Outdoor Installation

Workshop on LPWAN Solutions for the Internet of Things

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United Nations Educational, Scientific and Cultural Organization

IAEA

Goals

- To understand the requirements for successful outdoors installations
- To see examples of proper equipment weatherproofing
- To review powering requirements and how to provide power to theIoT devices

Typical installation

Installed equipment typically includes:

- One or more ***gateways***
- ***Antennas*** and mounting brackets
- ***Antenna mount*** (non-penetrating, wall mount, etc.)
- Pigtail
- ***PoE injector*** and twisted pair cable (UTP, FTP or STP)
- Appropriate ***connectors*** or ***adapters***
- ***Lightning arrestors*** and ***grounding cable***

Gteway siting requirements

In a point to multipoint deployment, the ***location of the* Gateway** is by far the must important concern, in order to have the best possible coverage.

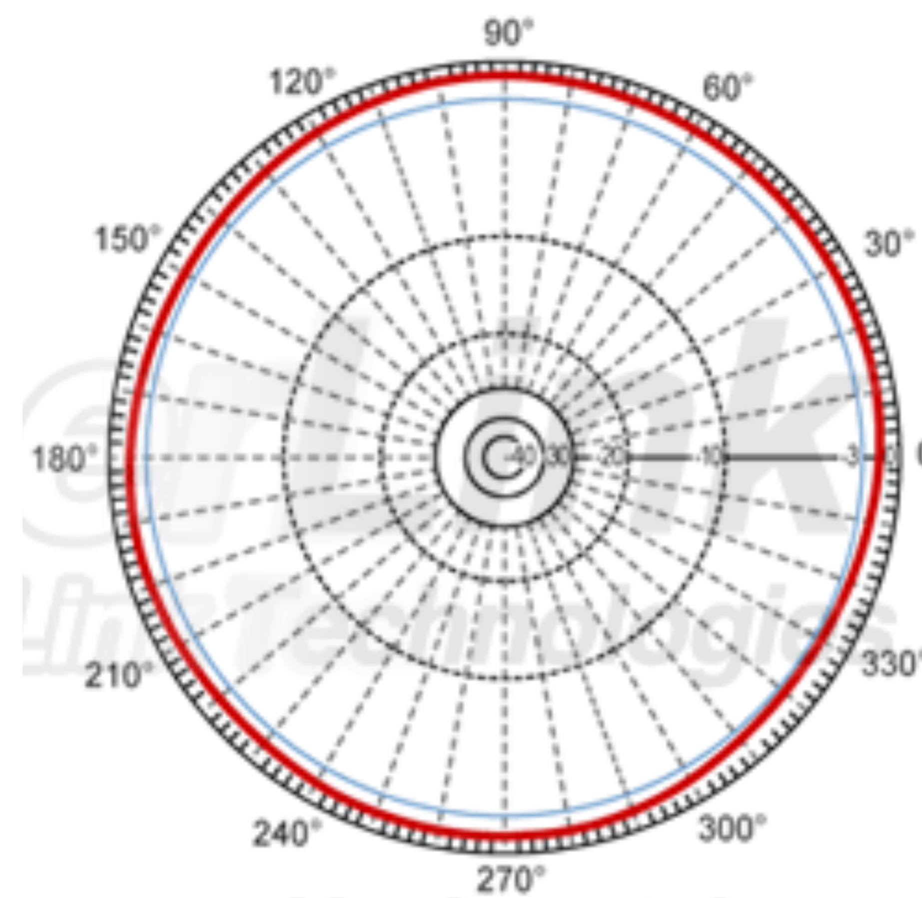
Other important considerations:

- Internet access
- Access to the power grid
- Physical security of the equipment
- Accessibility of the site
- Antenna placement on the building or tower

Horizontal radiation pattern

The horizontal pattern of an omni antenna approaches a circle. A small pipe near the antenna (such as part of the mount) can act as a reflector, changing the gain up to 3 dB in some directions, disrupting the radiation pattern.

A large object, such as the back of a parabola, can completely block the signal in a given direction.



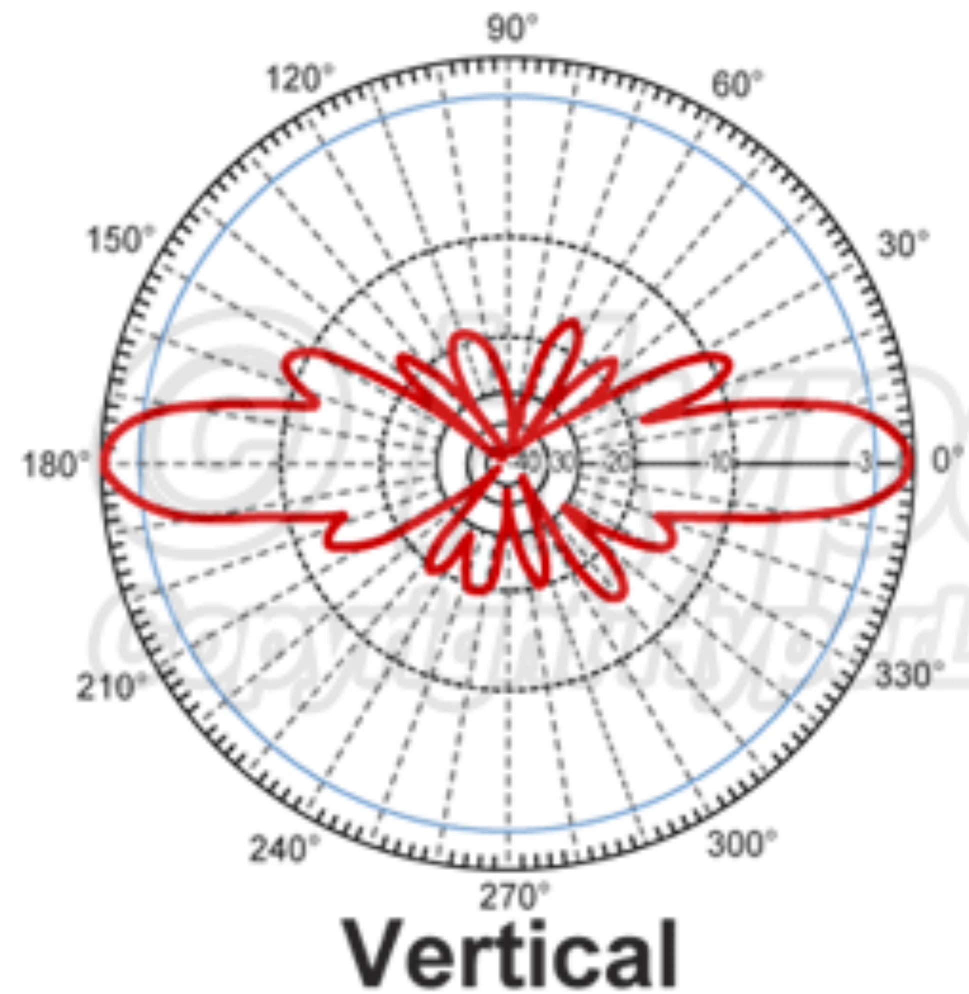
Horizontal

Vertical radiation pattern

The gain of an omni is obtained by narrowing the vertical radiation pattern.

This applies when the antenna is far from conducting objects, and constitutes a good approximation when the antenna is at the very top of the tower.

The vertical radiation pattern will change substantially if the omni is located further down on the tower, as it interacts with the physical structure.



Guyed towers

A climbable ***guyed tower*** is normally made of aluminum with a triangular cross section, about 30 cm per side.

Each section is about 3 m long and several sections can be bolted together to attain the required height.

The tower must be properly guyed to withstand the expected wind in the area, as well as to support the weight of the equipment and one or two people.

Free-standing pole

A ***free-standing pole*** is often less expensive to build than a tower.

Such a tower can be built cheaply by attaching foot rests to any sizable pipe.

Tower installation safety

Many countries require special training for people to be allowed to work on towers above a certain height.

Avoid working on towers during strong winds or storms.

Always work on towers with a partner!

Always wear a harness securely attached to the tower when working at heights.

It is **extremely** hazardous to work in the dark. Give yourself plenty of time to complete the job long before the sun sets.

Penetrating roof mounts

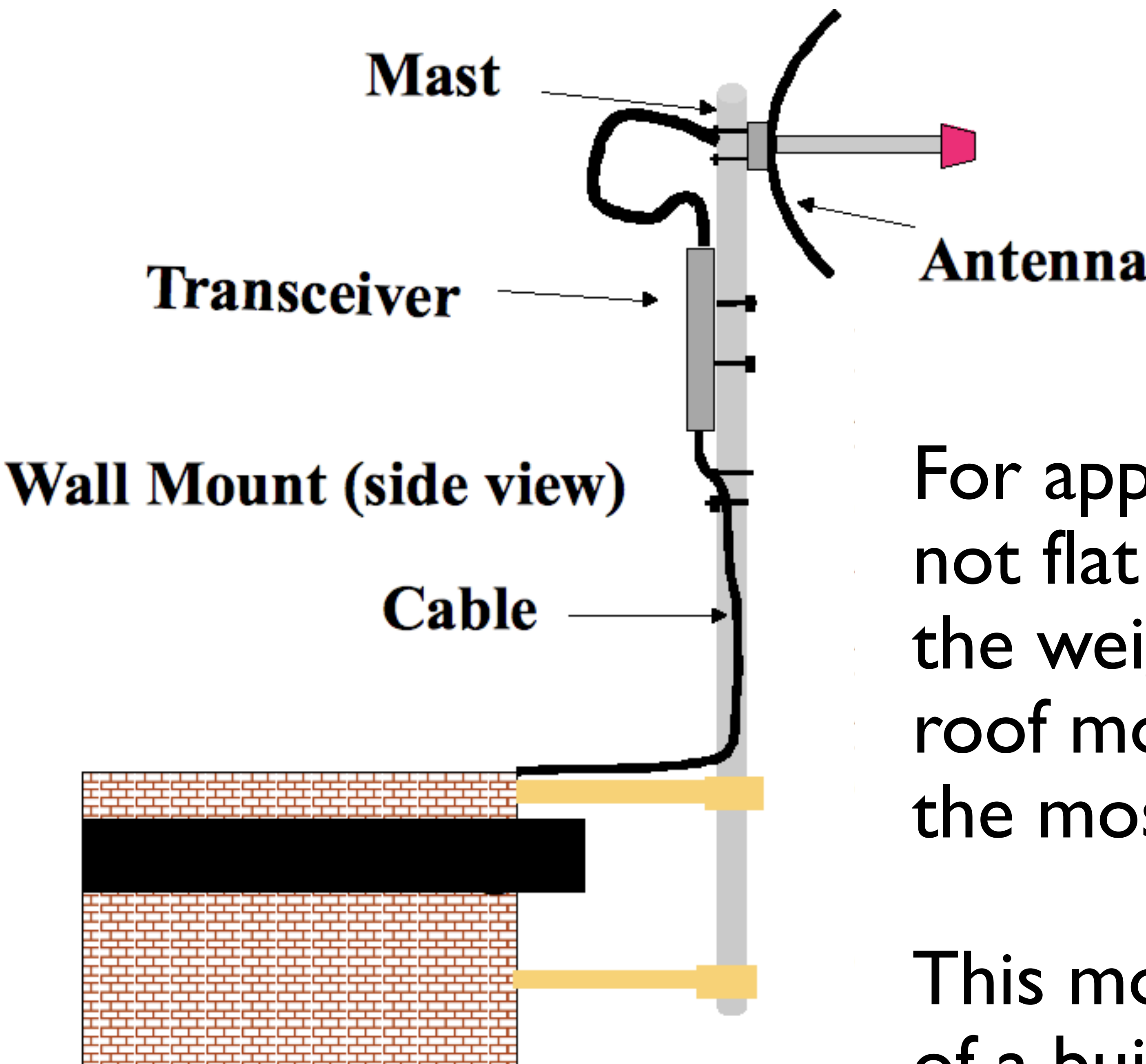
Care must be taken in order to prevent water from seeping in through the attachment bolts.

Seal all penetrating holes with appropriate sealant (such as amalgamating putty or silicone sealant).

Non-penetrating roof mounts

This metal base can be weighed down with sandbags, rocks, or water bottles to make a stable platform without penetrating a roof.

Wall mounts



For applications where the roof is not flat or strong enough to hold the weight of a non-penetrating roof mount, the ***wall mount*** is the most effective solution.

This mount is affixed to the side of a building, wall, or chimney.

Gateway Installation tips

- Do your Gateway configuration in the lab, not in the field!
- Make sure that the device enclosure and the antenna connector are weatherproof
- Use weatherproofing tape (**not** electrical tape or duct tape)
- Use black nylon zip ties (white ties break down in UV)

.

Whenever possible, use conduit and weatherproof cables

- If possible, shield the radio from sun and rain.

Weatherproof Enclosures

When buying enclosures that are to protect equipment installed outdoors:

- Make sure that they can withstand the prevailing conditions of the site.
- There are two organizations that have developed widely adopted standards for enclosures:
    - *National Electrical Manufacturers Association* (*NEMA*) in North America
    - *International Electrotechnical Commission* (*IEC*) in Europe with its Ingress Protection specifications

Outdoors Gateway

DIY outdoors
Gateway

NEMA 4 Metal Box
48V PoE inyector
DC-DC downconverter
UTP cable gland
Antenna connector gland

IP Ratings

1st digit	Definition	2nd digit	Definition
0	no protection	0	no protection
1	Against penetration of solid objects of 50 mm diameter or more	1	Against vertical dripping water
2	Against penetration of solid objects of 12.5 mm diameter or more	2	Against vertical dripping water at an angle of up to 15°
3	Against penetration of solid objects of 2.5 mm diameter or more	3	Against vertical dripping water at an angle of up to 60°
4	Against penetration of solid objects of 1 mm diameter or more	4	Against splashing water in all directions
5	Protected against dust	5	Against water jets in all directions
6	Dust-proof	6	Against powerful water jets in all directions
		7	Against temporary immersion up to 1m
		8	Continuous immersion under specific conditions

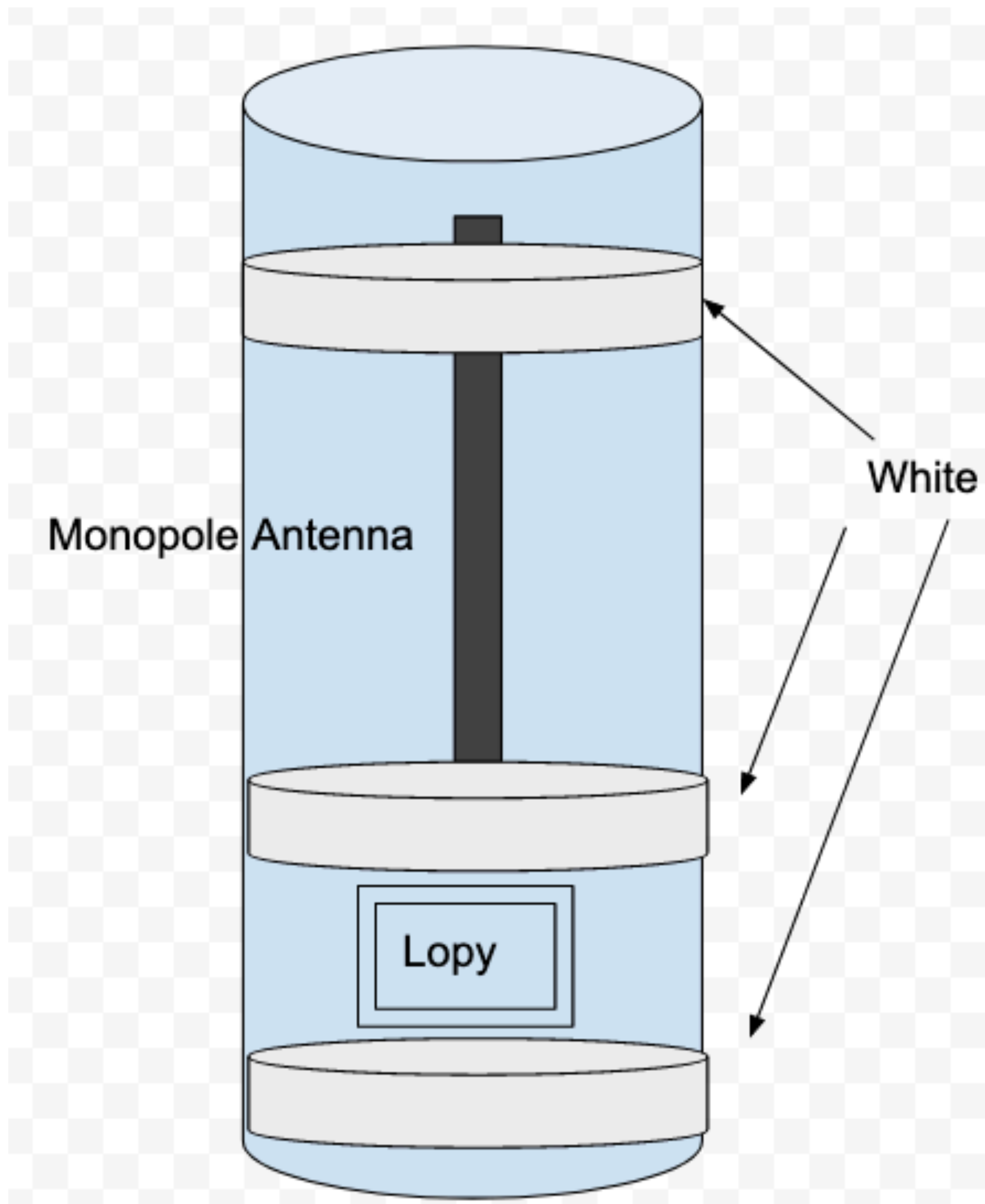
Correspondence between NEMA and IP

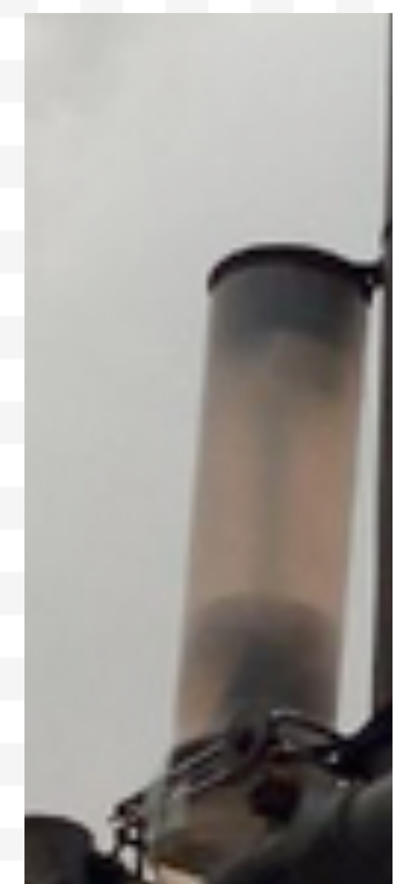
NEMA type	NEMA definition	IP class
1	Protection against dust, light, indirect splashing, but is not dust-tight	IP10
2	Drip-tight. Similar to type 1 but with additional drip shields where condensation may occur	IP11
3 and 3S	Weather resistant. Protects against rain and sleet.	IP54
3R	Protection against falling rain and ice	IP14
4 and 4X	Watertight against jet directed water	IP56
5	Dust-tight	IP62
6 and 6P	Submersible depending on specified conditions of pressure and time	IP67

Weatherproof Enclosures

DIY outdoors enclosure for end-node

8 cm diameter PVC pipe

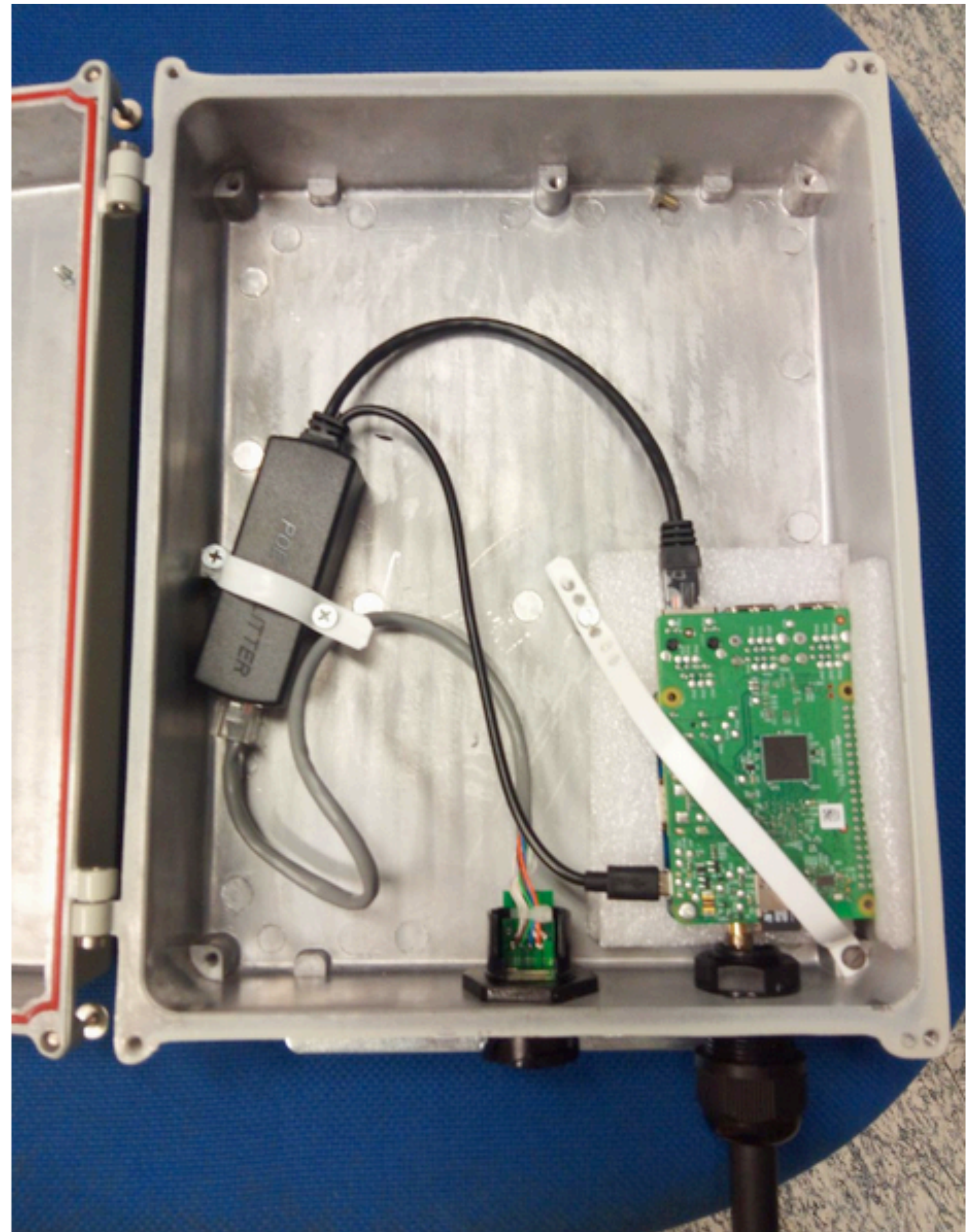




DIY Outdoors Gateway

DIY outdoors
Gateway

NEMA 4 Metal Box
48 V PoE inyector
DC-DC downconverter
(Transkin 48-5V,2A)
Cable gland and
weatherproof cable
Antenna gland

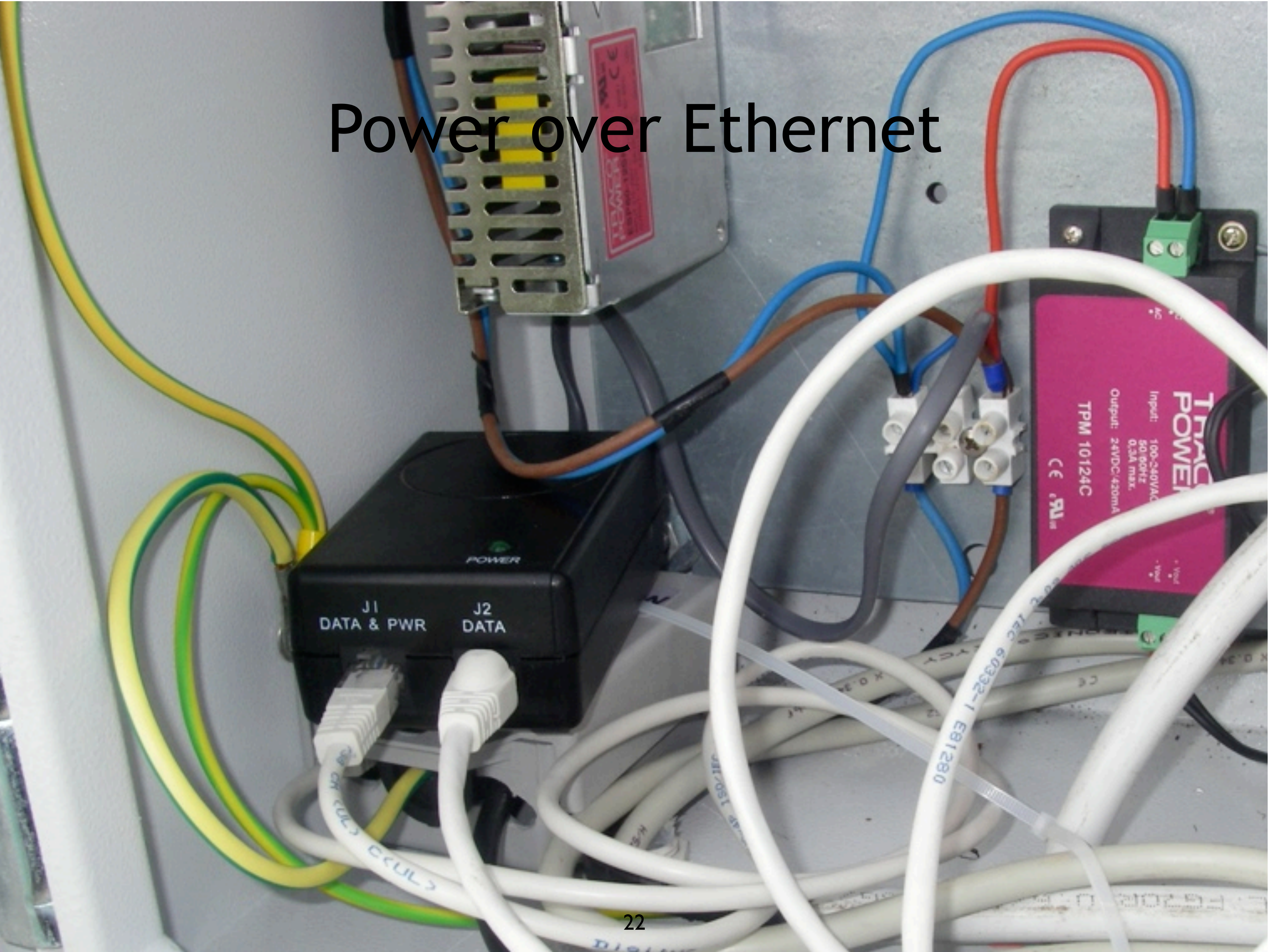


Weatherproof Ethernet Cable

Spreadsheet for consumption calc.

Input data framed in red			Intermediate results framed in blue			Final results framed in green			
			IoT Electrical power consumption calculator						
Radio		duration, ms	# per hour	Current, mA	mA per day	mA per year	mA per hour	Wh per year	Battery usage,%
	Transmit	70	12	38	0.2128	77.672	0.008866666667		21.68
	Receive	80	12	15	0.096	35.04	0.004		9.78
Sensor					0	0	0		
	Temperature	20	12	15	0.024	8.76	0.001		2.45
	Humidity	20	12	15	0.024	8.76	0.001		2.45
	GPS	60	12	130	0.624	227.76	0.026		63.58
	Other				0	0	0		0
Microcontroller					0	0	0		
	Active	200			0	0	0		0
	Sleeping	1000	12	0.008	0.00064	0.2336	0.000026666666		0.07
	Idle				0	0	0		0
Total					0.98	358	0.04	1290	100
Battery Voltage	volts	3.6							
Battery Capacity	mAh	800							
Battery self discharge per year		15.00%		Battery self discharge depends on the material and type of battery					
	mWh	2880							
Battery duration	years	1.90							

Power over Ethernet



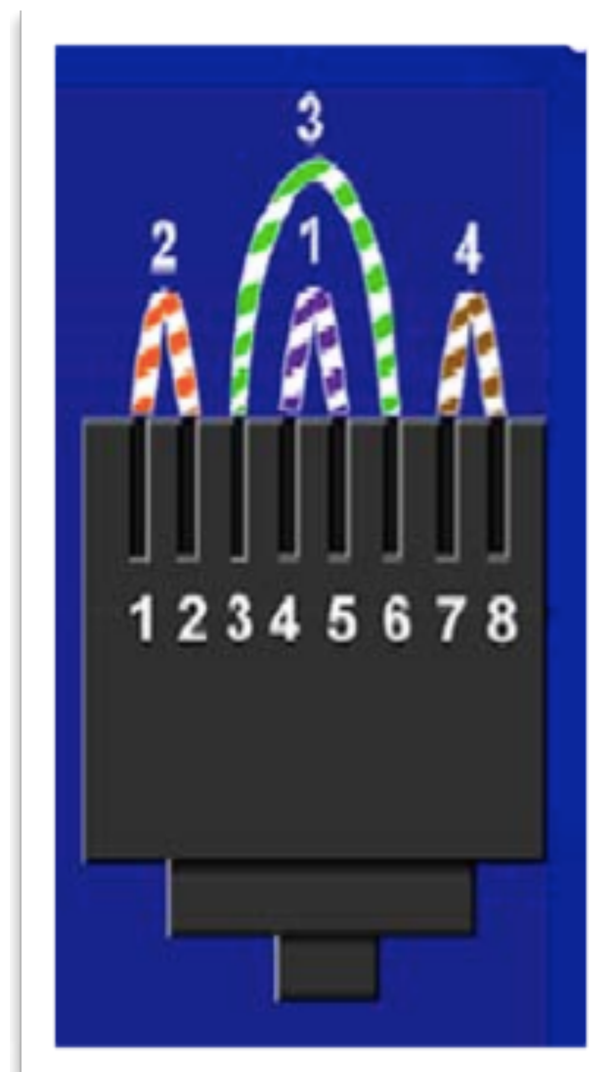
Why Power over Ethernet (PoE)?

- Saves money and installation time
- More flexibility in the placing of devices
- Quite useful for outdoor installs, allowing for a long distance between the AP and the computer
- Does not require an electrician to install
- Saves copper !

End span or mid span

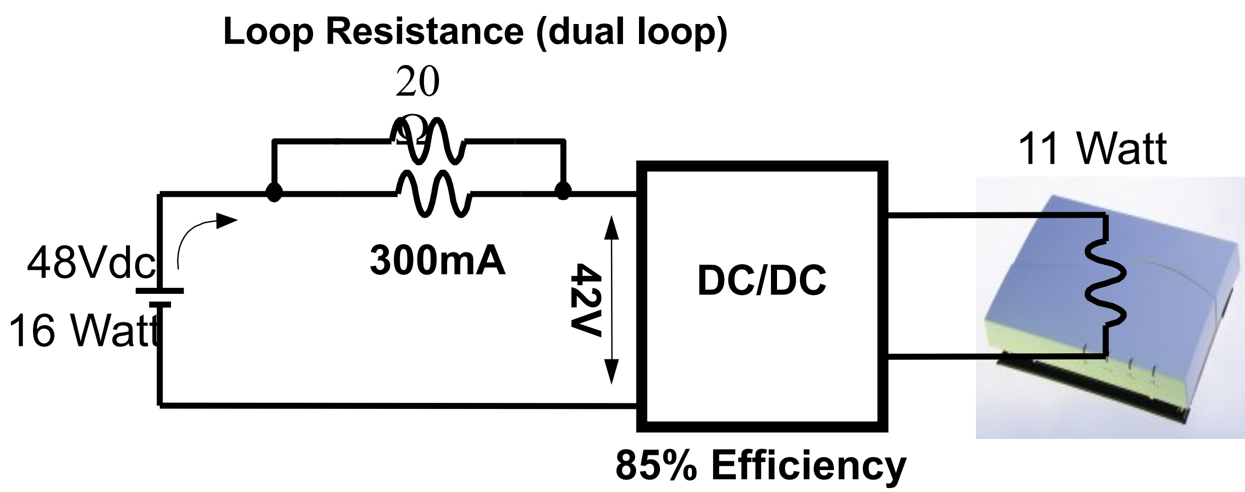
- PoE (802.3af) runs at 48V DC, with a max current of 350mA, capable of feeding a maximum load of 12.95W accounting for the cable losses

- **End span 802.3af** provides power on either the data pairs (1+2, 3+6) or spare pairs (4+5, 7+8)
- **Mid span 802.3af** provides power on the spare pairs (4+5, 7+8).



Power over Ethernet

Example



Assuming:
48Vdc feeding
300mA continuous, 500mA peak current
Maximum 20 ohm loop resistance
Delivering 48VDC Power over CAT 5 Spare Pairs (pins 4+5 & 7+8)

Example: 20 meter cable

Assume your power supply provides 12VDC @ 1.5 A, for a total available power of:

```
12 V * 1.5 A = 18 Watts
```

Typical CAT5e resistance is about 0.1 Ω per meter, per conductor. When using two pairs of wire, the total loop resistance of a 20 meter CAT5e cable would be:

```
0.1 Ω/m * 20 m * = 2 Ω
```

Example: 20 meter cable

Because of line resistance, we will lose some voltage at the other end of the cable. The voltage drop will be:

$$V_{drop} = 1.5\ A * 2\ \Omega$$
$$V_{drop} = 3$$

After subtracting the drop, the actual expected voltage at the far end will be:

$$V = 12 - 3$$
$$V = 9$$

Your output voltage is only about 9 volts, far less than your equipment is expecting!

Providing enough power

To provide the proper voltage, you will need to use a different power supply. It should provide at least V_{drop} higher voltage at the same current as the original supply (in this case, a 15 V @ 1.5 A power supply should be sufficient).

It is also important to provide sufficient current to power your device. If you install an access point, and later add more radio cards, the additional power draw may be more than your supply can provide. Be sure to add the power requirements of all of the components (radio cards when transmitting, motherboard, etc.) when determining the proper power supply for your installation.

Energy harvesting sources

Energy harvesting is the process by which light, thermal, kinetic, chemical and radio frequency energy can be converted into electrical energy to power some device.

Kinetic energy in the form of wind, vibration, ambient noise, piezoelectric, electrostatic, fluid flow, magnetic induction, wave and tides is used in many applications.

Energy harvesting sources

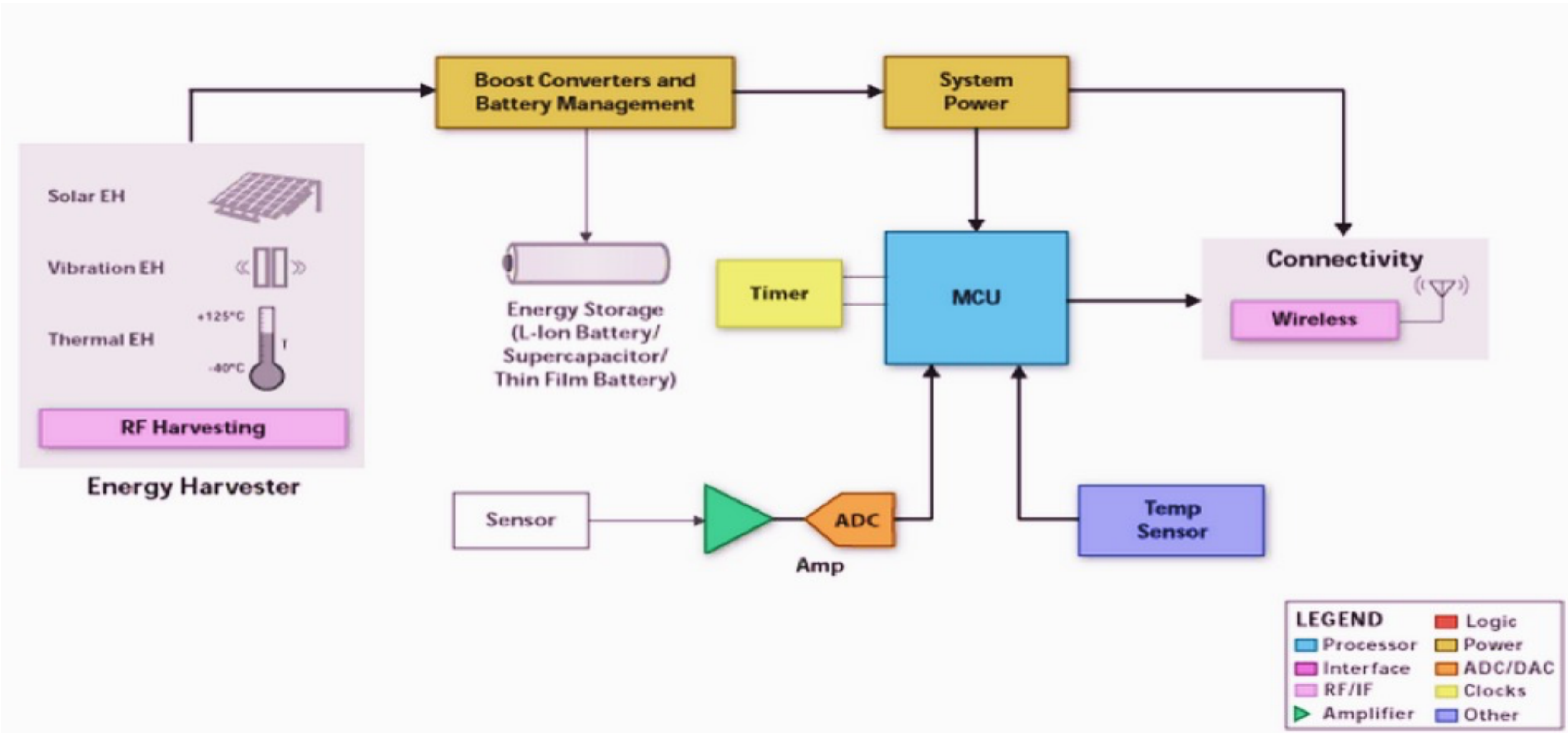
While Solar, Hydraulics and wind energy are the predominant renewable sources of energy, for IoT applications the most widely used are:

- Photovoltaic
- Piezoelectric
- Thermoelectric
- Radiofrequency

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/

RF Energy

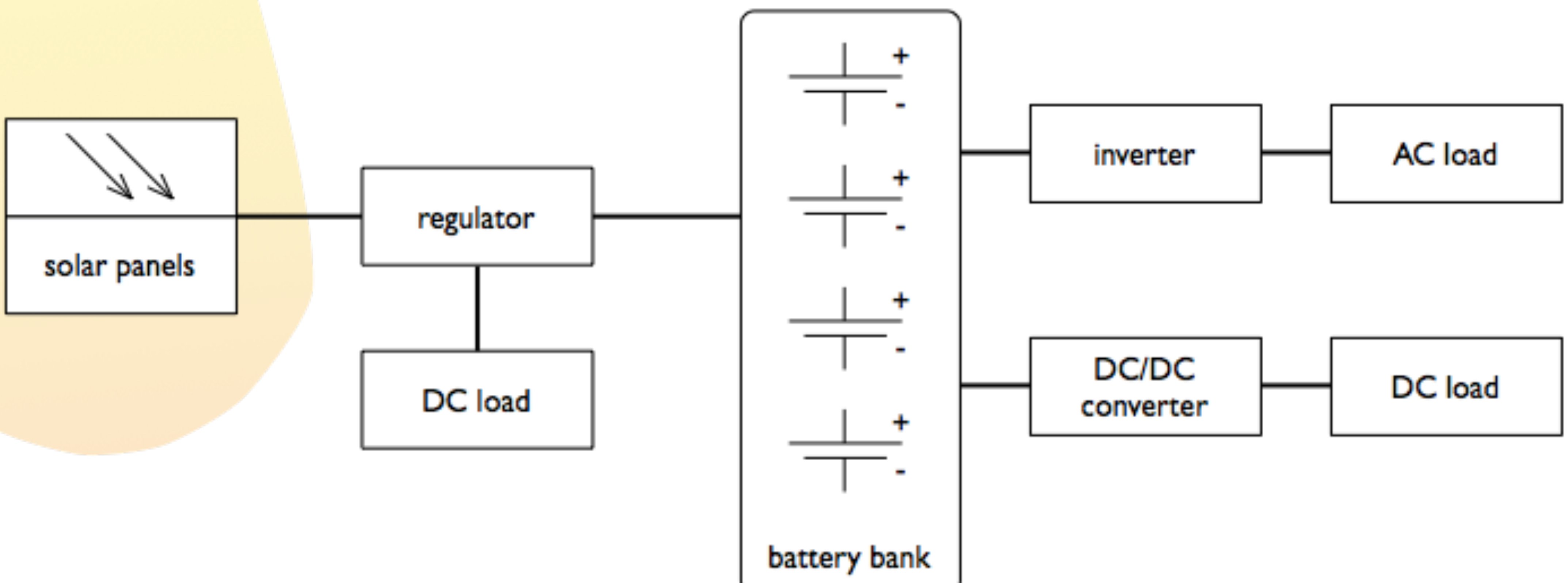
RF energy has been leveraged in RFID in which the reader transmits a powerful enough wave so that a passive tag can use it to power its receiver and transmitters stages.

This idea has been applied to other RF sources like WiFi with discouraging results, due to the quadratic decay of RF power with distance.

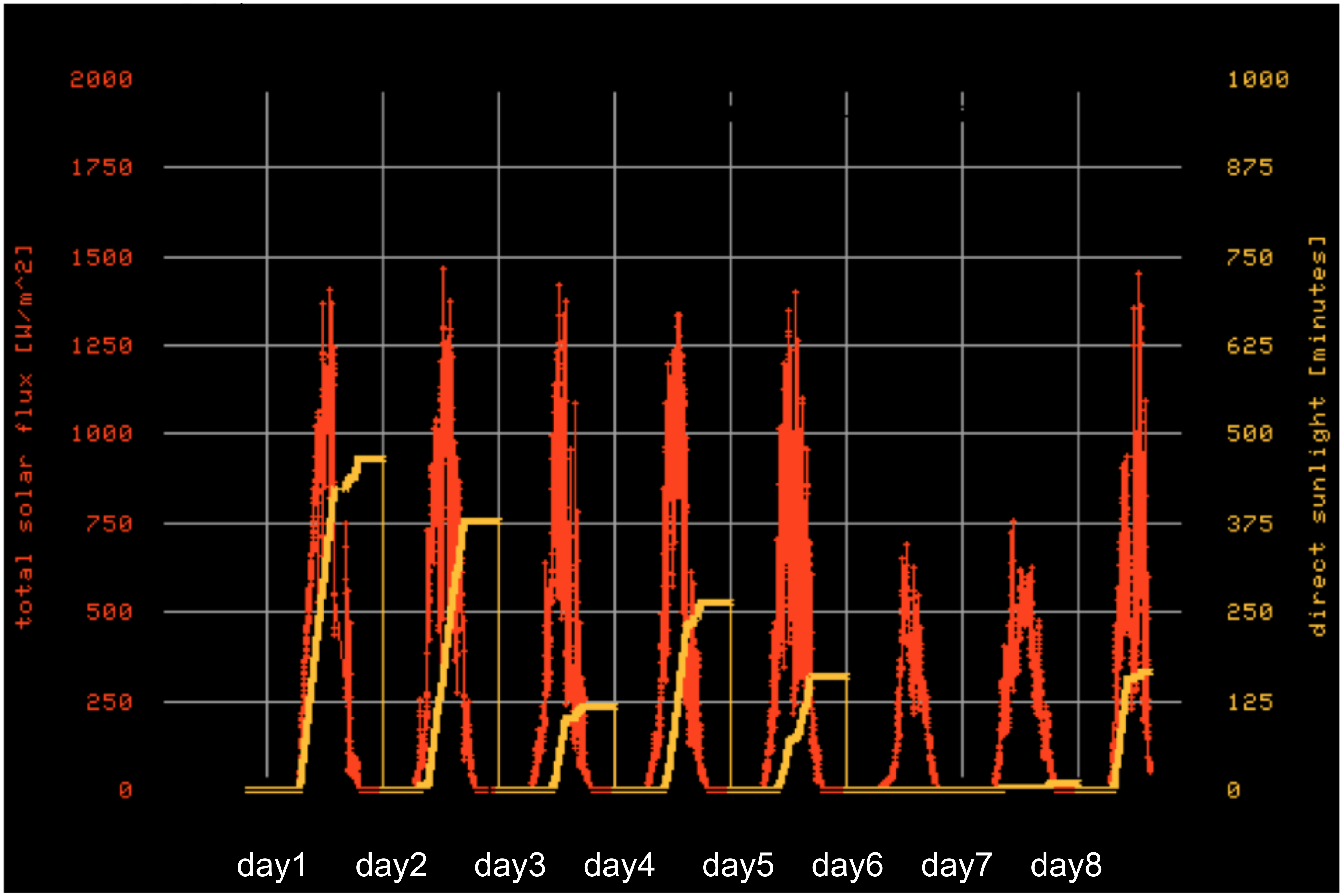
An interesting twisting of this concept will be presented next.

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.



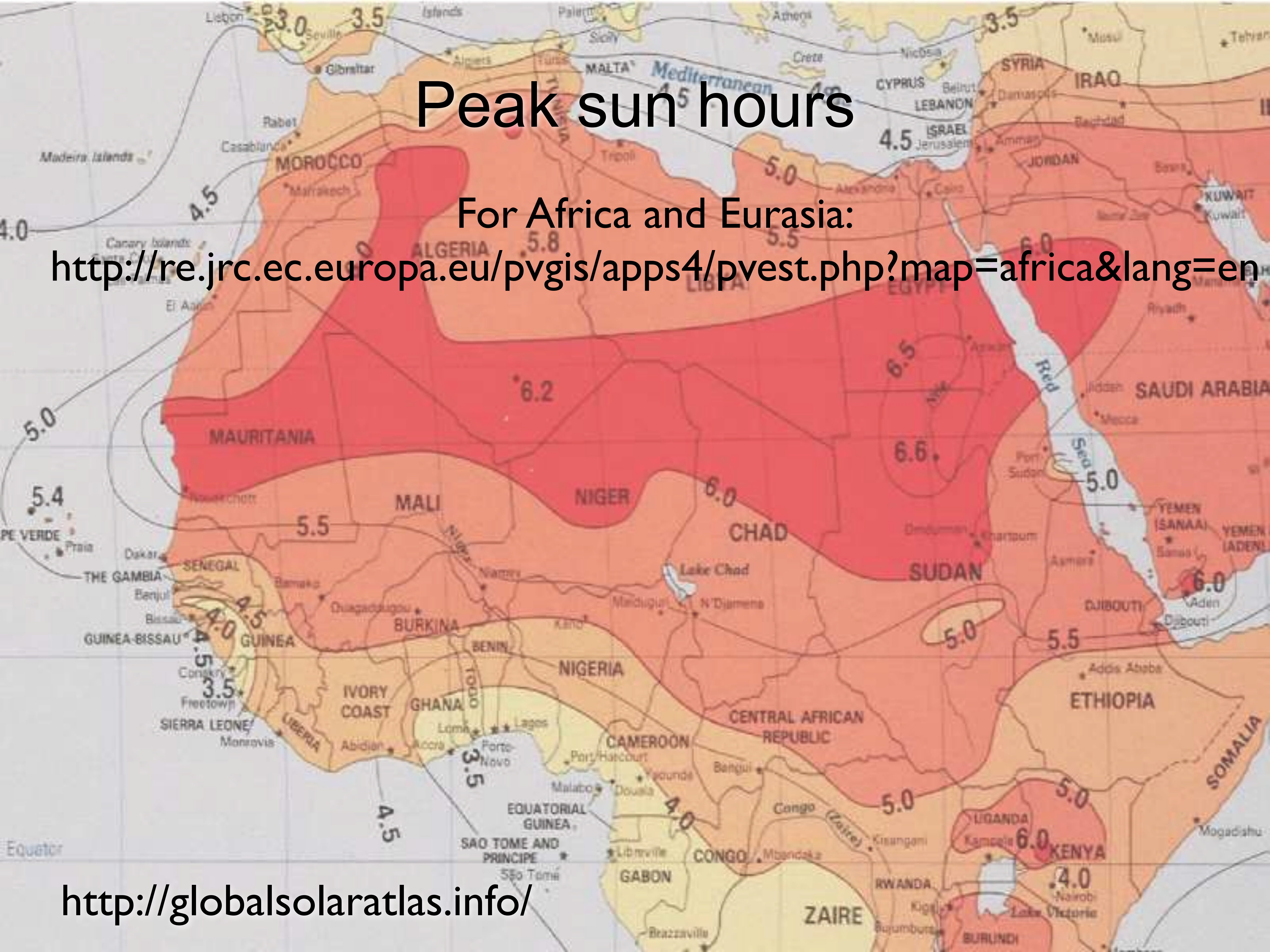
Real data: irradiance and sunlight



Peak sun hours

For Africa and Eurasia:

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



http://globalsolaratlas.info/

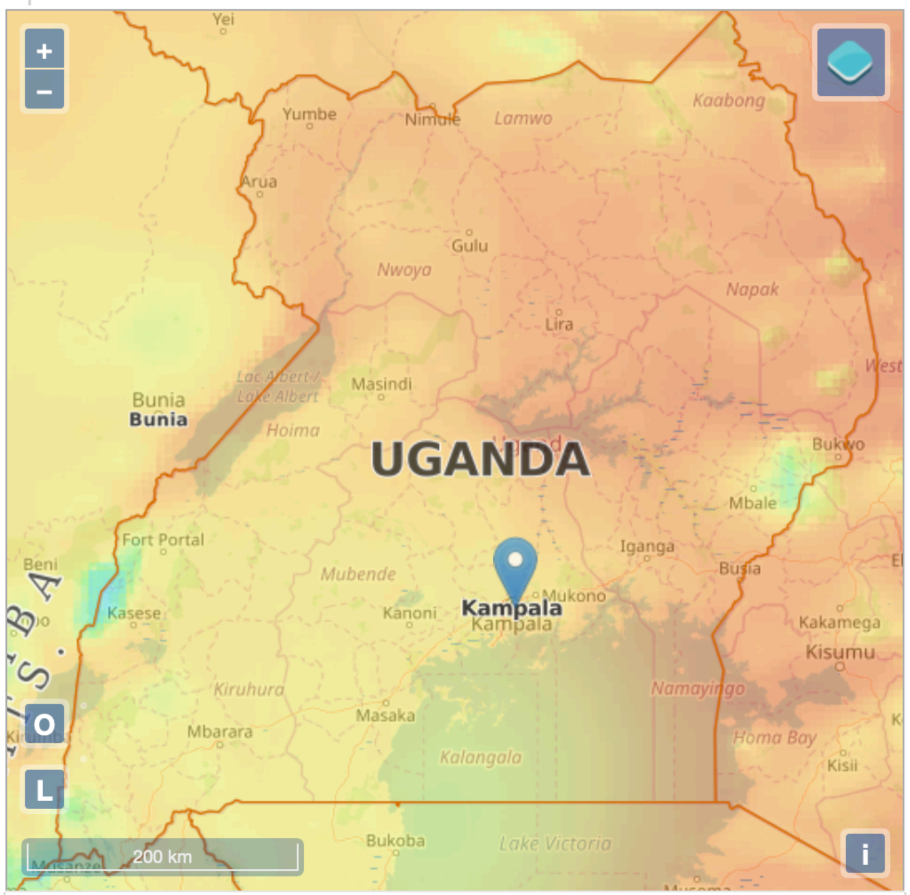
Average daily Irradiance

AVERAGE DAILY IRRADIANCE DATA: RESULTS

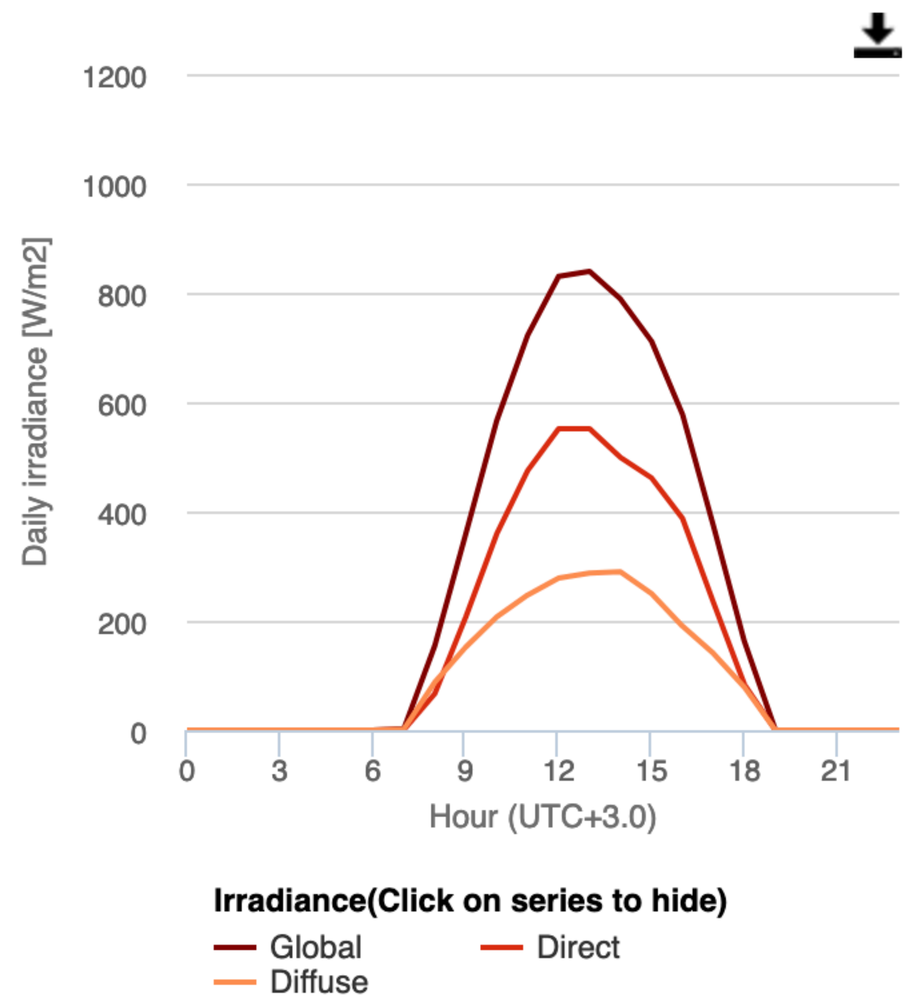
Fixed-plane

Summary

Provided inputs:	
Location [Lat/Lon]:	0.318, 32.581
Horizon:	Calculated
Database used:	PVGIS-SARAH
Month:	January



Daily average irradiance



https://globalsolaratlas.info/

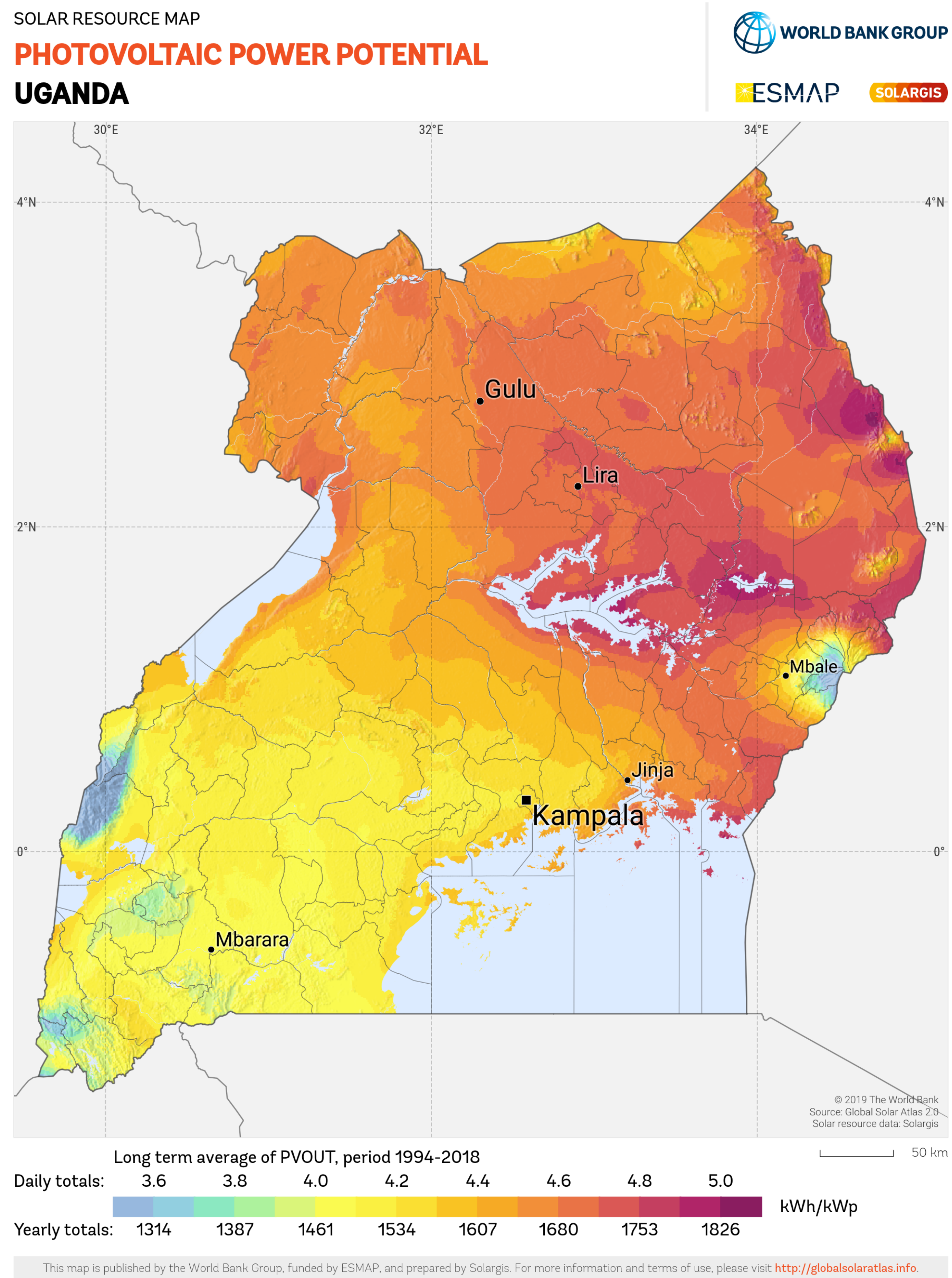
01°37'33", 32°31'10"
Amolatar, Uganda
Time zone: UTC+03, Africa/Juba [EAT]

Open detail Bookmark Share

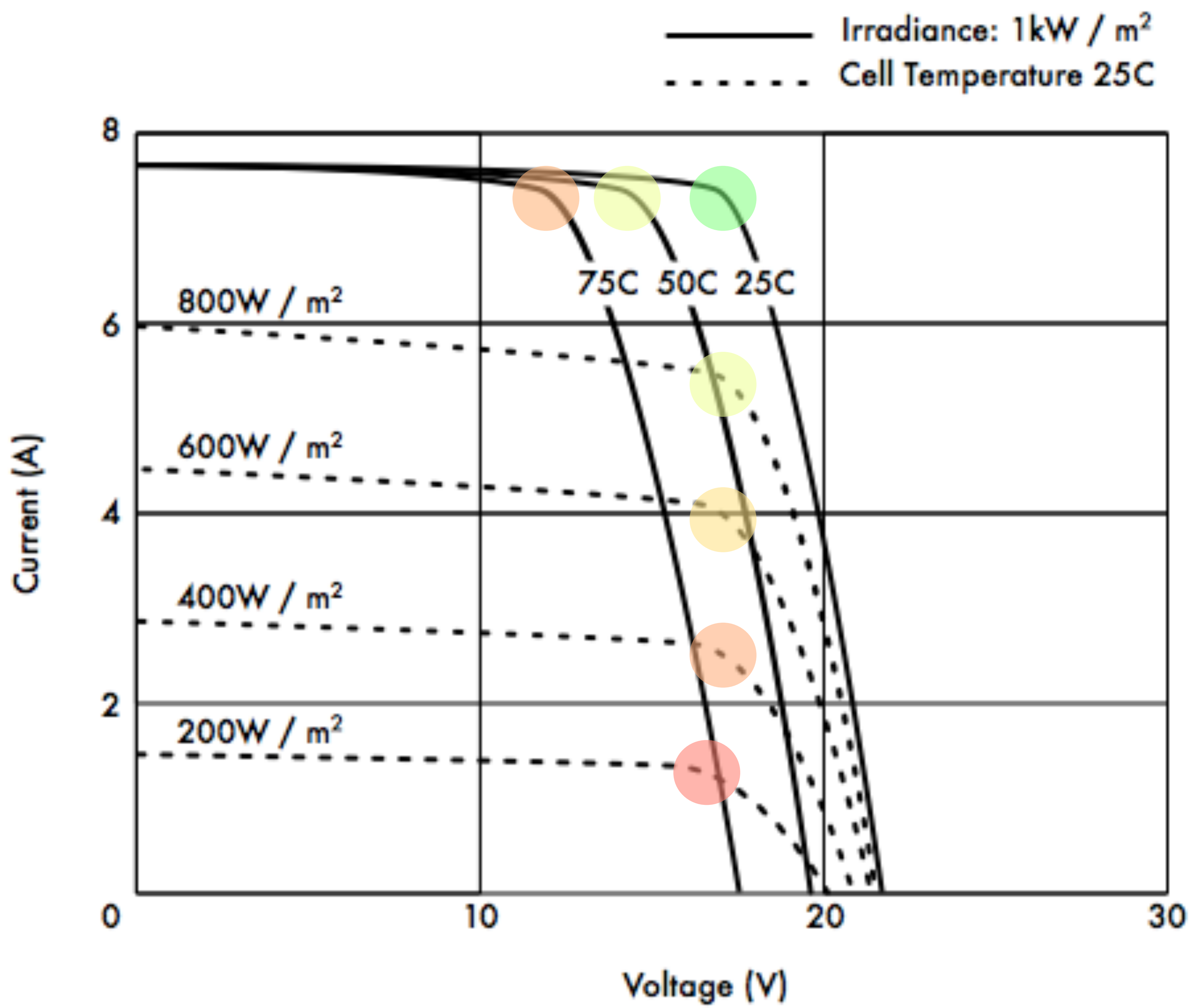
SITE INFO

Map data

PVOUT specific	1743	kWh/kWp
DNI	1881	kWh/m^2
GHI	2221	kWh/m^2
DIF	822	kWh/m^2
GTI opta	2229	kWh/m^2
OPTA	5 / 180	°
TEMP	24.1	°C
ELE	1034	m



Solar panel IV curve for different amounts of irradiance and temperature



Optimizing panel performances

Optimal elevation angle = Latitude + 5°

Batteries

The ***battery*** stores the energy produced by the panels that is not immediately consumed by the load. This stored energy can then be used during periods of low solar irradiation (at night, or when it is cloudy) called n-sun days.

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

- ***Over discharge*** 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 should prevent extracting any more energy from from the battery.
- The proper values to prevent over charging and over discharging should be programmed into your charge controller to match the requirements of your battery bank.

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.

LiPo (Lithium-Polymer) battery

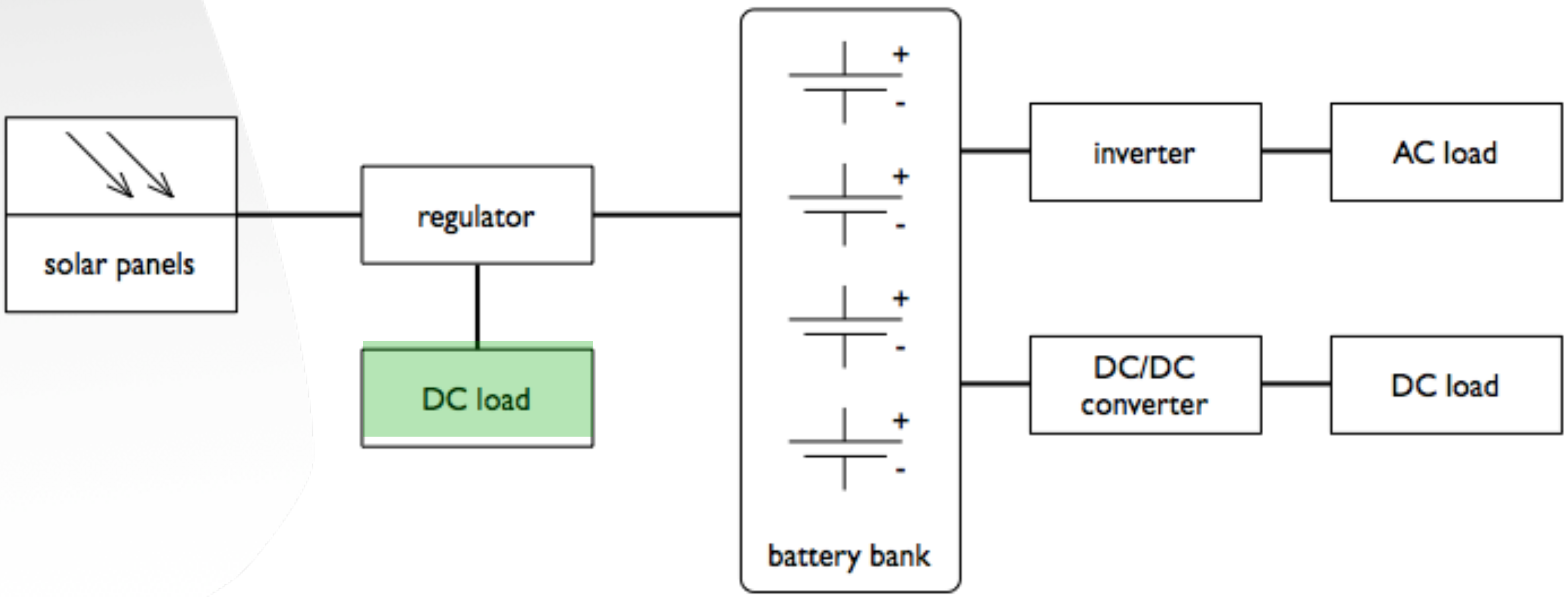
- Each cell will be around 4.2V when fully charged
- The minimum voltage is around 3.2 V per cell, discharging below this value will shorten the lifespan
- Capacity is expressed in mA/h, amount of energy storable
- Handle with precaution, lithium can explode
- Never "trickle" charge a LiPo battery
- The colder it is, the shorter your run times will be

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 a voltage regulator built in

Spreadsheet for PV dimensioning

Simplified spreadsheet for photovoltaic calculations

Solar radiation data for a given site available from:

https://eosweb.larc.nasa.gov/sse/RETScreen/ , Worldwide coverage

http://globalsolaratlas.info/ , Worldwide coverage

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

Input data framed in red | Intermediate results framed in blue | Final results framed in green

Electrical Load Calculation

Device	Consumption,W	Hours/day	Energy/day, Wh
GPS	1.5	24	36
WiFi Client	8	24	192
Laptop	15	12	180
WiFi AP	3	24	72
Ethernet Switch	4	24	96
Total energy consumption/day, Wh			36

Battery capacity calculation, considering the number of no-sun days and the allowed depth of discharge

Required autonomy, days	Depth of Discharge	Battery capacity,Wh	Battery voltage,V	Battery Capacity, Ah	Number of batteries
4	0.5	288	12	24.0	2

Panel capacity calculation

Panel Peak power, Wp
10

Load energy,Wh	Battery charging allowance	Energy /d, Wh	PSH	Daily Photovoltaic power, W	Number of panels
36	1.5	54	5.5	9.8	1

Conclusions

- Outdoor equipment must be properly mounted and protected from the weather.
- Antennas should be placed so that most of the energy is directed towards the other end of your link while avoiding reflections.
- Powering equipment with POE will simplify installations.
- Turning off non essential services is key for energy saving
- Energy harvesting is quite useful for IoT applications
- Batteries for energy storage and proper charge regulators are required for intermittent energy sources and they should never be completely discharged

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/