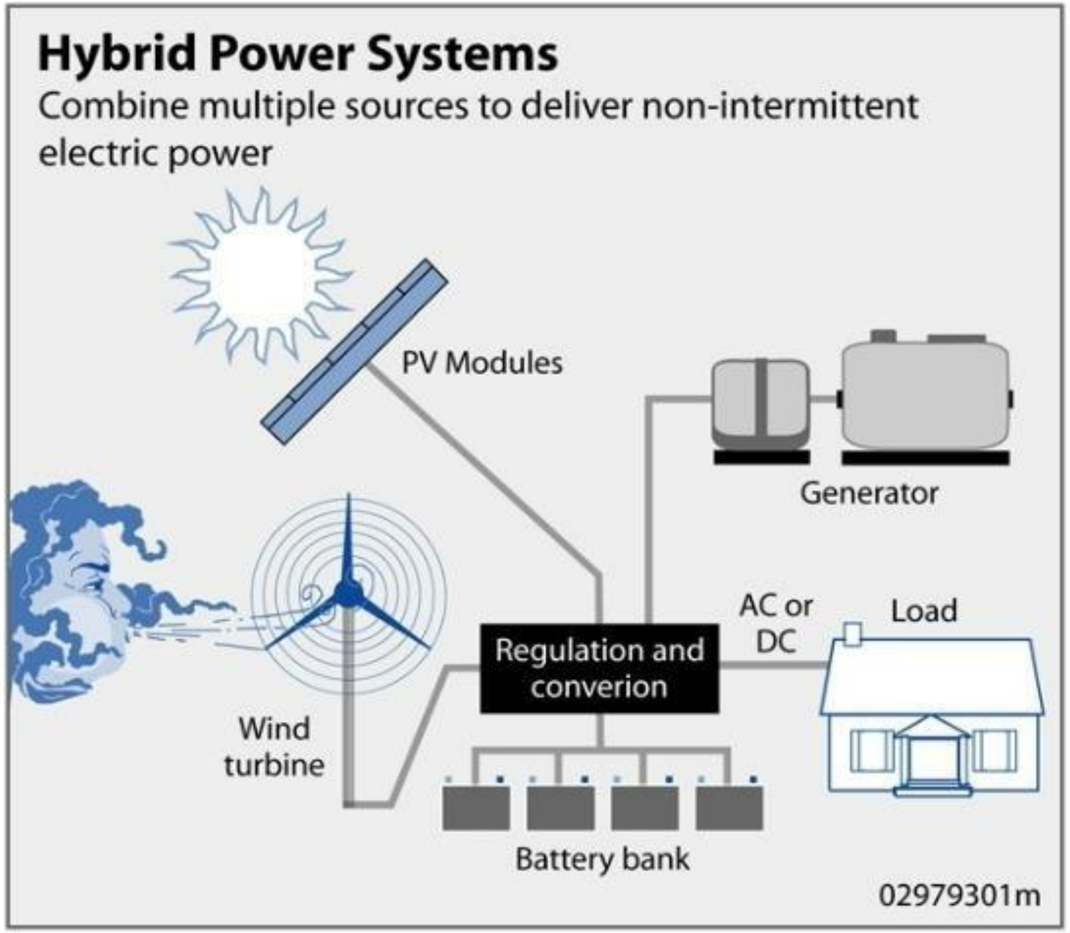
HYBRID SYSTEM

A hybrid energy system is a combination of multiple energy systems. It can be based on two or more renewable systems (i.e. solar/wind/hydro/biomass) or renewable/non-renewable systems (i.e. wind/diesel, solar/diesel etc)



Source: US Department of Energy, Small “Hybrid” Solar and Wind Electric Systems (Washington, D.C., US Government, 2011).

HYBRID SYSTEM CHALLENGES

- Financial

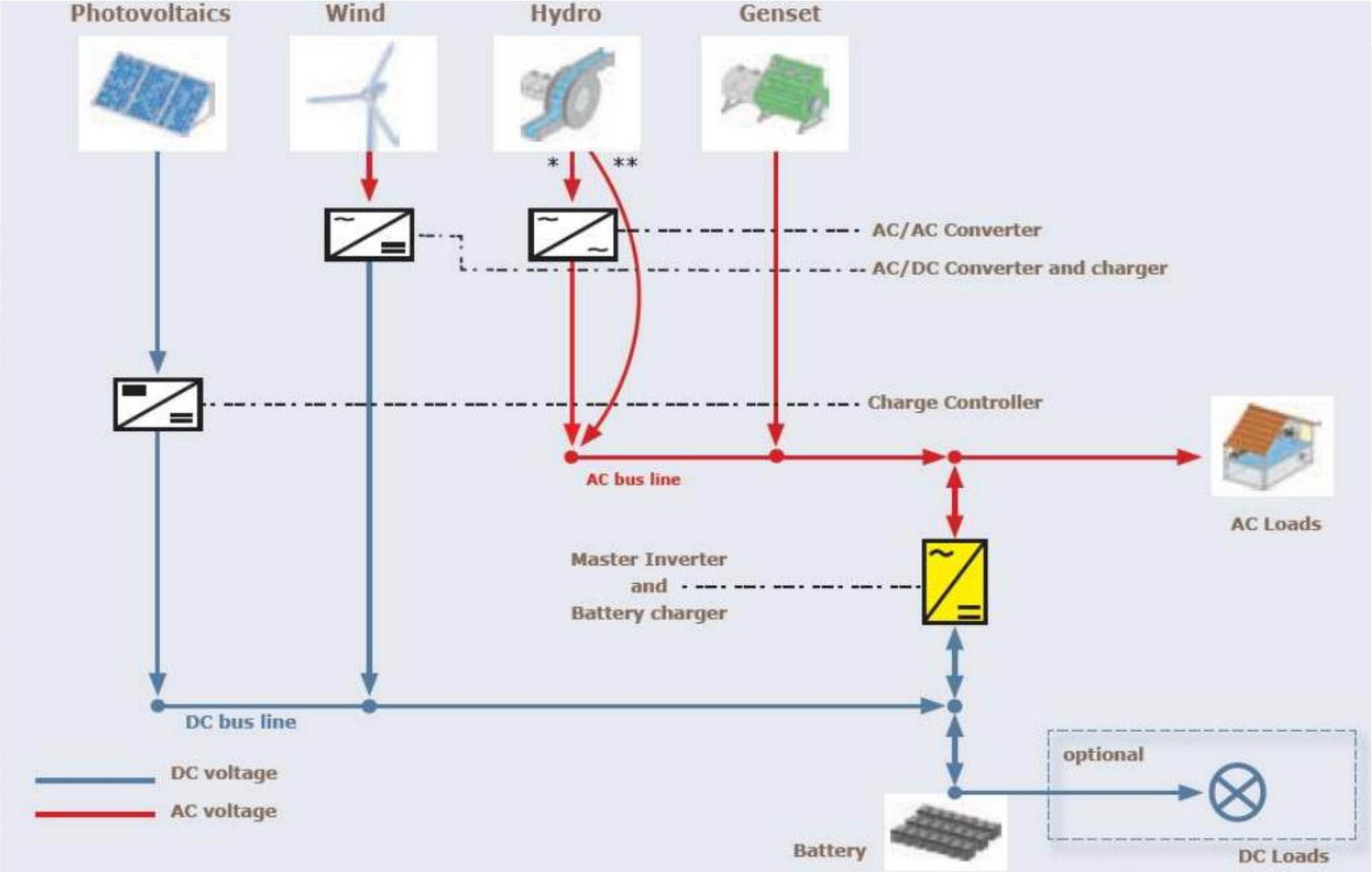
The multiple components required to form a hybrid system generally make them expensive to build.

- Technical

There is no single optimal hybrid energy system configuration. Rather, optimizing is based on the availability of renewable and non-renewable resources, on site-specific energy infrastructure, production costs and incentive policies. Planning a hybrid system thus necessitates an adequate study period for each proposed project site.

https://www.unescap.org/sites/default/files/35.%20FS-Hybrid-energy-system.pdf

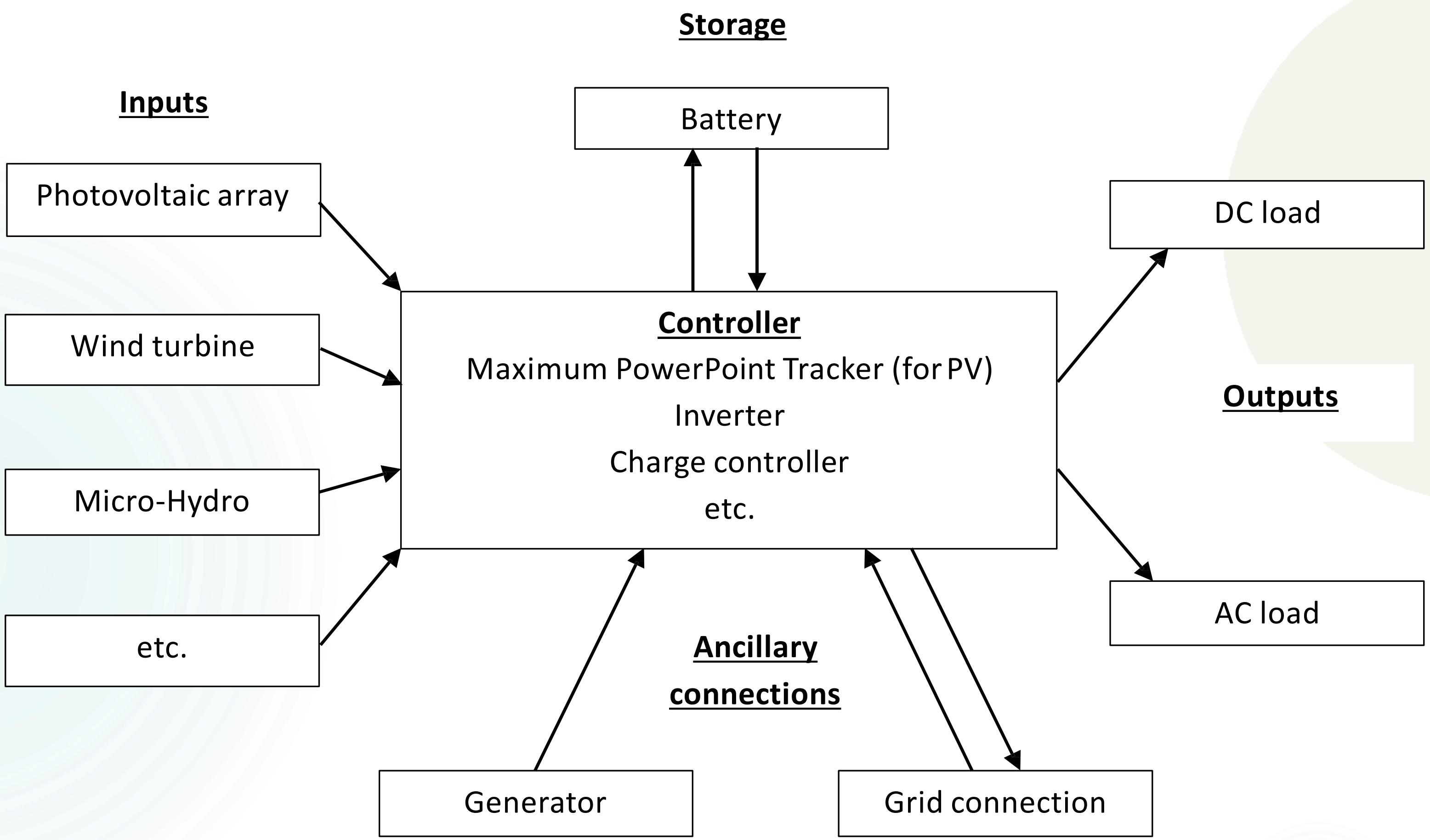
Electricity generation coupled at AC/DC bus line



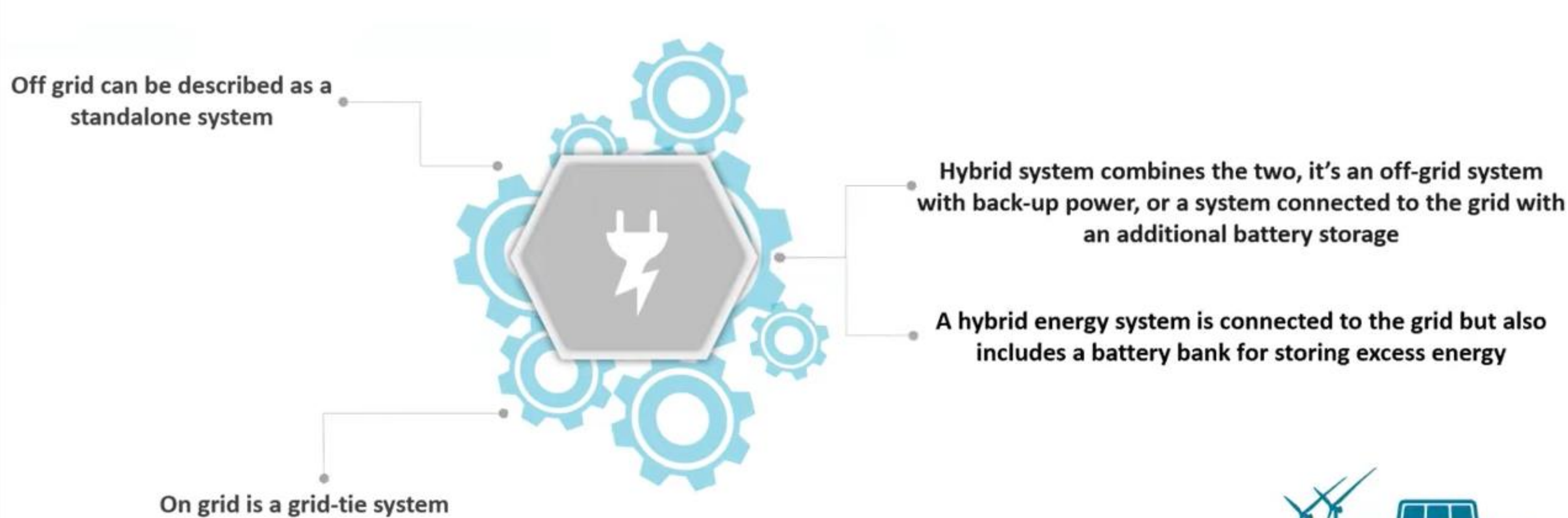
Need for hybrid systems

- The systems are complementary. During the summer months when there's not much wind there should be ample sunlight and during the dark winter months, it is usually quite windy.
- Two different energy sources provide a diversity of supply, reducing the risk of power outages.
- High-cost ancillary equipment such as the battery and the inverter required for a single system must be specified to carry the full system load. A second system can thus be added without increasing its capacity or adding cost for more of these components.
- Because of the supply diversity, the capacity of the battery can most likely be reduced.
- Higher reliability (quality & available power)
- Reduction of energy storage capacity

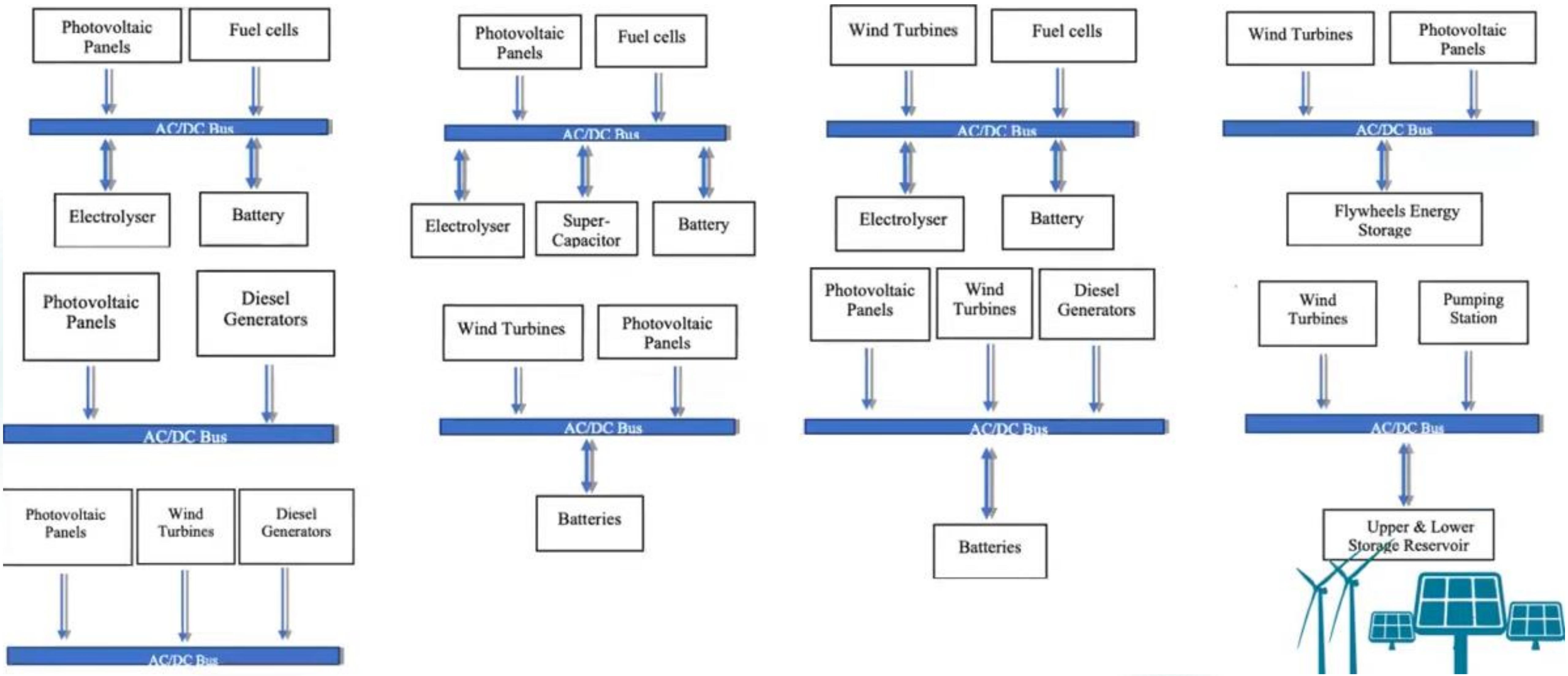
COMPONENTS OF HYBRID SYSTEMS



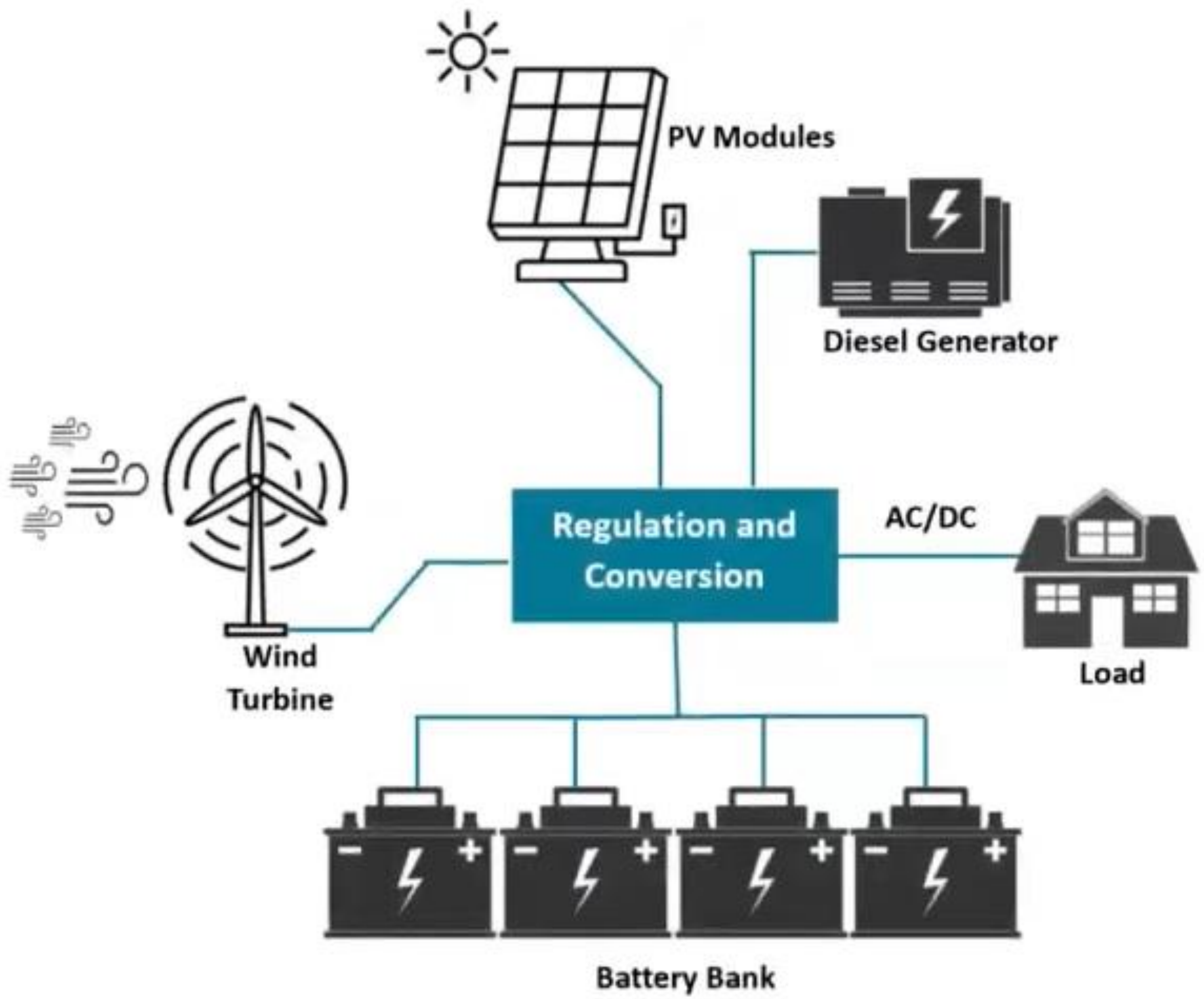
Difference between Hybrid systems & On/Off-grid

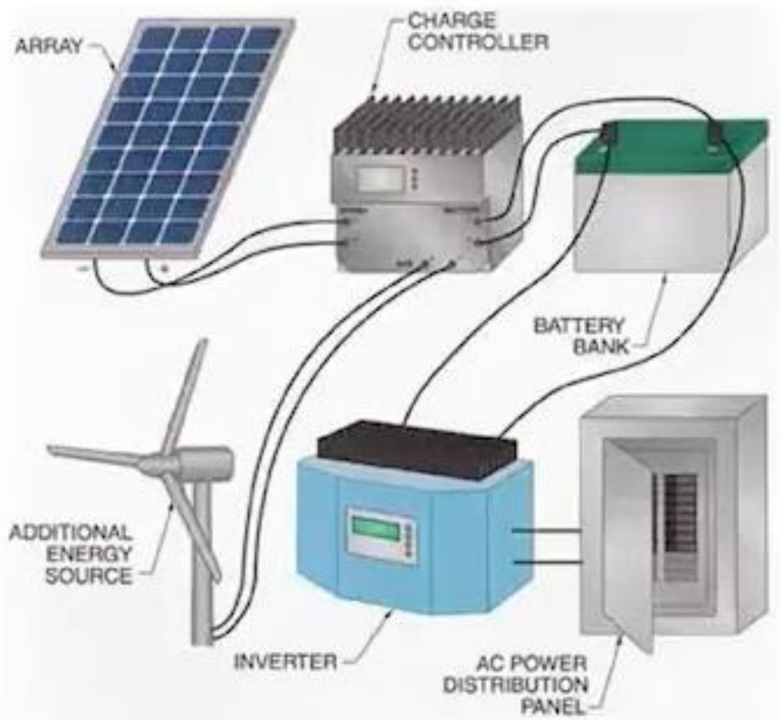


Configuration models of hybrid systems



Combining PV and Wind





Combining PV and Wind

- Determine the capacity of a PV system (alone) to meet the demand.
- Determine the capacity of wind turbine to meet the demand (by a wind turbine alone).
- Determine the trade-off between PV and Wind.
- Determining the size of the storage system.

Example

	Daily demand (kWh)	Mean power demand (kW)	Solar input kWh/(m^2.day)	Mean windspeed (m/s)
January	125	5.21	1.2	6.4
February	125	5.21	2.1	5.4
March	125	5.21	3.0	5.4
April	120	5.00	4.3	5.2
May	100	4.17	4.9	4.8
June	80	3.33	4.5	3.7
July	80	3.33	4.4	3.1
August	80	3.33	3.8	4.3
September	100	4.17	2.1	5.3
October	120	5.00	2.1	5.7
November	125	5.21	1.4	6.2
December	125	5.21	0.8	6.3

Monthly mean solar inputs and wind speeds

Estimate the size of a PV system

	Daily demand (kWh)	Mean power demand (kW)	Solar input $kWh/(m^2.day)$	Mean windspeed (m/s)
February	125	5.21	2.1	5.4

$$CF_{PV} = \frac{Solar\ input\ (kWh/(m^2.day))}{24(kWh/(m^2.day))}$$

CF_{PV} = 2.1/24 = 0.088

$$Rated\ output\ (kW) = \frac{Actual\ (required) output\ (kW)}{Capacity\ factor}$$

Rated output (PV capacity) = 5.21/0.088 = 59.5 kW

Estimate the size of a PV system....

$$Output\ (kW) = Input\left(\frac{kW}{m^2}\right) x\ Area\ (m^2)\ x\ efficiency$$

$$Area\ (m^2) = \frac{Output\ (kW)}{Input\ \left(\frac{kW}{m^2}\right)\ x\ efficiency}$$

PV Area = 59.5/(1 x 0.12) = 496 m^2

Estimate the capacity of a wind turbine

CF_{wind} @ 5.4 m/s = 0.231

$$Rated\ output\ (kW) = \frac{Actual\ (required)output\ (kW)}{Capacity\ factor}$$

<u>Rated output (Wind capacity) = 5.21/0.23 = 22.7 kW</u>

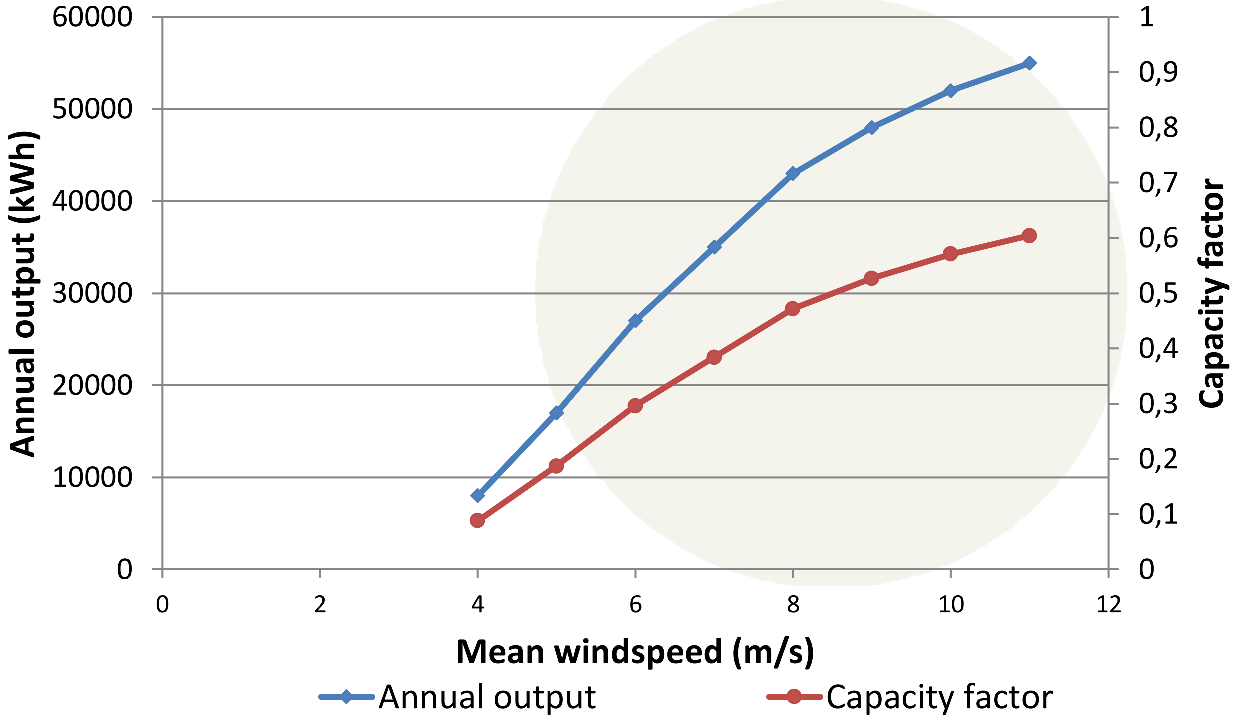


Figure: Annual output and capacity factor of 10.4 KW rated wind turbine

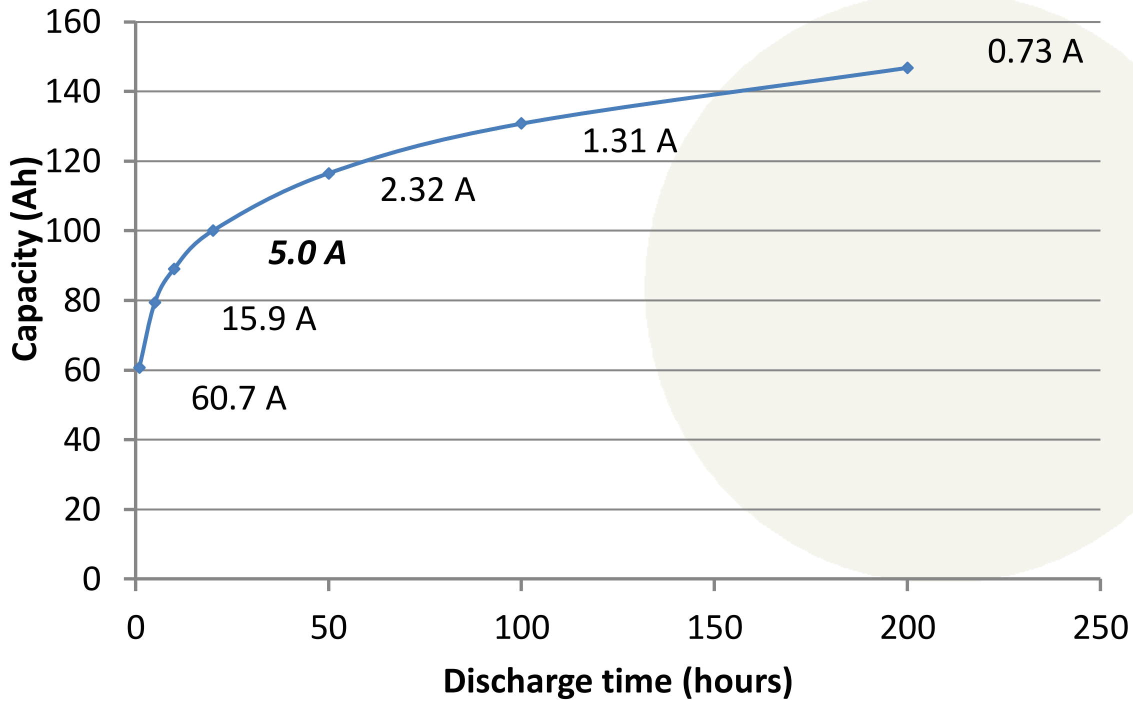
BATTERIES

- Batteries are needed to store energy
- They are usually specified as voltage and capacity in Amp-hours
- E = V x capacity
- A 12V 100Ah battery stores up to 1200 Wh, enough energy to run a 10W light bulb for 120hours

Capacity against discharge time

Peukert's Law

$$t = H\left(\frac{C}{I.H}\right)^{k}$$



Where:

C is the rated capacity in amp-hour

H is the rated discharge time in hours

I is the discharge current, in amps

t is the time taken to discharge at current I, in hours

k is Peukert's constant – can be taken as 1.2 for deep-cycle batteries.

LITHIUM BATTERIES

The storage solutions are based on the same lithium-ion battery technology used in electric and hybrid vehicles made by Mercedes-Benz and smart. Up to eight battery modules with an energy output of 2.5 kWh each can be combined to form an Energy Storage with up to 20 kWh for domestic applications. In terms of industrial applications, units can be scaled up to 100 MWh.

BATTERY selection

- Cost
- Energy Density
- Depth of Discharge
- Self-discharge
- Life expectancy
- Charge time
- Memory Effects
- Environmental Considerations

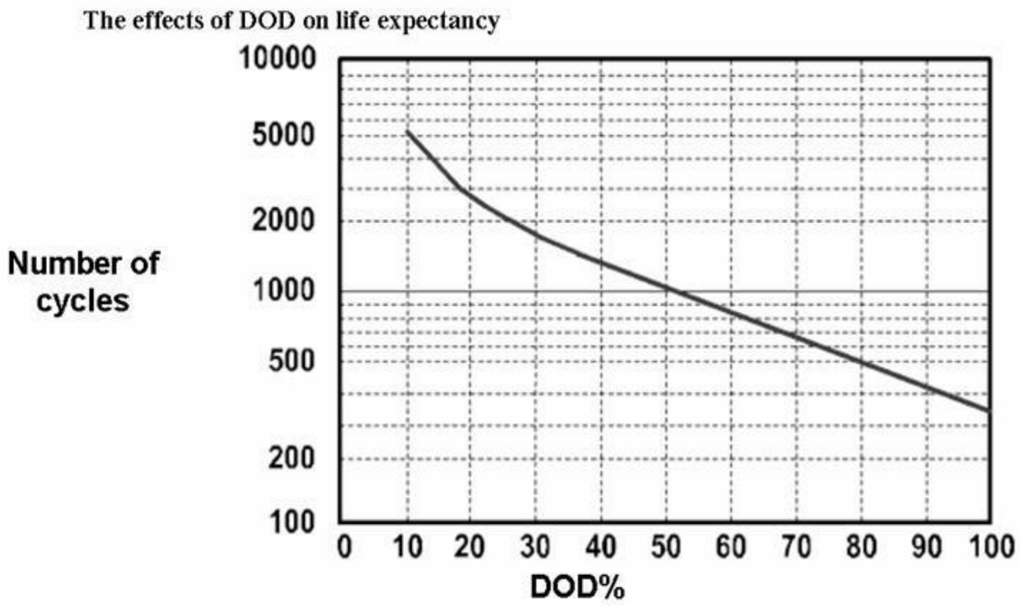
STATE OF CHARGE AND DEPTH OF DISCHARGE

- A state of charge (SOC) of 100% corresponds to a completely charged battery and an SOC of 0% corresponds to a completely discharged battery.
- SOC would be used as a "fuel gauge" to indicate the charge left in a battery.
- Depth of discharge (DOD) is the converse of SOC. If a battery has a DOD of 80% this corresponds to a SOC of 20%.
- DOD + SOC always equals 100%.

LIFE EXPECTANCY

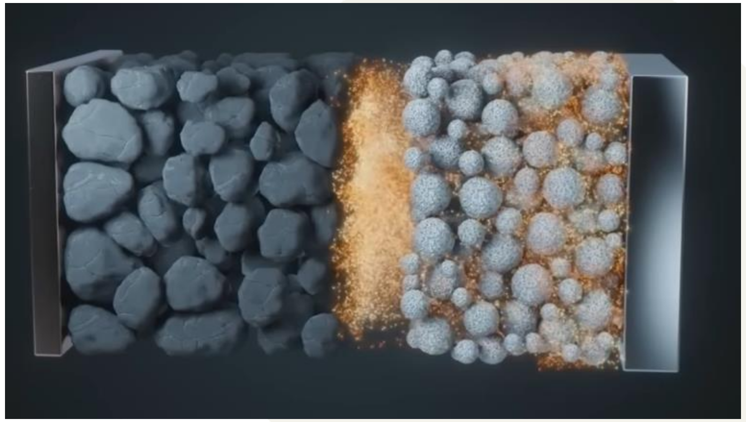
- For good life expectancy, batteries must not be discharged too much. It is highly recommended to increase the battery size rather over discharging

- Even though battery capacity at high temperatures is higher, battery *life* is shortened. Battery life is reduced at higher temperatures - for some batteries for every 10 degrees C over 25, battery life is cut in half.

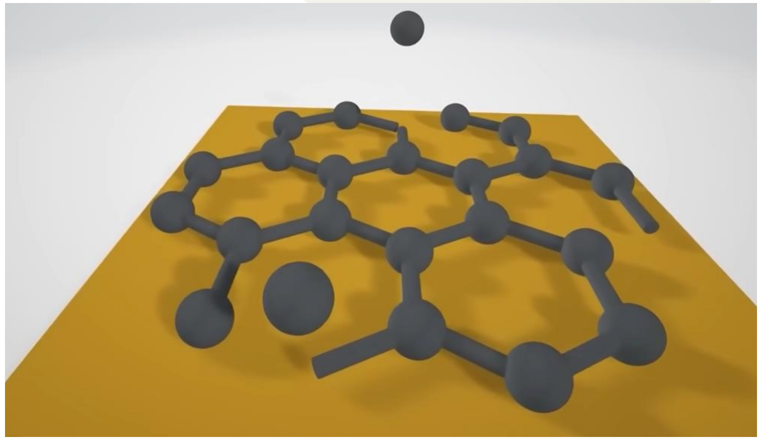


BATTERY technologies

From **Lithium Ion** to **Graphene –Aluminium Ion** Battery



Graphene Battery charges 60 times quicker
Is lighter, safer (no fire risk)



BATTERY sizing

Q = (E X D)/(DOD x η)

$$DoD = \frac{Duration\ of\ current\ (hours)}{Time\ to\ discharge\ at\ that\ current\ (hours)}$$

Where

- E = Battery capacity in Ah
- D = Days of autonomy (number of days of storage required)
- DOD = Allowed depth of discharge
- η = Concerned Efficiencies

ASSESSING ELECTRICITY CONSUMPTION

- Prediction can be misleading
- Appliance power ratings not accurate.
- Metering actual consumption advisable

EXAMPLE – OFF GRID HYBRID SYSTEM

Also determine the battery capacity needed for a residential facility with provided demand profile run on PV system.

Days of autonomy = 5
DOD = 50%
η_{inv} = 90%
η_{cb} = 97%

Load/applian ce	Power rating of appliances (W)	Quantity	Hours of use per day (h)
CFL-hall and living room	11	3	3
CFL-Kitchen	20	1	1.5
Lights-outside and garage	100	2	0.2
TV	60	1	1
microwave	700	1	0.4
Food mixer	400	1	0.1
Refrigerator	80	1	Average -5
Totals			

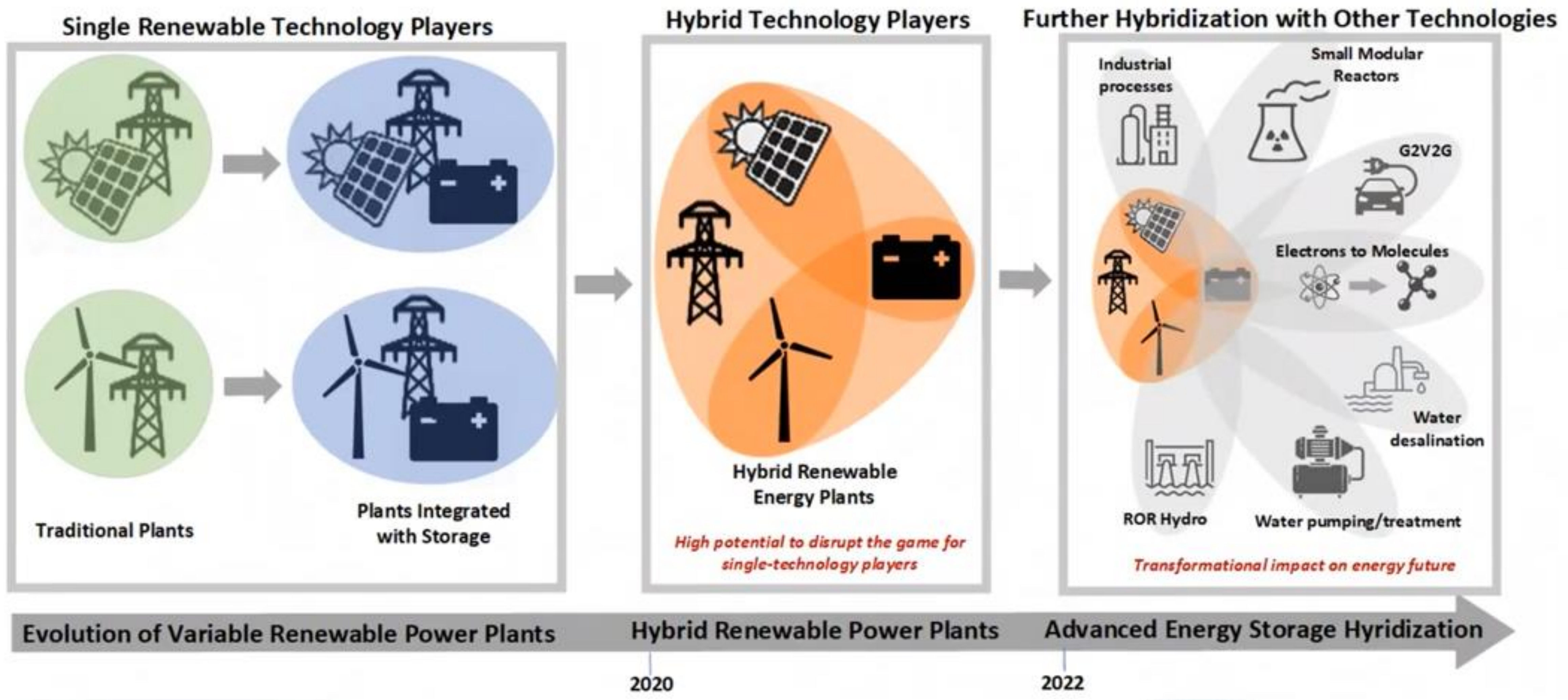
Load/appliance	Power rating of appliances (W)	Quantity	Total Power (W)required	Hours of use per day (h)	Daily energy requirement (Wh)
CFL-hall and living room	11	3	33	3	99
CFL-Kitchen	20	1	20	1.5	30
Lights-outside and garage	100	2	200	0.2	40
TV	60	1	60	1	60
microwave	700	1	700	0.4	280
Food mixer	400	1	400	0.1	40
Refrigerator	80	1	80	Average -5	400
Totals			1493		949

Battery Capacity

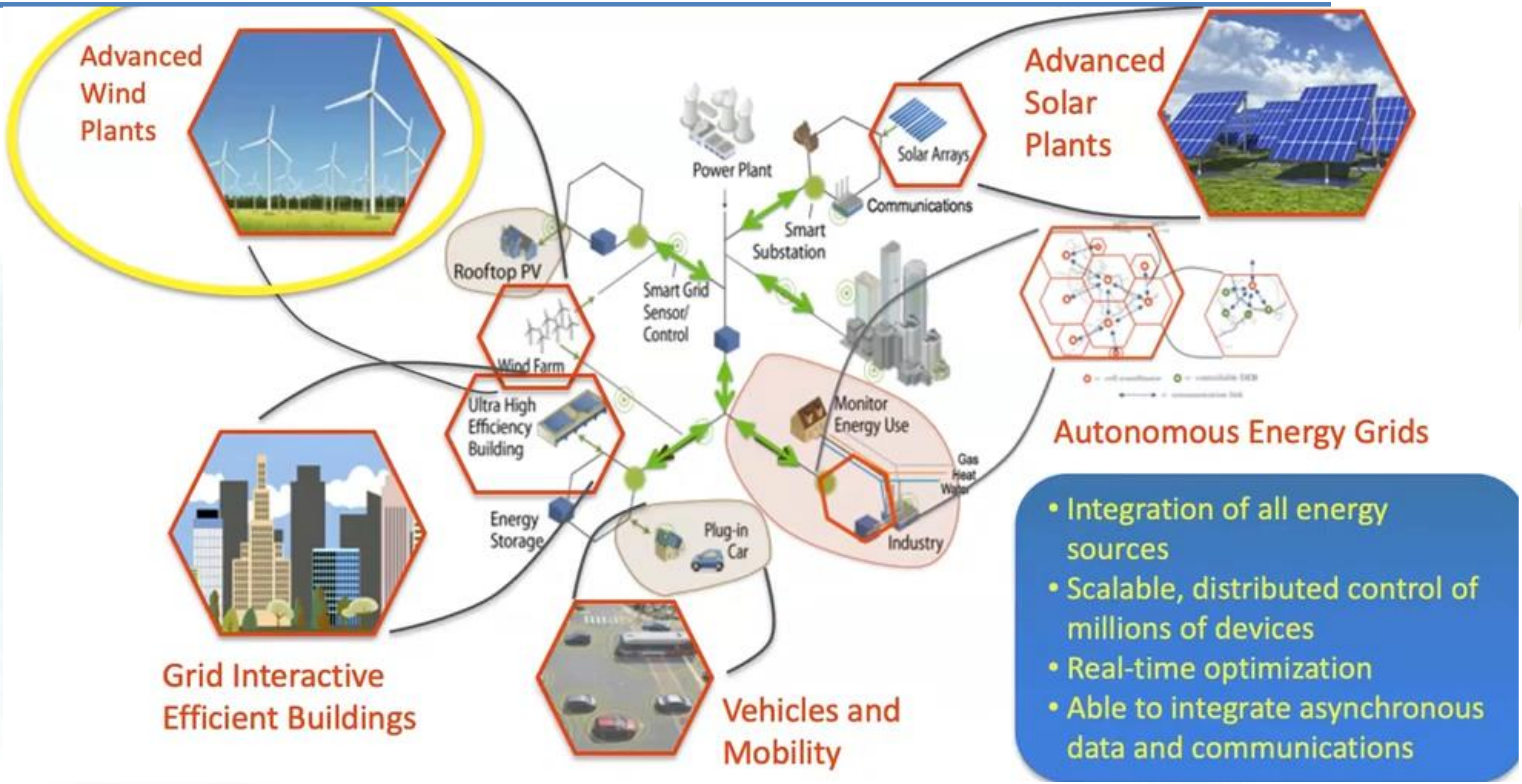
Days of autonomy = 5
DOD = 50%
η_{inv} = 90%
η_{cb} = 97%

- Q = (5 x 949)/(0.5 x 0.9 x 0.97) = 10.87kWh
- = 10.87/24 = 453Ah

Why hybrid? Value: 1+1>2 Cost: 1+1<2



Why hybrid? Synergy of different systems and applications



- Integration of all energy sources
- Scalable, distributed control of millions of devices
- Real-time optimization
- Able to integrate asynchronous data and communications