Solar Energy

Basics of Solar Energy and photovoltaic systems

Emmanuel M Biriziza, Energy Specialist, UN-HABITAT

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In this video you will learn:

- The basics of electricity
  - Basics components of PV system
    - Understanding the pros and cons of solar PV technology

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Electricity Basics

Electricity Basics

- **Electric charge:** the build up of electrical energy measured in coulombs (ampere-hours). Naturally it occurs as static electricity. Batteries store electric charge.
- **Electric current:** the rate of flow of electric charge measured in amperes
- **Electric potential:** the potential difference in electrical energy between two points e.g. between the positive and negative terminals of a battery. It is measured in volts.
- **Electromagnetism:** the relationship between electricity and magnetism, which enables electrical energy to be generated from mechanical energy (as in a generator) and vice versa (as in a motor).
- **Electrical quantities**
  - Primary: Voltage (Volts), Current (Amperes), Resistance (Ohms)
  - Secondary: Power (Watts), Energy (Watt-hours), Time (hours)

Electricity Basics

- Basic elements of electricity
  - Voltage, Current, Resistance, Power, AC and DC
  - Parallel and Series connection
- Calculation
  - Ohm's Law
  - Power Law
- Wattage and Watt hour
- Daily power consumption and Peak load

Power = Volts x Current	**P = V X I**	Watts
Volts = Power ÷ Current	**V = P ÷ I**	Volts
Current = Power ÷ Volts	**I = P ÷ V**	Amperes
Resistance = Volts ÷ Current	**R = V ÷ I**	Ohms
Energy = Power x Time	**E = P x t**	Watt-Hours

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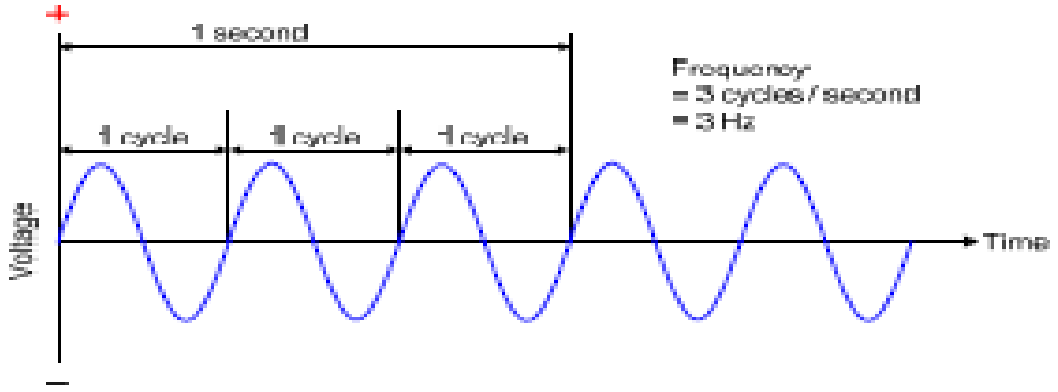
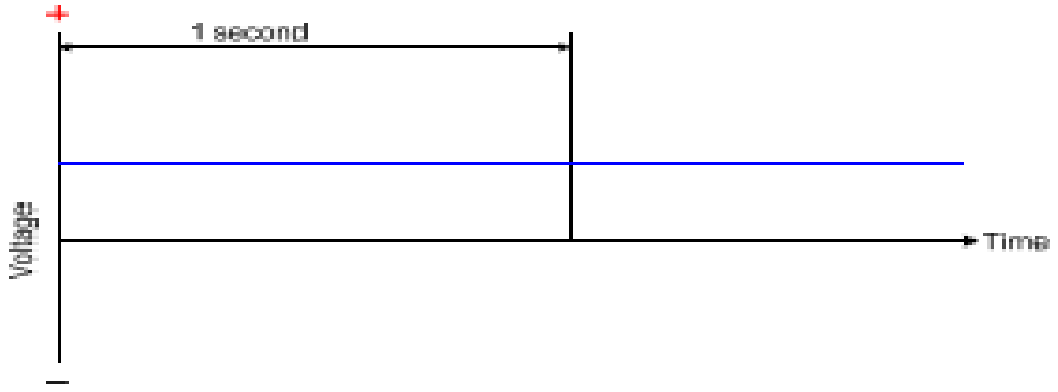
Electricity Basics

- Forms of Current: AC and DC

Alternative Current
Polarity changes
(No Polarity)



Direct Current
Fixed Polarity



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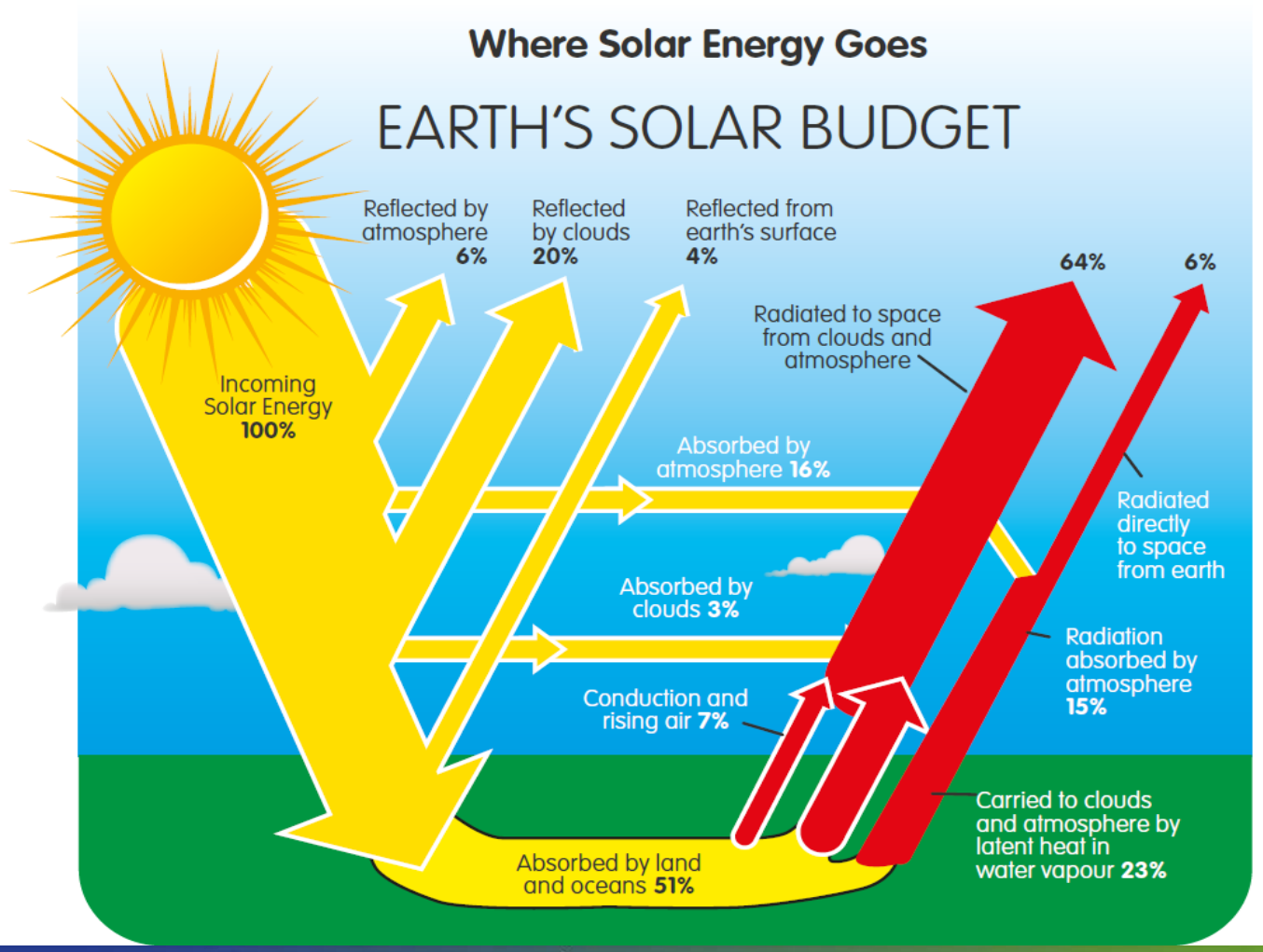
Solar Energy Basics

Solar Energy: The Resource



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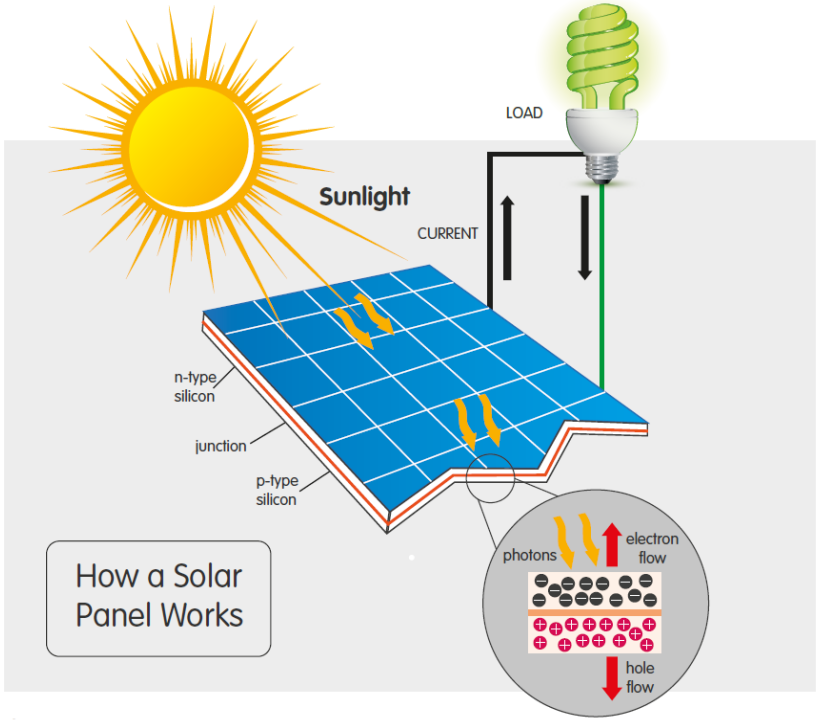
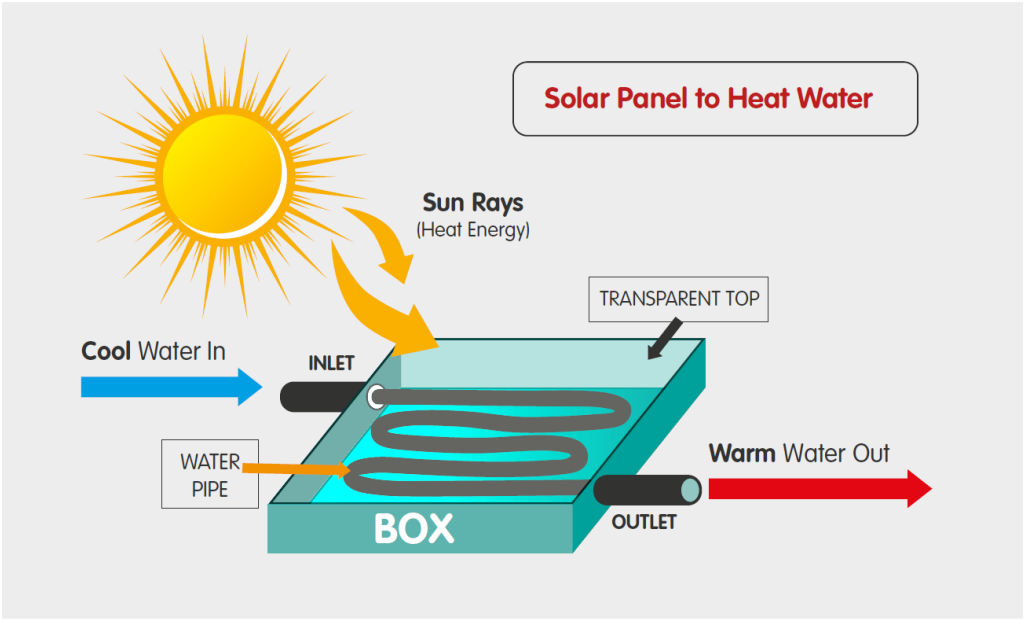
Solar Energy: Technologies and Applications

- **Solar PV** – conversion of sunlight to electricity
- **Passive** – provides light and harnesses heat from sun to warm homes and businesses
- **Water Heating** – harnesses heat from the sun to provide hot water
- **Process Heat** – heat or cool commercial and industrial buildings
- **Concentrating Solar Power** – harness heat from the sun to provide electricity for large power stations (steam technology)

Solar Energy: Technologies





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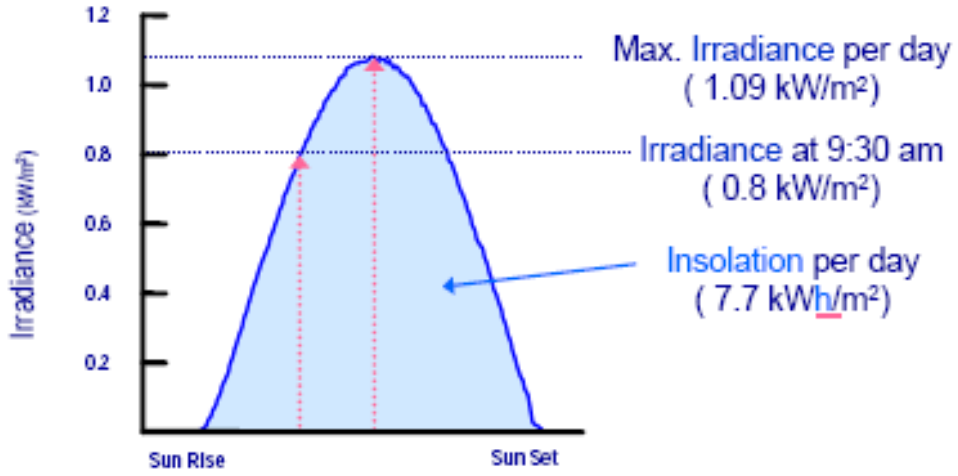
Solar Energy: Key Factors

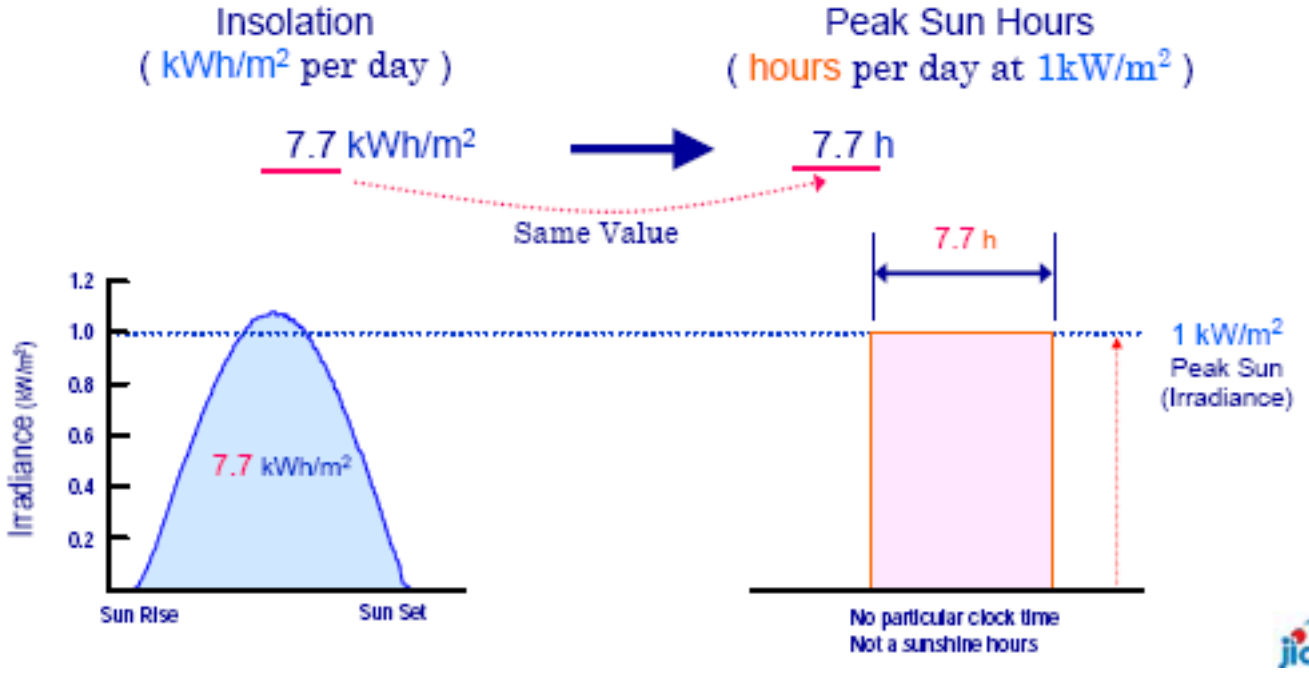
- The amount of solar energy (insolation) available at a particular location on the earth's surface is affected by:
  - Latitude (the location's distance north or south of the equator),
  - The earth's tilt, and
  - Time of year
- The average insolation for a particular location is known as **irradiance** and is measured in Watts per square meter (W/m2).

Solar Energy: Peak Sun-hour

Irradiance : Intensity of Solar energy kW/m²
Insolation : Quantity of Solar energy kWh/m²
(Irradiation)



Peak Sun Hours is used to calculate power generation of PV modules



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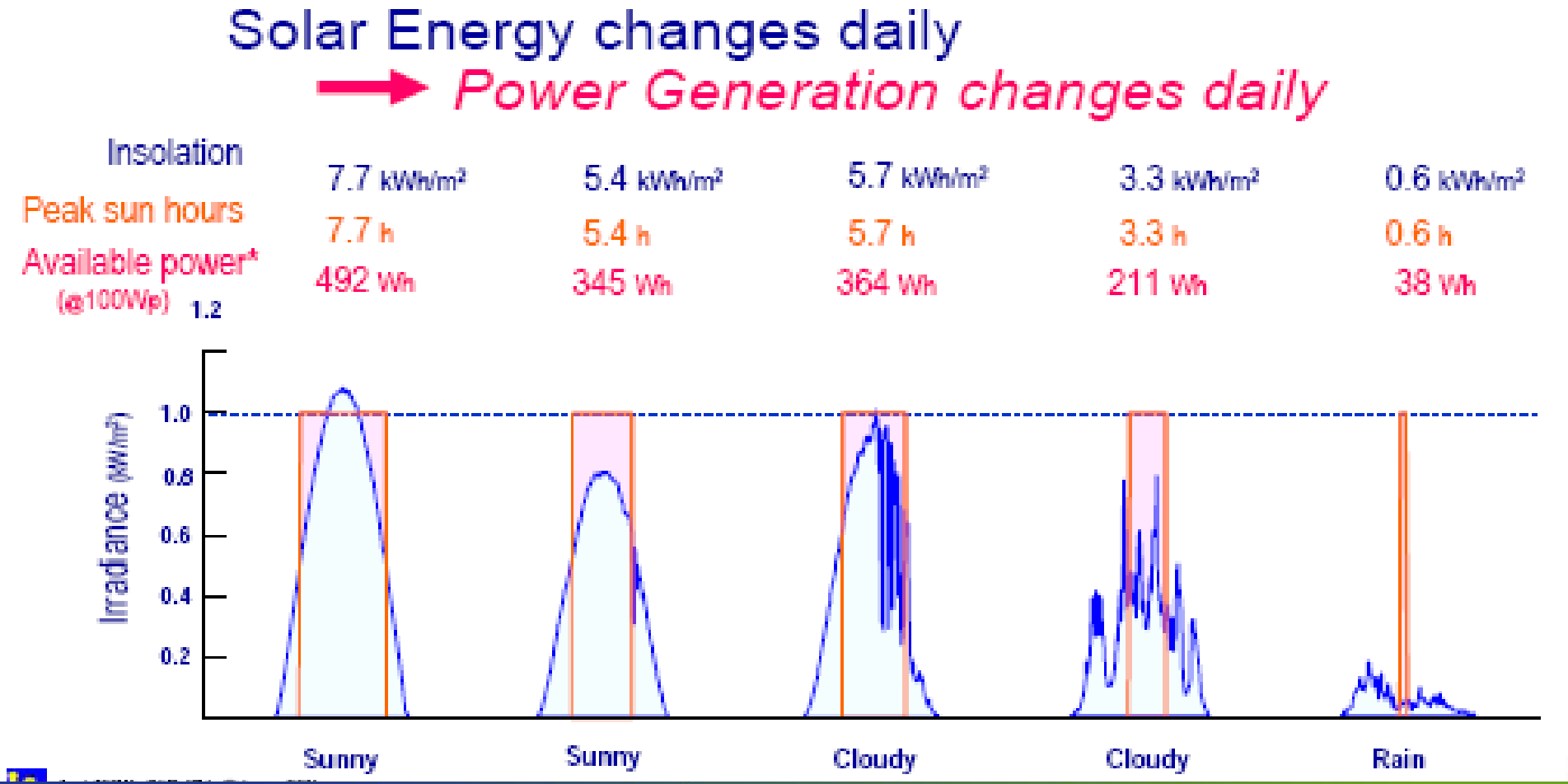
Solar Energy: Daily Insolation



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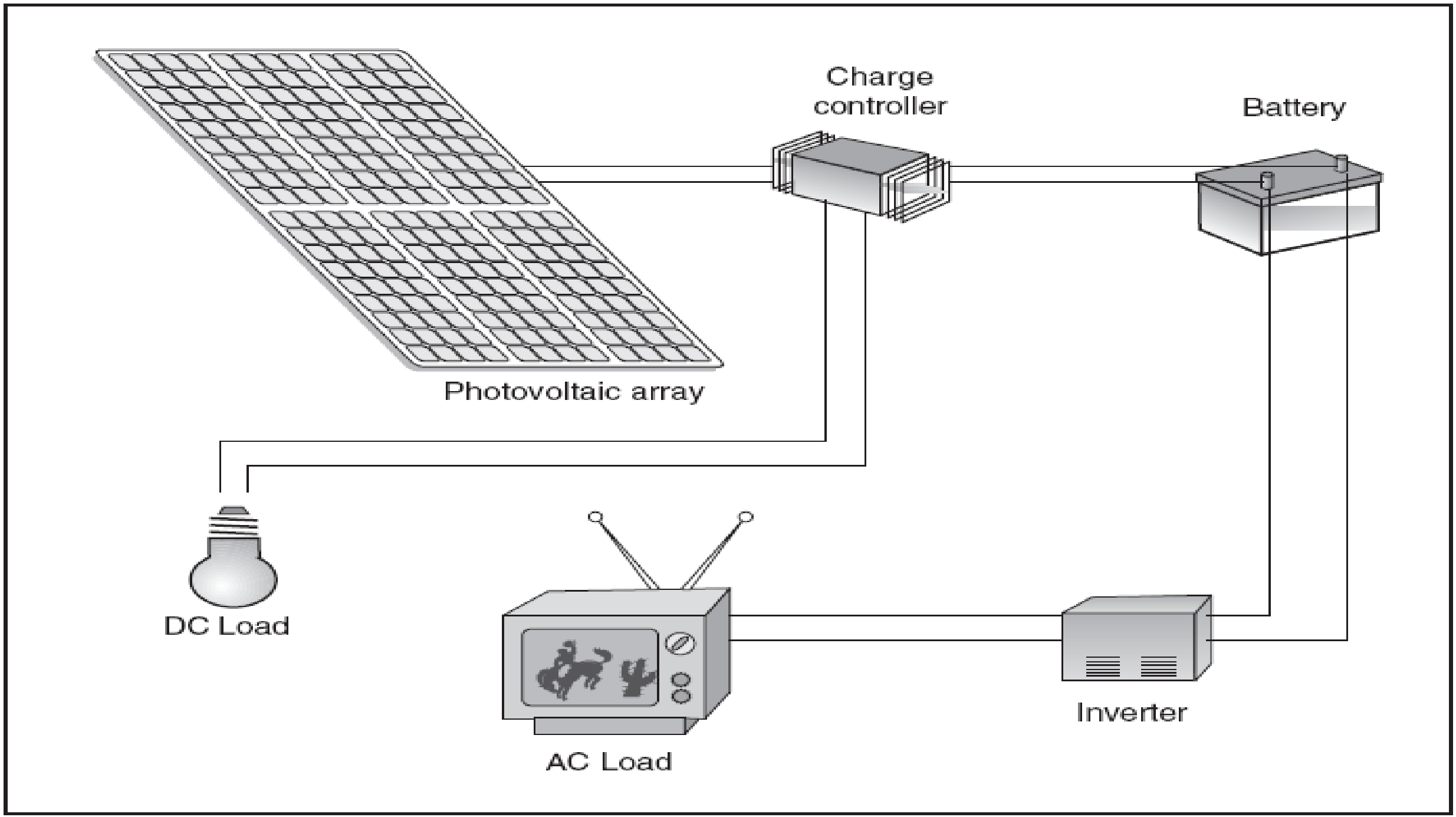
Components of Solar PV System

Components of Solar PV System

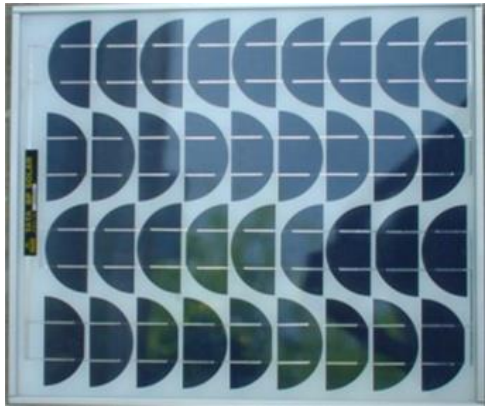
- Solar Panels – convert light into electricity (DC)
- Batteries - store electricity to provide energy on demand at night or on overcast days; voltage and current stabilization; supply surge currents
- Inverters - required to convert the DC power produced by the PV module into AC power;
- Converters – covert the voltage from one level to another
- Controllers - manage the energy storage to the battery and deliver power to the load;
- Others – Wires, Electrical Accessories, Appliances, and Structure.


Charge
controller
Battery
Photovoltaic array
DC Load
AC Load
Inverter

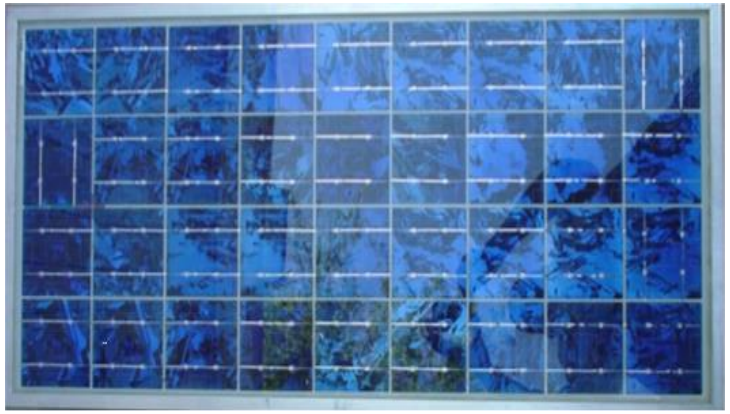
Solar PV: Terminologies

Solar Modules: Types

Mono-crystalline



Poly-crystalline

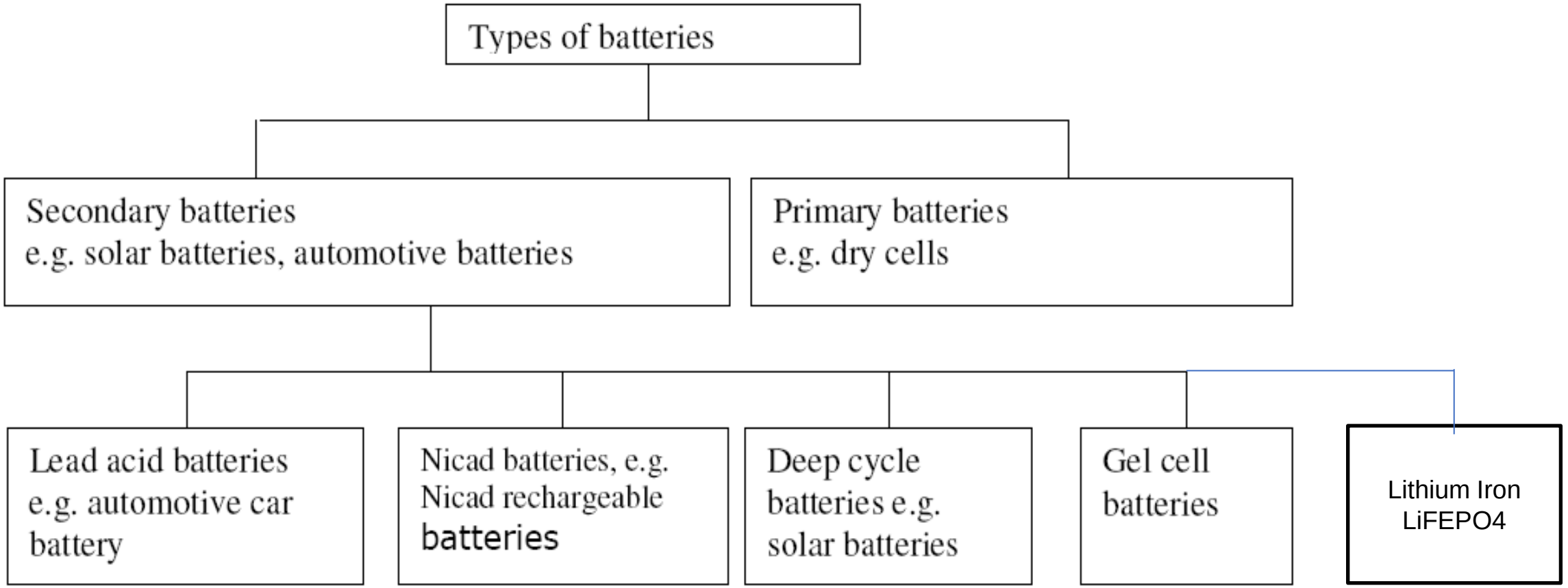


Amorphous

Solar Modules: Characteristics

Monocrystalline	**Polycrystalline**	**Amorphous**
Single colour tone	Multiple colours	Strips
Efficiency 11-16%	Efficiency 9-13%	Efficiency 3-6%
Longer life span (20 years)	Long life span (about 20 years)	Short life span (up to 10 years), degrade in power after some time
Expensive	Less expensive	Cheaper
Less output in diffuse radiation	Less output in diffuse radiation	More output with diffuse radiation
Affected much by shading	Affected much by shading	Less affected by shading

Batteries: Classification



Batteries: Life

Battery life is affected by the following:

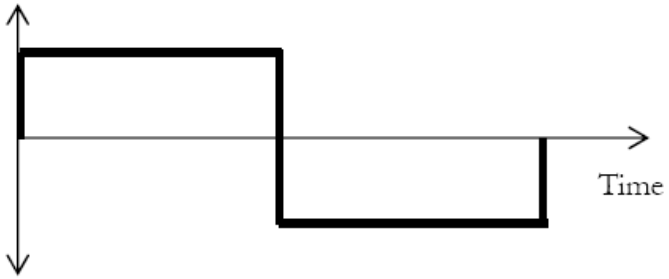
- **Age** – most of solar batteries operates efficiently in the first three years
- **Temperature** – if the temperature around the battery gets above 40^{o}C, its lifetime and performance will be reduced.
- **Self-discharge** – all batteries lose charge by themselves. As the battery gets older, the rate of self-discharge increases.
- **Rate of discharge/charging** – the actual life cycle of the battery is shortened by deep discharge and overcharging the battery. LiFEPO4

Charge Controller

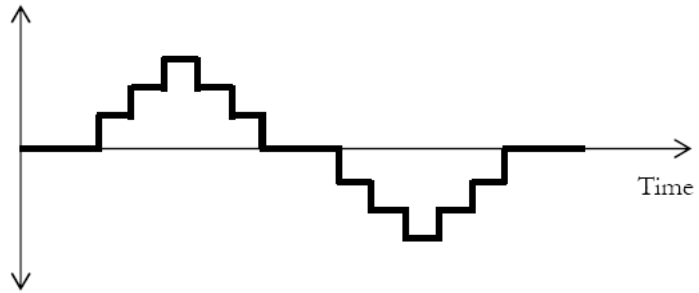
- This is an electronic device, which regulates the operation of the solar system.
- It controls the amount of power entering and leaving the battery.
- Prevents the solar panel from overcharging the battery and protects the battery from being over-discharged.

Inverters

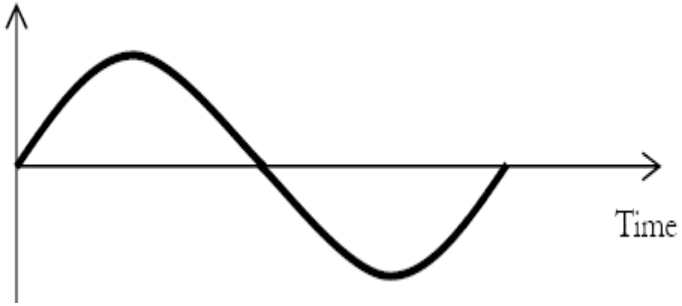
A devise to convert DC power to AC



Square wave



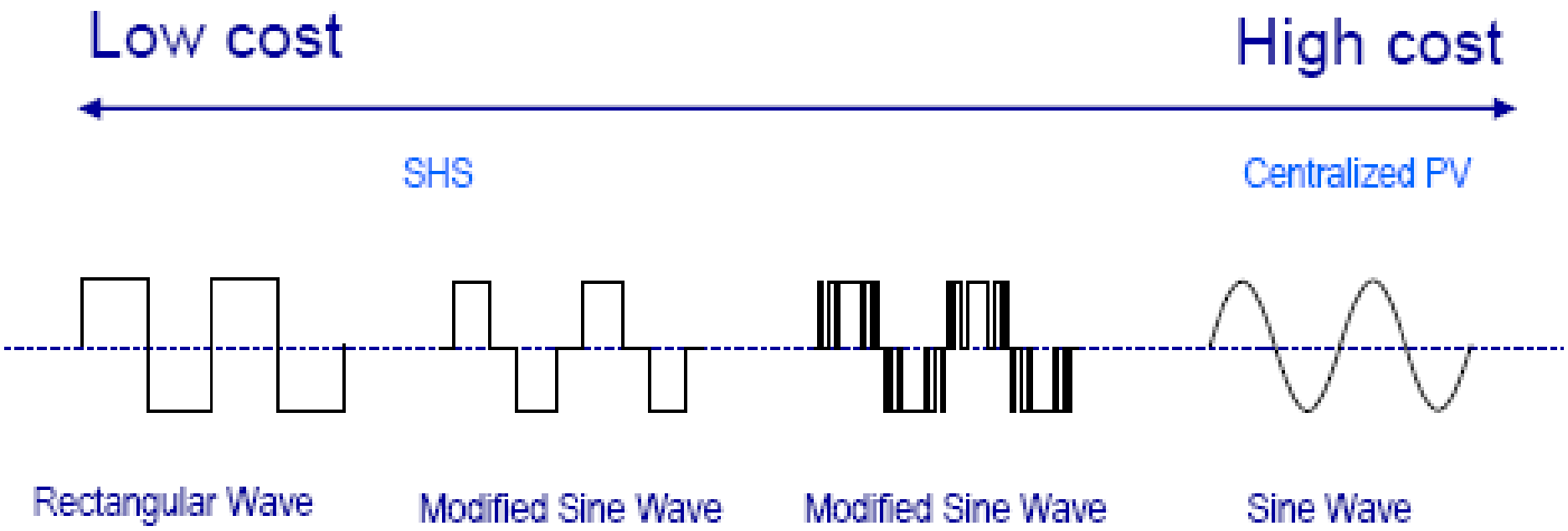
Modified sine wave



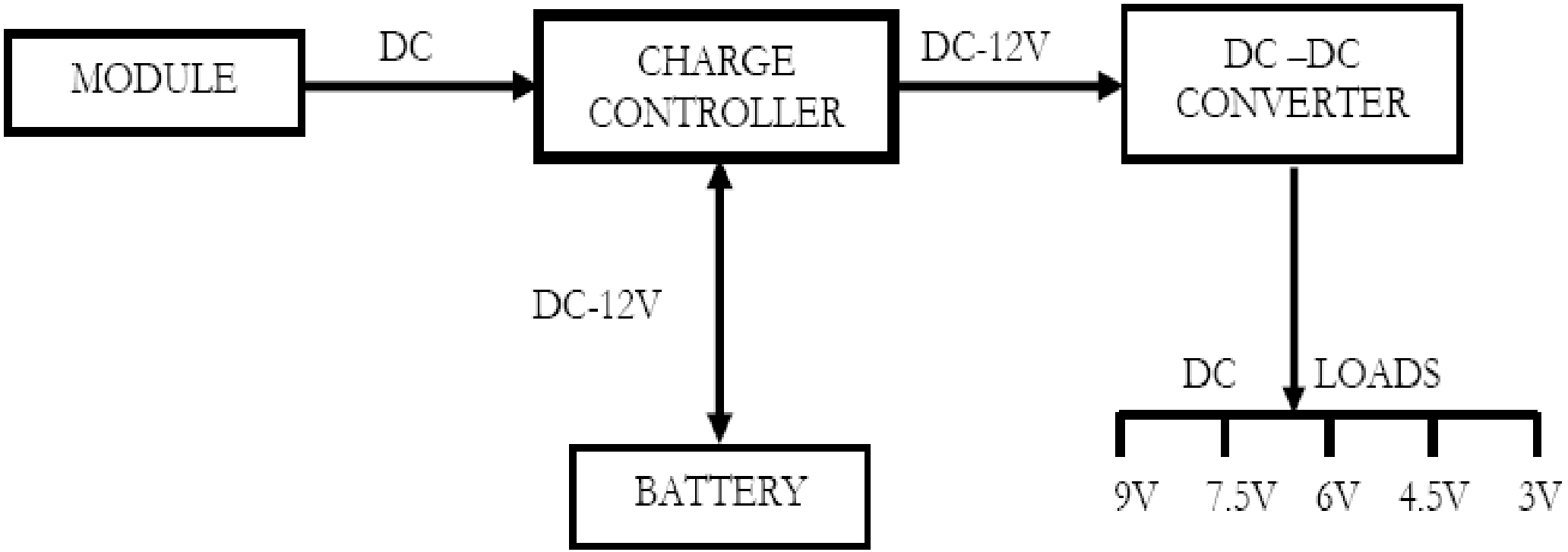
Pure sine wave

Inverters

- Sine wave output is ideal
- Due to cost limitation, modified sine wave types are common for small-scale application
- Rectangular wave type might have some problem with some appliances



DC-DC Converters



Solar PV System Advantages and Limitations

Solar PV Pros and Cons

Advantages

- Provides clean – green energy /Renewable energy source
- Highly promising future in terms economics and scale
- Low operation and maintenance cost/ No mechanically moving parts
- Noise free
- Flexibility/modularity

Limitations

- Intermittency nature and dispatchability issues
- Additional components (for AC loads, storage issue, etc)
- Large space for installations (low efficiency ~ 15-25%)
- High initial cost

Additional References

- Solar PV Training & Referral Manual: https://docslib.org/doc/4192987/solar-pv-training-referral-manual
- Training Manual for Engineers on Solar PV Systems: https://www.researchgate.net/publication/268387350_Training_Manual_for_Engineers_on_Solar_PV_System
- Solar PV Installation Training Handbook: https://energypedia.info/images/2/2e/Solar_PV_Installation_-_Training_Handbook_2017.pdf
- Solar Training Manual (intermediate): https://www.hamk.fi/wp-content/uploads/2018/09/Training-Manual.pdf
- Solar Electric Systems for Africa: A Guide for Planning and Installing Solar Electric Systems in Rural Africa: https://books.google.co.ke/books?id=nPfp9CgTDxcC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

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