IoT Powering

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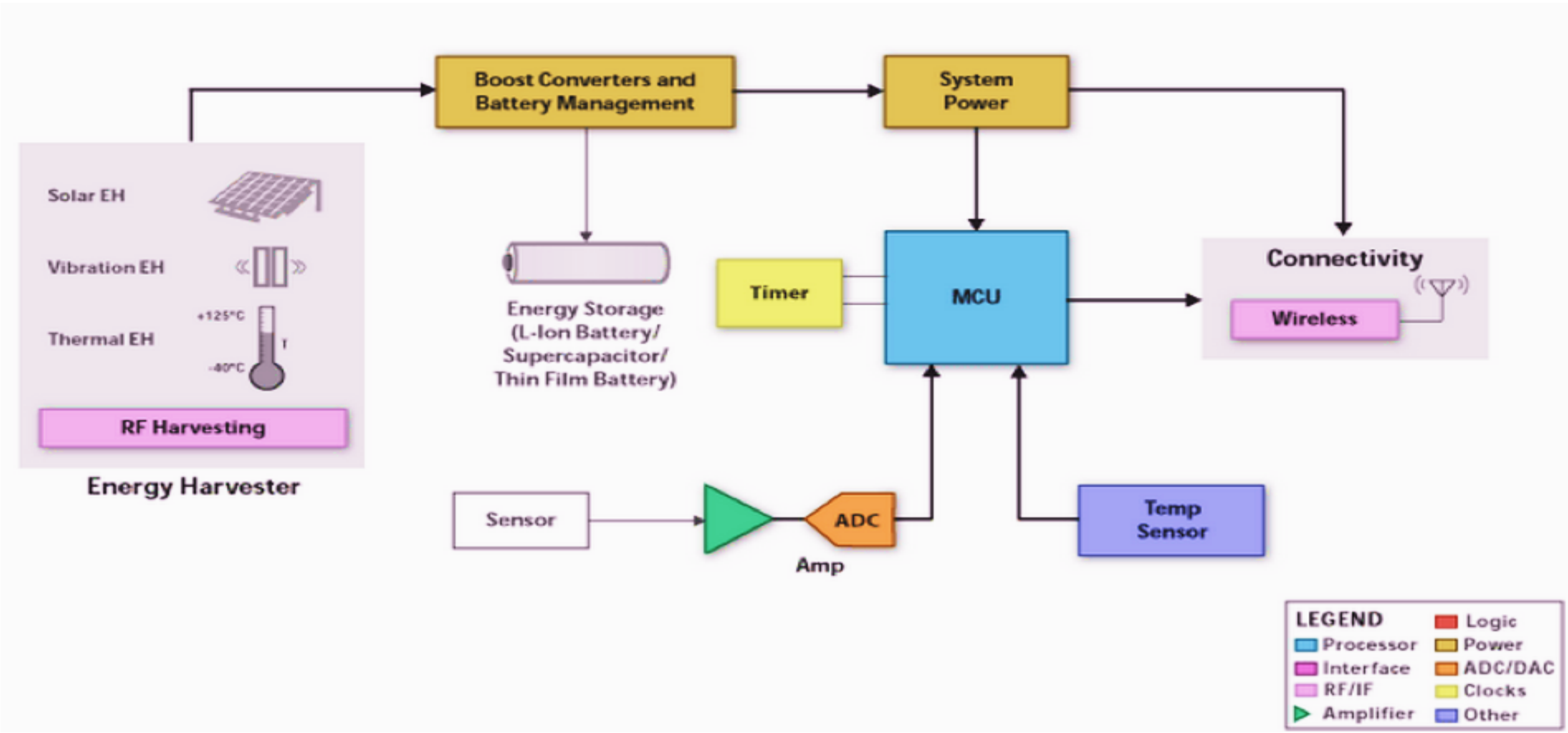
IoT Powering considerations

- Gateways can be grid connected
- End devices normally off-grid
- Sensors can consume considerable energy
- Keep node sleeping as much as possible
- End devices can consume little power and be powered by energy scavenging.
- Photovoltaic is widely used. We will cover it in detail
- Many other sources of energy can be harvested
- Most alternative energy sources are intermittent and will require storage devices like batteries or (super)capacitors.

Energy harvesting for IoT



http://eu.mouser.com/applications/benefits_energy_harvesting/

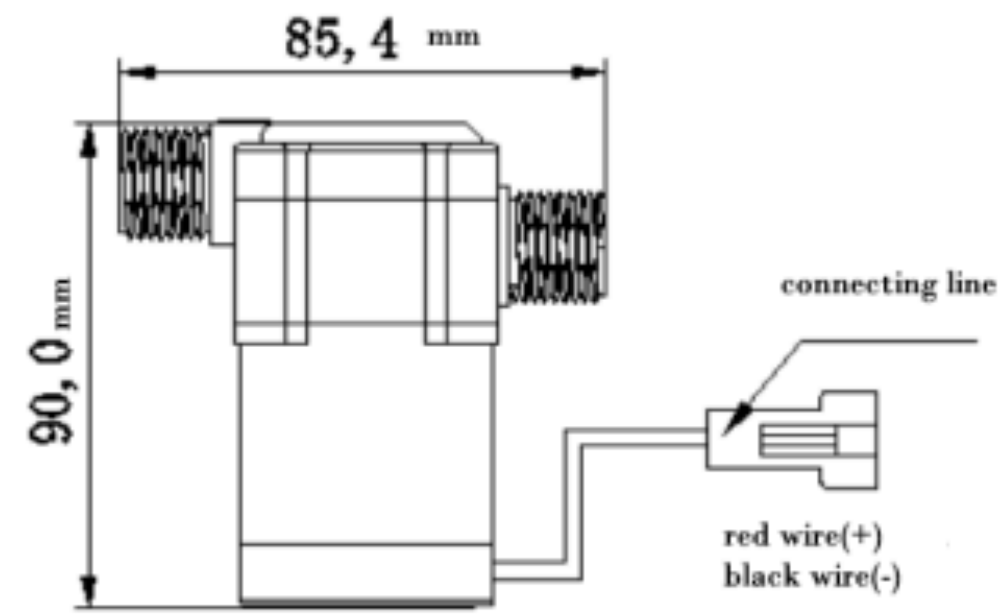
Energy Source	Power Density and Performance
Acoustic noise	3 nW/cm^3 @ 75 dB, 0.96 μW/cm^3 at 100 dB
Airflow	1 μW/cm^2
Ambient Light	100 mW/cm^2 (sun), 100 μW/cm^2 (office)
Ambient Radiofrequency	1 μW/cm^2
Hand Generators	30 W/kg
Heel Strike	7 W/cm^2
Push Button	50 J/N
Shoe Inserts	330 μW/cm^2
Temperature Variation	10 μW/cm^2
Thermoelectric	60 μW/cm^2
Vibration (micro generator)	4 μW/cm^3 (human, Hz), 800 μW/cm^3 (machine, kHz)
Vibration (Piezoelectric)	200 μW/cm^3

Micro hydro generator

Introduction

Micro hydro power is clean, renewable energy. Here is a micro hydro generator which can supply stably output voltage and output current with the help of one voltage stabilizing circuit and one rechargeable battery.

We can install it at home to save household energy, like using spray shower to light LEDs etc.



Features

Weight	165 g
Output voltage	3.6V
Output current	300mA
Maximum working pressure	1.75 MPa
Working pressure	0 ~ 1.75MPa

Consumption of some devices

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Table 3. Features of Typical Sensors

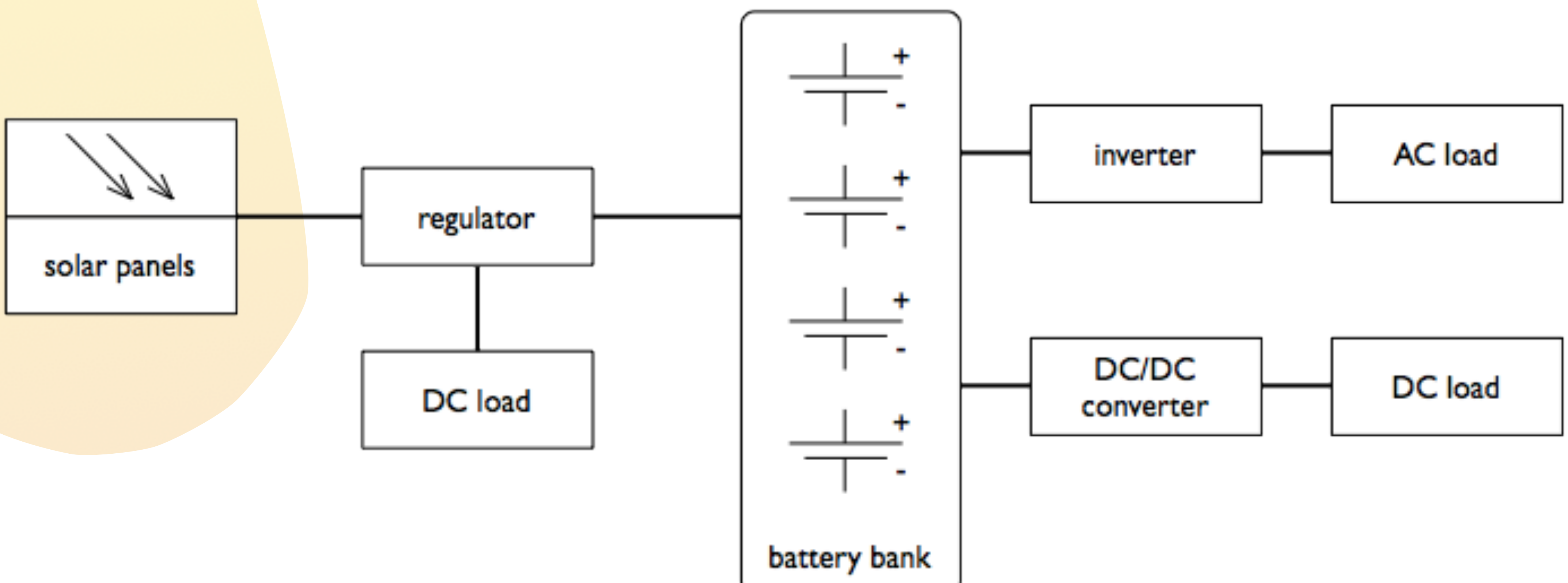
Name	Type	Sensing time	Active current
SLG64-0075	Liquid-Flow	30ms	5.1mA
SFM4100	Gases- Flow	4.6ms	12.5mA
VTISCA3000	Acceleration	10ms	120µA
VTISCP1000	Airpressure	110ms	25µA
SensorionSHT15	Humidity	210ms	300µA
AvagoAPDS-9002	Illumination	1.0ms	2.0mA
HitachiHM55B	Magneticfield	30ms	9.0mA
FastraxiTRAX03	Position	4.0s	32mA
DallasDS620U	Temperature	200ms	800µA

Effect of LoRa SF on consumption

You can change the values in columns A, B, C, D and H to suit your particular case.									
	SF 7	SF 7	SF 7	SF 7	SF 7	SF 7	SF 12	SF12	SF 12
	Active T, ms	#of times/h	current, mA	mA/h	mA/year	battery %	Active T, ms	mA/year	battery %
Transmit	70	12	38	0.0088666	77.67	18	1650	1,800.83	83.99
Receive	10	12	15	0.0005	4.38	1	165	71.09	3.32
Receive 2	70	12	15	0.0035	30.66	6	70	30.16	1.41
Temperature	20	12	15	0.001	8.76	2	20	8.62	0.40
Humidity	20	12	15	0.001	8.76	2	20	8.62	0.40
CO2	60	12	130	0.026	227.76	48	60	224.03	10.45
sleep	1000	3600	0.004	0.004	35.04	8	10	0.34	0.02
battery	1000	3600	0.004	0.004	35.04	8	10	0.34	0.02
			Sum	0.0488666	428.07		2005	2,144.02	
Years of duration with a 3.6 V	800	mA.h battery =			1.87				0.37

Photovoltaic system

A basic photovoltaic system consists of five main components: the **sun**, the ***solar panel***, the ***regulator***, the ***batteries***, and the ***load***. Many systems also include a ***voltage converter*** to allow use of loads with different voltage requirements.



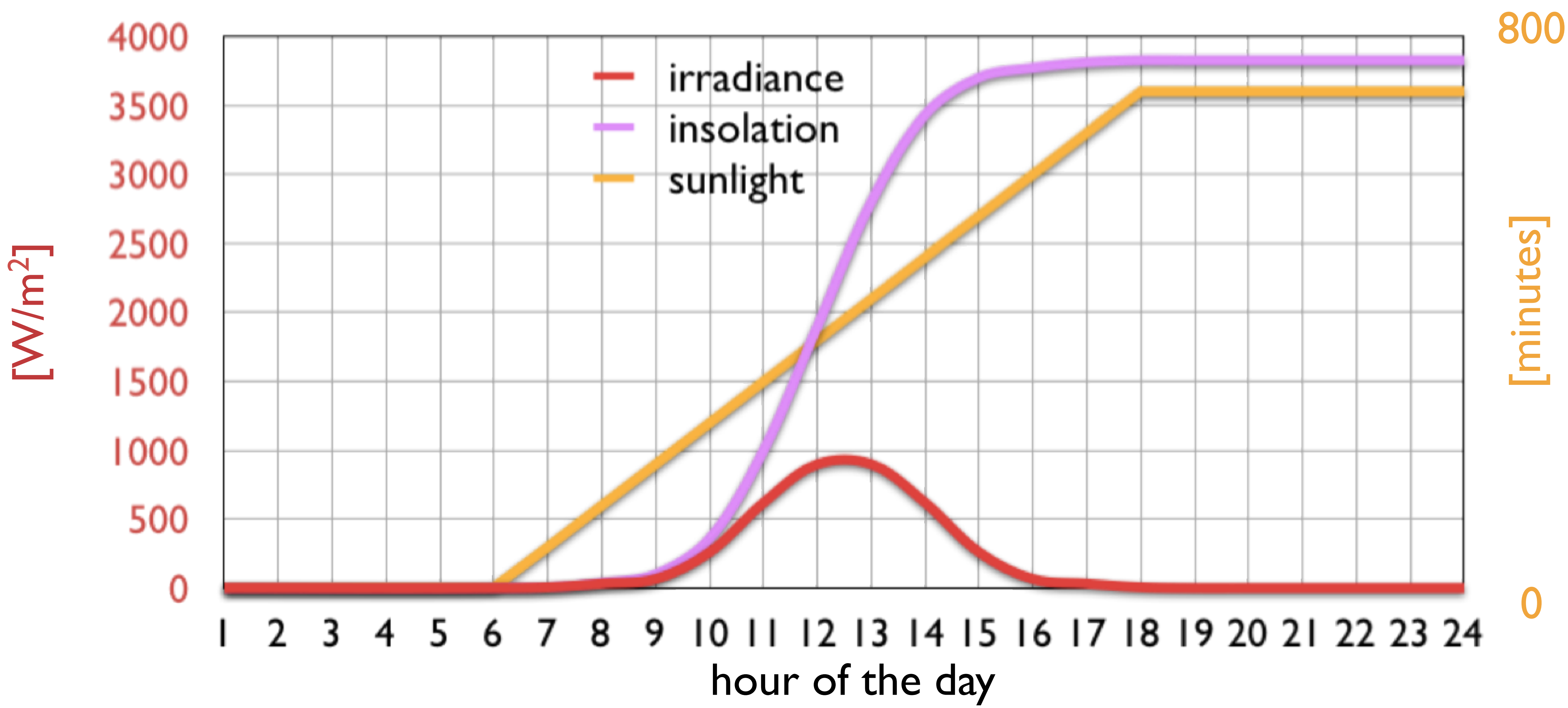
Solar power

A photovoltaic system is based on the ability of certain materials to convert the electromagnetic energy of the sun into electrical energy. The total amount of solar energy that lights a given area per unit of time is known as ***irradiance*** and it is measured in ***watts per square meter*** (***W/m²***).

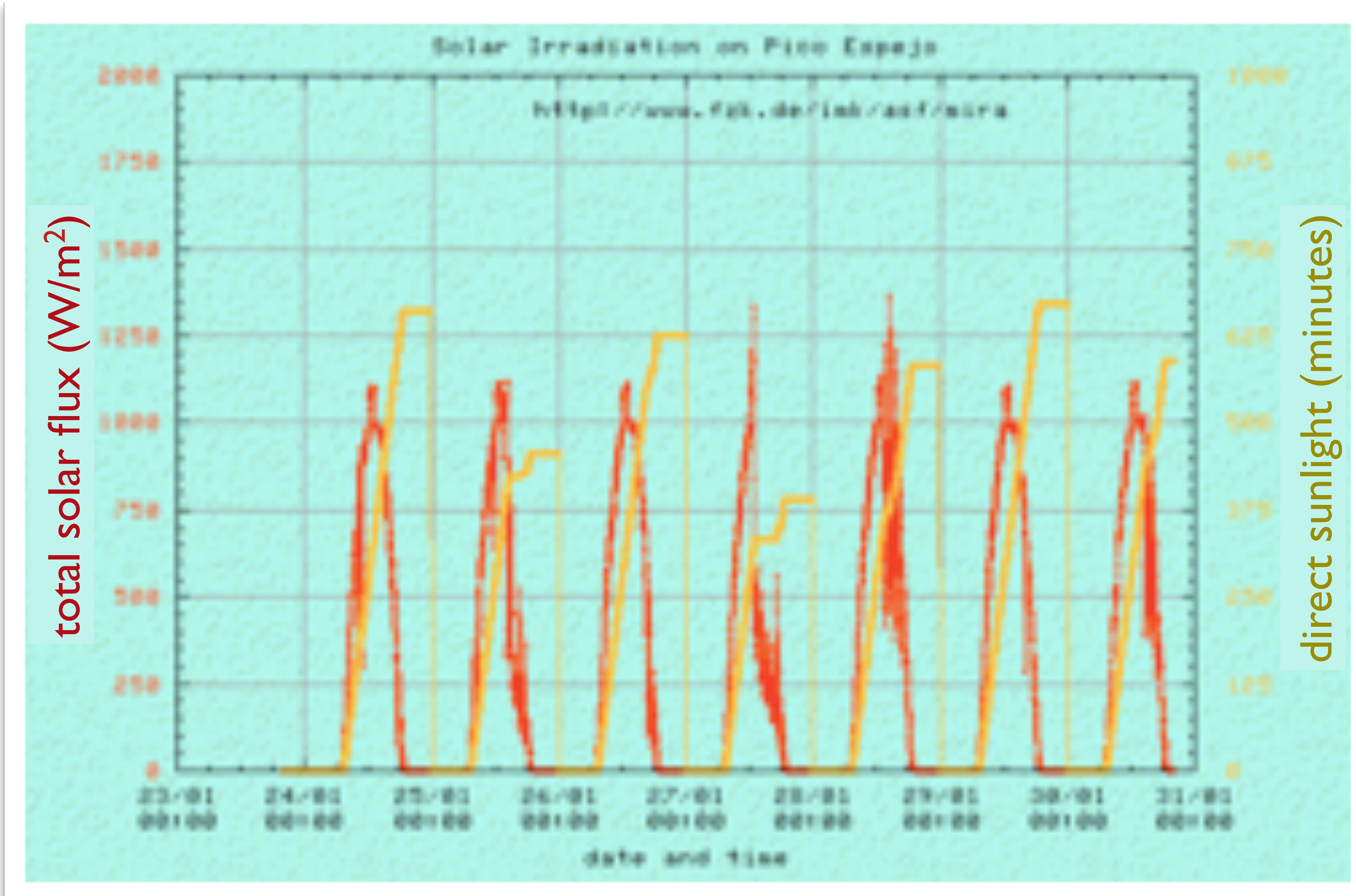
This energy is normally averaged over a period of time, so it is common to talk about total irradiance per hour, day or month.

Irradiance, irradiation, and sunlight

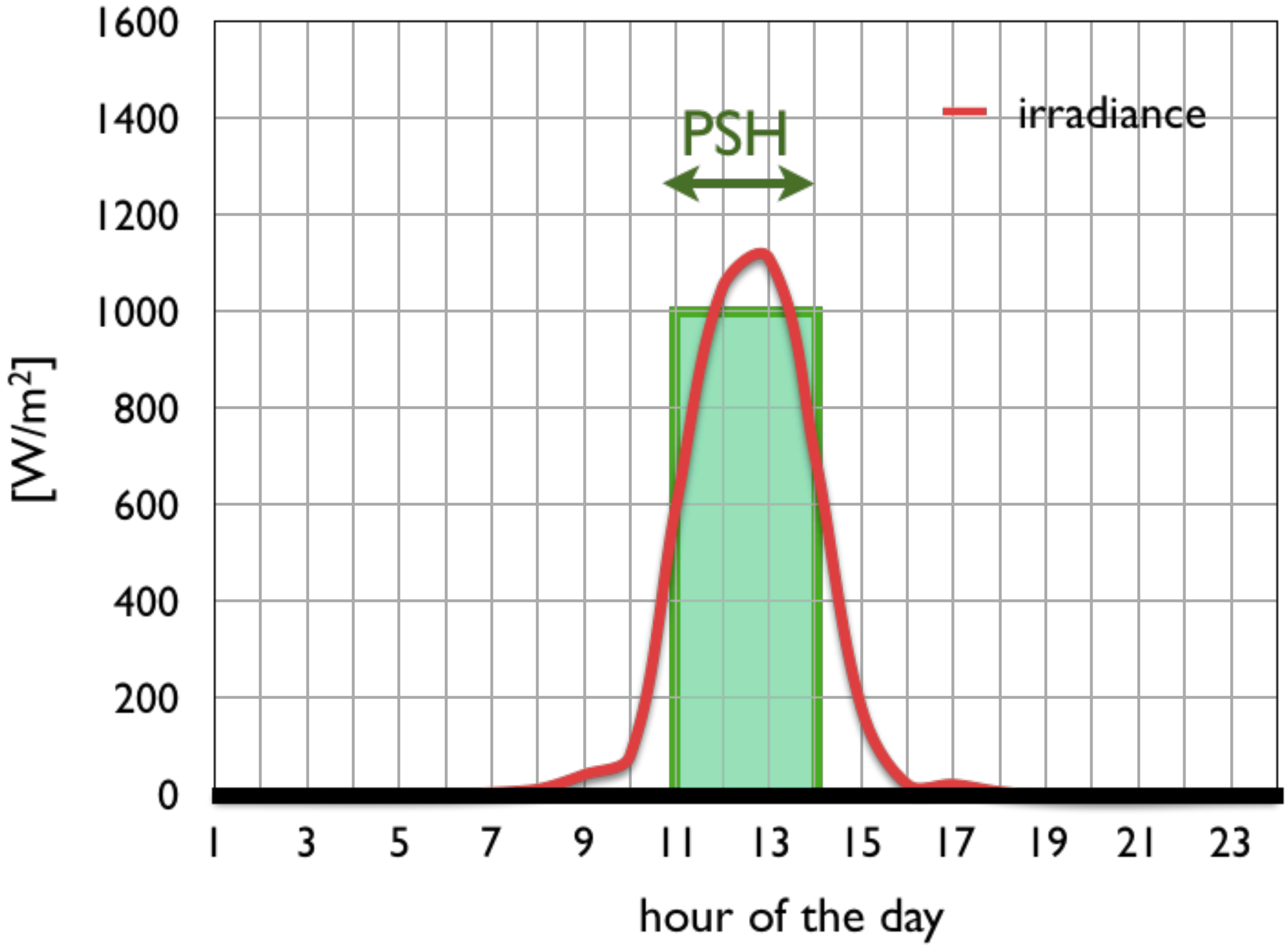
This graph shows **solar irradiance** (in W/m^2), **insolation** (cumulative irradiance) and **sunlight** (in minutes):



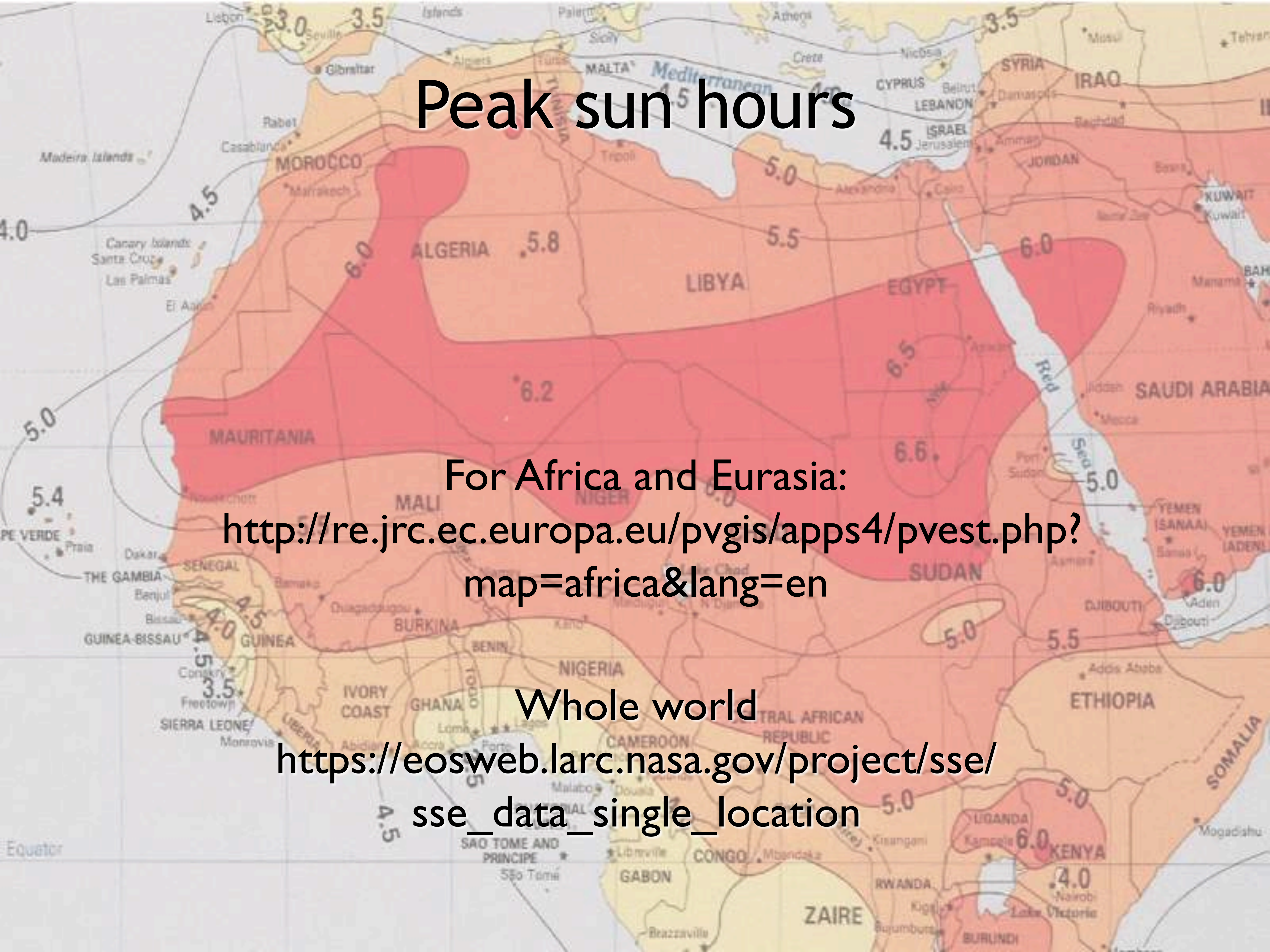
Real data: irradiance and sunlight



Peak Sun Hours = kW h/m^2



Peak sun hours



For Africa and Eurasia:
http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?map=africa&lang=en

Whole world
https://eosweb.larc.nasa.gov/project/sse/sse_data_single_location

https://eosweb.larc.nasa.gov/project/sse/sse_data_single_location

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy - Available Tables

Latitude 10.46 / Longitude -84.4 was chosen.

Geometry Information

Elevation: **251** meters
taken from the
NASA GEOS-4
model elevation

	Northern boundary **11**	
Western boundary **-85**	Center Latitude **10.5** Longitude **-84.5**	Eastern boundary **-84**
	Southern boundary **10**	

Parameters for Tilted Solar Panels:

Monthly Averaged Radiation Incident On An Equator-Pointed Tilted Surface ($kWh/m^2/day$)

Lat 10.46 Lon -84.4	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
SSE HRZ	4.74	5.23	5.91	5.75	4.75	4.43	4.25	4.20	4.43	4.15	4.15	4.41	4.69
K	0.53	0.54	0.57	0.54	0.45	0.42	0.41	0.40	0.43	0.42	0.46	0.51	0.47
Diffuse	1.71	1.88	2.00	2.23	2.29	2.25	2.26	2.31	2.26	2.08	1.86	1.68	2.07
Direct	4.98	5.13	5.65	4.98	3.52	3.17	2.87	2.68	3.09	3.09	3.68	4.58	3.95
Tilt 0	4.70	5.18	5.84	5.66	4.66	4.34	4.17	4.13	4.37	4.10	4.11	4.37	4.63
Tilt 10	5.05	5.42	5.94	5.58	4.70	4.40	4.21	4.12	4.38	4.21	4.34	4.72	4.75
Tilt 25	5.36	5.56	5.83	5.23	4.58	4.33	4.12	3.97	4.22	4.22	4.51	5.04	4.74
Tilt 90	3.63	3.18	2.52	1.69	2.09	2.13	2.00	1.75	1.84	2.31	2.91	3.54	2.46
OPT	5.41	5.56	5.94	5.66	4.70	4.40	4.21	4.14	4.38	4.24	4.52	5.11	4.85
OPT ANG	34.0	25.0	12.0	0.00	9.00	12.0	10.0	4.00	6.00	18.0	30.0	36.0	16.3

Equivalent Number Of NO-SUN Or BLACK Days (days)

Lat 10.46 Lon -84.4	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 day	0.94	0.66	0.70	0.89	0.81	0.94	0.91	0.89	0.90	0.95	0.89	0.68

Solar Panel

The most obvious component of a photovoltaic system are the ***solar panels***.

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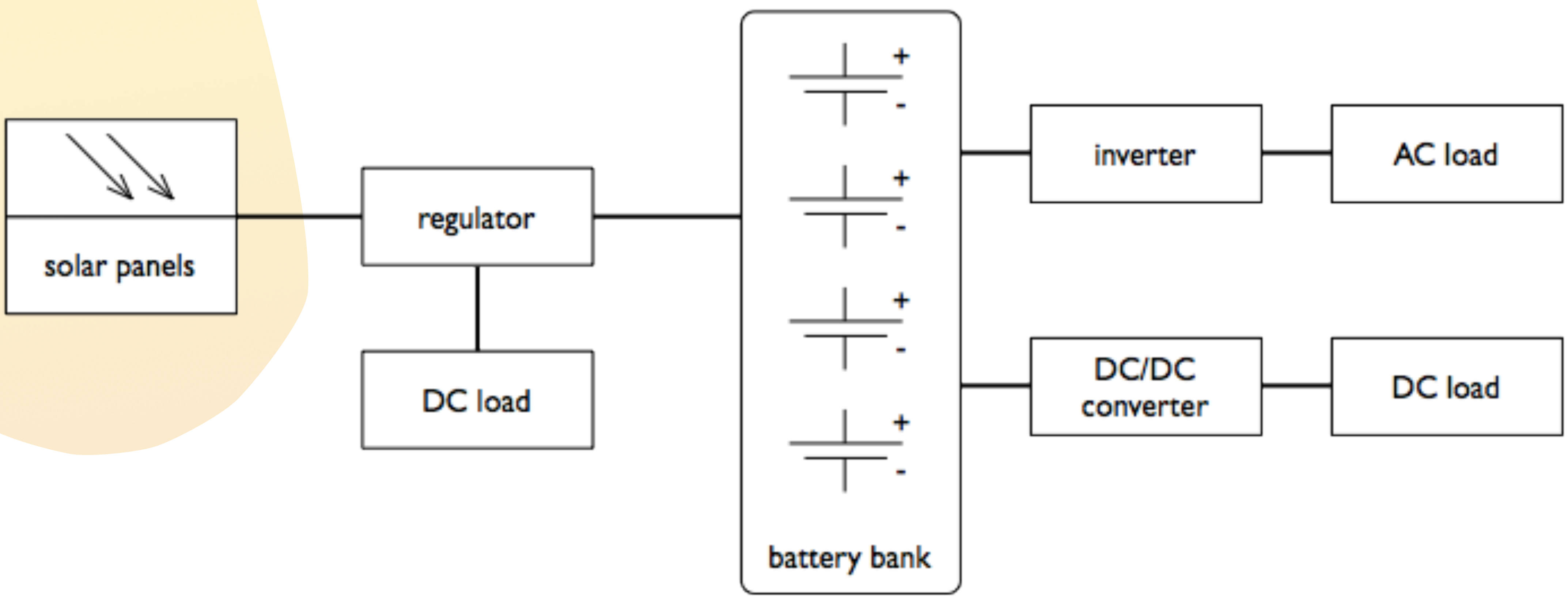
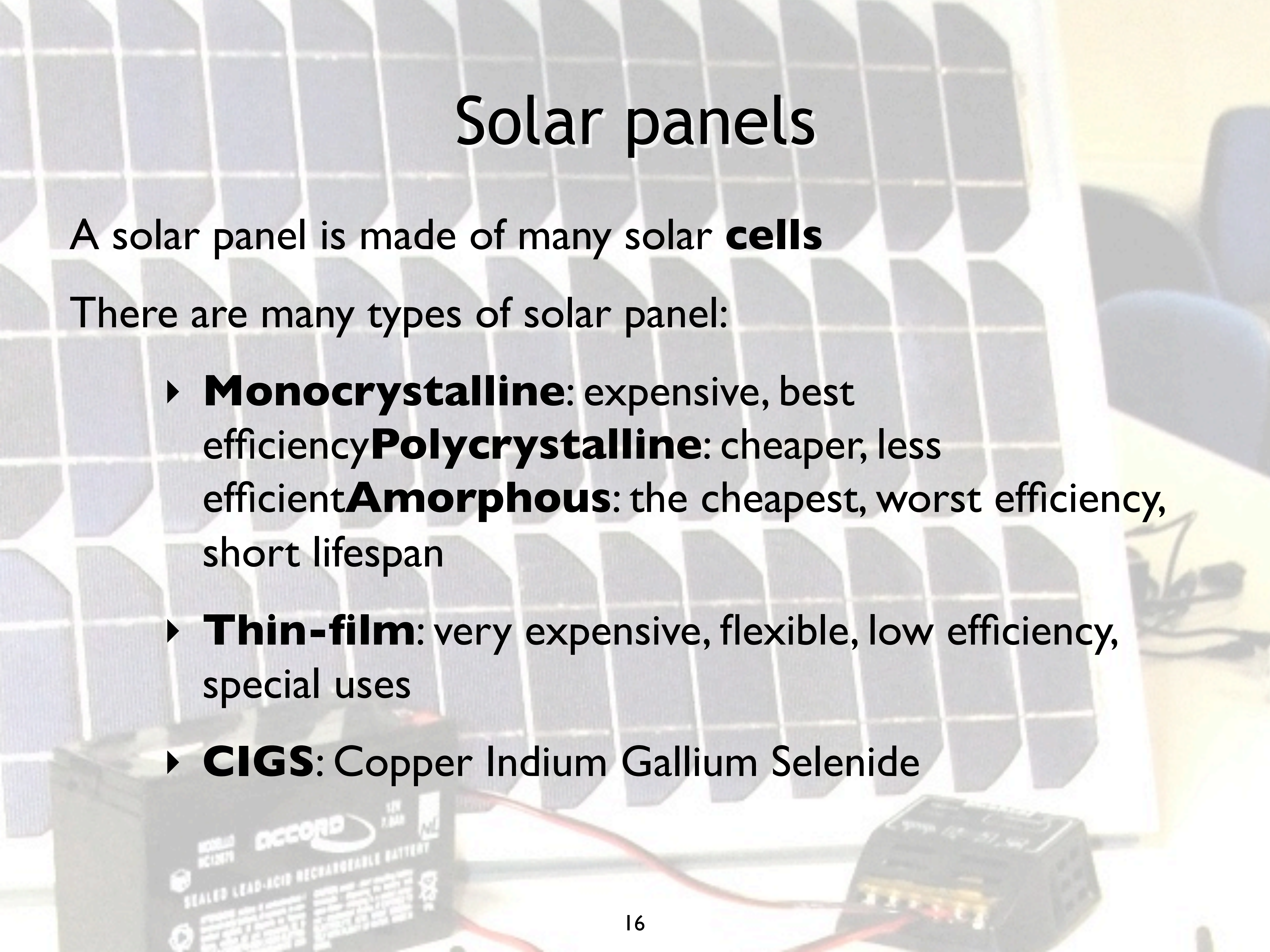




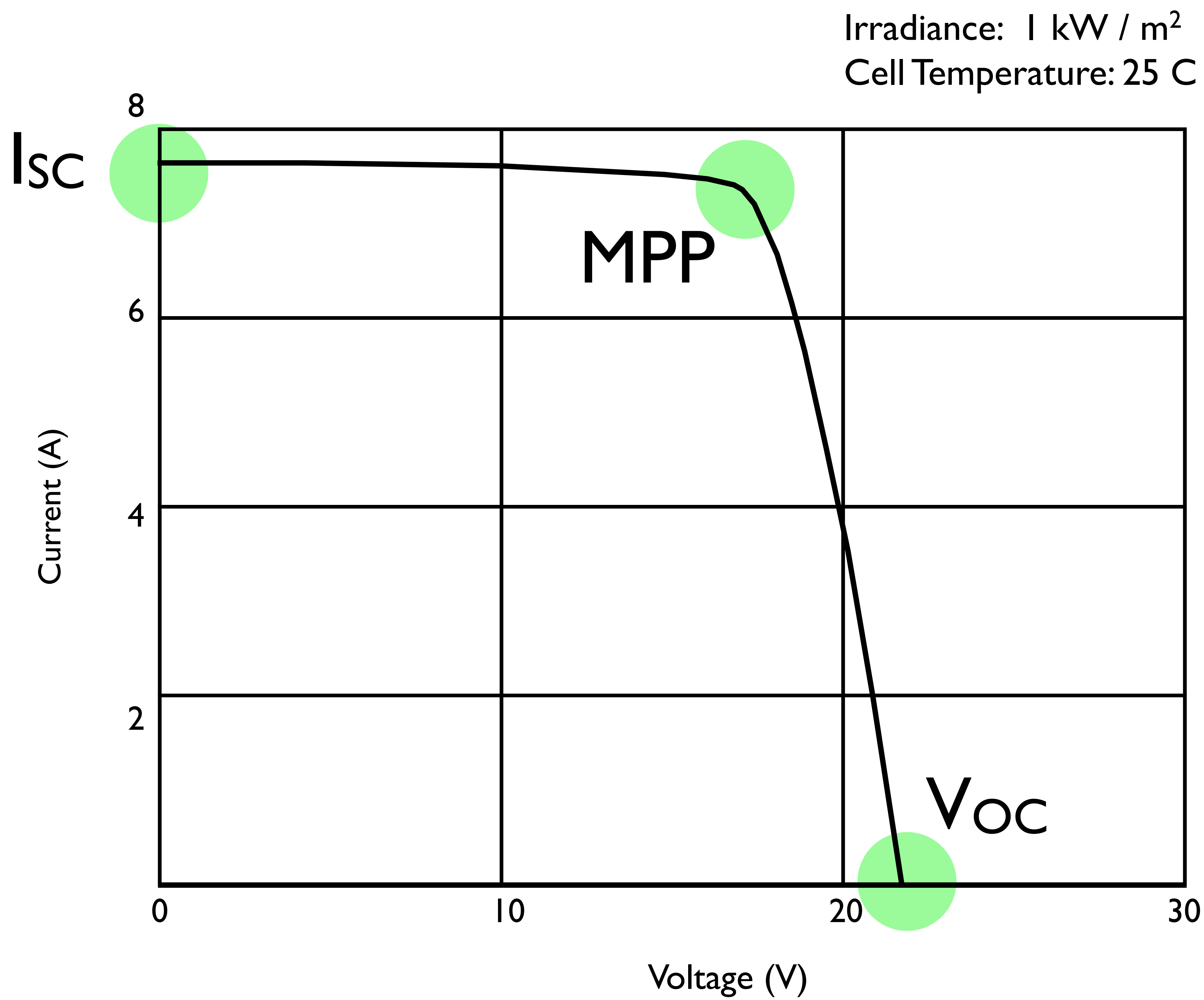
Solar panels

A solar panel is made of many solar **cells**

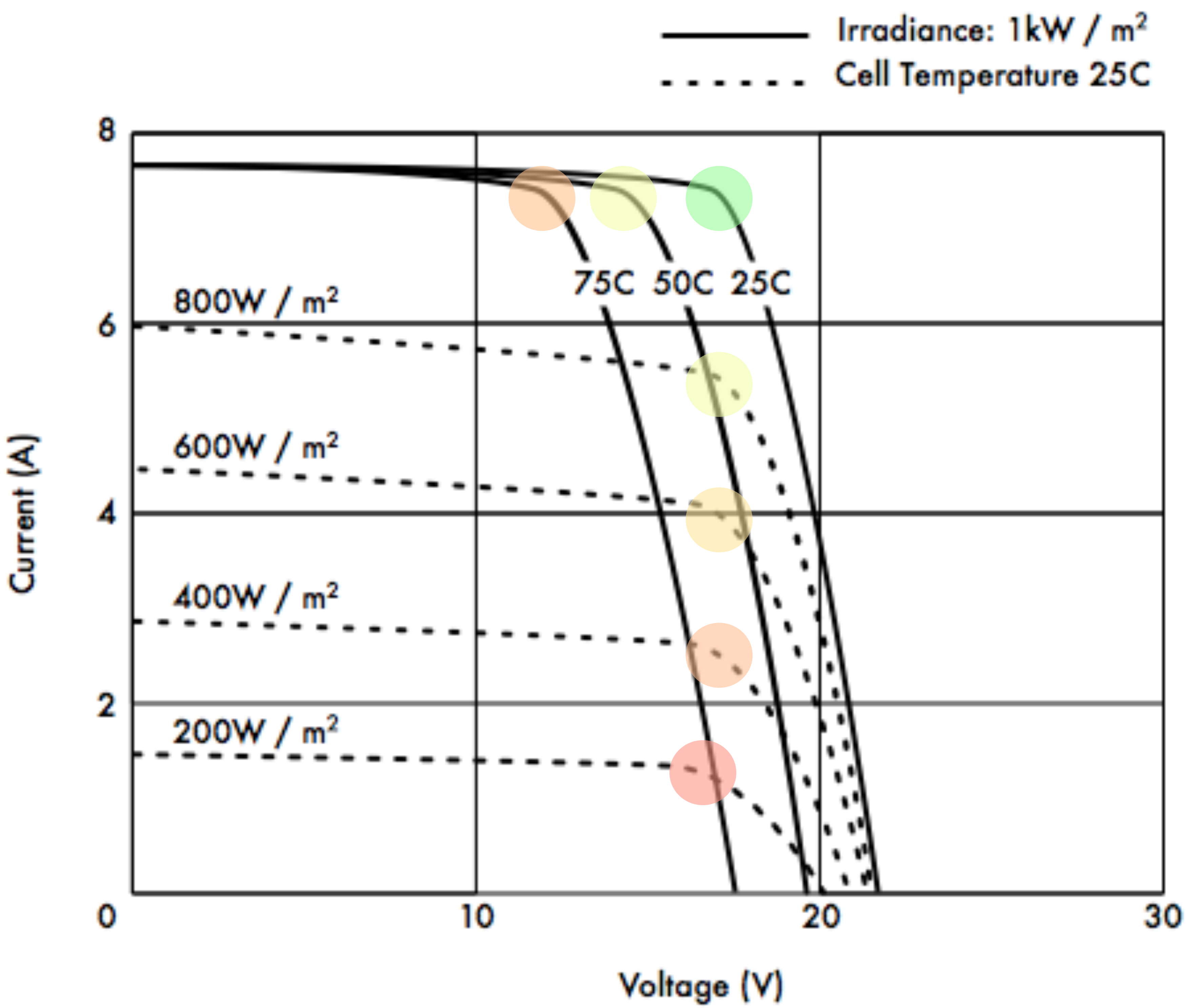
There are many types of solar panel:

- **Monocrystalline**: expensive, best efficiency**Polycrystalline**: cheaper, less efficient**Amorphous**: the cheapest, worst efficiency, short lifespan
- **Thin-film**: very expensive, flexible, low efficiency, special uses
- **CIGS**: Copper Indium Gallium Selenide

Solar panel IV curve



Solar panel IV curve for different amounts of irradiance and temperature

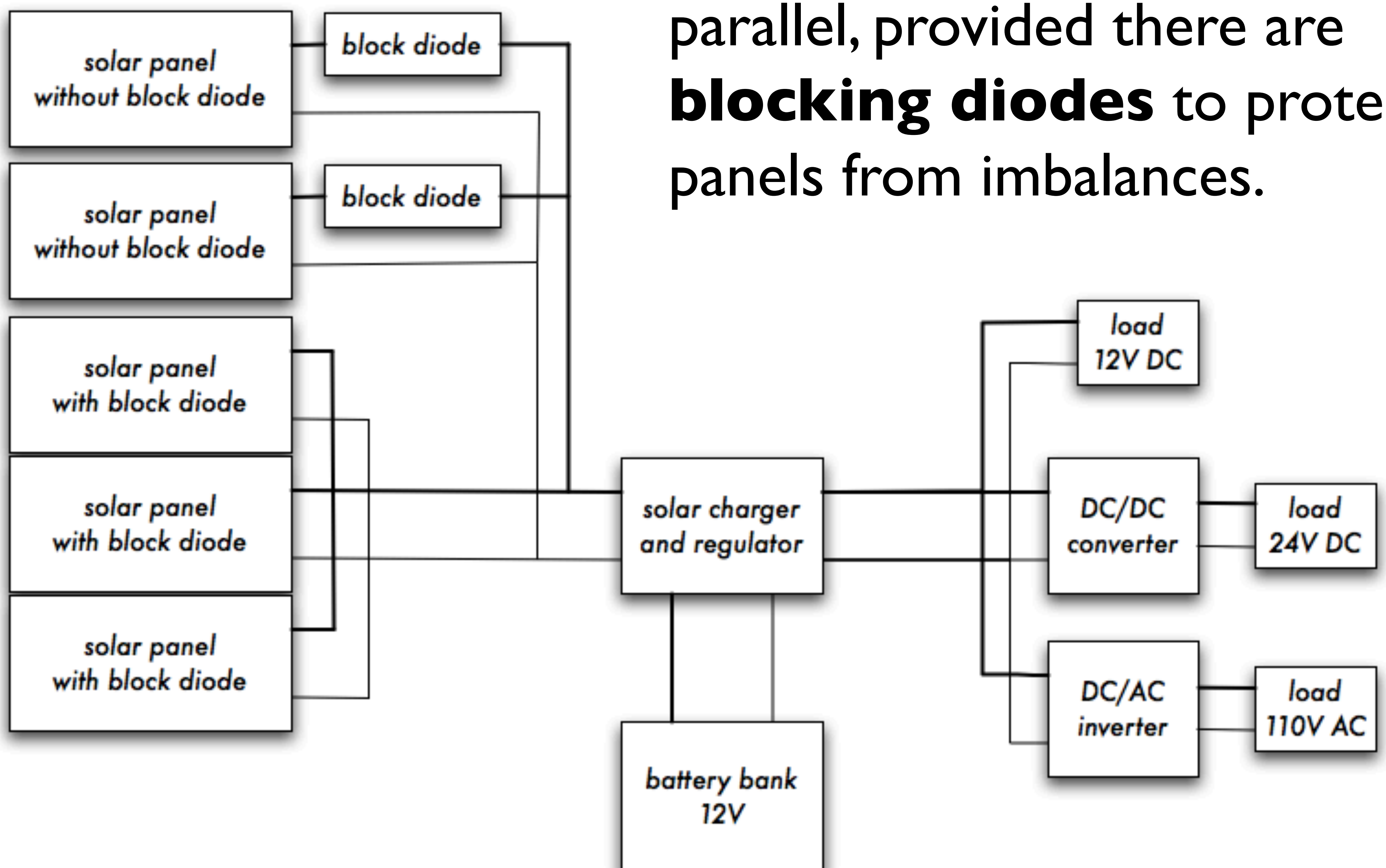


Optimizing panel performances

Optimal elevation angle = Latitude + 5°

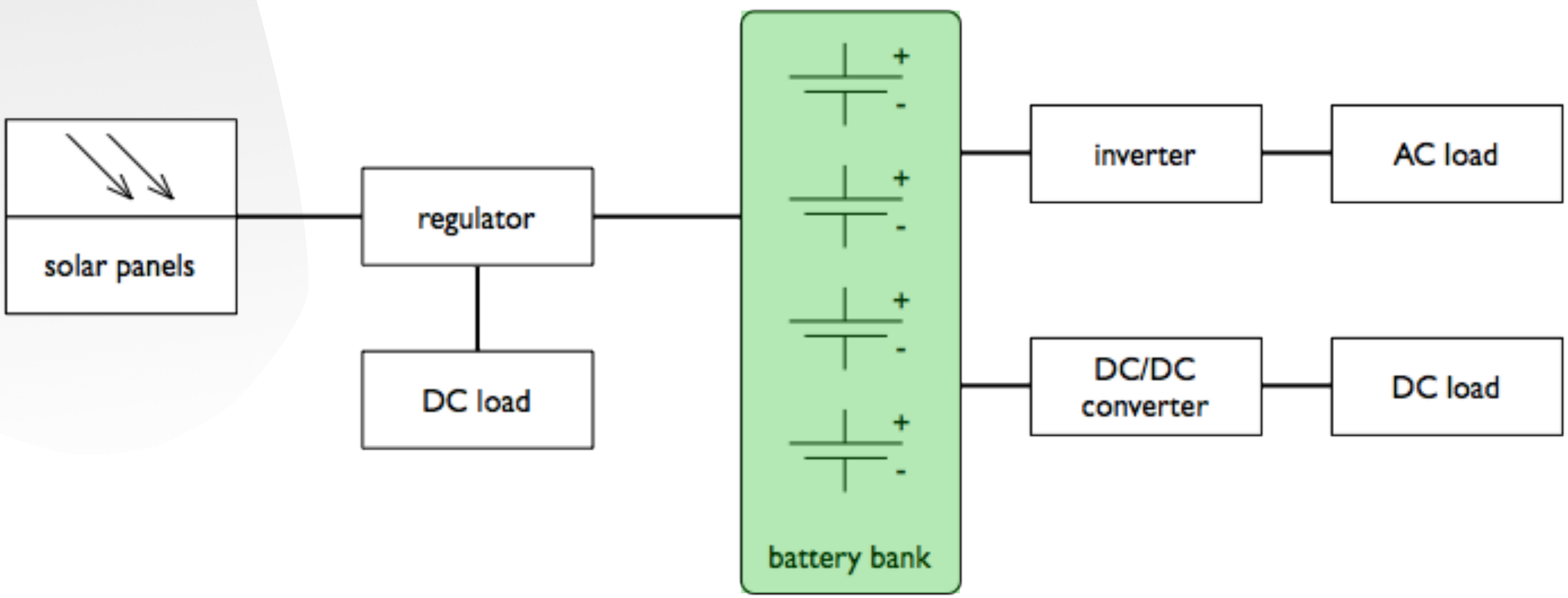
Photovoltaic system

If more power is required, multiple solar panels may be joined in parallel, provided there are **blocking diodes** to protect the panels from imbalances.



Batteries

Batteries are at the heart of the photovoltaic system, and determine the operating voltage.



Batteries

The most common type of batteries used in solar applications are maintenance-free lead-acid batteries, also called **recombinant** or **VRLA** (valve regulated lead acid) batteries. They belong to the class of deep cycle or stationary batteries, often used for backup power in telephone exchanges.

They determine the ***operating voltage*** of your installation, for best efficiency all other devices should be designed to work at the same voltage of the batteries.

Designing a battery bank

- The size of your battery bank will depend upon: the storage capacity required the maximum discharge rate the storage temperature of the batteries (lead-acid only). The storage capacity of a battery (amount of electrical energy it can hold) is usually expressed in amp-hours (Ah).

  - A battery bank in a PV system should have sufficient capacity to supply needed power during the longest expected period of cloudy weather.

LiPO (Lithium-Polymer) battery

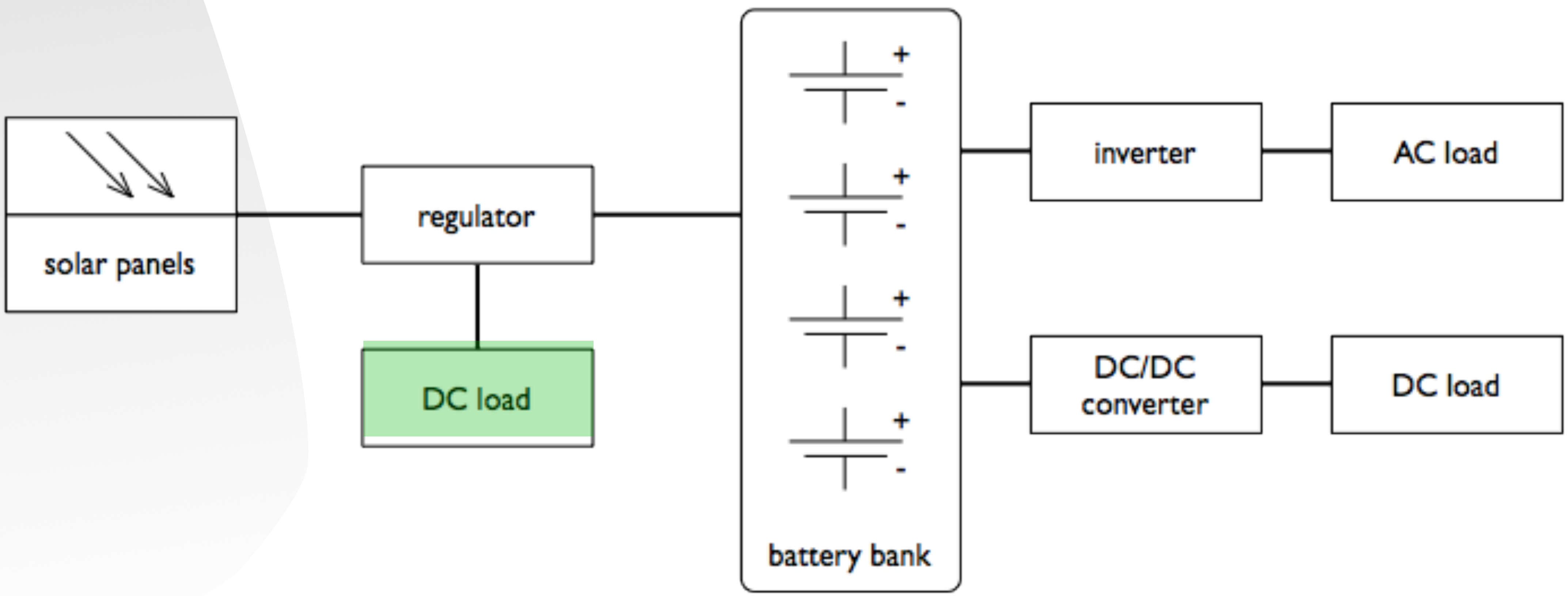
- Each cell will be around 3.7 V when fully charged
- The minimum voltage is around 3 V per cell
- Capacity expressed in mA/h, amount of energy storable
- Handle with precaution, lithium can explode
- Can be attached directly to a small solar panel, but for bigger ones a voltage regulator is required to protect the battery

Supercapacitors

- High capacity device with capacitance much higher than normal capacitors but with lower voltage ratings.
- They bridge the gap between rechargeable batteries and electrolytic capacitors
- Store up to 100 times more energy per mass or volume than electrolytic capacitors, charge and discharge much faster than batteries and tolerate more C/D cycles than batteries

Regulator

The ***regulator*** is the interface between the solar panels and the battery, and provides power for moderate DC loads.



IoT devices often have de voltage regulator built in

Regulator


PROSTAR
PROSTAR-30
SOLAR CHARGE CONTROLLER
VERSION: PS-30
MORNINGSTAR corporation
CHARGING
TEMP. SENSOR
BATTERY STATUS
BLINK: LOW
ON: LVD
BATTERY TYPE
1 – GEL
2 – SEALED
3 – FLOODED
SOLAR
BATTERY
LOAD
SENSE

Monitoring the state of charge

There are two special states of charge that can occur during the cyclic charge and discharge of the battery. They should both be avoided in order to preserve the useful life of the battery.

- ***Overcharge*** takes place when the battery arrives at the limit of its capacity. If energy is applied to a battery beyond its point of maximum charge, the electrolyte begins to break down. This produces bubbles of oxygen and hydrogen, a loss of water, oxidation on the positive electrode, and in extreme cases, a danger of explosion.

Monitoring the state of charge

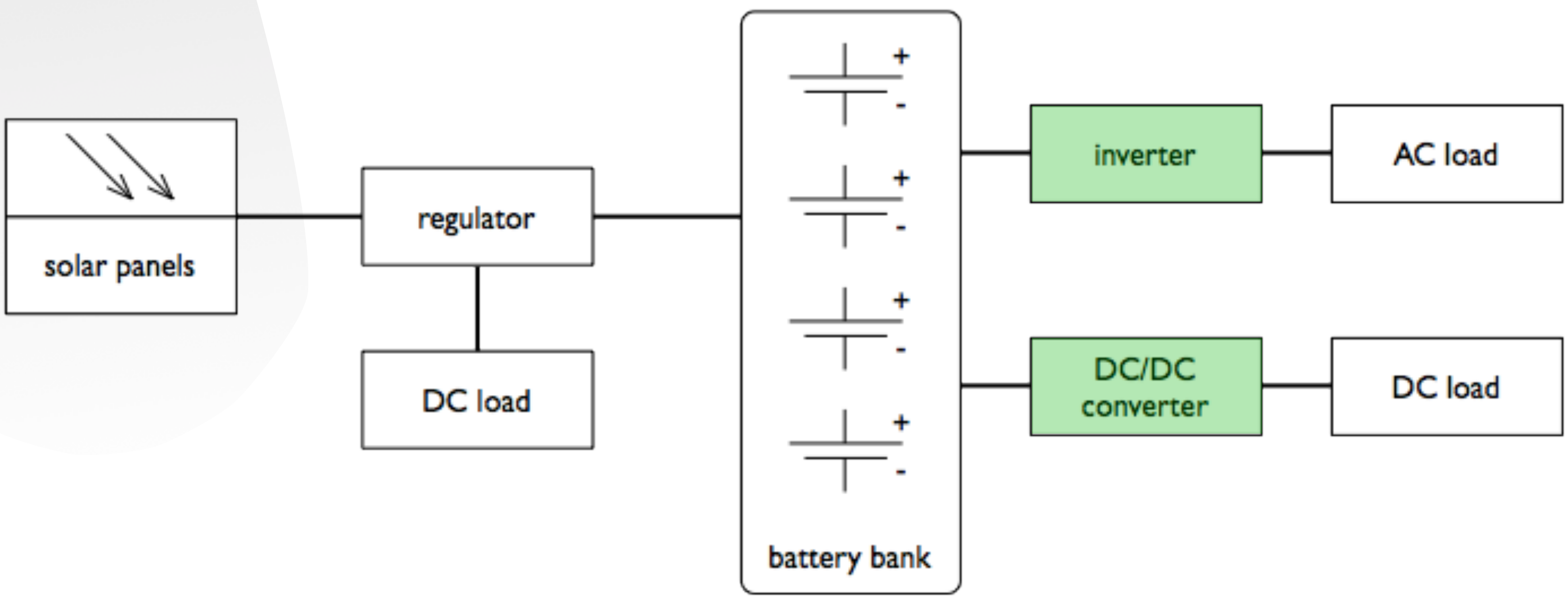
- ***Overdischarge*** occurs when there is a load demand on a discharged battery. Discharging beyond the battery's limit will result in deterioration of the battery. When the battery drops below the voltage that corresponds to a 50% discharge, the regulator prevents any more energy from being extracted from the battery.
- The proper values to prevent overcharging and overdischarging should be programmed into your charge controller to match the requirements of your battery system.

Maximizing battery life

Lead acid batteries degrade quickly if they are discharged completely. A battery from a truck will lose 50% of its design capacity within 50 -100 cycles if it is fully charged and discharged during each cycle.Never discharge a 12 Volt lead acid battery below 11.6 volts, or it will forfeit a huge amount of storage capacity. In cyclic use it is not advisable to discharge a truck battery below 70%. Keeping the charge to 80% or more will significantly increase the battery's useful lifespan. For example, a 170 Ah truck battery has a usable capacity of only 34 to 51 Ah.

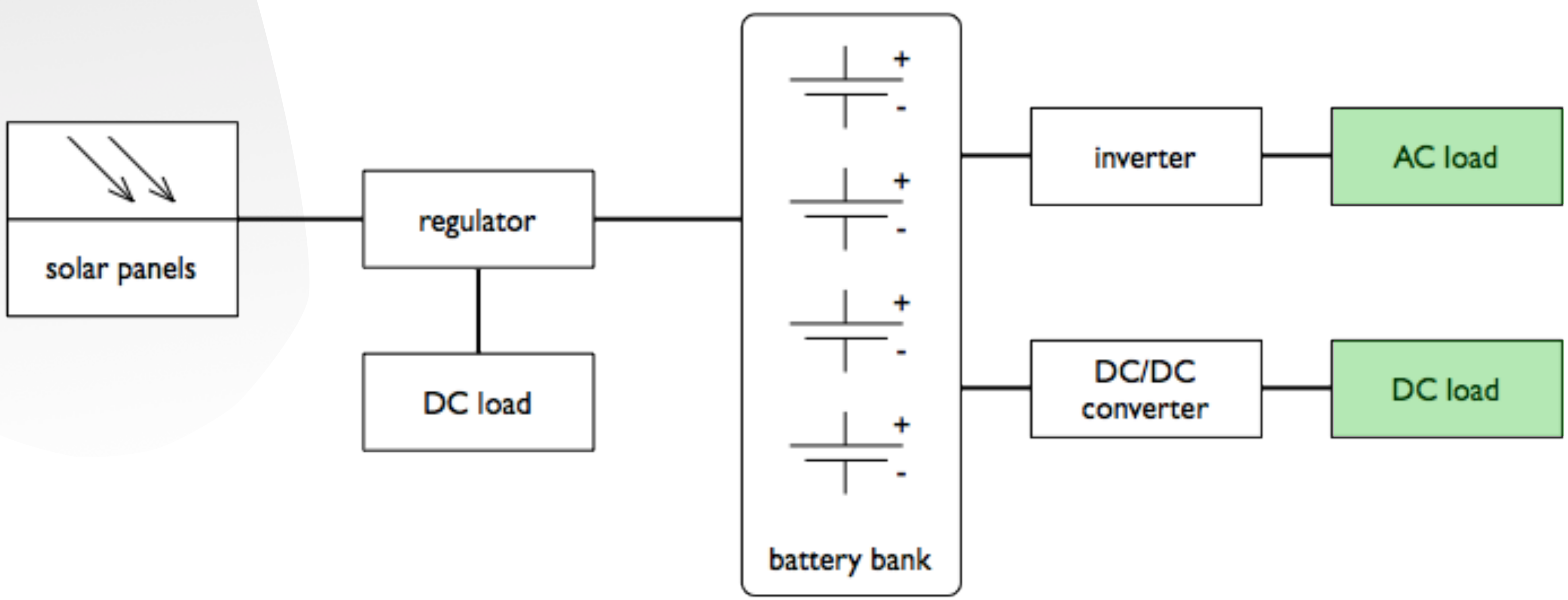
Voltage converters

An ***inverter*** turns DC into AC, usually at 110V or 220V. A ***DC/DC converter*** changes the input DC voltage into a desired value.



The load

The ***load*** is the usable energy that the solar system must supply.



The Load

The ***load*** is the equipment that consumes the power generated by your energy system.

The load is expressed in watts, which are

$$\text{watts} = \text{volts} \times \text{amperes}$$

If the voltage is already defined, the load can be expressed in amperes.

Power consumption

The amount of power consumed can be calculated with this formula:

$$P = V \times I$$

P is the power in Watts, ***V*** is voltage in Volts, and ***I*** is the current in Amperes.For example:

$$6 \text{ Watts} = 12 \text{ Volts} \times 0.5 \text{ Ampere}$$

If this device is operating for an hour it will consume 6 Watt-hours (Wh), or 0.5 Ampere-hours (Ah) at 12V. Thus the device will draw 144 Wh or 12 Ah per day.

Spreadsheet for dimensioning

	Consumption,W	Hours/day	Energy/day, Wh					
	Electrical Load Calculation							
	1.5	24	36					
	8	24	192					
	15	12	180					
	3	24	72					
:h	4	24	96					
onsumption/day, Wh			36					
city calculation, considering the number of no-sun days and the allowed depth of discharge								
nomy, days		Depth of Discharge		Battery capacity,Wh		Battery voltage,V	Battery Capacity, Ah	Numb
4		0.5		288		12	24.0	
ty calculation		Panel Peak power, Wp						
		10						
Vh	Battery charging allowance		Energy /d, Wh	PSH		Daily Photovoltaic power, W		Numb
36	1.5		54	5.5		9.8		

Wind power

A ***wind generator*** is an option for an autonomous system on a hill or mountain.

The average wind speed over the year should be at least 3 to 4 meters per second.

Hint: locate the generator as high as possible

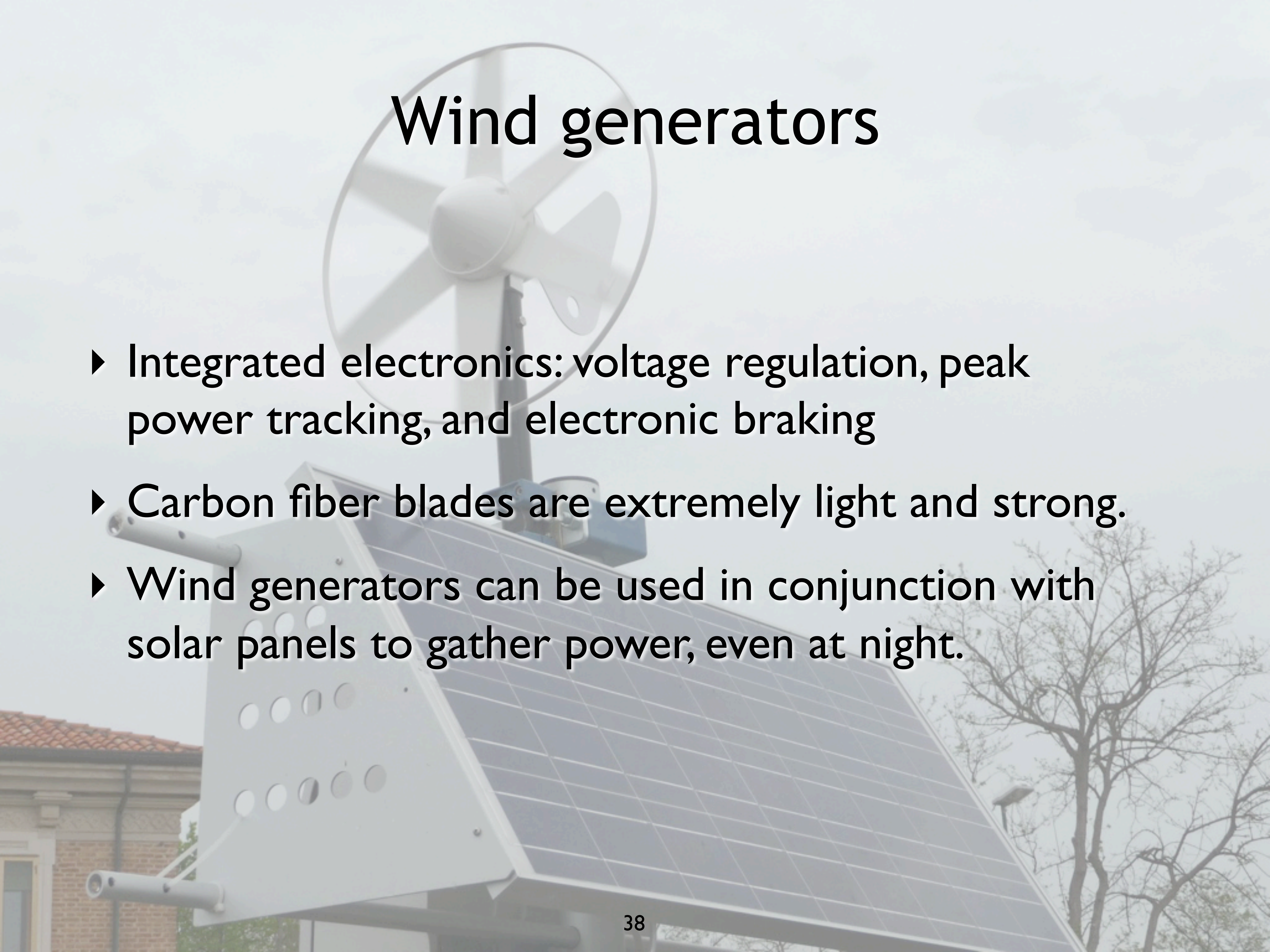
Wind power

The maximum available wind power is given by:

$$P = 0.5 * 1.225 * v^3 \ [W/m^2]$$

where v is in m/s, and assuming air density of 1.225 kg/m^3.
This corresponds to dry air at standard atmospheric pressure at sea level and 15 Celsius.

The efficiency of wind generators range between 20 and 40%



Wind generators

- Integrated electronics: voltage regulation, peak power tracking, and electronic braking
- Carbon fiber blades are extremely light and strong.
- Wind generators can be used in conjunction with solar panels to gather power, even at night.

Conclusions

- Many forms of ambient energy can be harvested
- Sleeping is essential for energy saving
- Solar or wind power are mature technologies to provide energy
- Batteries for energy storage and proper charge regulators are required for intermittent energy sources

Thank you for your attention

For more details about the topics presented in this lecture, please see the book ***Wireless Networking in the Developing World***, available as free download in many languages at:

http://wndw.net/