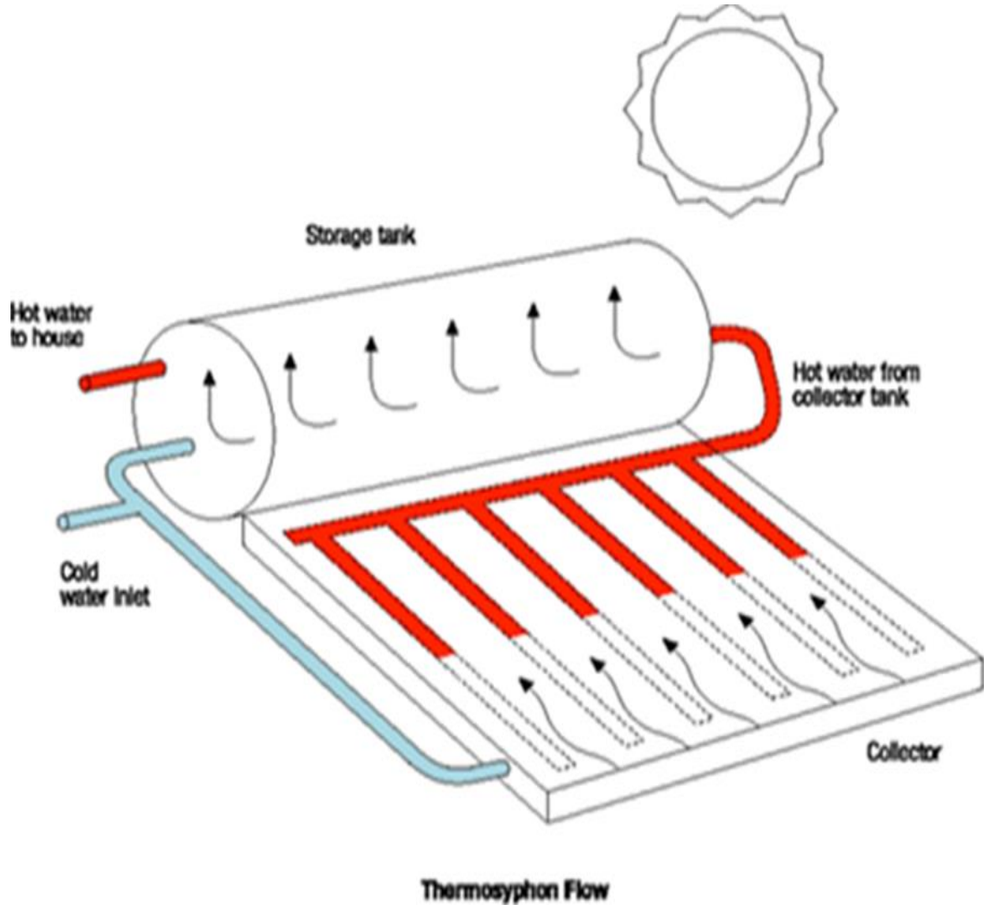
Light is directed towards towers where water is transformed into steam.

Significant Impact

Provides electricity to more than 140,000 homes in California.

Solar Water Heater

The water heater heats the water and keeps it warm in an insulated tank. When it is opened, the hot water is released and the temperature is regulated automatically. It combines thermal sensors, a storage tank and a back-up system to ensure continuous hot water.



Thermosyphon Flow

Benefits of Solar Energy

Énergie renouvelable

An inexhaustible source available for billions of years.

Écologique

Does not produce greenhouse gases or air pollution.

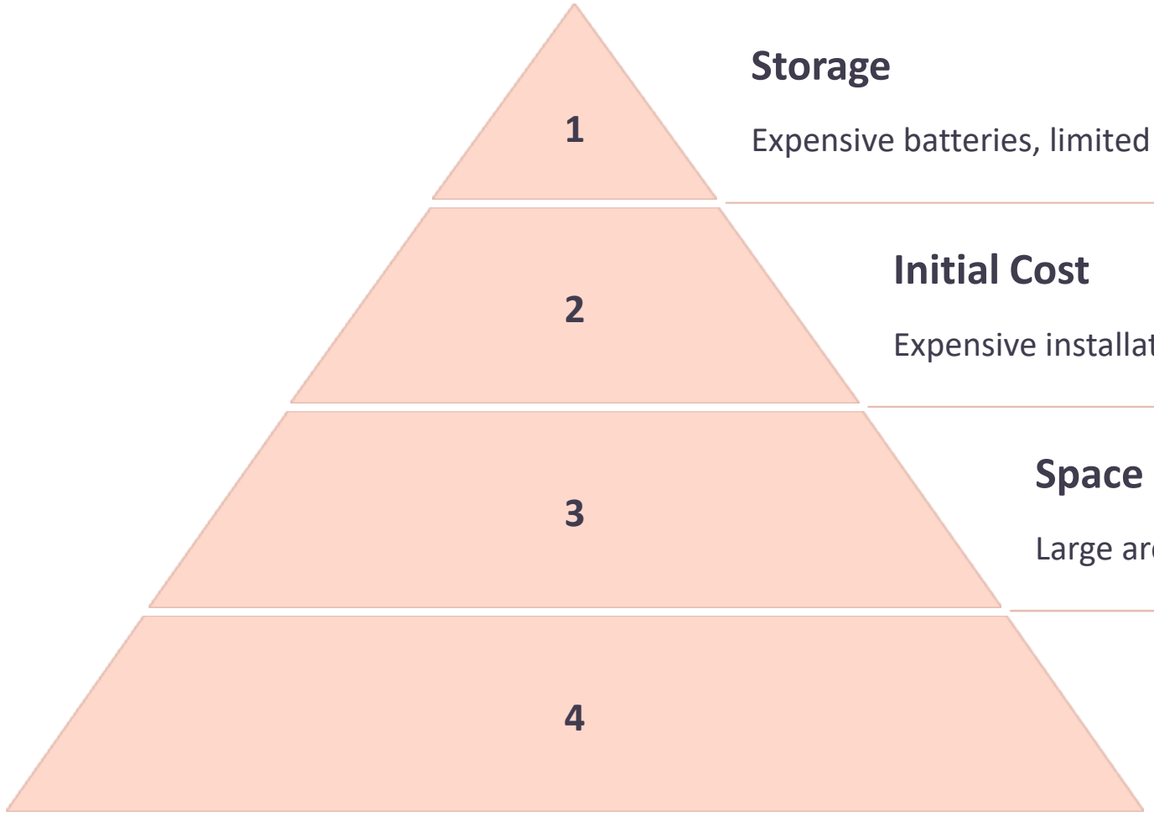
Indépendance

Reduces dependence on fossil fuel imports.

Économique

Low operating and maintenance costs after installation.

Solar Energy Challenges



Storage

Expensive batteries, limited lifespan.

Initial Cost

Expensive installation despite the drop in prices.

Space Required

Large areas needed for power plants.

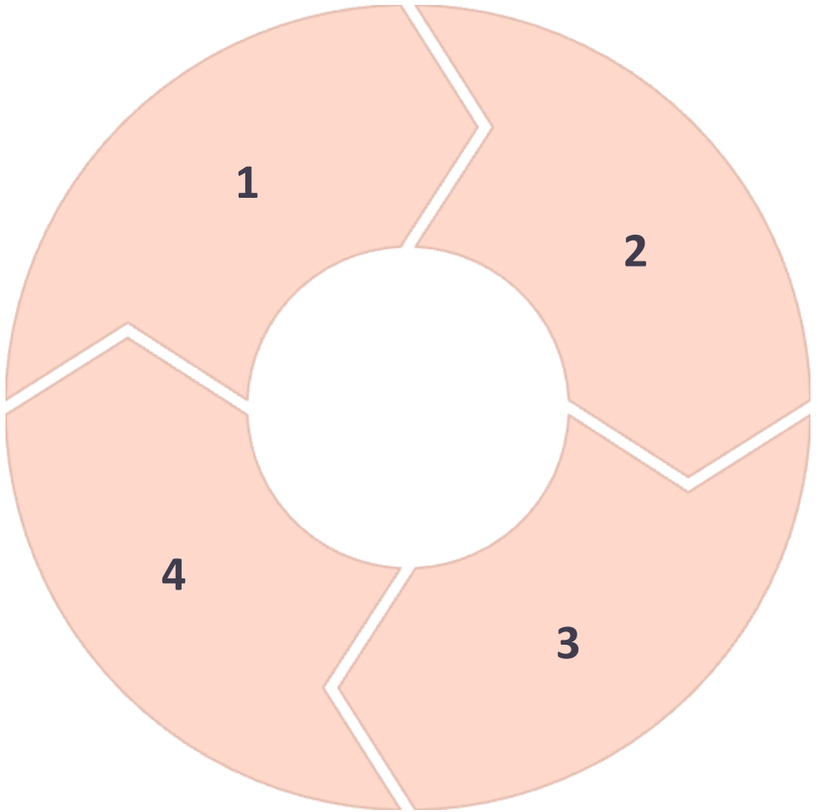
Intermittency

Weather-dependent production.

Solar Energy Technologies

Photovoltaic

Direct conversion of radiation to electricity



Solar thermal

Using the Sun's Heat

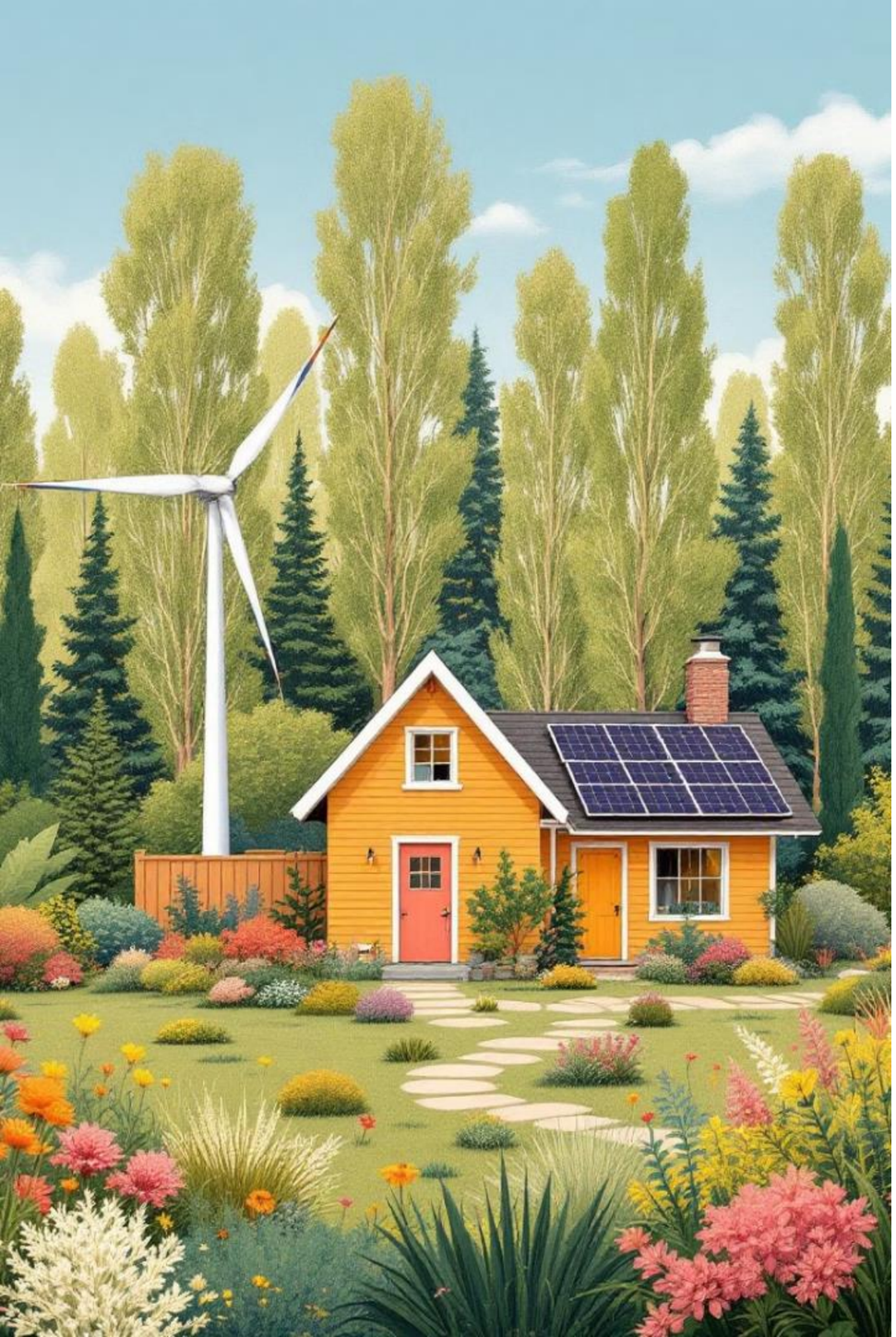
Distribution

Produced Energy Management Systems

Storage

Battery technologies to conserve energy

These technologies complement each other to maximize the use of solar energy. Each has its own advantages and specific applications.



Types of Solar Systems

1

Off-Grid Systems

Operate independently of the power grid. Require batteries for storage. Ideal for remote areas.

2

Hybrid systems

Combine solar energy with other sources. Provide increased reliability. Optimize resource utilization.

3

On-Grid systems

Connected to the public power grid. Sell surplus energy. Reduce the electricity bill.

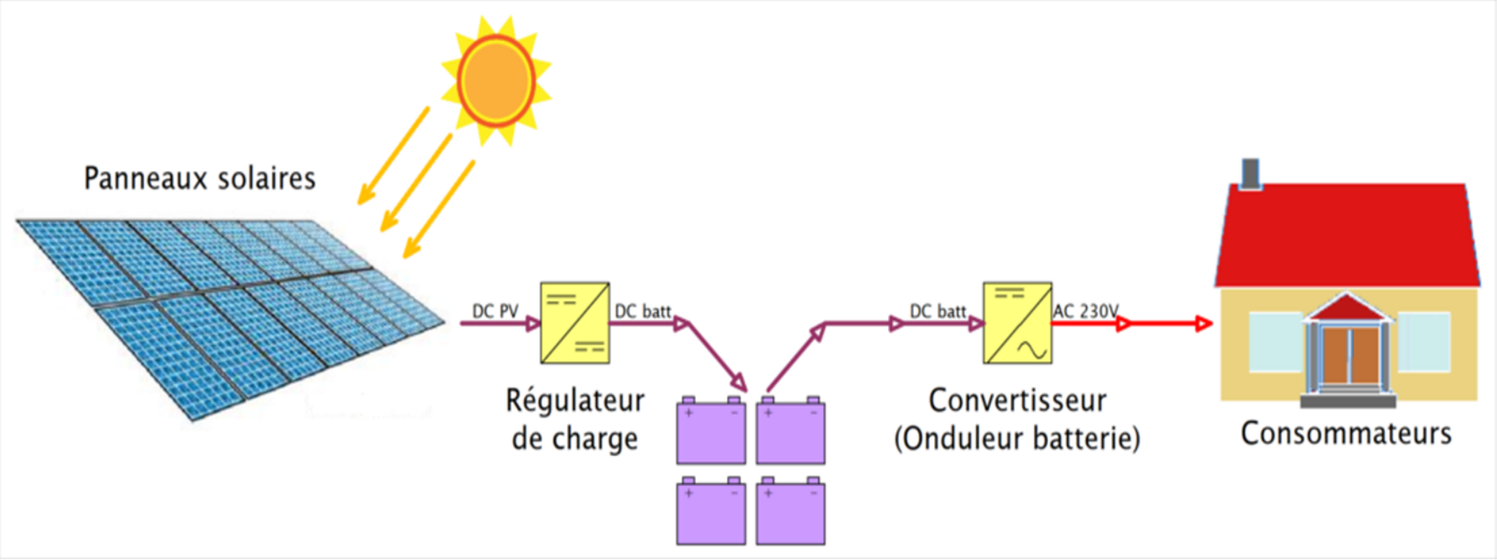
Off-Grid Solar System

Principe

Solar panels produce enough energy during the day to cover the needs of the day and night. The energy is stored in batteries to be released at any time.

Applications

Isolated sites, telecommunications, disconnected agricultural facilities, humanitarian emergency infrastructure.



Advantages and disadvantages of the autonomous system

Advantages

- Total independence
- Ideal for remote areas
- Low operating costs
- Reduce carbon footprint

Disadvantages

- High initial cost
- Weather dependence
- Need for efficient storage
- Maintenance and control of batteries

Hybrid Solar System

1

Principe

Combines solar energy with another source (power grid or generator). Optimizes consumption by favoring solar energy.

2

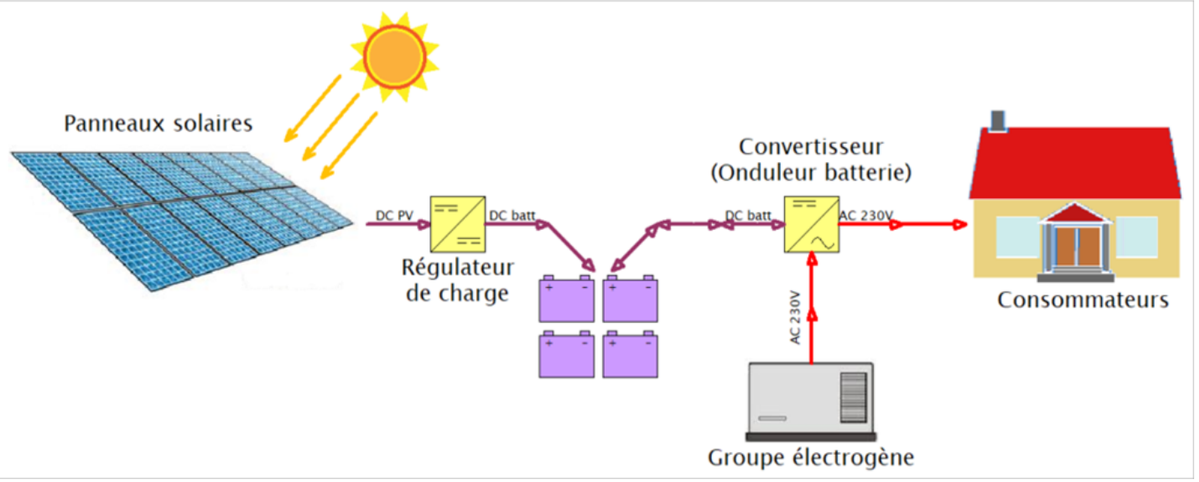
Applications

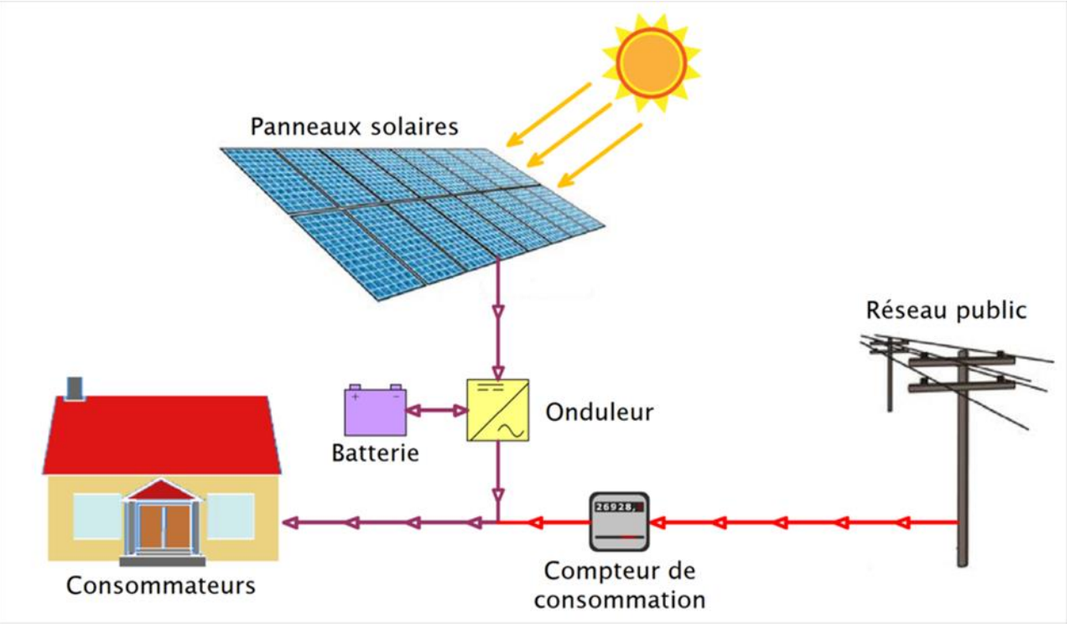
Semi-isolated areas, companies reducing their dependence on the grid, industrial sites, medical centers.

3

Example

A farm combining solar panels and diesel generator to ensure a stable power supply.





Advantages and disadvantages of the hybrid system

Flexibilité et fiabilité accrues

The system adapts to different conditions and ensures continuous feeding.

Réduction des coûts énergétiques

Optimizes the use of available sources based on their performance.

Installation plus complexe

Requires more sophisticated installation and management than other systems.

Investissement initial élevé

Requires a large budget for the purchase of various equipment.

On-Grid Solar System

1 2 3

Principe

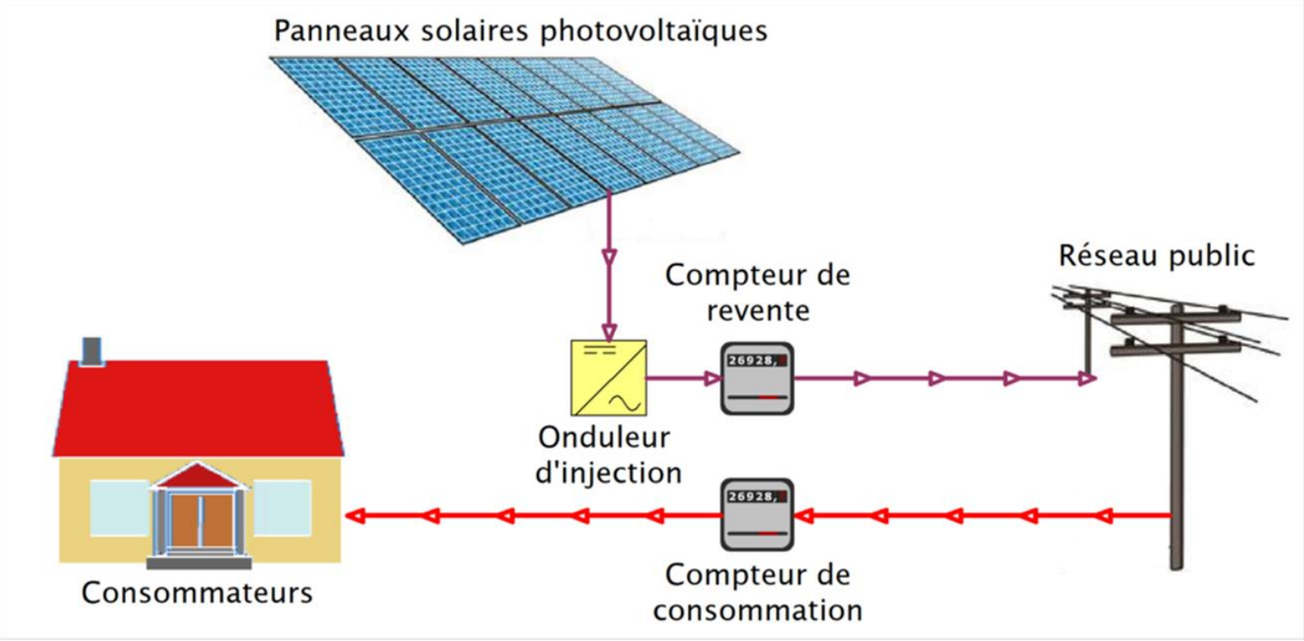
Connected to the public power grid. Produces solar energy and feeds it directly into the grid.

Applications

Urban areas, businesses, commercial projects, renewable energy generation fed into the national grid.

Example

A house in the city that injects its surplus energy into the grid in exchange for financial compensation.



Advantages and disadvantages of the connected system

30%

Coût réduit

Cheaper installation than systems with batteries. Faster return on investment.

100%

Dépendance

Total dependence on the electricity grid. No power in the event of a power cut.

20%

Entretien

Low maintenance required. No batteries to replace periodically.

Choosing the right solar system

Your situation

Location, network access

Your needs

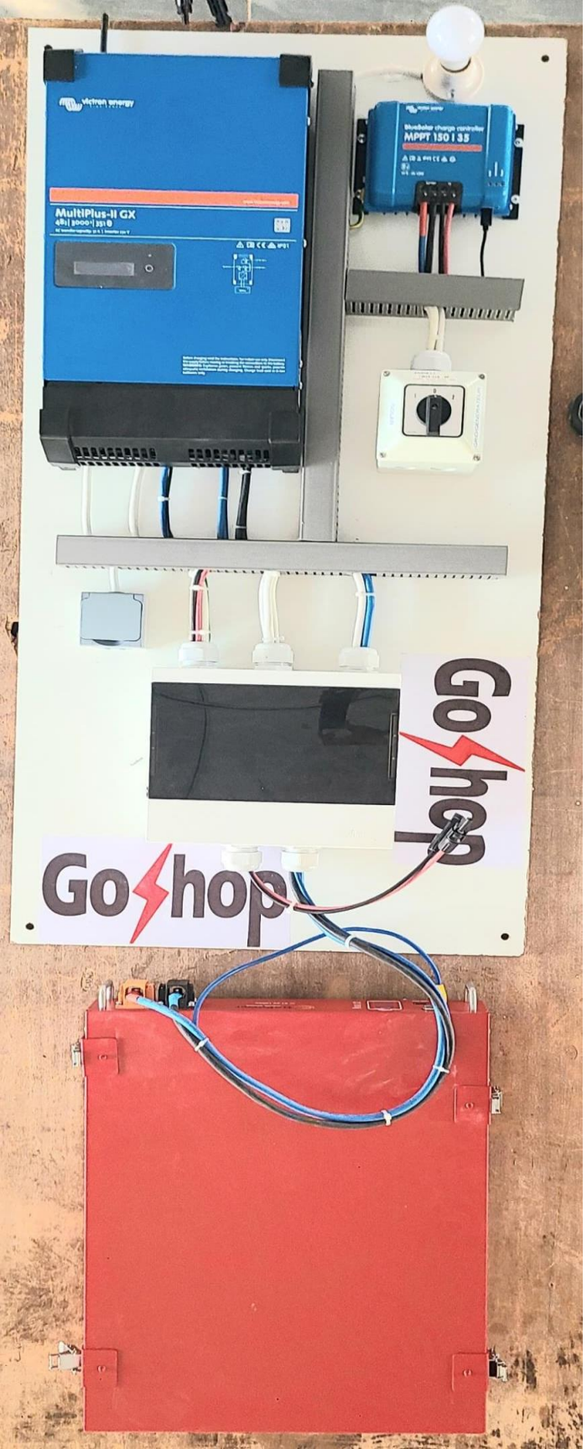
Consumption, required autonomy

Your budget

Initial investment, profitability

The right solution

Off-Grid, Hybrid or On-Grid



Components of a solar kit

Solar Panels

They capture the sun's energy and convert it into electricity.

Charge Controller

It protects the battery from power surges and deep discharges.

Batteries

They store energy for later use.

Inverter

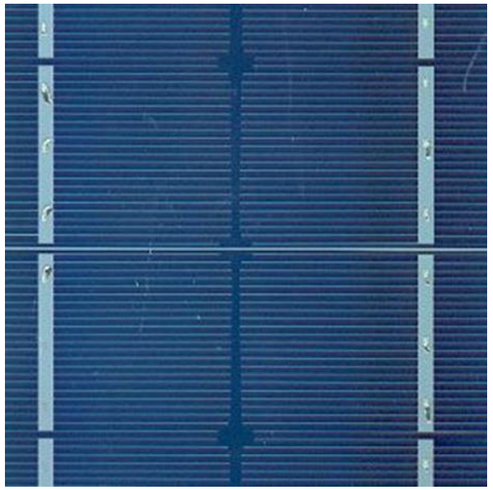
It transforms direct current (DC) into alternating current (AC).

Go shop ACADEMY

Types of solar pannels

Monocristallins

High efficiency (15-22%). Works well in low light. Higher cost. Aesthetic black color.

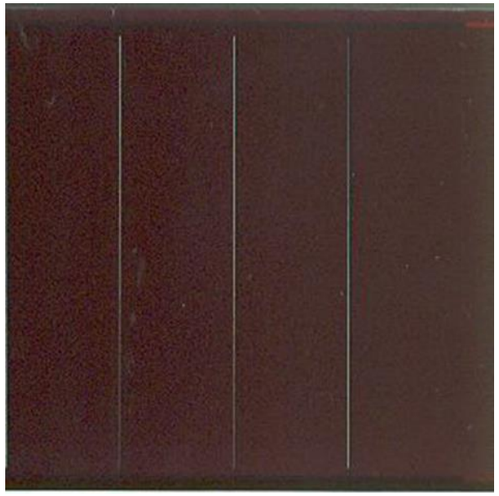


Polycristallins

Average yield (13-18%). Cheaper. Requires more surface area. Grainy bluish colour.

Amorphes

Low efficiency (7-12%). Effective on cloudy days. Flexible and suitable for mobile installations.



Panel features

Power Pmpp (Watt-peak)

Indicates the maximum electricity production under optimal sunlight.

Open Circui Voltage Voc

It is measured at the terminals of the panel in the absence of current

Voltage Vmpp

It is measured at the point of maximum power

Current Impp

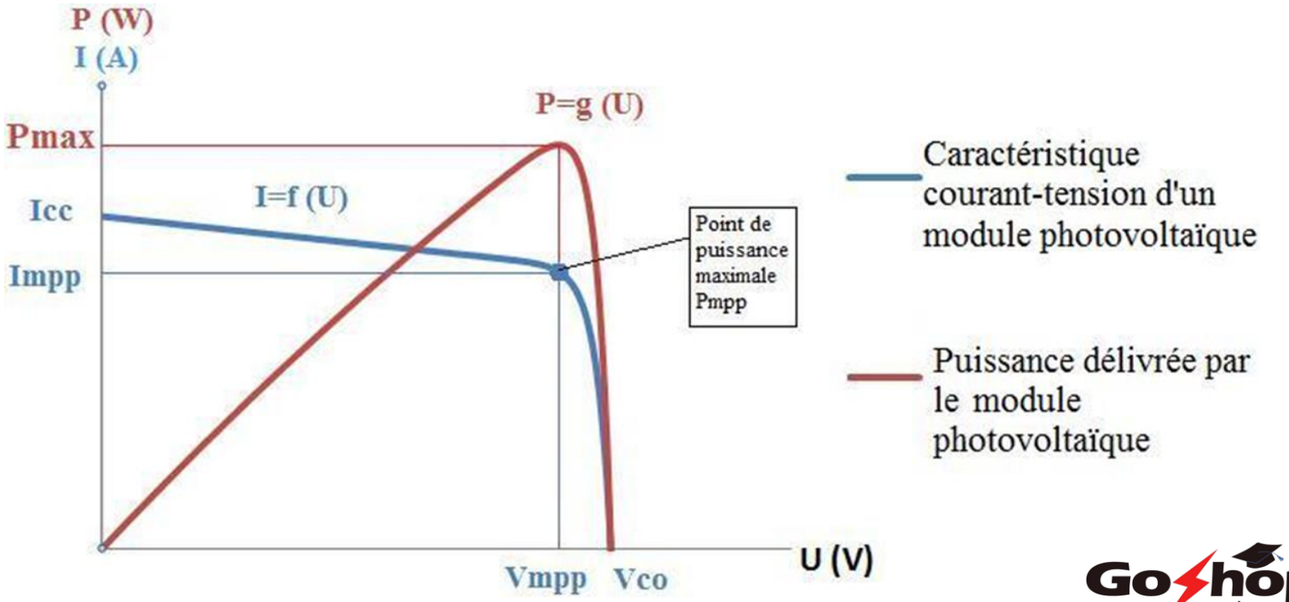
It is measured at the point of maximum power

Current Icc

the maximum current it can provide when its terminals are directly connected to each other without resistance (short circuit).

Lifespan

About 25-30 years with a yield loss of about 0.5% per year.



Role of the charge controller

1

Regulation

Controls the voltage and current sent to the battery.

2

Overload protection

Avoids overcharging that damages the battery and creates hazards.

3

Discharge prevention

Prevents over-discharge that reduces service life.

4

Night protection

Blocks current backflow to the panels overnight.

Types of Controllers

1

PWM Regulator

Inexpensive. Suitable for small systems. Works with equal voltages.

2

MPPT Regulator

More efficient (+30% efficiency). Optimizes tension. Allows for a variety of configurations.

Types de batteries solaires

Plomb-Acide

Cheap but heavy. Require regular maintenance. Lifespan: 3-7 years.

Gel

Resistant to extreme temperatures. Lifespan: 7-12 years.

AGM

Maintenance-free. Good resistance to discharges. Lifespan: 5-10 years.

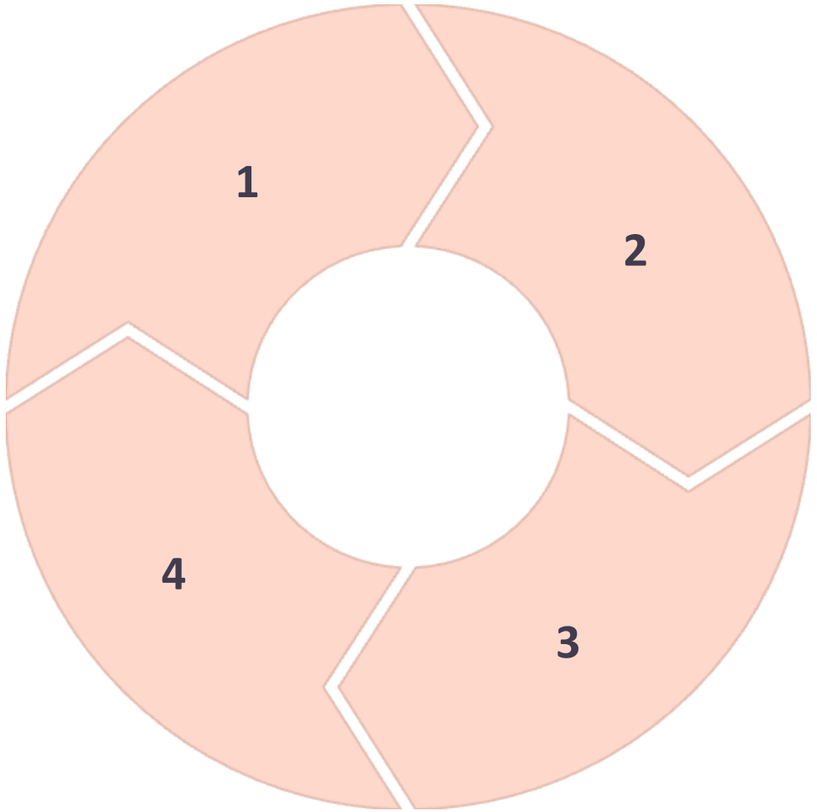
Lithium-ion

Lightweight and efficient. High efficiency. Lifespan: 10-15 years.

Battery features

Capacity (Ah)

Represents the amount of energy stored.



Nominal voltage (V)

For example, a 51.2 V lithium battery in the voltage range is 43.2 – 57.6 V

Influencing factors

Depth of discharge, temperature, maintenance and battery type.

Number of cycles

Number of charges/discharges before loss of efficiency.

Inverter- charger

Fonction

Converts direct current (DC) to alternating current (AC) and charges the battery.

Types

Modified or pure sine wave.

Features

Rated power (kVA), input DC voltage, load current and efficiency (>90%).

Lifespan

About 10-15 years depending on usage.

Accessories

MC4 Cables & Connectors

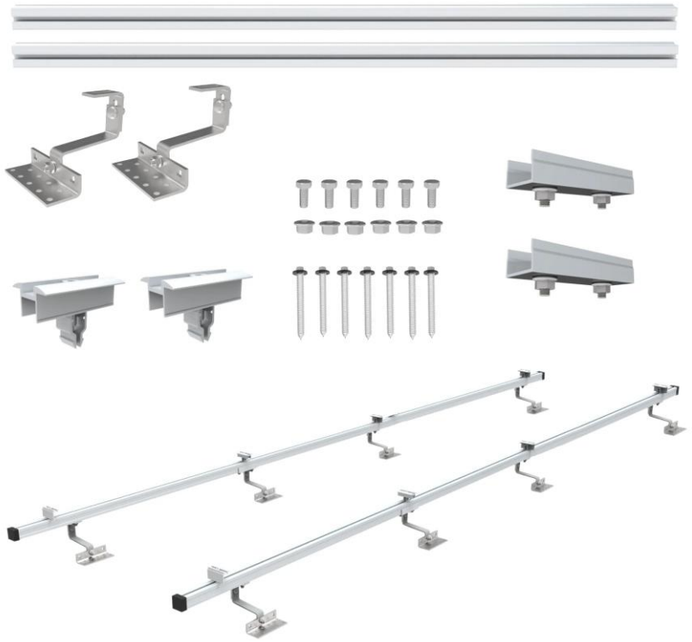
Carry electricity. UV and weather resistant. Ensure tight connections.

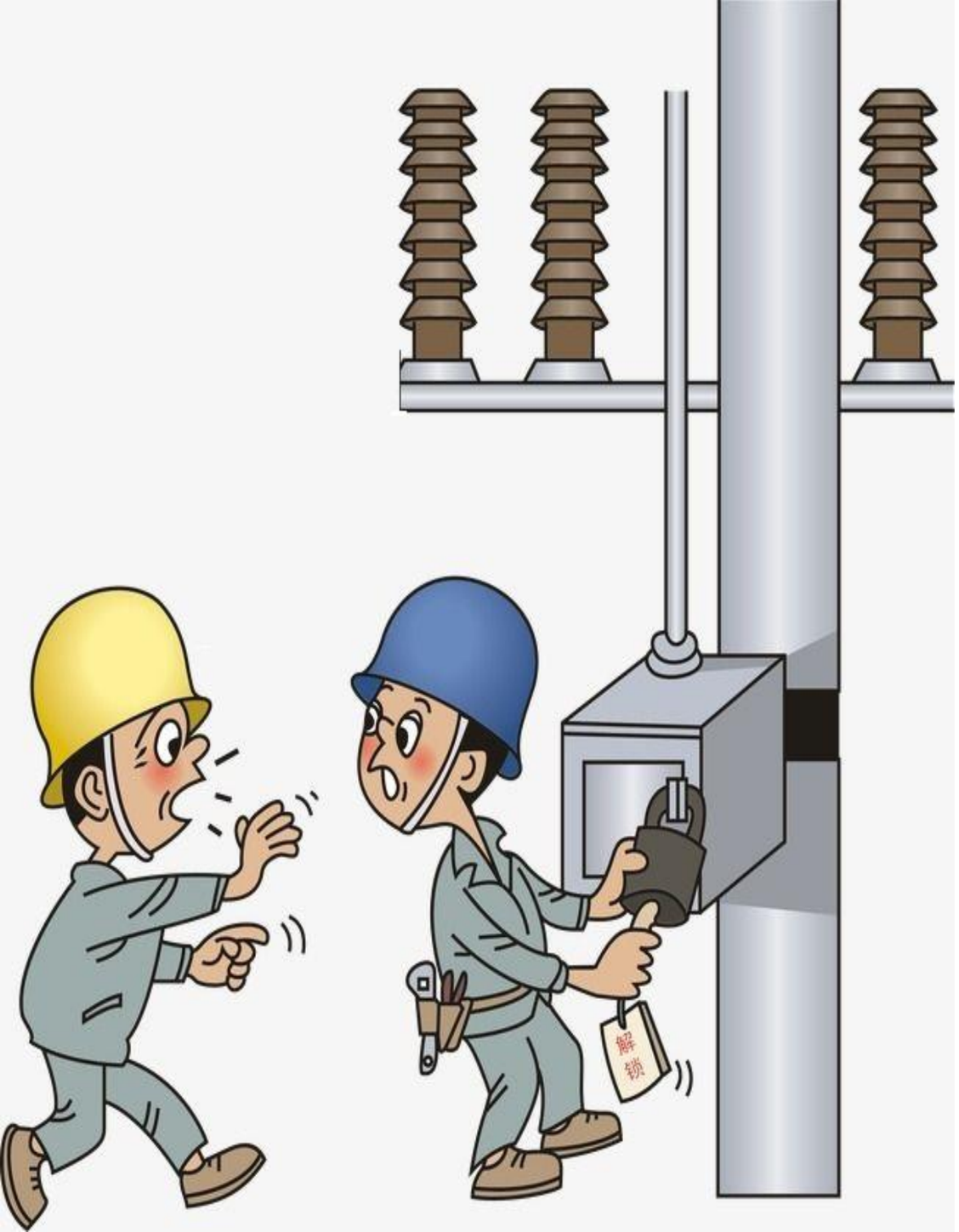
Fuses & Circuit Breakers

Protects against short circuits and power surges.

Brackets & Fasteners

Allows panels to be installed on roofs, floors or mobile structures.





Electrical safety

Never touch bare wire

Direct contact with electricity can be deadly.

Use circuit breakers

They prevent short circuits and overloads.

Avoid overloading the sockets

The overloaded multiplies cause fires.

Turn off the power supply before surgery

This is the golden rule for all electrical manipulation.

Conclusion

Electricity is essential to our daily lives. This course covered its basics, from the fundamentals to circuits and power generation, to exploring photovoltaic systems and emphasizing safety.