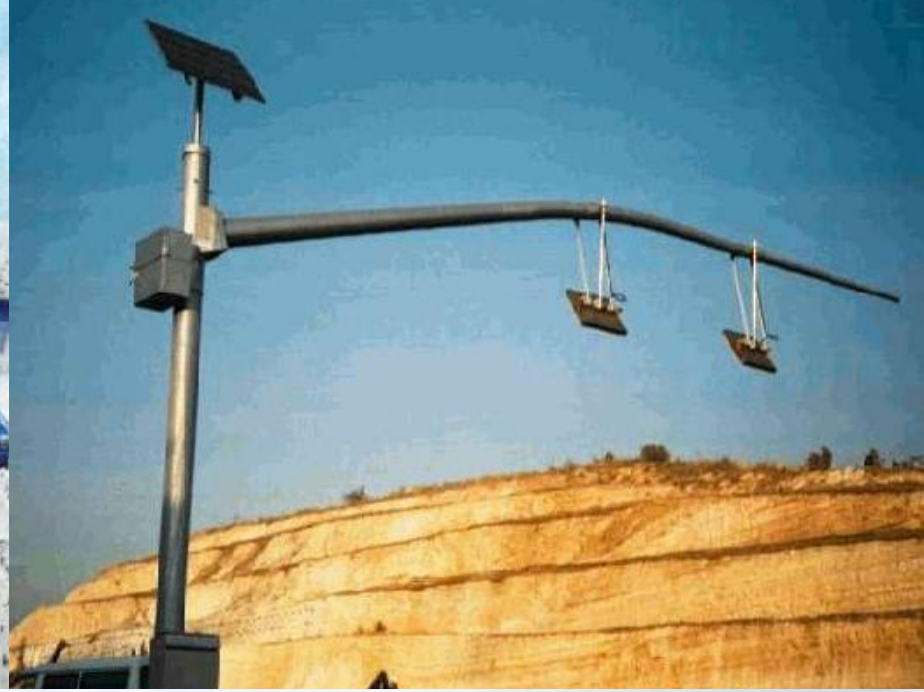
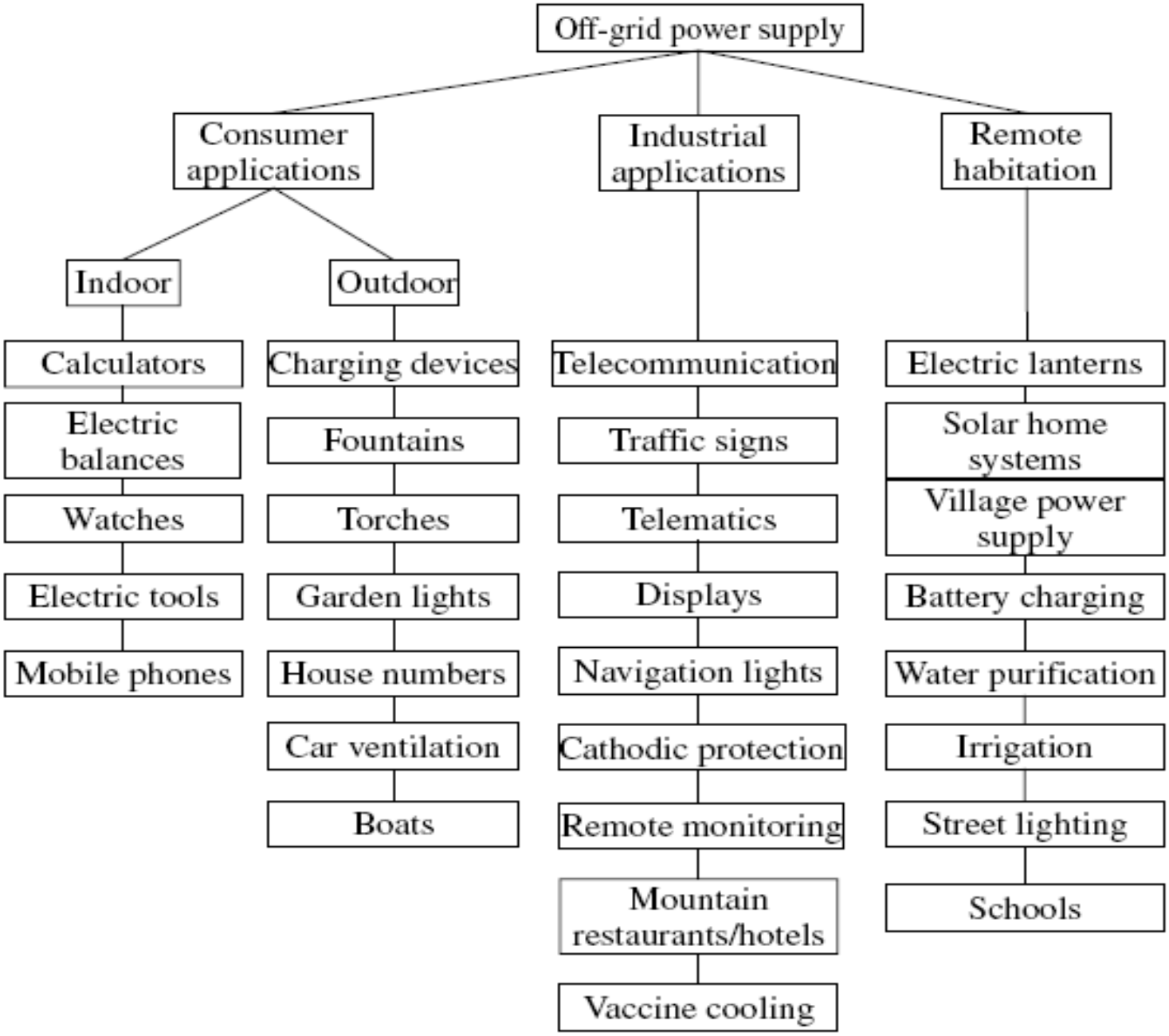
Grid-off (stand alone) PV systems

Electrical power for remote areas



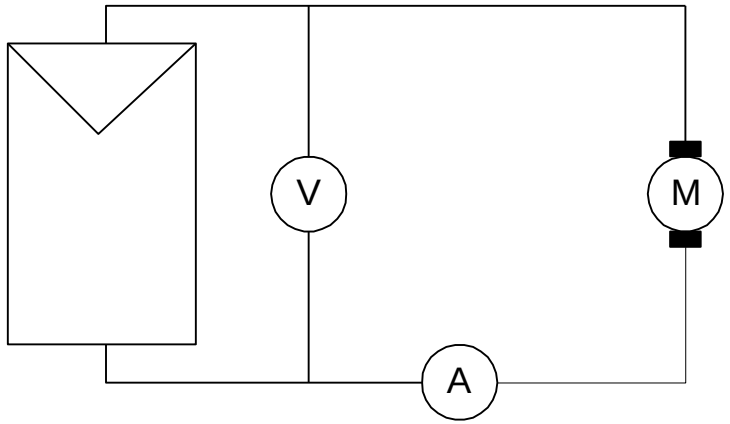

11 06


Off-grid power supply
Consumer applications
Industrial applications
Remote habitation
Indoor
Outdoor
Calculators
Electric balances
Watches
Electric tools
Mobile phones
Charging devices
Fountains
Torches
Garden lights
House numbers
Car ventilation
Boats
Telecommunication
Traffic signs
Telematics
Displays
Navigation lights
Cathodic protection
Remote monitoring
Mountain restaurants/hotels
Vaccine cooling
Electric lanterns
Solar home systems
Village power supply
Battery charging
Water purification
Irrigation
Street lighting
Schools

Grid-off photovoltaic systems

a) Systems without energy accumulation.

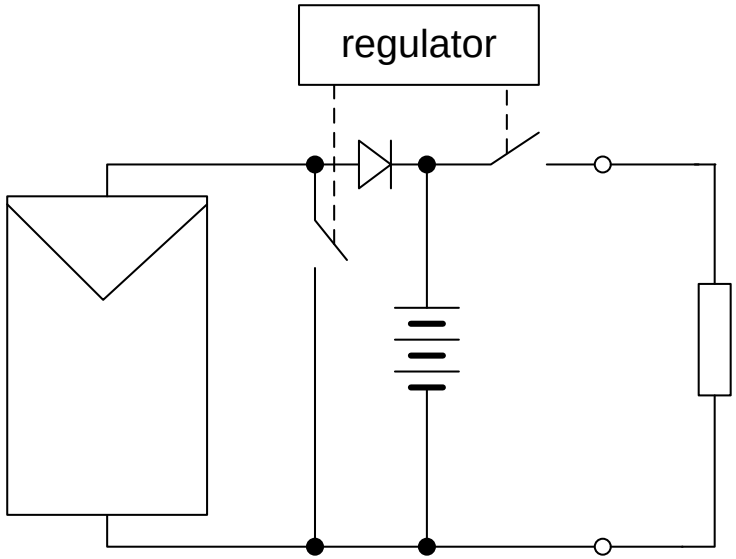
no sun - no energy



b) **Systems with energy accumulation**

battery

regulators (DC/DC converters)



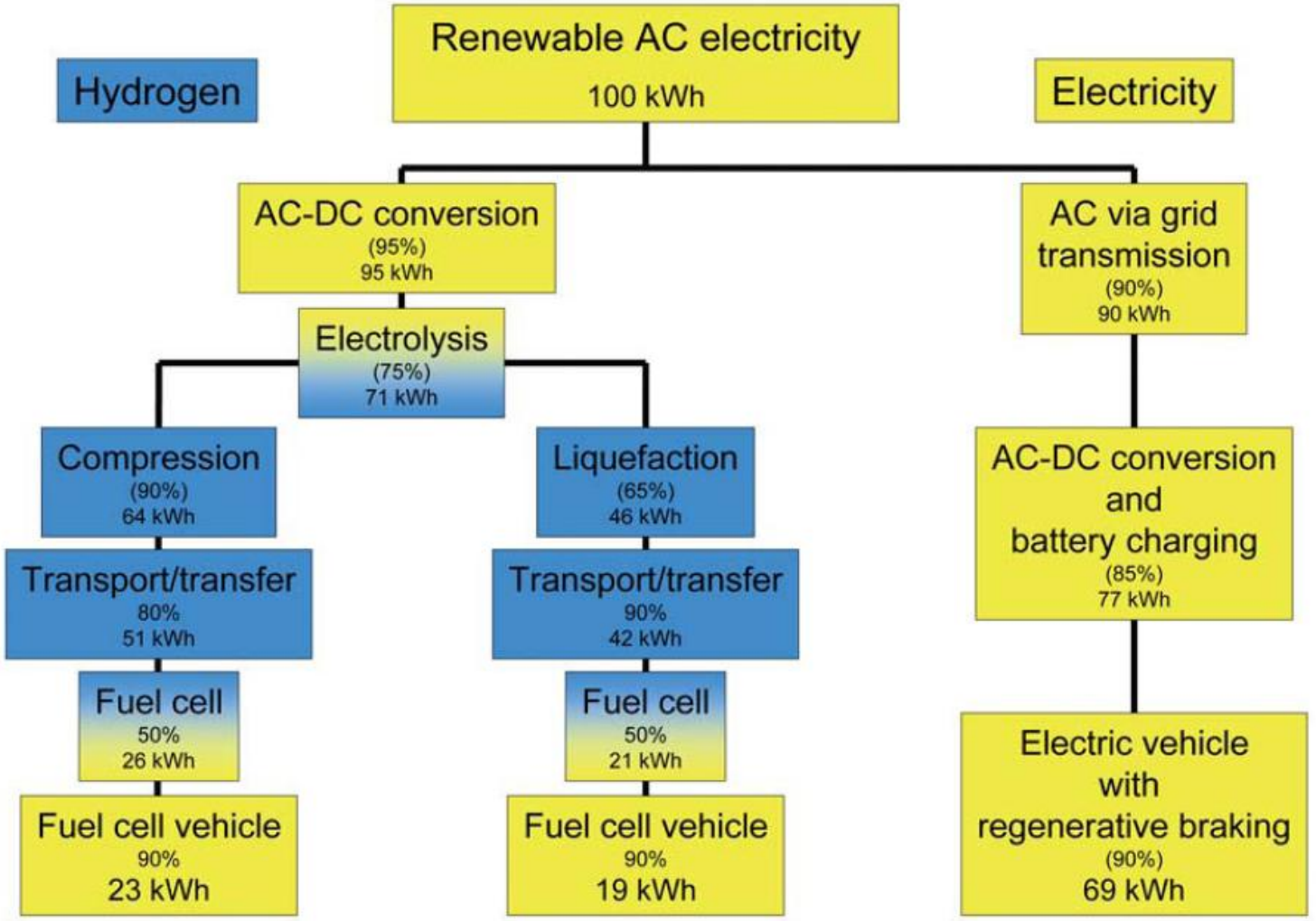
Grid-off PV systems

PV system produces energy when the Sun is shining

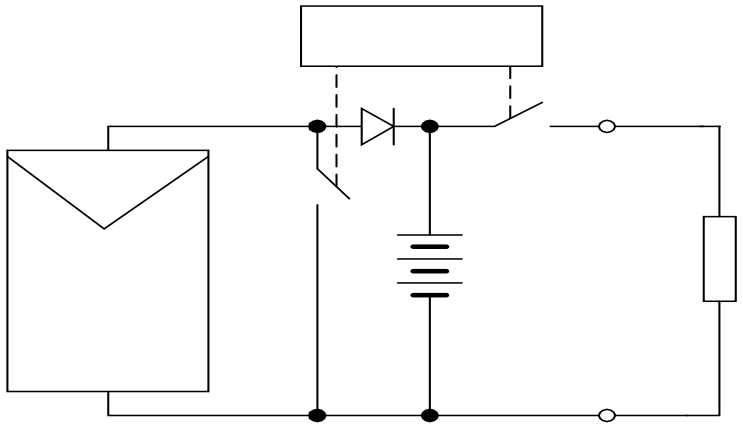
The energy produced should be stored for later use

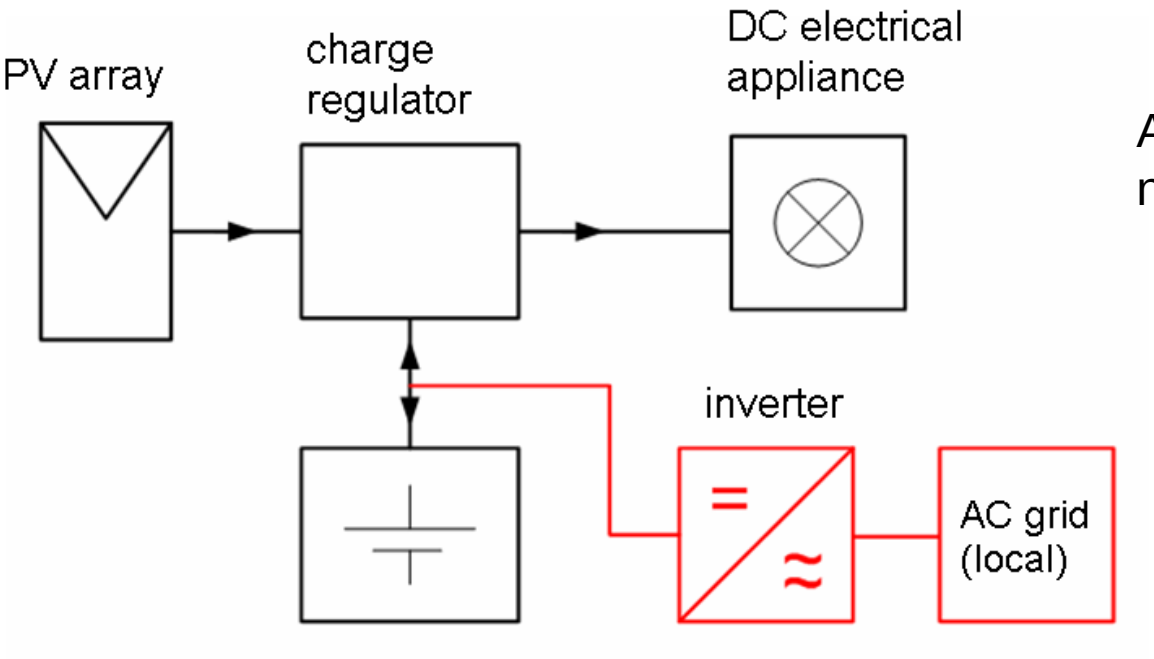
Energy storage type		**Storage medium**	**Storage vessel**	**Power transformation system**
Mechanical	Potential	Water	Upper and lower basins	Motor-generator driven pump turbine
		Compressed air	Air containers	Motor-generator driven compressor turbine
	Kinetic	Rotating mass	Flywheels	Motor-generator
Thermal		Water, solids	Heat containers	Thermal power plant
Chemical	Synthetic fuels	H_2, CH_4, methanol, etc.	Containers	Combustion motors
	Fuel cells	Synthetic fuel (H_2, methanol, etc)	Fuel cell's casing	Electrolyser plus converter
	Secondary batteries	Electrodes – electrolyte systems	Battery casing	Converter
Electrical	Electrostatic field	Electrical charge	Capacitor	Converter
	Electromagnetic field	Moving charge	Superconductive coil	Converter

H_2 Economy Does Not Makes Sense
U. Bossel, Proc. IEEE, 94, 1826, Oct. 2006



Most often the energy is stored
by charging accumulator batteries

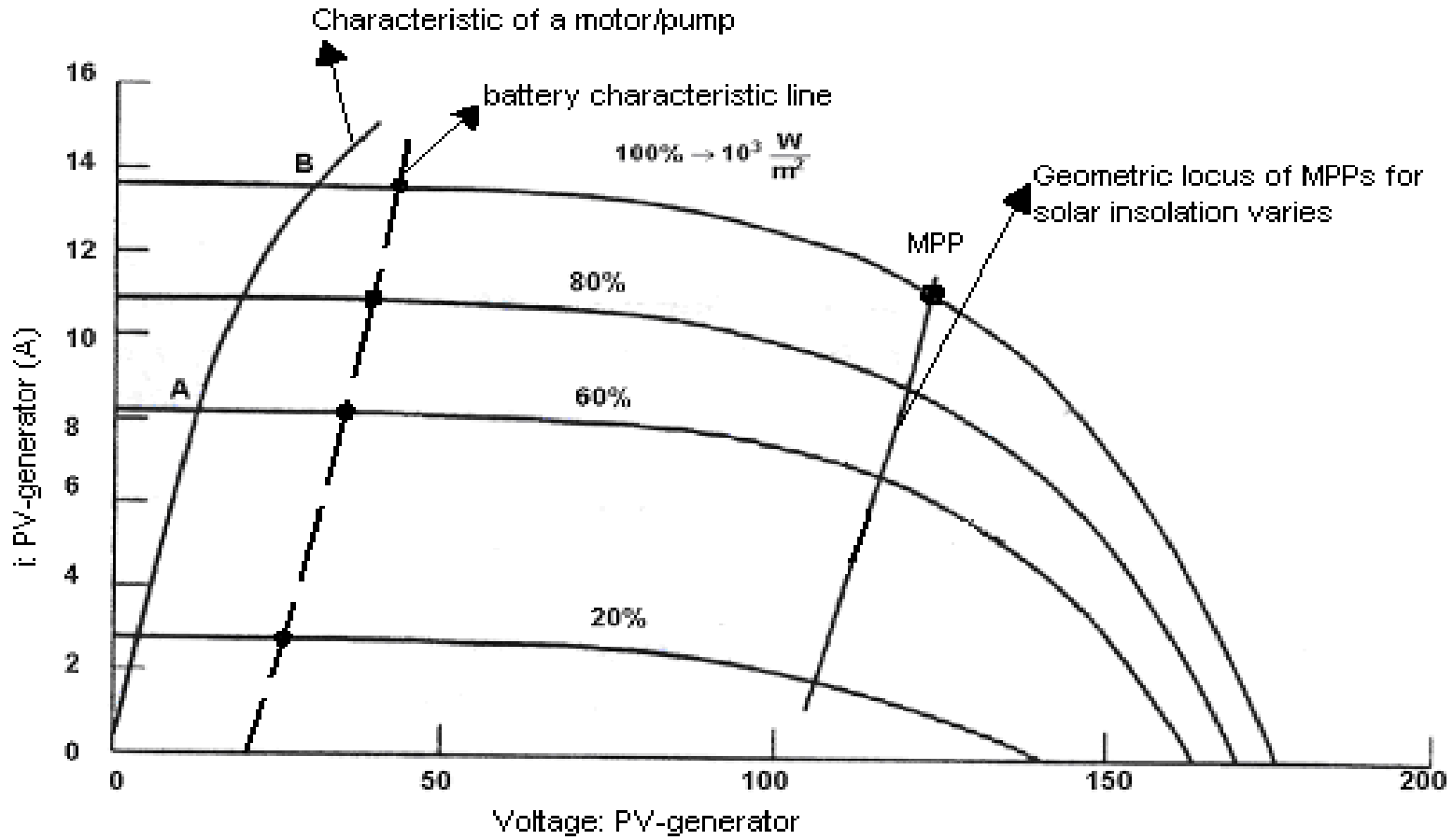




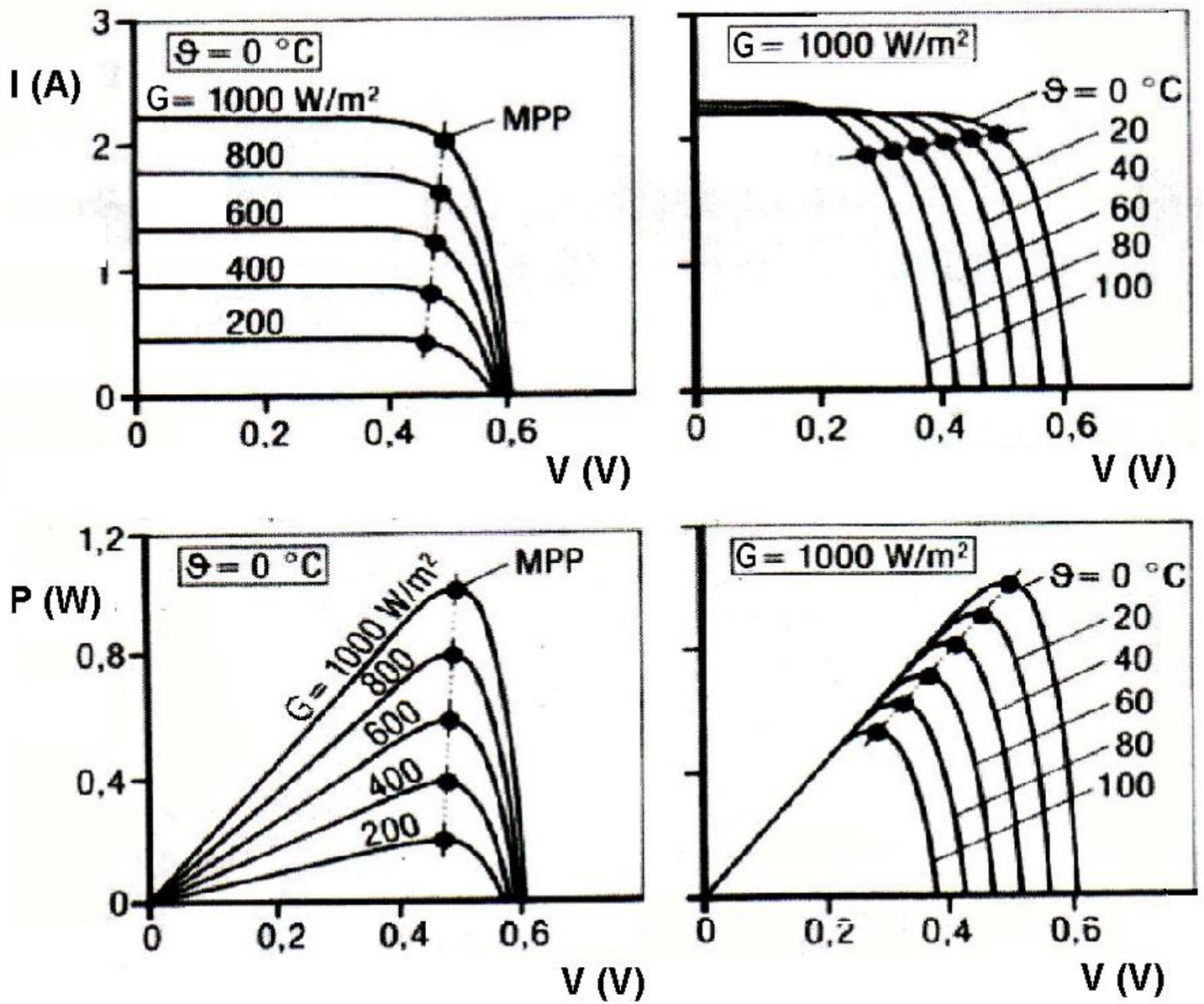
A simple regulator does
not usually operate at MPP

The “size” of a PV system means the size of both the generator (PV modules) and the accumulator (batteries or other storage device)

Type	Voltage (V)	Energy density (Wh/litr)	Energy density (Wh/kilogram)	Lifetime (cycles)
Pb	2,1	70	30	300
NiMH	1,4	240	75	800
$LiCoO_2$	3,7	400	150	1000
$LiMn_2O_4$	4,0	265	120	1000
$LiFePO_4$	3,3	220	100	3000


Characteristic of a motor/pump
battery characteristic line
100% → 10³ W/m²
Geometric locus of MPPs for solar insolation varies
MPP
B
A
80%
60%
20%
i: PV-generator (A)
Voltage: PV-generator
0
2
4
6
8
10
12
14
16
0
50
100
150
200

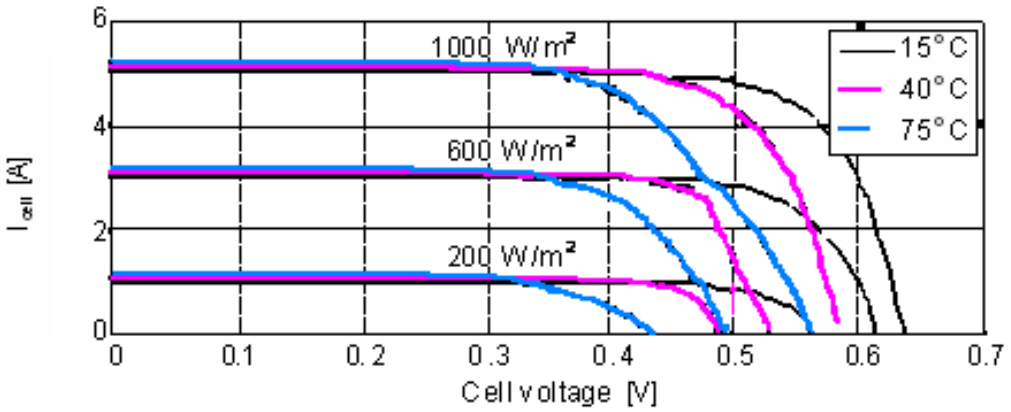
Maximum power point varies with both irradiance and temperature

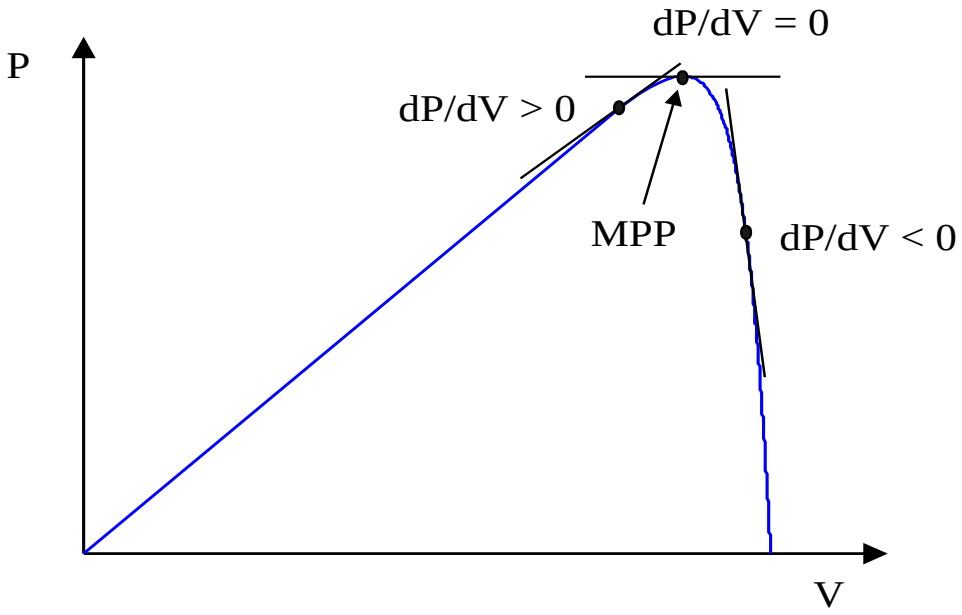


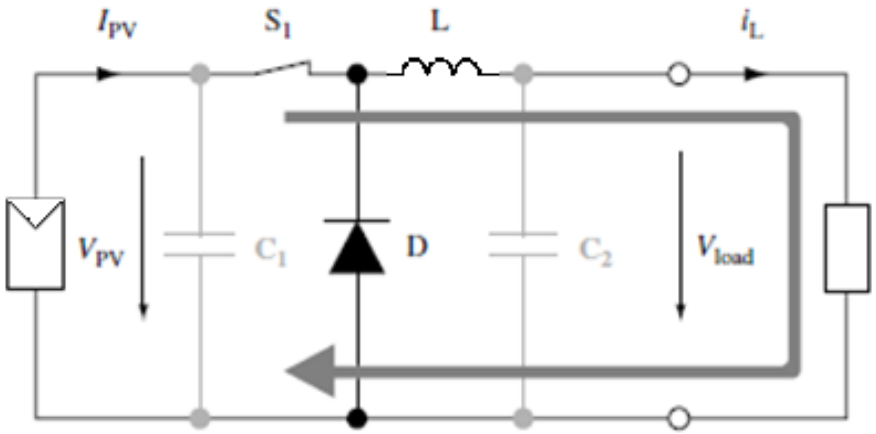
Maximum Power Point Tracking - MPPT

The task of MPPT is to track this MPP regardless of weather or load conditions so that the PV system draws maximum power from the solar array.

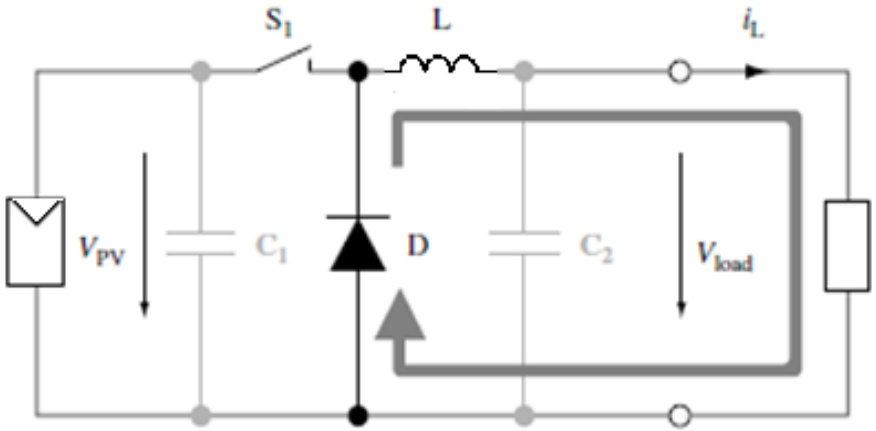
The MPPT is a nonlinear and time-varying system that has to be solved.

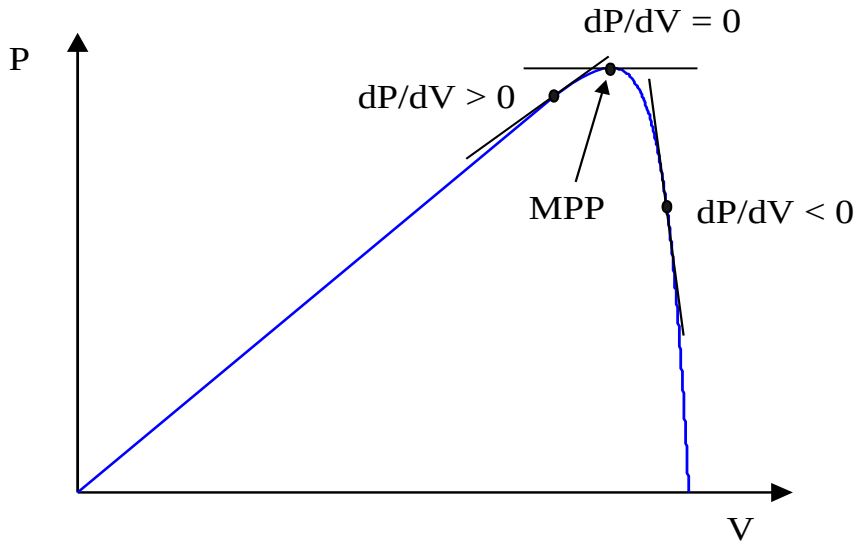


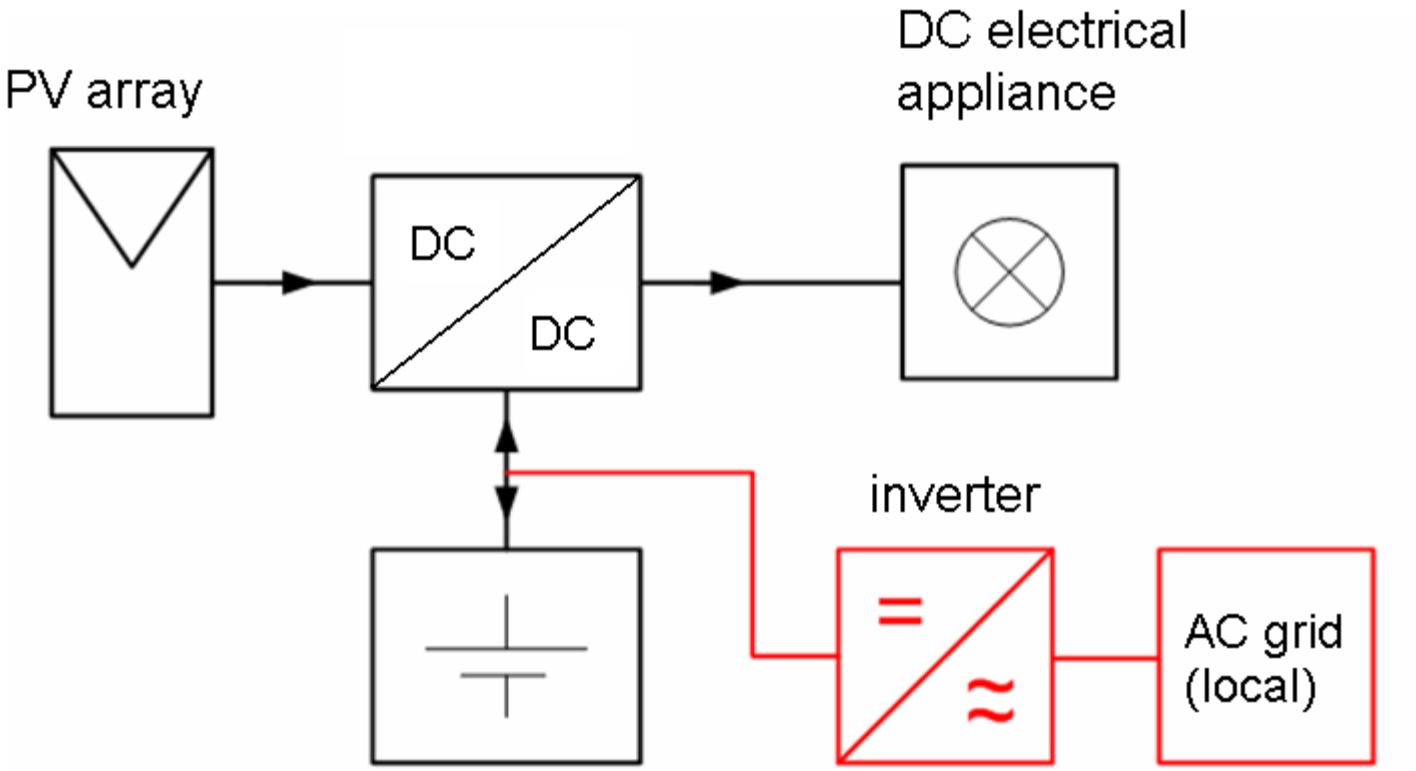




$$V_{PV} = V_L \frac{t_{on} + t_{off}}{t_{on}}$$






PV array
DC electrical appliance
DC
DC
inverter
=
≈
AC grid (local)

A stand alone photovoltaic system sizing

1. Determination of the energy demand and optimisation of the consumption

2. Development of the concept: Setting the voltage level and the type of PV system (DC, AC, combined DC and AC, with or without a back-up generator)

3. Choice and dimensioning of the system components for power conditioning: Converters to match the power generation and consumption sides are chosen according to the system type

4. Sizing the solar generator and the storage battery

5. Dimensioning the solar charge controller

6. Dimensioning the cables

The size of the PV array is based on mean solar daily radiation (G_{do}), and an argument based on daily energy balance to supply daily load L

The generator capacity C_A $$C_A = \frac{\eta_G A_G G_{do}}{L}$$

A_G and η_G are the area and conversion efficiency of the PV generator

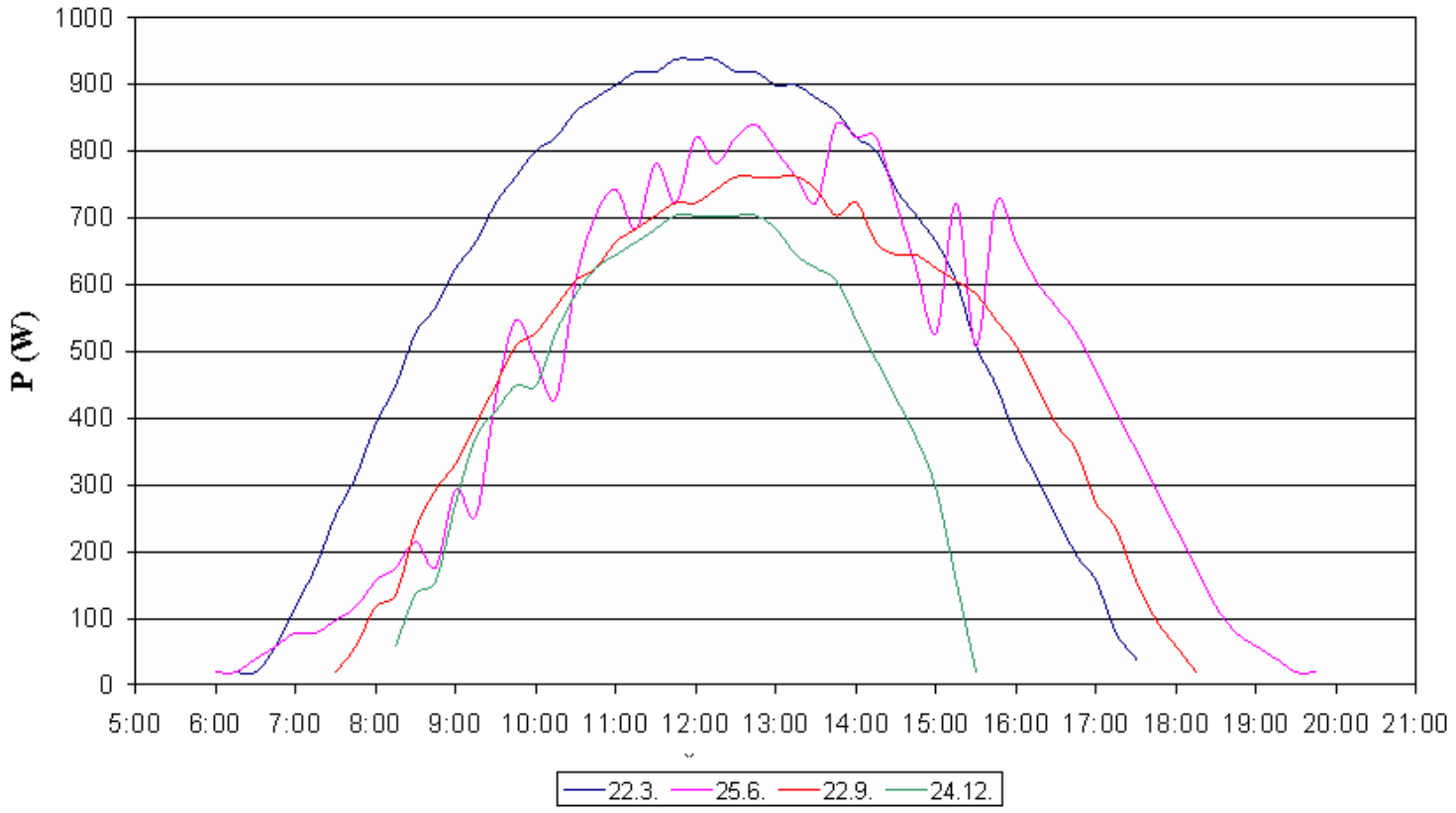
G_{do} is the mean value of the daily irradiation on the surface of the PV field

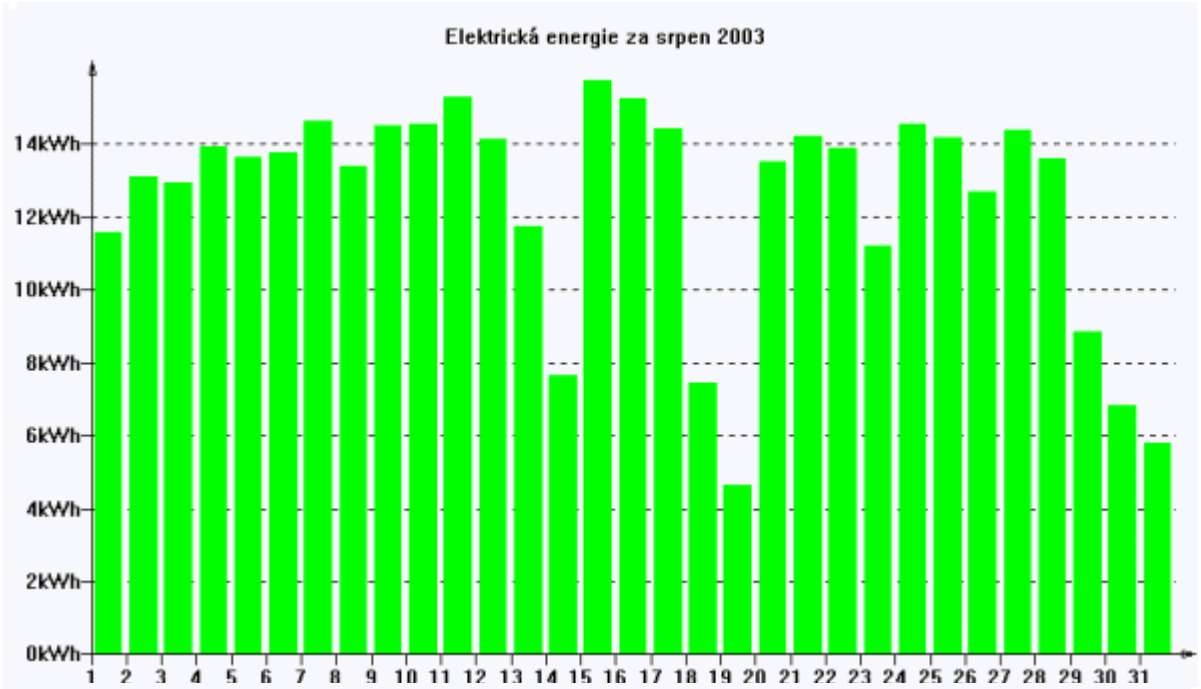
L is the mean value of the daily energy consumed by the load

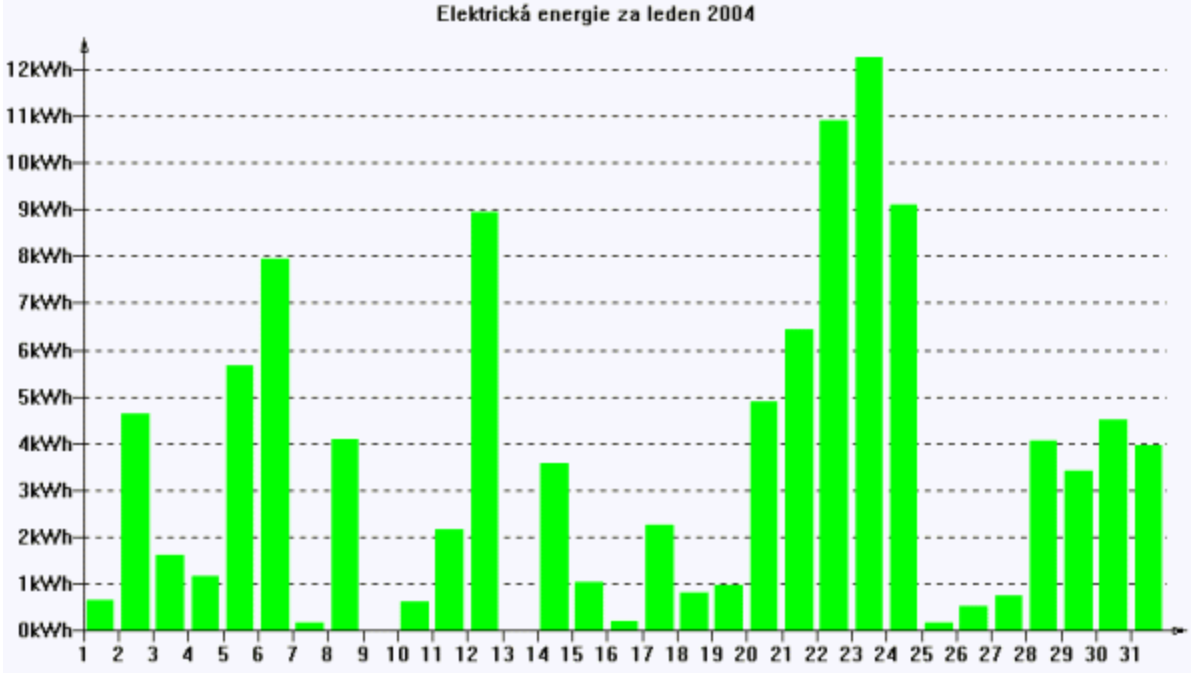
C_A depends on the local solar climate conditions

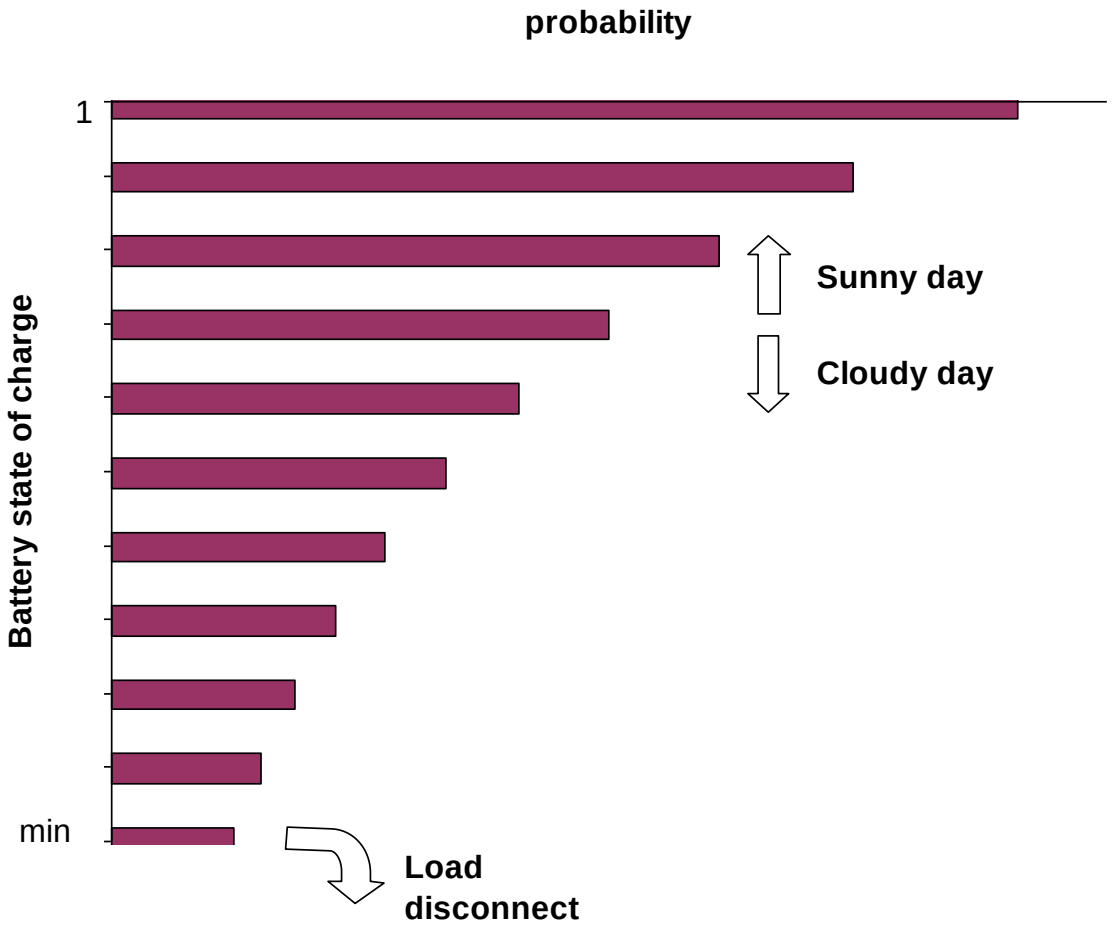
The accumulator capacity, C_S, is defined as $$C_S = \frac{C_u}{L}$$

C_u is the useful energy storage capacity of the accumulator


P (W)
1000
900
800
700
600
500
400
300
200
100
0
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22.3.
25.6.
22.9.
24.12.


Elektrická energie za srpen 2003
14kWh
12kWh
10kWh
8kWh
6kWh
4kWh
2kWh
0kWh
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Elektrická energie za leden 2004
12kWh
11kWh
10kWh
9kWh
8kWh
7kWh
6kWh
5kWh
4kWh
3kWh
2kWh
1kWh
0kWh
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


probability
1
Battery state of charge
min
Sunny day
Cloudy day
Load
disconnect

A time interval of n_{cycle} days when the daily solar radiation is equal to G_d, below the average value of G_{do}. During this time interval (or climatic cycle), a part or all of the load demand has to be supplied by the battery.

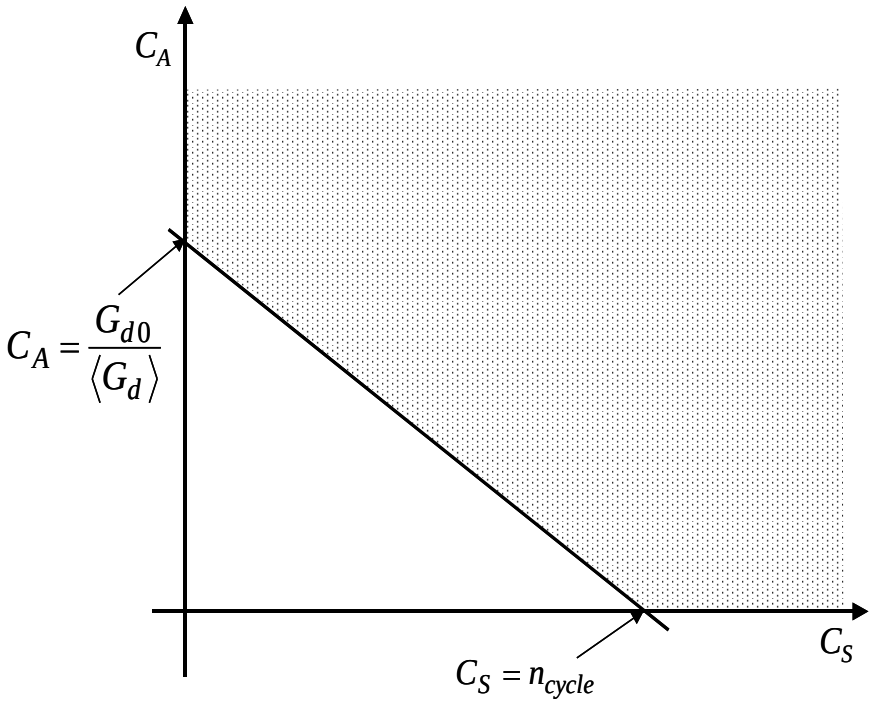
To maintain a continuous electricity supply to the load, the required battery size C_u in energy units

$$C_u \geq n_{cycle}(L - C_A \frac{L}{G_{do}} G_d)$$

If the battery size C_u is replaced by the days of storage

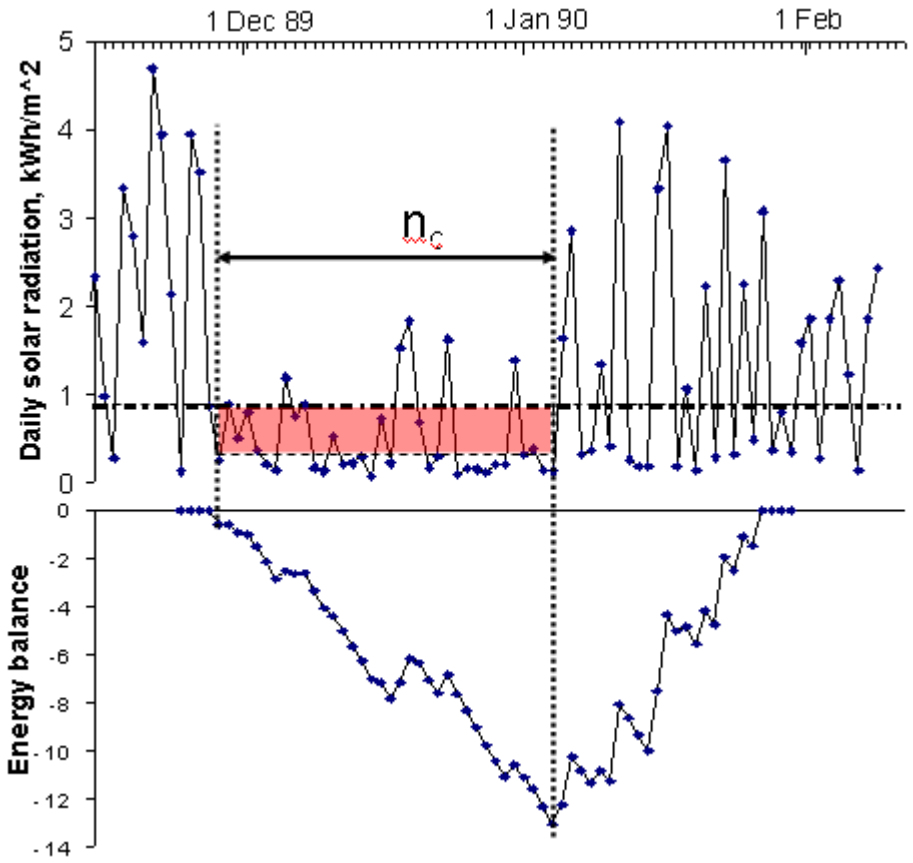
$$C_S = C_u / L$$

$$\frac{1}{n_{cycle}} C_S + \frac{G_d}{G_{do}} C_A \geq 1$$



C_A = 1.1 and 3 ≤ C_S ≤ 5 are common values for rural electrification purposes

1.2 ≤ C_A ≤ 1.3 and 5 ≤ C_S ≤ 8 are common ranges on the so-called professional market

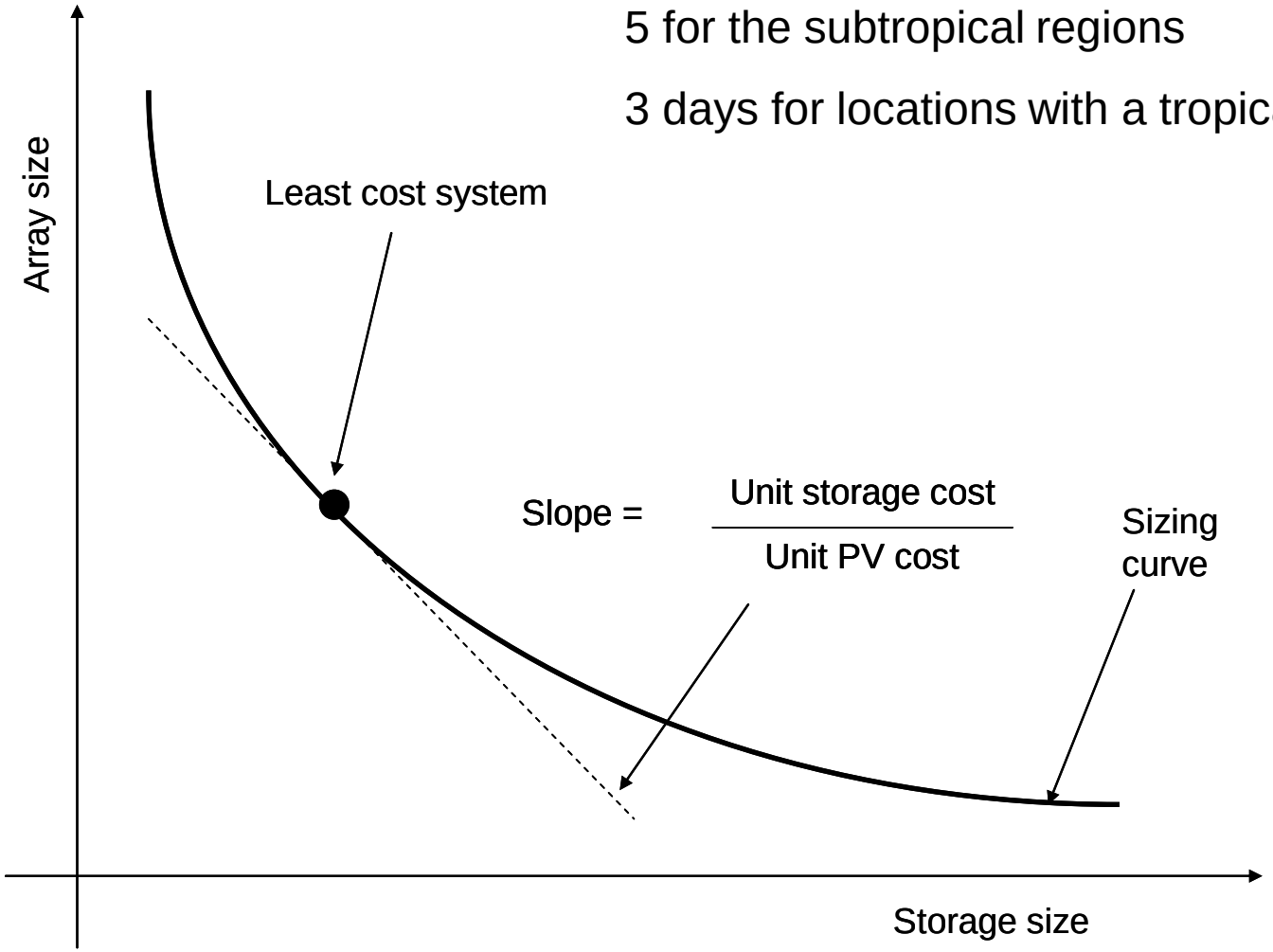

1 Dec 89
1 Jan 90
1 Feb
Daily solar radiation, kWh/m^2
5
4
3
2
1
0
n_c
Energy balance
0
-2
-4
-6
-8
-10
-12
-14

The size of battery is connected with a period without sufficient irradiance

15-20 days for northern Europe,

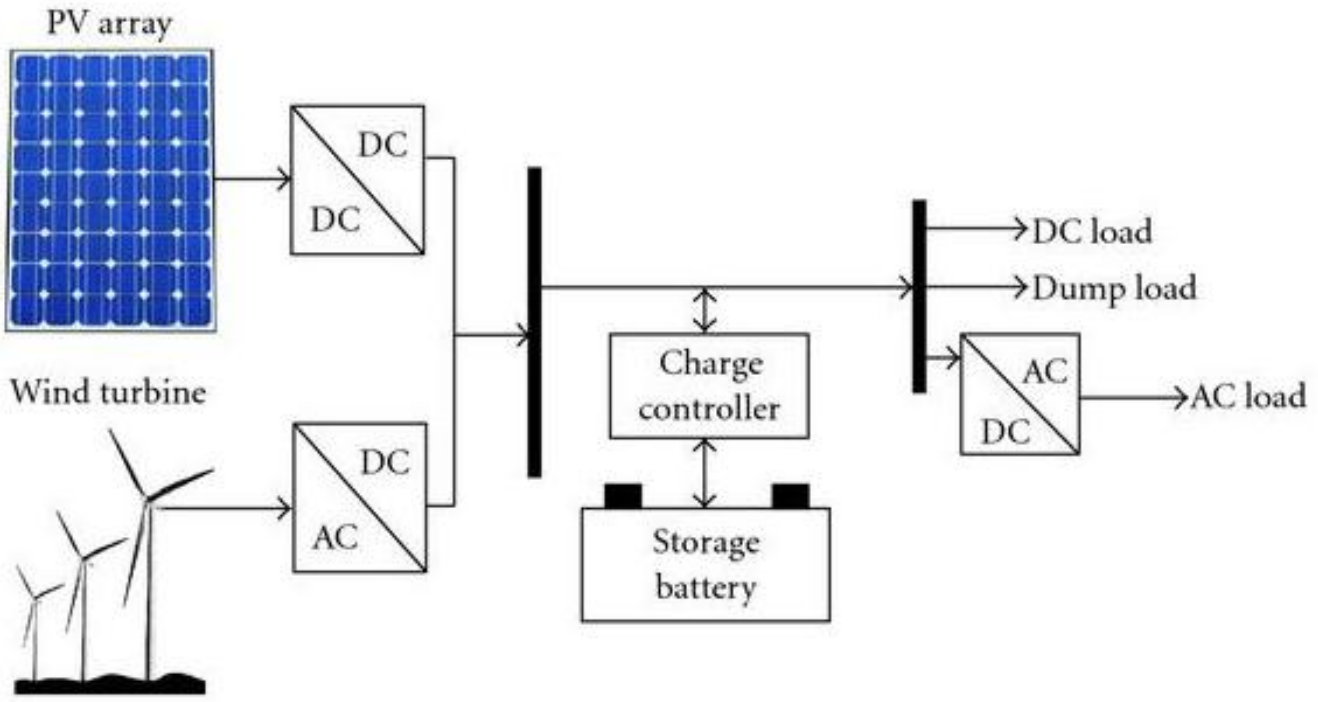
5 for the subtropical regions

3 days for locations with a tropical climate



If solar insolation is highly seasonal, the PV array and battery store providing a sufficiently reliable service may be too expensive

A hybrid system with a back - up diesel generator or (and) a wind turbine or (and) a hydropower may be a better option.



The Isle of Eigg ’ s renewable energy system