

ODA-UNESCO project:  
Promotion of energy science education for sustainable  
development in Lao PDR

Theme 5:  
ພະລັງງານແສງຕາເວັນ  
**SOLAR ENERGY**

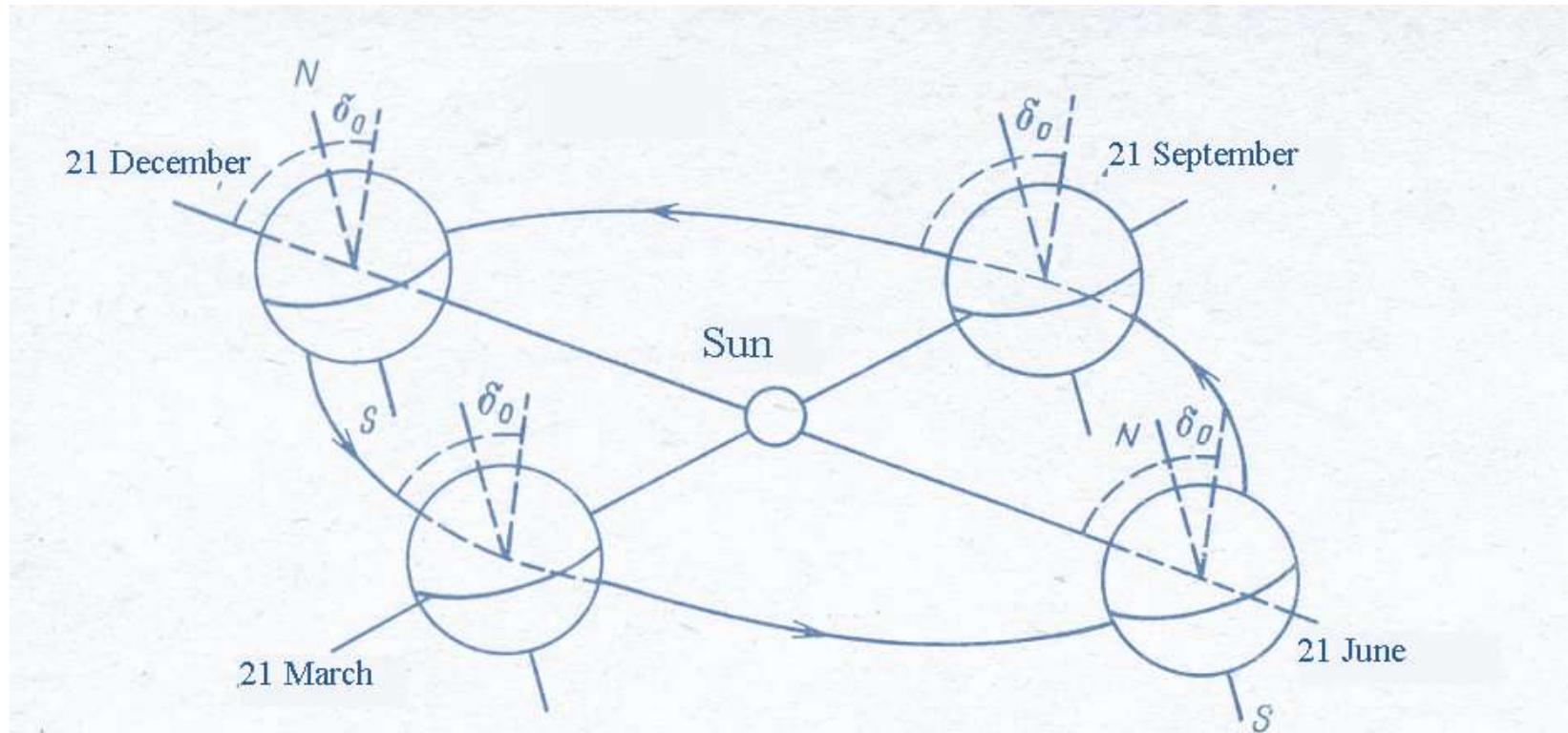
By: Dr Khamphone Nanthavong  
Faculty of Engineering, National University of Laos  
Solar energy

## Contents

- Sun-Earth Geometry
- Solar Radiation
- Solar energy Utilization principle
  - Thermal Application
  - Photovoltaic Application

# Sun-Earth Geometry

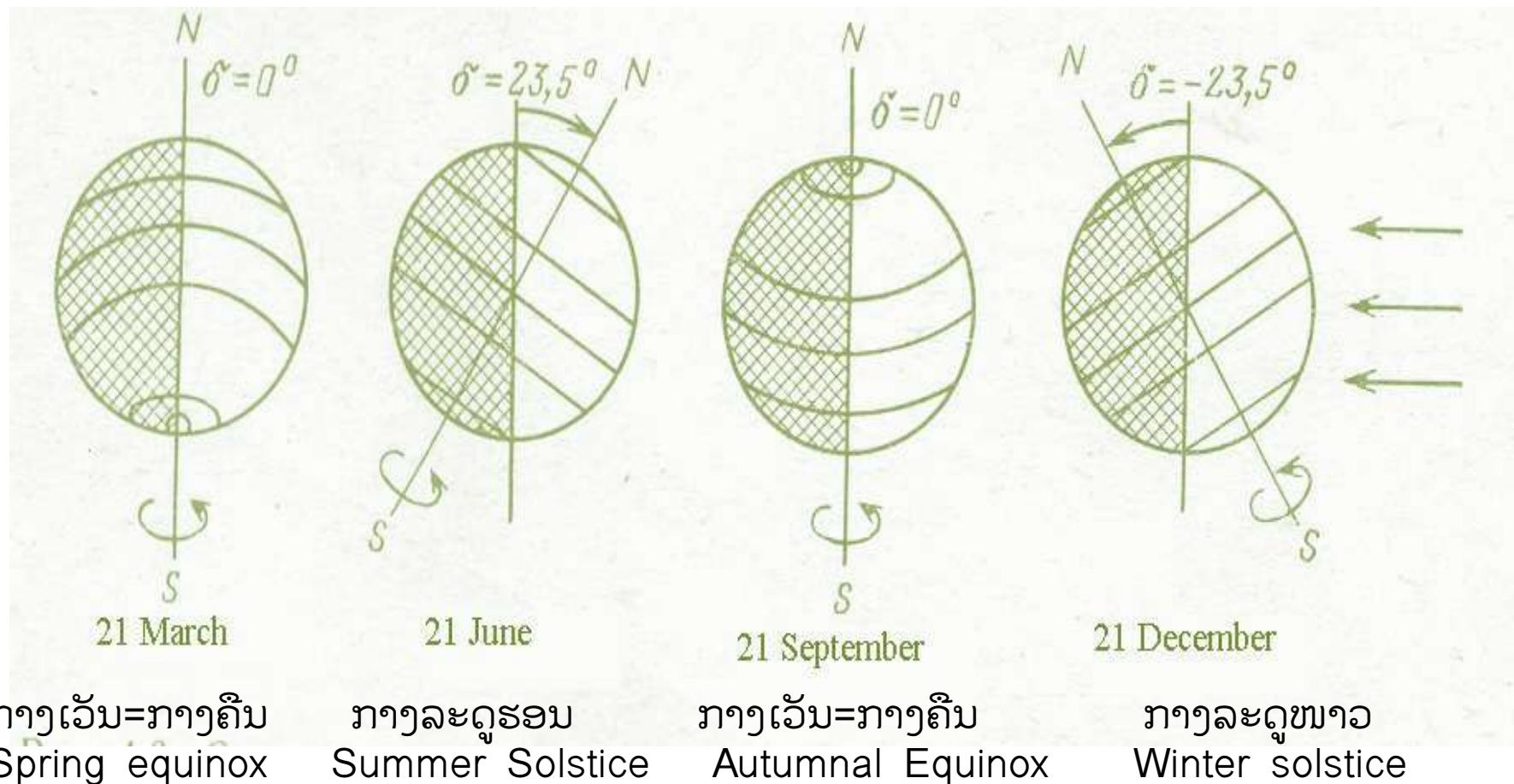
## □ The Earth in the Sun System



- The Earth Turning around the Sun → seasonal changes
- Rotating of the Earth around its axis → day & night

# Sun-Earth Geometry

## □ The Earth in the Sun system



# Sun-Earth Geometry

## □ A Position on the Earth Surface

$\varphi$ - Latitude Angle

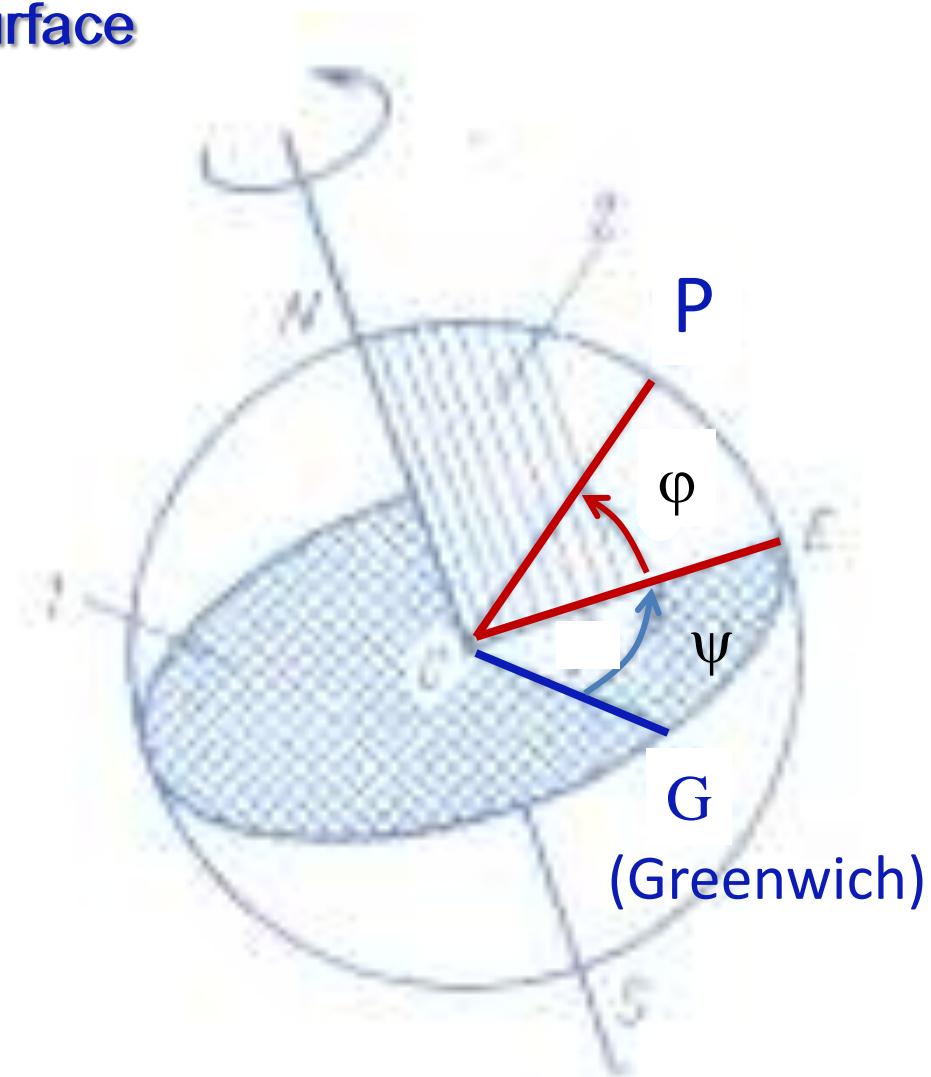
$\psi$ - Longitude Angle

GMT- Greenwich

Mean Times

Lao Time zone =

GMT+7



# Sun-Earth Geometry

## □ A Position on the Earth Surface

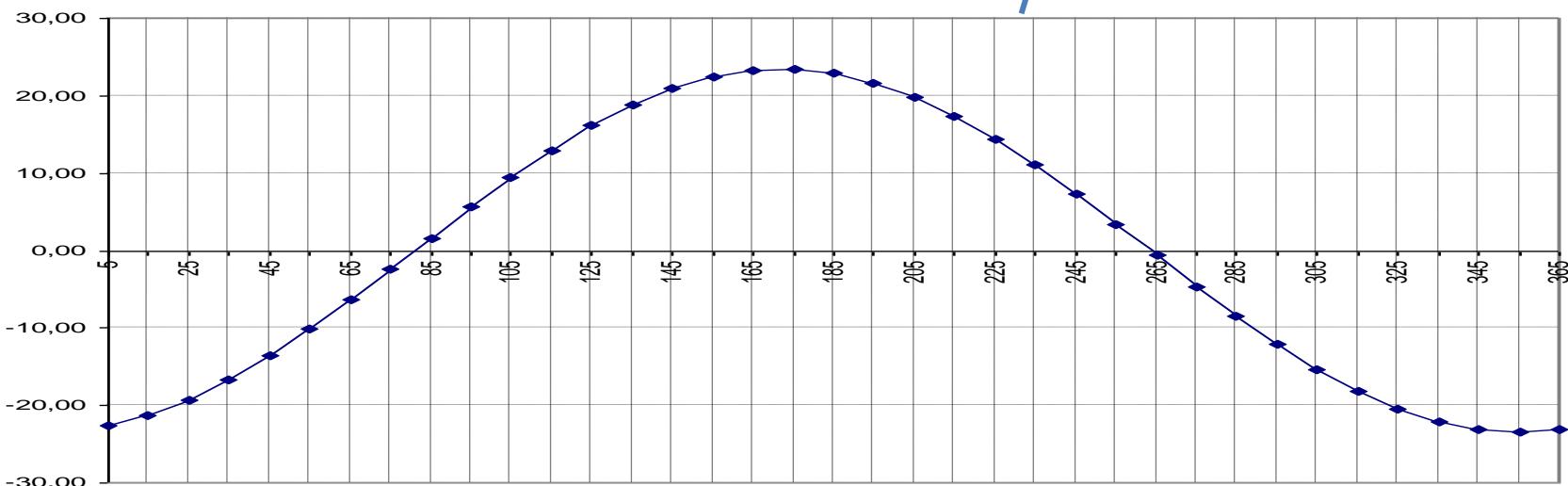
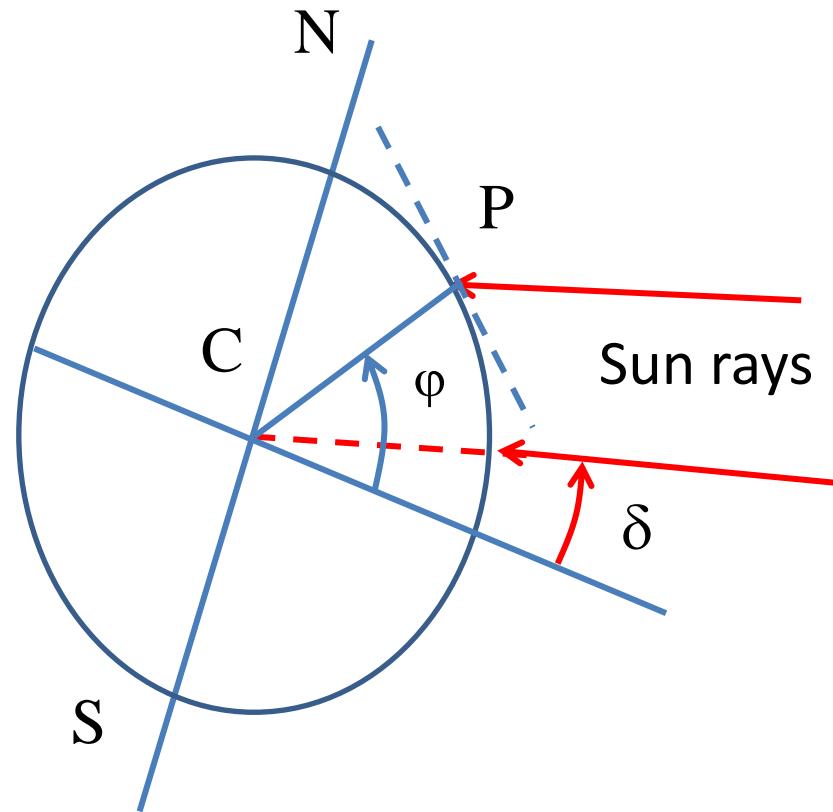
$\delta$ - Declination Angle

$$\delta = 23,45 \sin \left[ \frac{360}{365} (284 + n) \right]$$

n- day number in a year,

n=1 → 1 January

n=2 → 2 January



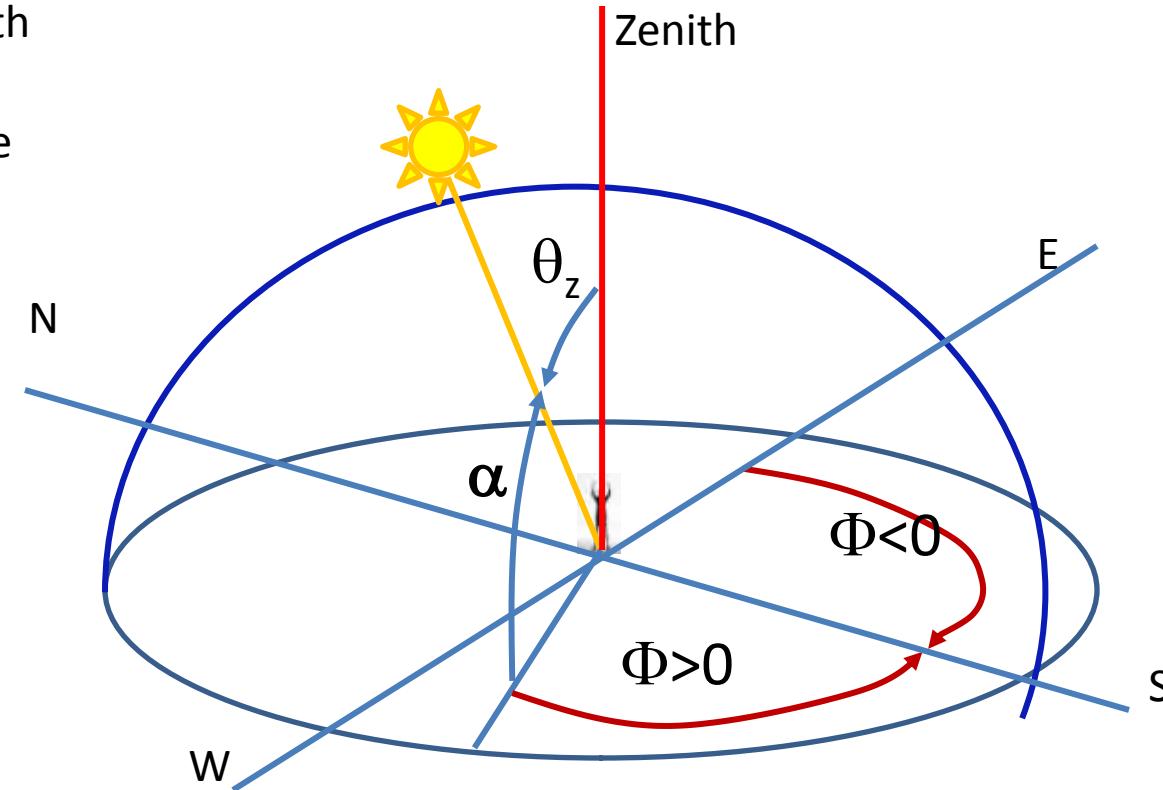
# Sun-Earth Geometry

## □ A Position on the Earth Surface (ການກຳນົດທີ່ຕັ້ງຢູ່ໜ້າໄລກ ຖຽບຖານຕາເວັນ)

$\alpha$ -Solar altitude

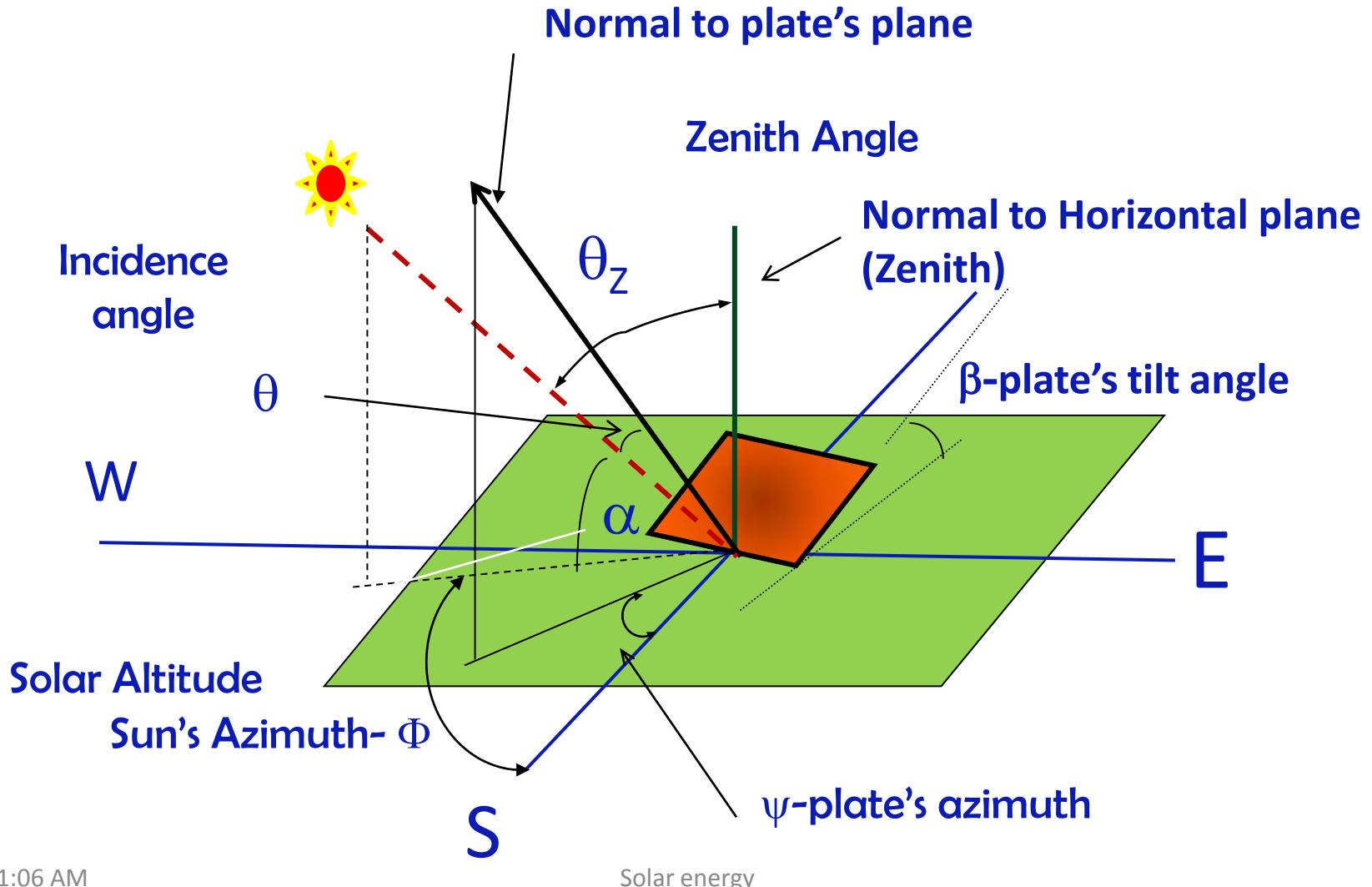
$\phi$ -Solar azimuth

$\theta_z$ -Zenith angle



# Sun-Earth Geometry

## A Plate on the Earth surface

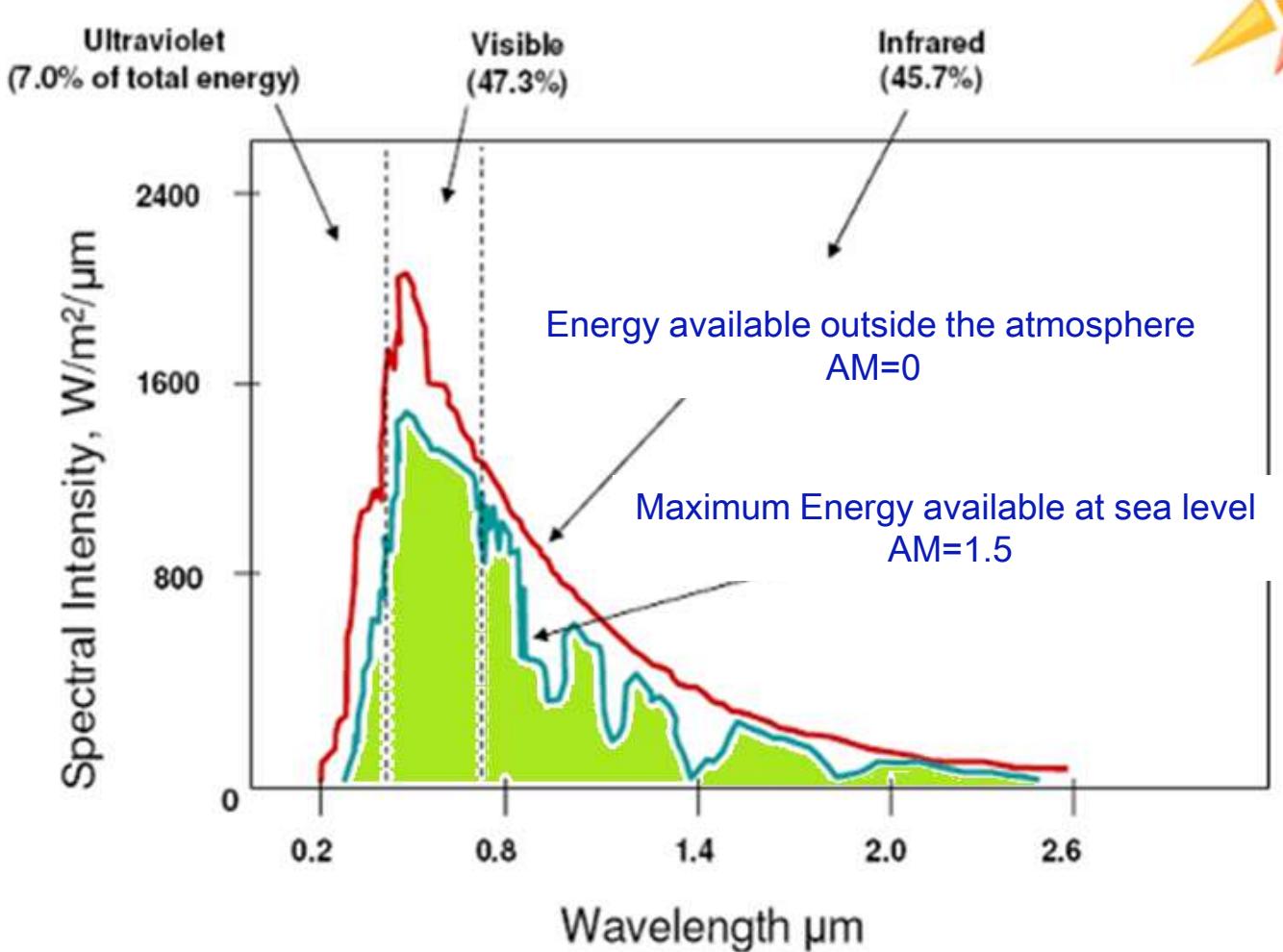


# Solar radiation

Area under the red curve = extraterrestrial solar radiation =  $1367 \text{ W/m}^2$

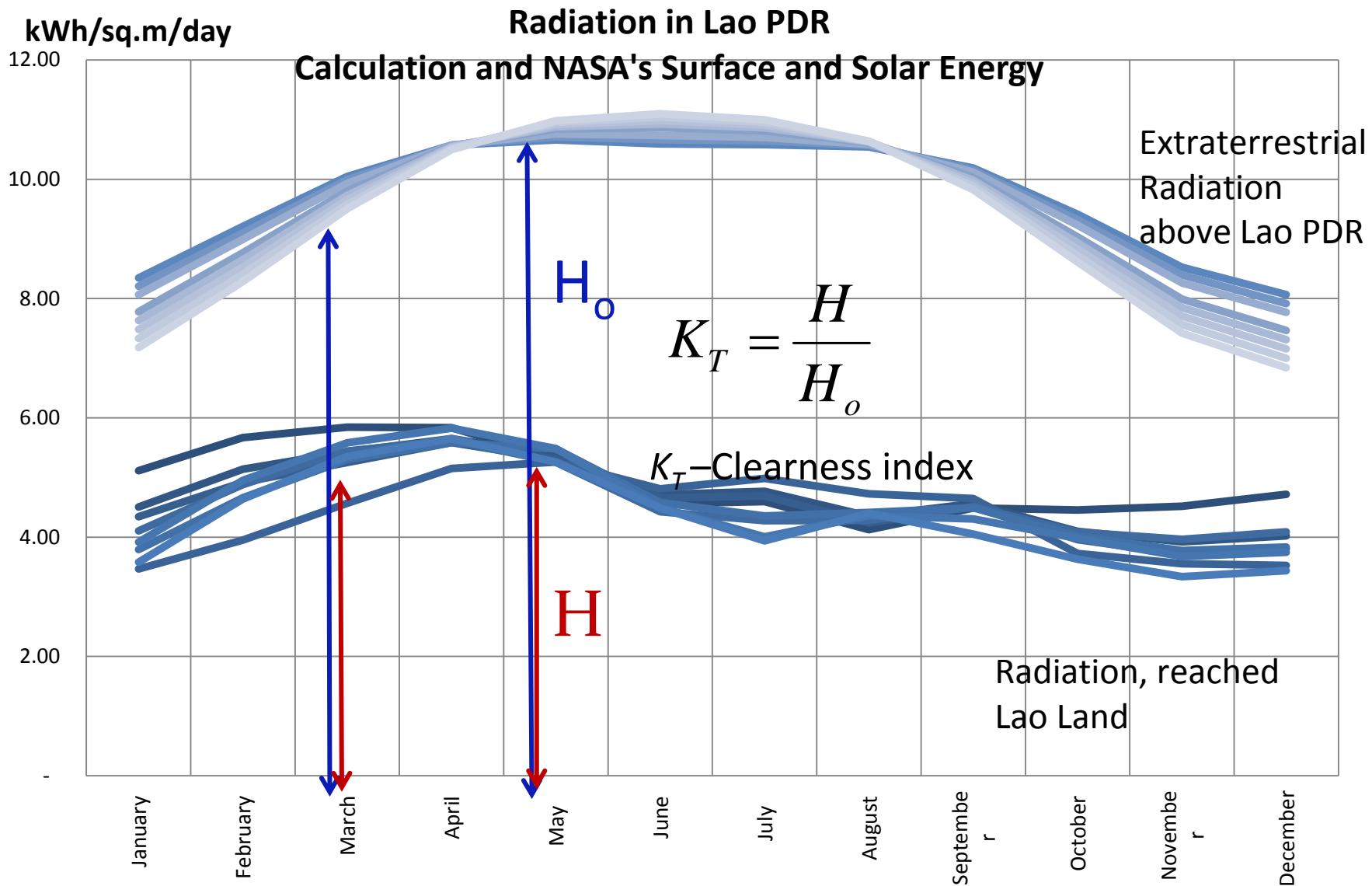
Area under the Blue curve (green zone) = solar radiation reached the Earth's surface at sea level

$$AM = \frac{1}{\sin \alpha}$$

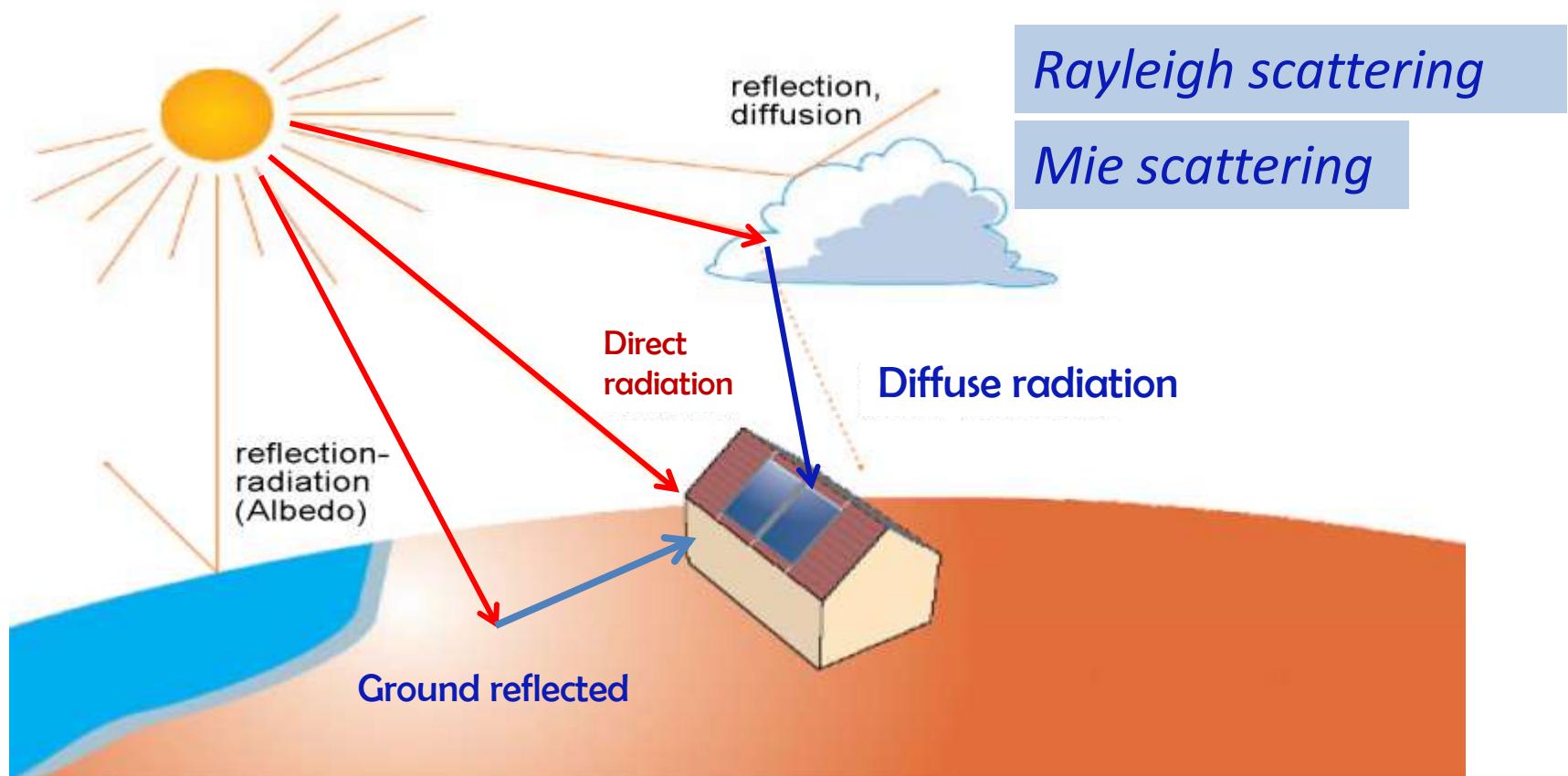


Sky Transmission factor = (Area under green curve)/(Area under red curve)

# ລັງສືແສງຕາວົນ: ສປປ ລາວ



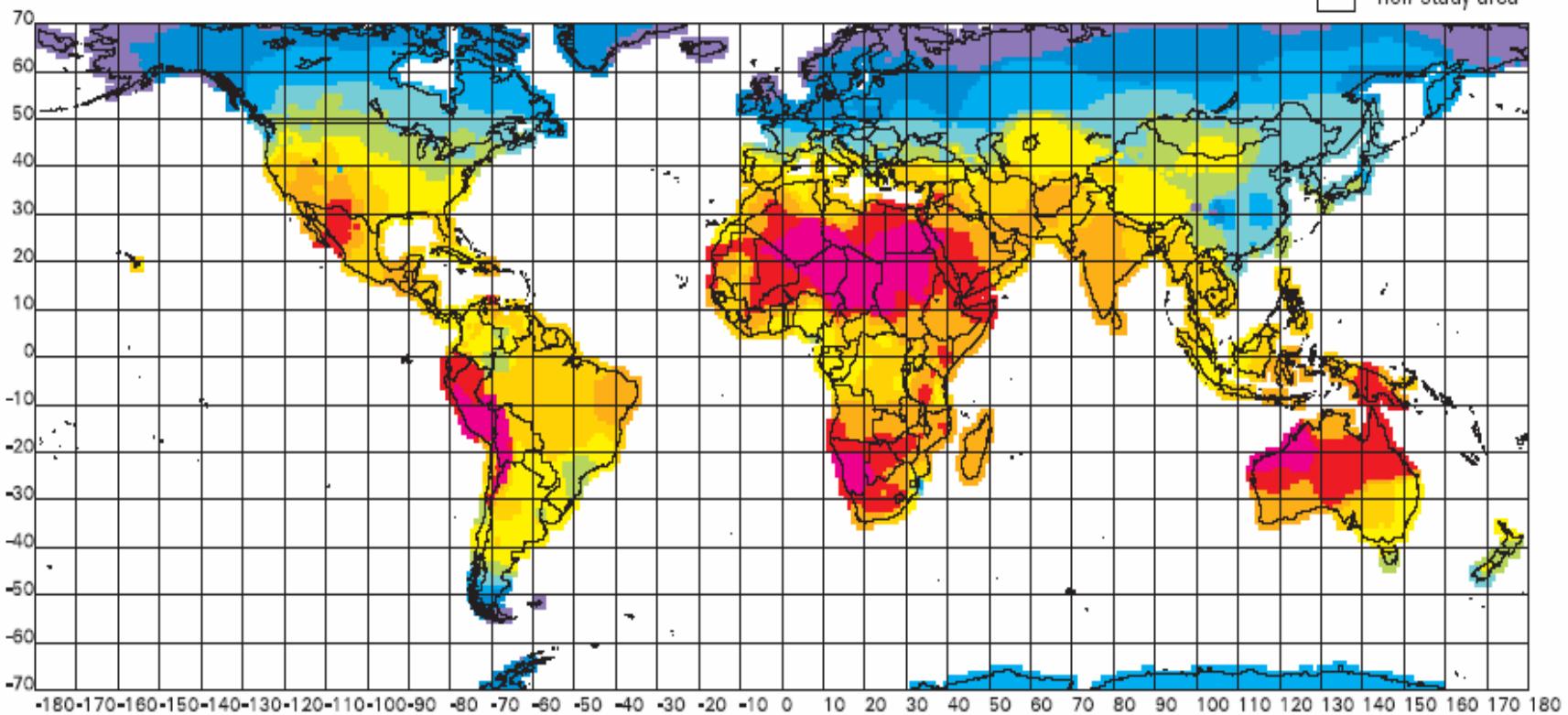
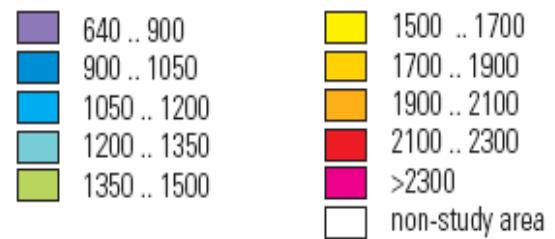
# Solar radiation on a tilted surface



Irradiance on a tilted surface =  
**Direct (beam) + Diffuse + Ground reflected**

# Global Solar radiation

Annual Solar Insolation in kWh/m<sup>2</sup>



# Lao Solar irradiance

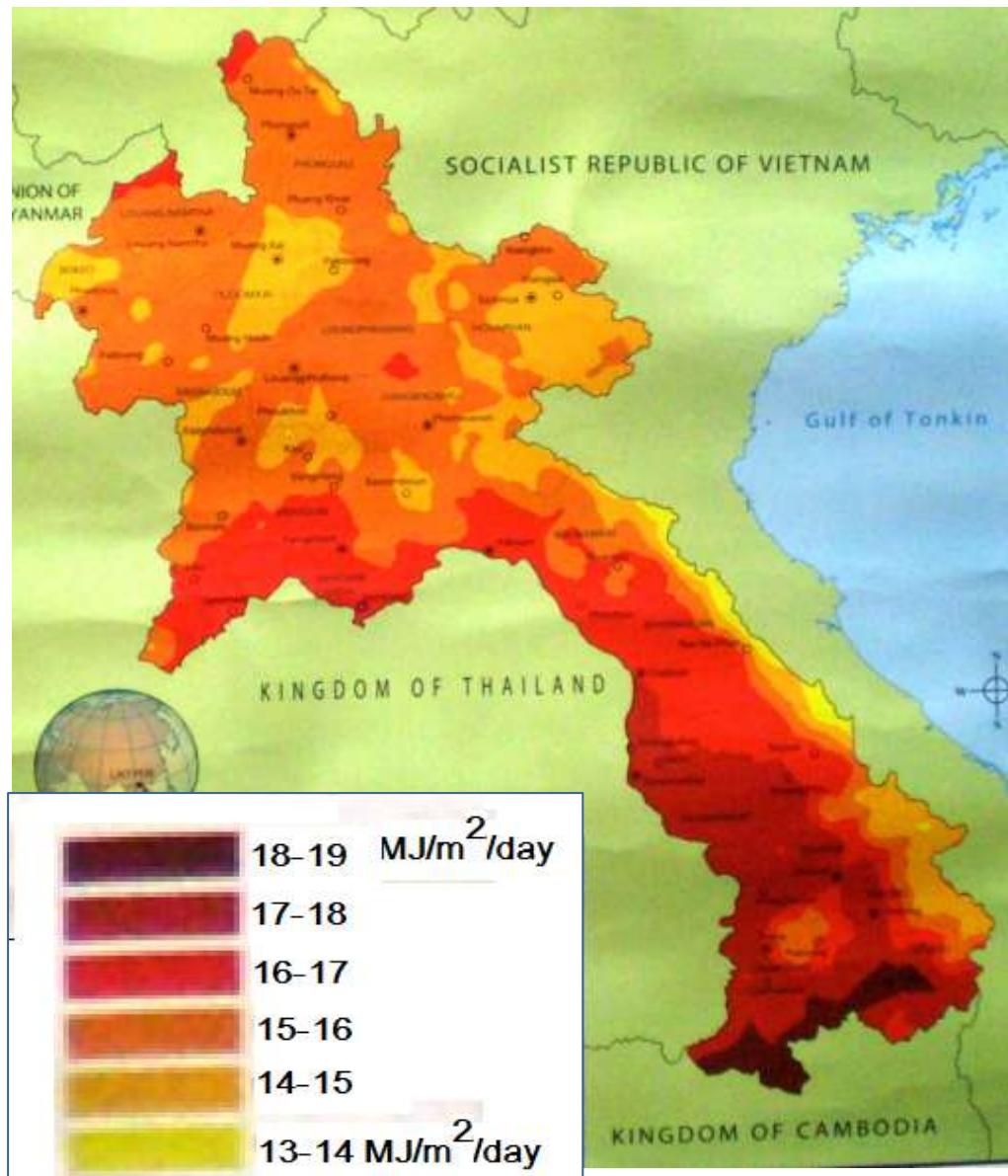
13-19

MJ/m<sup>2</sup>/day

or

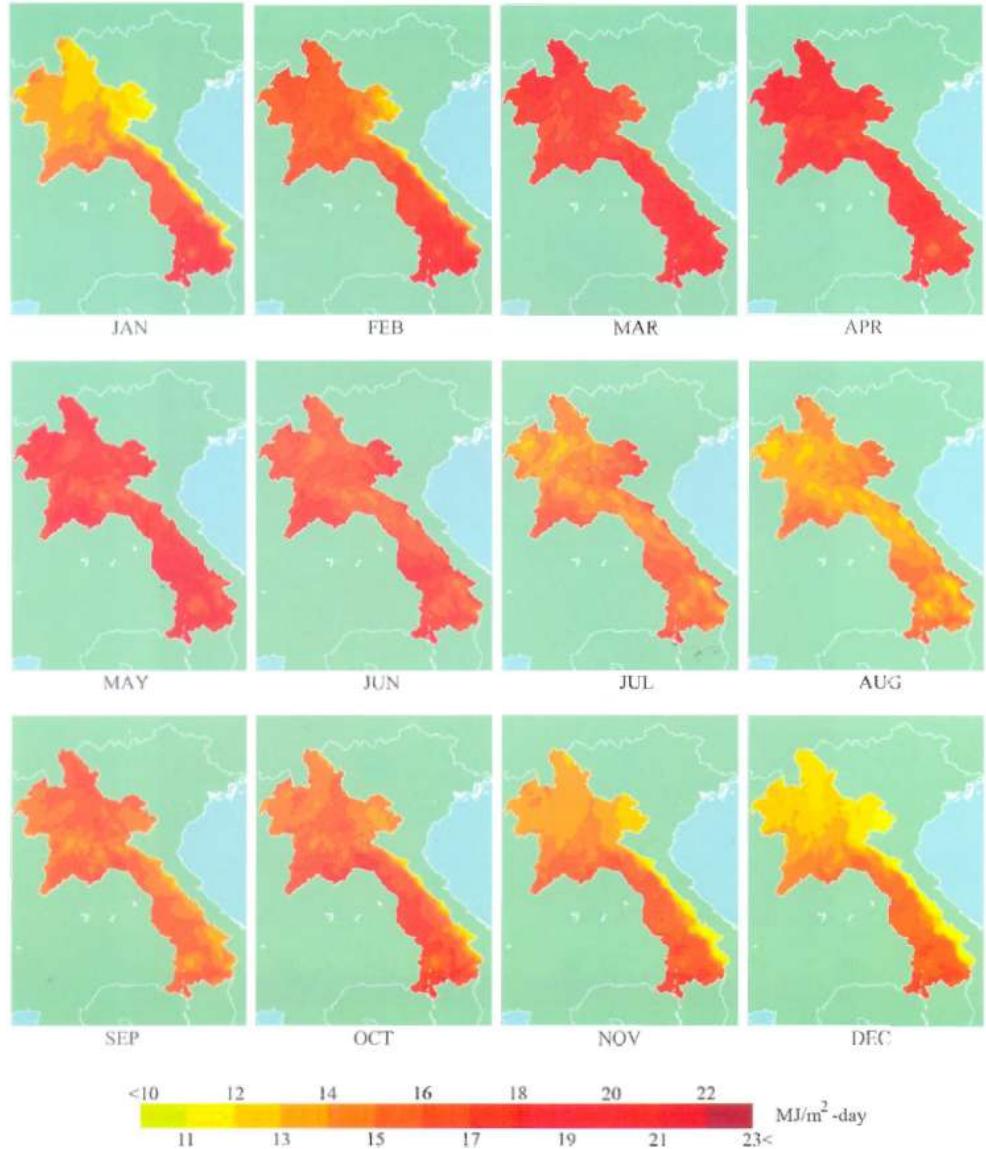
3.6-5.3

kWh/m<sup>2</sup>/day



# ທ່າແນງພະລັງງານແສງຕາເວັ້ນຢູ່ໃນ ສປປ ລາວ

- ແສງຕາເວັ້ນຢູ່ ລາວ
- Highest:3-4-5-6
- Lowest: 12-1,8

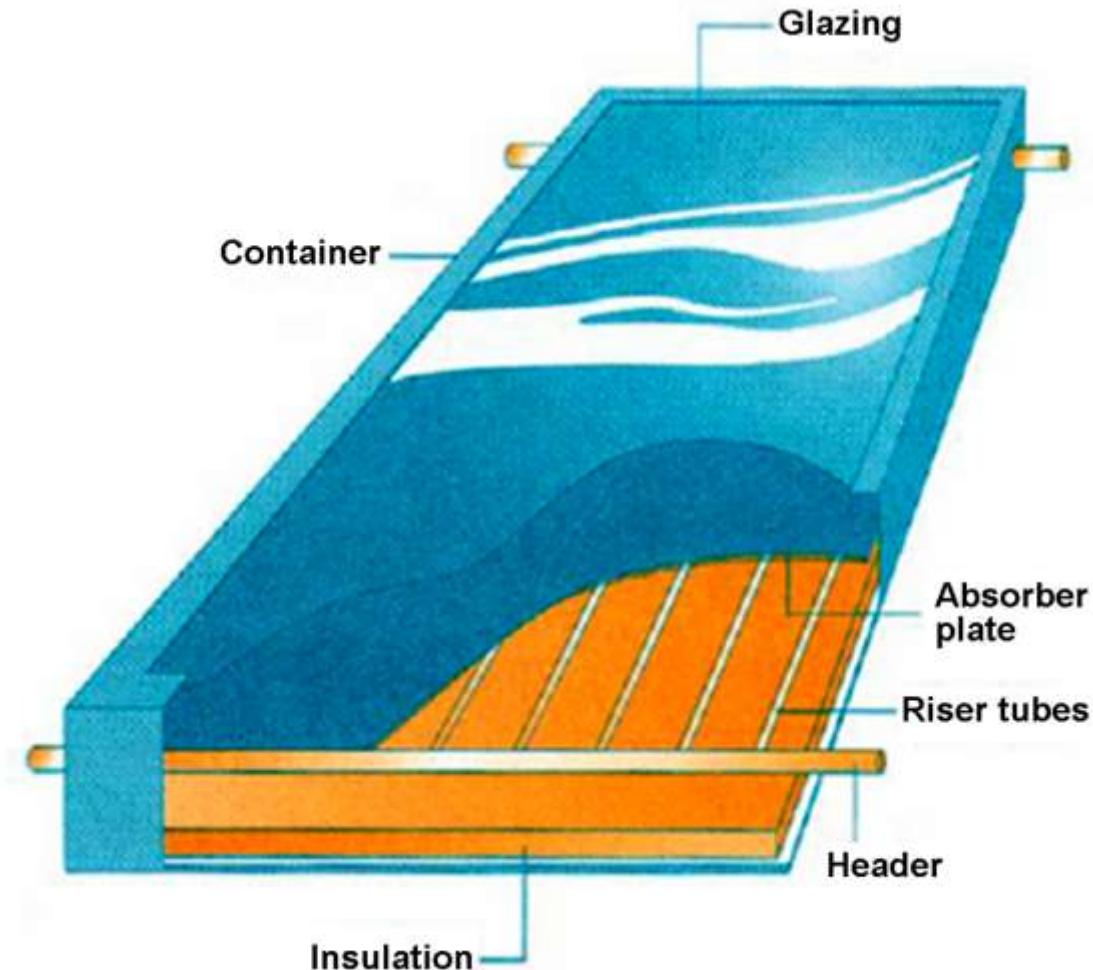


Source: MEM

# Solar energy: thermal application

## Solar water heating system

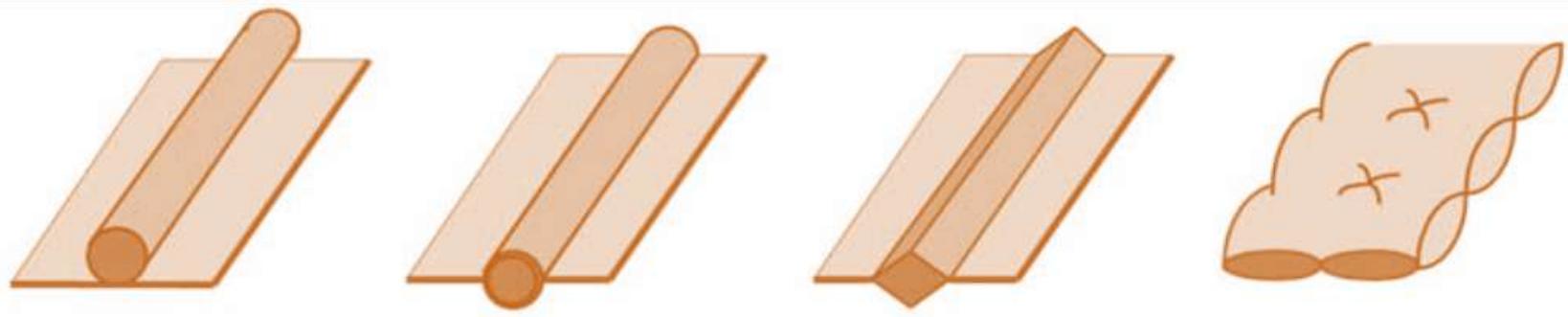
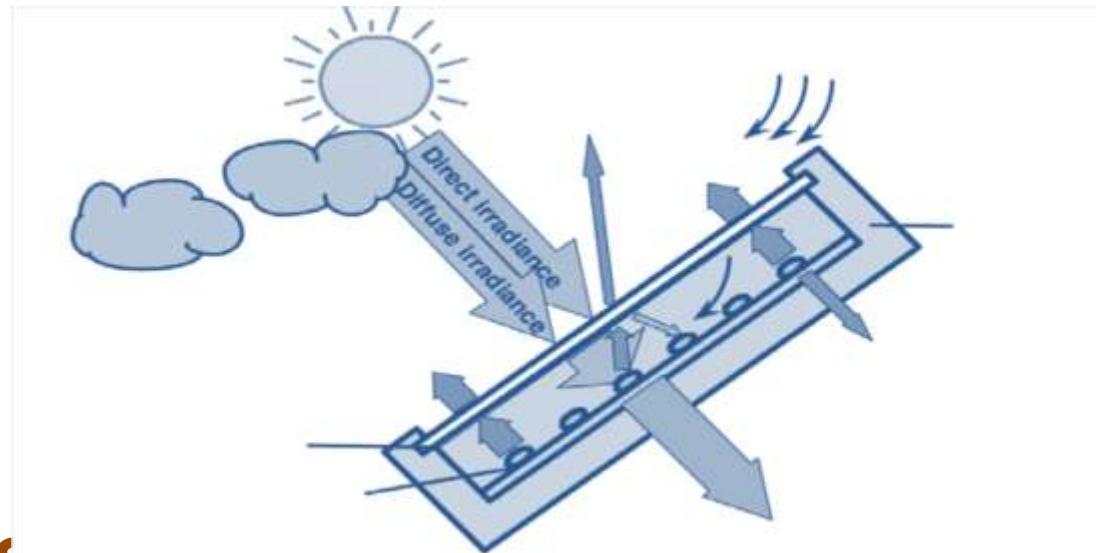
### Solar collector construction



# Solar energy: thermal application

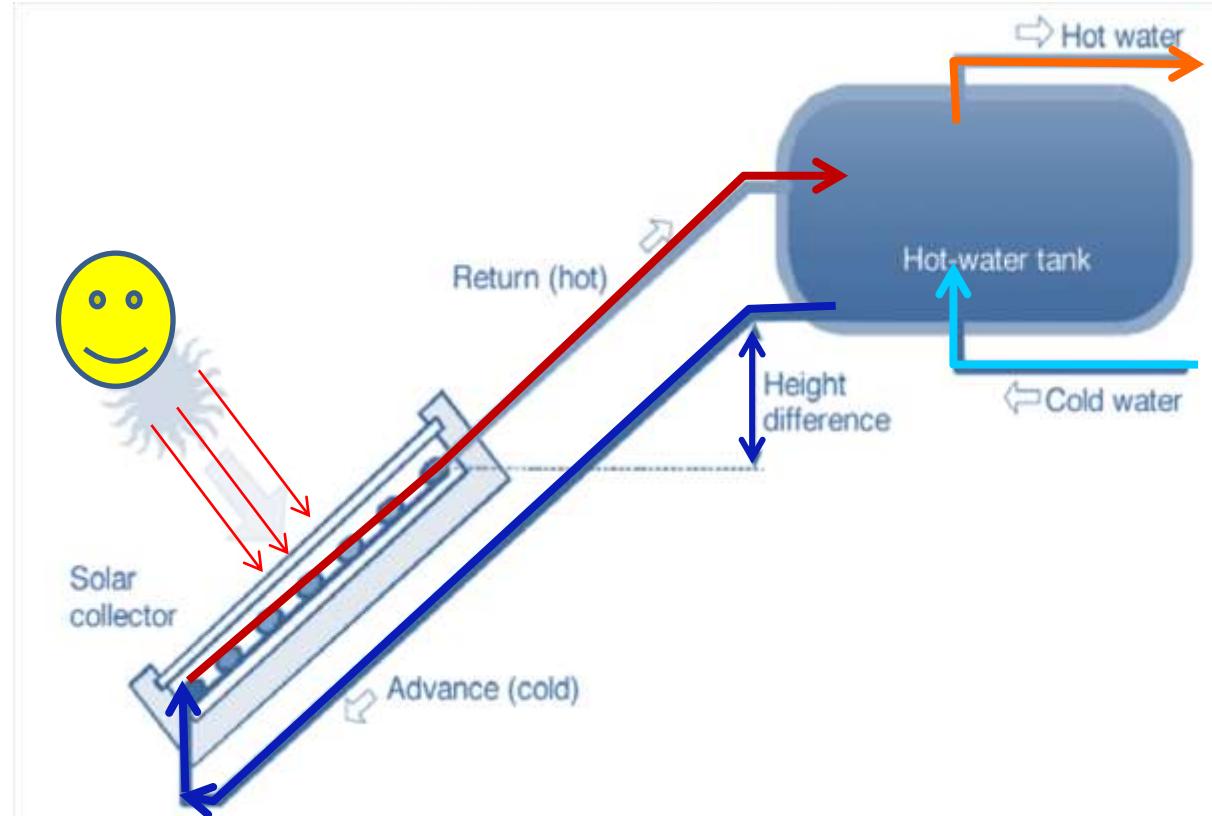
## Heat Transfer

## Absorbers



# Solar energy: Water Heating

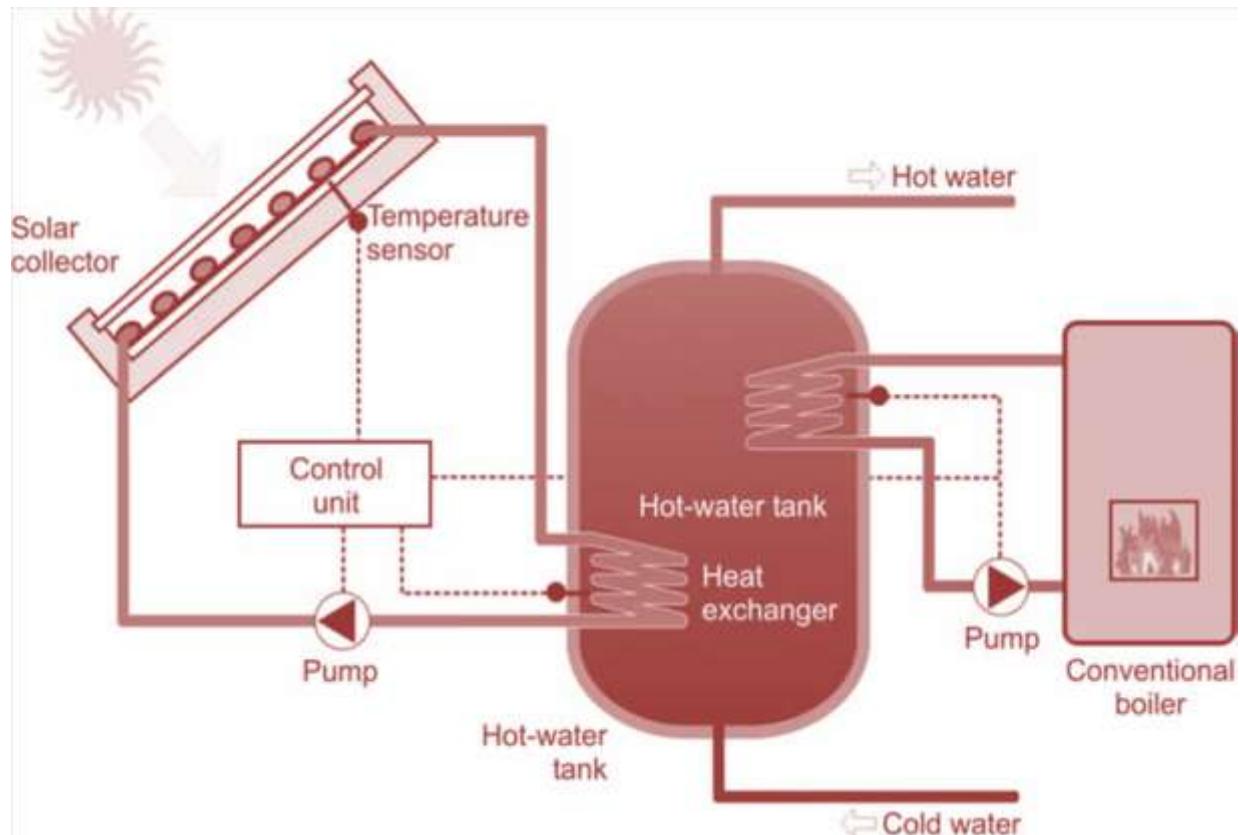
## Domestic Solar Water heating



Passive system

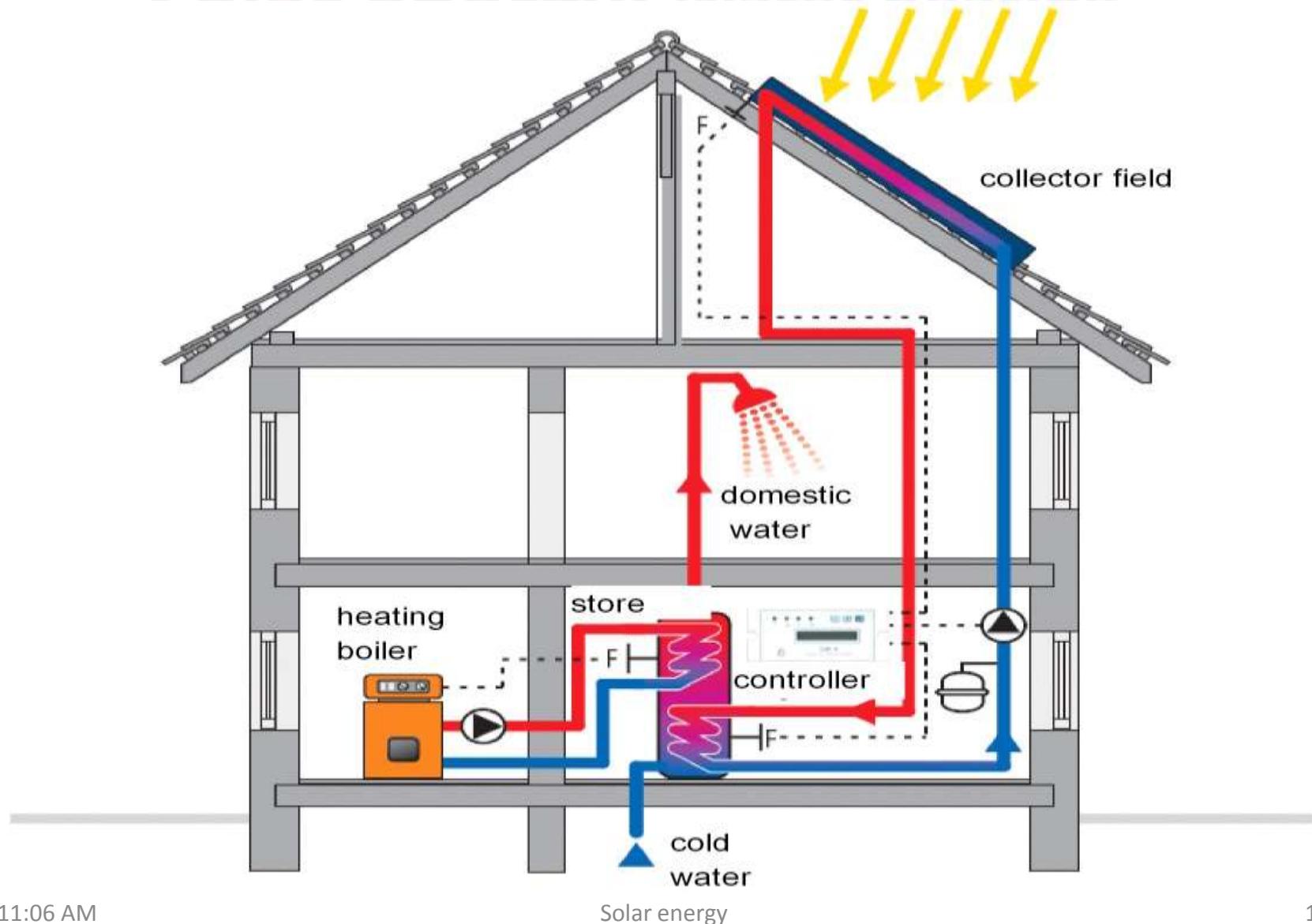
# Solar Energy: Water heating

## Domestic Solar Water heating



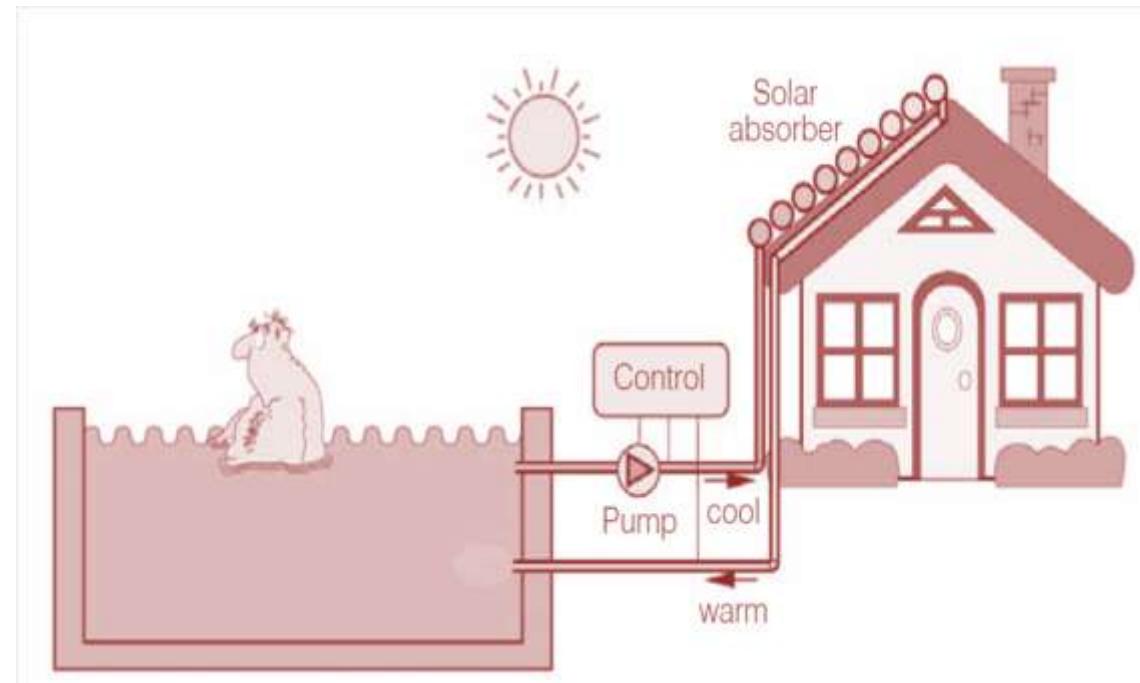
## Active system (hybrid)

# Solar energy: Water heating

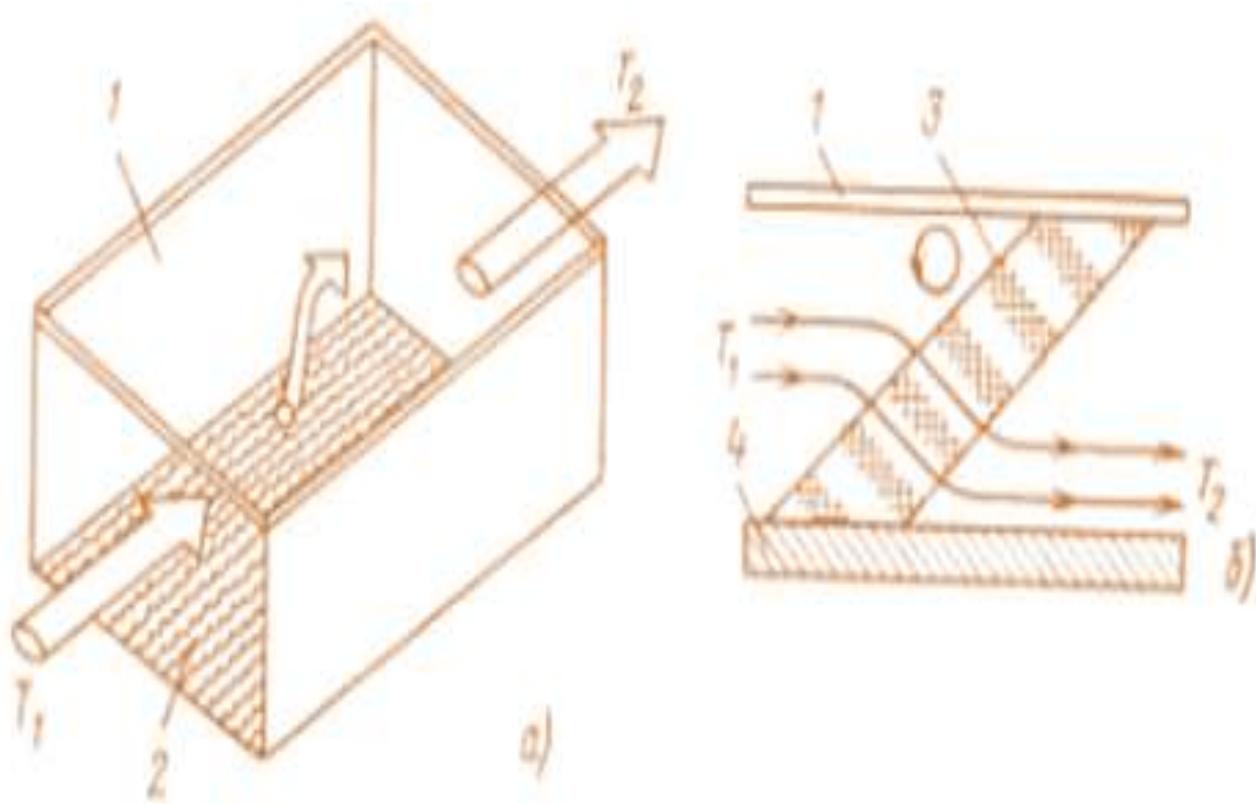


# Solar Energy: Water heating

Solar  
Water  
heating for  
Swimming  
pool

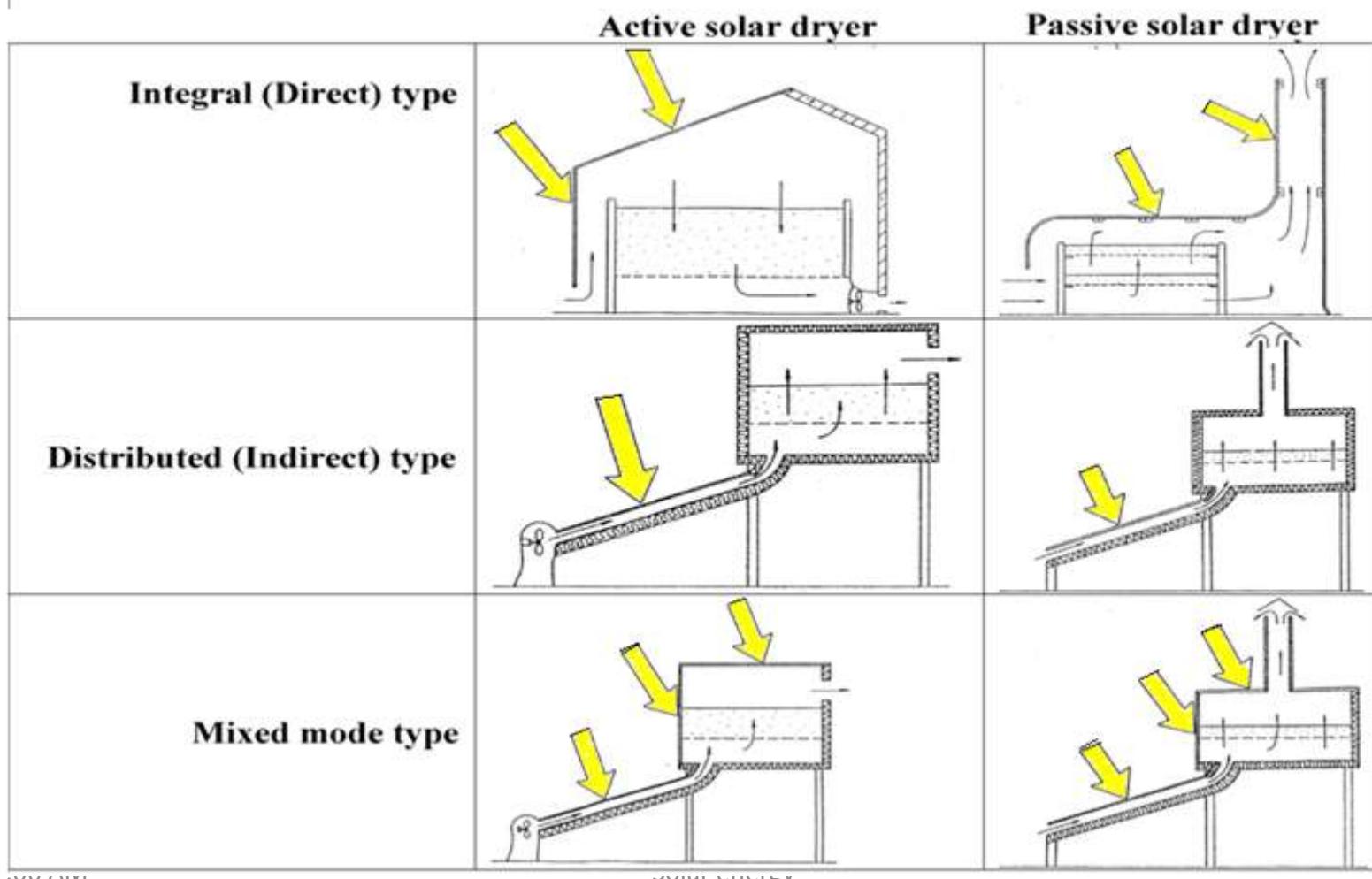


# solar energy: Air heater



## Solar Drying

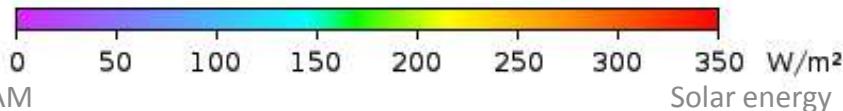
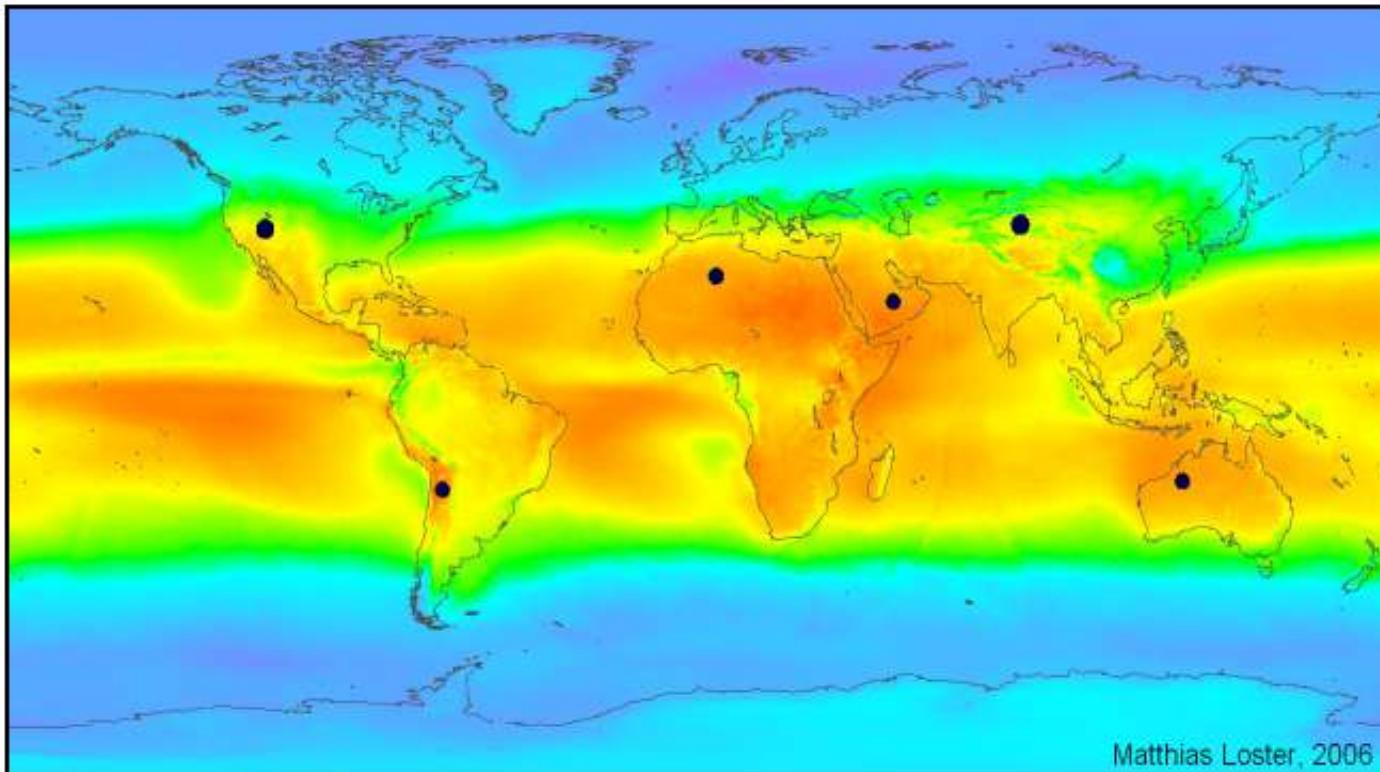
# solar energy: Solar Drying



# Conversion of solar energy to electricity

## Solar energy to Electricity

- Solar Thermal Power Plant: Indirect conversion, using traditional heat engine
- Solar Photovoltaic: direct conversion, using Solar cells

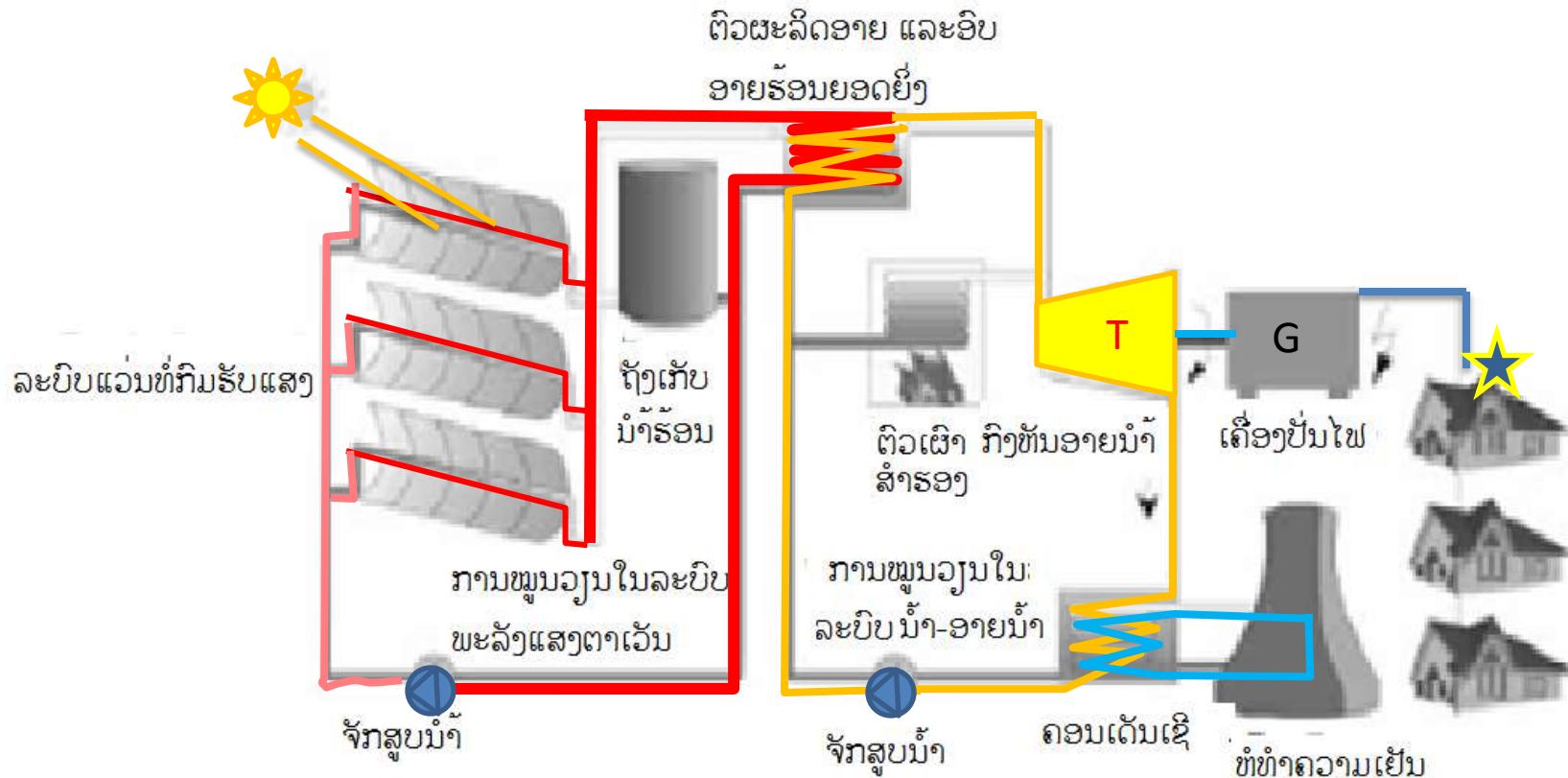


$$\Sigma \bullet = 18 \text{ TWe}$$

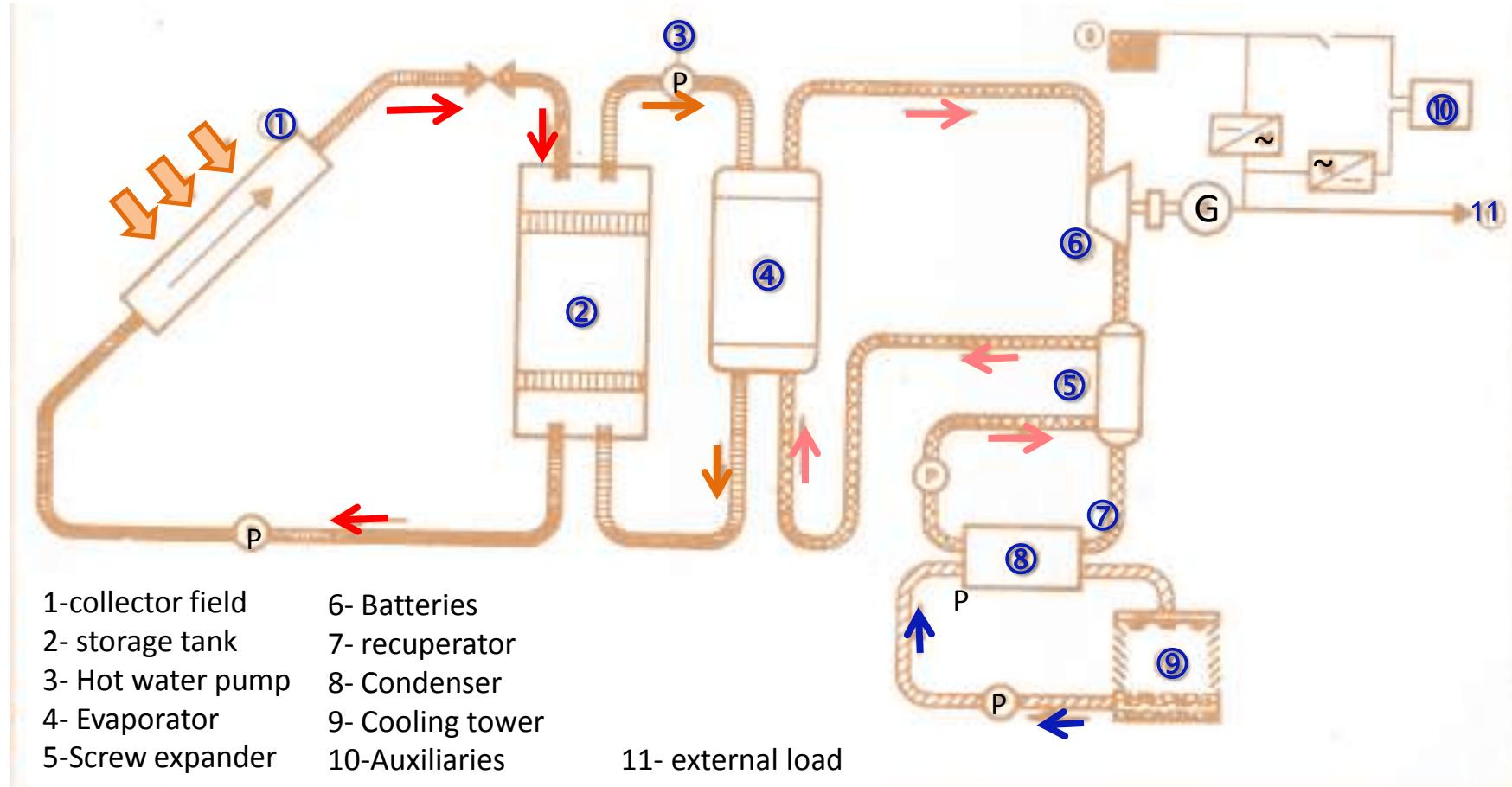
# ການນຳໃຊ້ຄວາມຮອນແສງຕາເວັນ

## Trough Solar Thermal Power Plant:

- ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ ຊະນິດແວ່ນທີ່ກົມ (Trough Solar Thermal Power Plant)
- 400 ອົງສາ



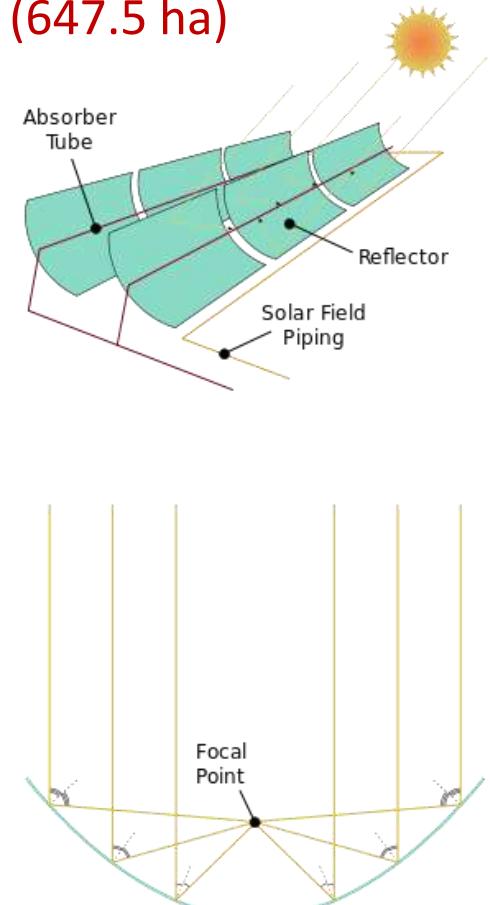
# ໄຟຟ້າຄວາມຮ້ອນແສງຕາເວັນ ຊະນິດແວ່ນທີ່ກົມ (Trough Solar Thermal Power Plant)



# ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ ຊະນິດແວ່ນທຶນ (Trough Solar Thermal Power Plant)

9 SEGS plants (California, USA): 354 Mwe. Average gross solar output for all nine plants at SEGS is around 75 MWe — a capacity factor of 21%

Total of 936,384 mirrors and cover more than 1,600 acres (647.5 ha)



Sources: Solargenix Energy, KJC Operating Company, [IEEE](#), [NREL](#)

## ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ ຊະນິດແວ່ນທຶນ (Trough Solar Thermal Power Plant)

ຂໍ້ມູນ: ຕົວເກີບແສງ: Trough solar collector; ເນື້ອທີ່ : 50 ha.

ກໍາລັງໄຟຟ້າ: 50MWe. Heat storage : molten salt (60% sodium nitrate + 40% potassium nitrate)

A feed-in tariff of €0.27/kWh for the next 25 years

Andasol Solar Power Station (Spain) - Europe's first commercial parabolic trough solar thermal power plant (March 2009)



Radiation: 2,200 kWh/m<sup>2</sup> per year

# ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ ຊະນິດແວ່ນທີ່ກົມ (Trough Solar Thermal Power Plant)

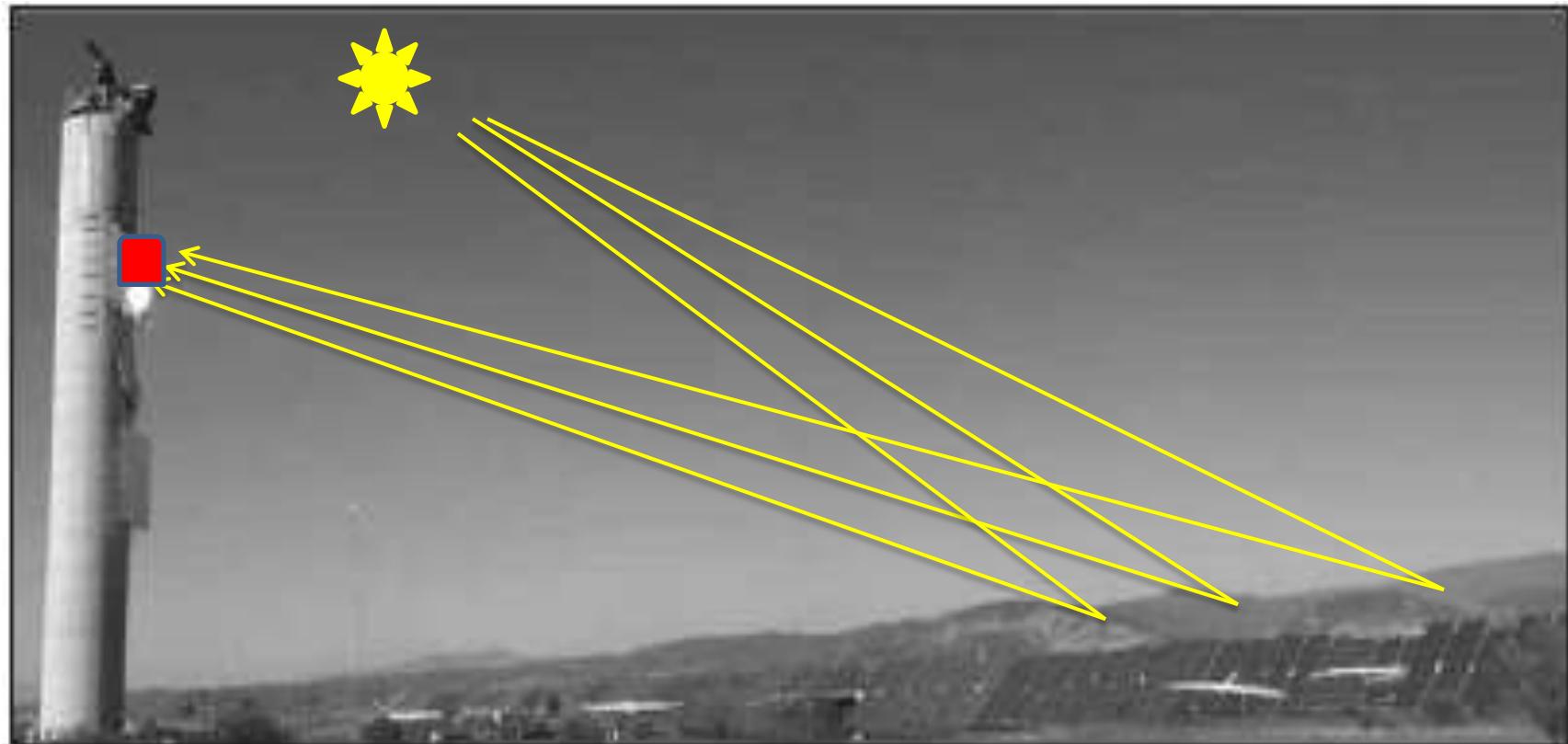
The first three units of Solnova in the foreground, with the two towers of the PS10 and PS20 solar power stations in the background

Spain, 150 MW



# Tower Solar Thermal Power Plant: Principle

- ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ ຊະນິດໜໍາໂຄຍ
- 1000 ອົງສາ



# Tower Solar Thermal Power Plant: Principle

- ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ ຊະນິດໜໍາໂຄຍ



Solar one (1982-88) → Two (1996-99): 10 MW power capacity

[http://earthobservatory.nasa.gov/Features/RenewableEnergy/Images/solar\\_two.jpg](http://earthobservatory.nasa.gov/Features/RenewableEnergy/Images/solar_two.jpg)

# Tower Solar Thermal Power Plant:

PS10: 11 MW, 624 large heliostats (120 square meters each),  
Steam turbine at a top Tower height: 115 meter;  
(PS20)



# Tower Solar Thermal Power Plant:

Capacity : 2 MW in 1983.

An array of 201 mirrors

100 m tower

The coolant entry temperature was 250 °C and the exit temperature 450 °C. Vapor pressure of 50 bar and a temperature of 430 °C.

The THEMIS Solar Power tower in the Pyrénées-Orientales, France.



# Tower Solar Thermal Power Plant:

Jülich solar tower power plant (Germany), 1.5 MW



# Solar Thermal Power Plant:

Capacity : The 11MW PS10 near Seville in Spain.



# Solar Thermal Power Plant: Disk type



*Helio-dish field layout*

Capacity : 20 kW

Concentrator : flat  
helio-dish, 9m dia

Reflector : 50 m<sup>2</sup> area

Cavity receiver : 65mm  
dia, 680 mm length  
coil with 10 mm tube

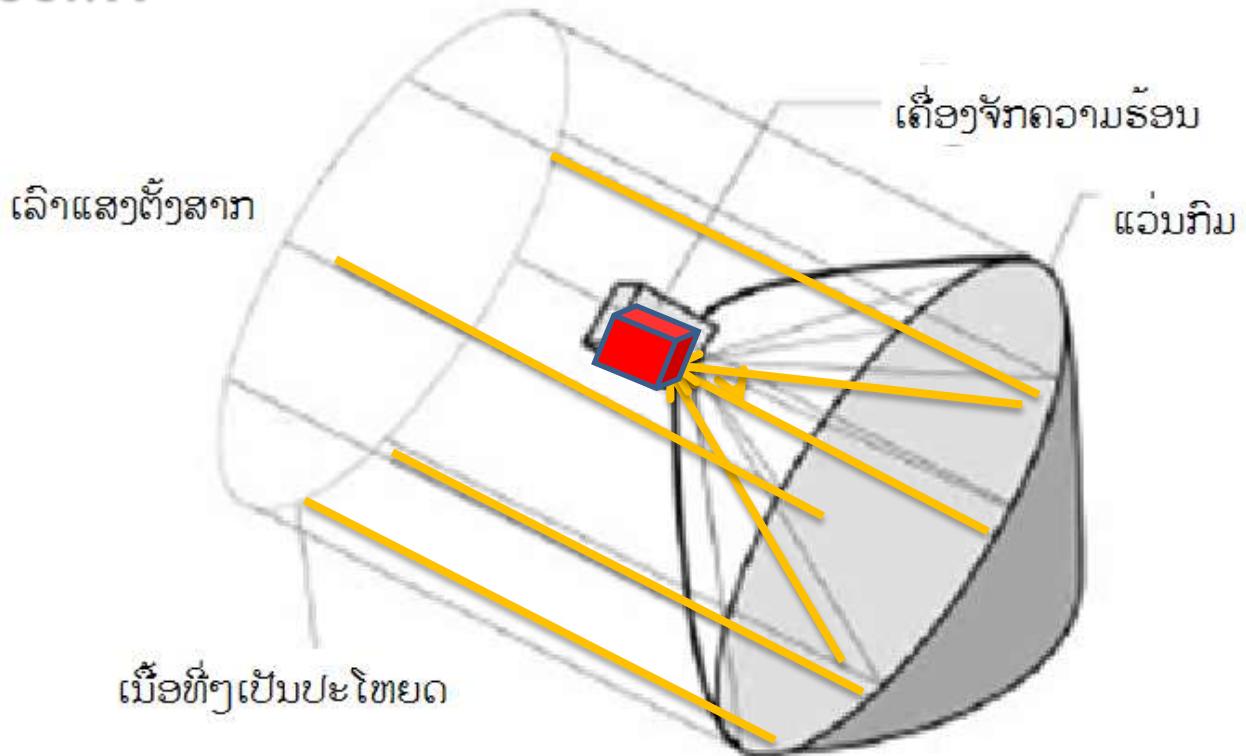
Concentration : 1500  
suns Steam output :  
180 Kg/hr, at 500 °C,  
70 atm.

Engine : 300 cc  
Reciprocating

# ໄຟຟ້າຄວາມຮອນແສງຕາເວັນ Solar Thermal Power Plant

## ◦ລະບົບຈານສະເຕີຣິລິງ Stirling Disk System

- 650 ອົງສາ;
- Capacity <100kW



# Solar Thermal Power Plant



California Edison 25 kW dish/Stirling system,  
under 1000 W/m<sup>2</sup>. 944 square foot, 82  
mirrors

# Solar Thermal Power Plant



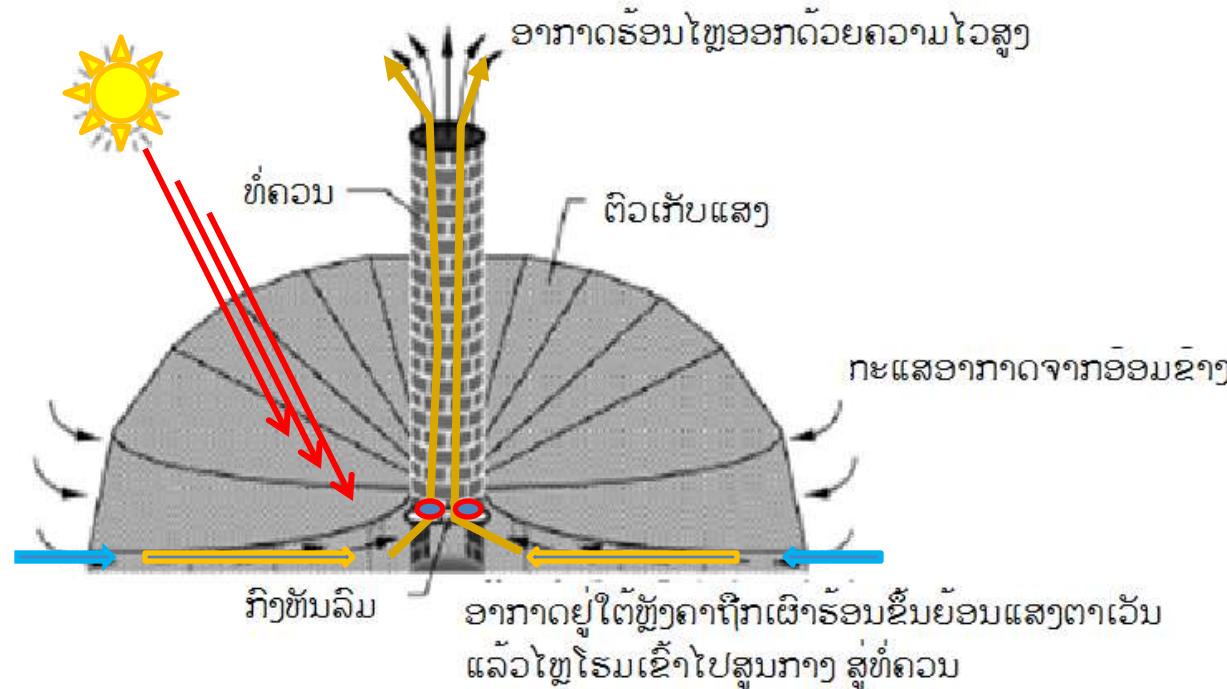
**Advanco/Vanguard 25 kW dish /Stirling system installed at Rancho Mirage, California.**

**The Vanguard concentrator is approximately 11 meters in diameter and made of 366 mirror facets, each facet measures 18 by 24 inches. The engine used is a United Stirling AB (USAB) Model 4-95 Mark II driving a commercial 480 volt/ac 60-Hz alternator.**

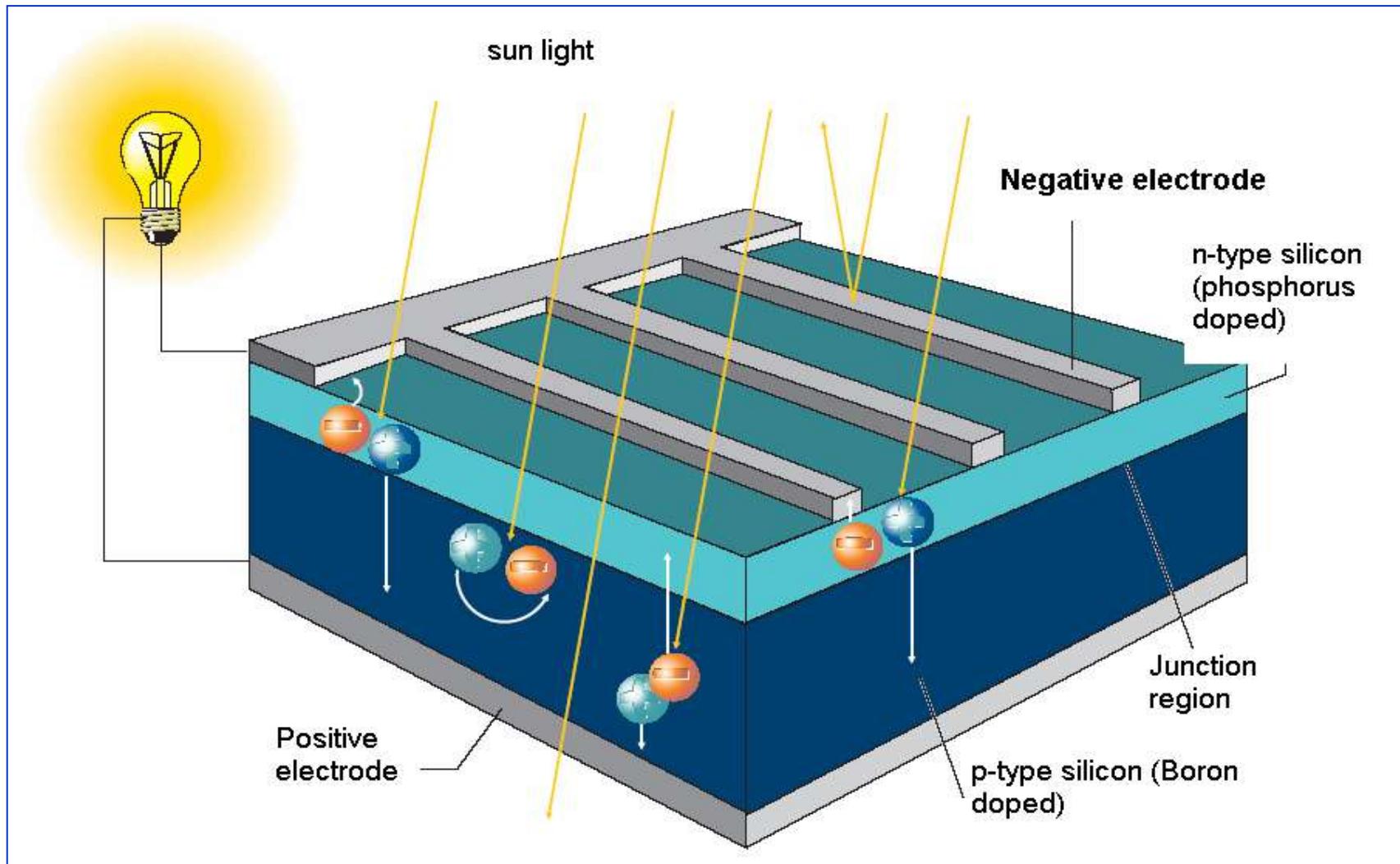
# Solar Thermal Power Plant

## ○Chimney STPP

- ไฟฟ้าความร้อนแสงจากอุบัติภัยธรรมชาติ
- พะลิดไฟฟ้าในลาถາ 0.15 \$/kWh



# Photovoltaic : Direct conversion of solar energy to electricity

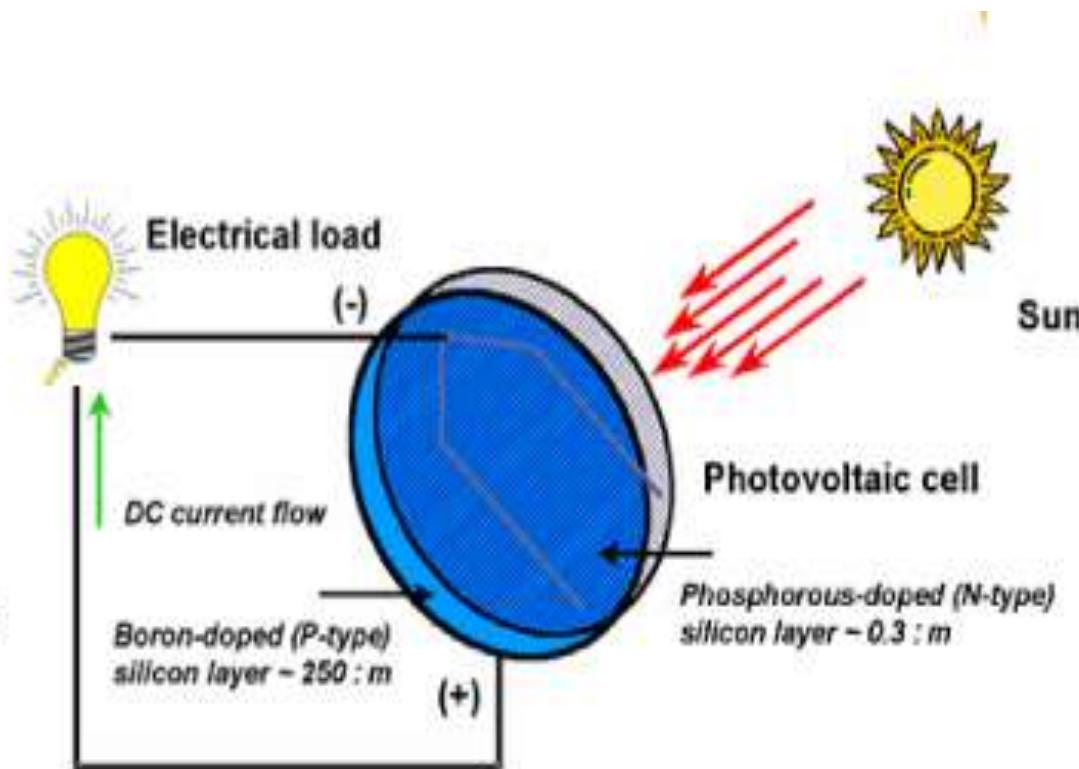


## Photovoltaic principle:

# Principle of Photovoltaic electricity generation



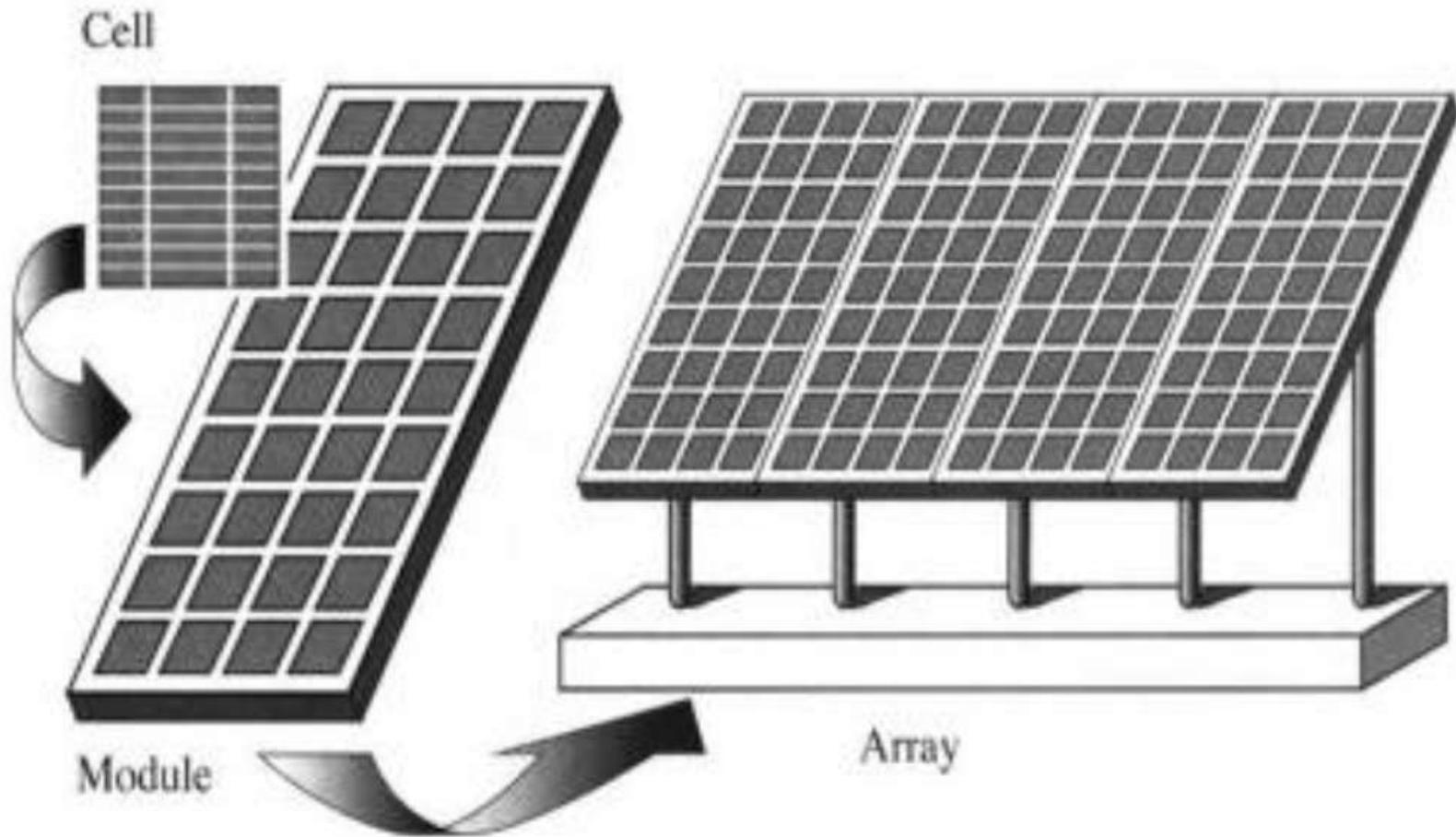
Courtesy of Florida Solar Energy Center



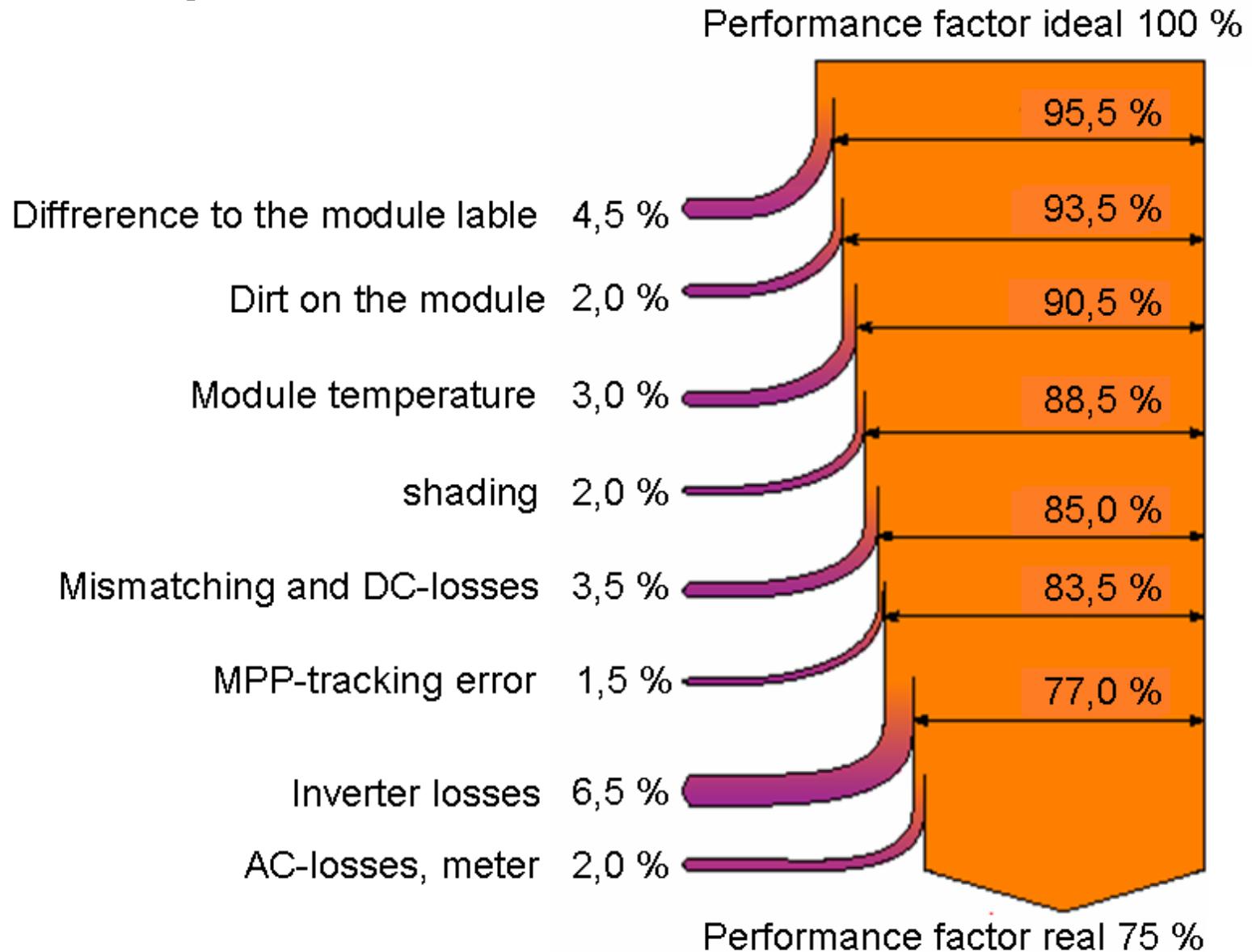
- When sunlight strikes the solar cell it “knocks loose” electrons, which generates a flow of DC current

# Solar Cell - Panel (Module) - Array

:



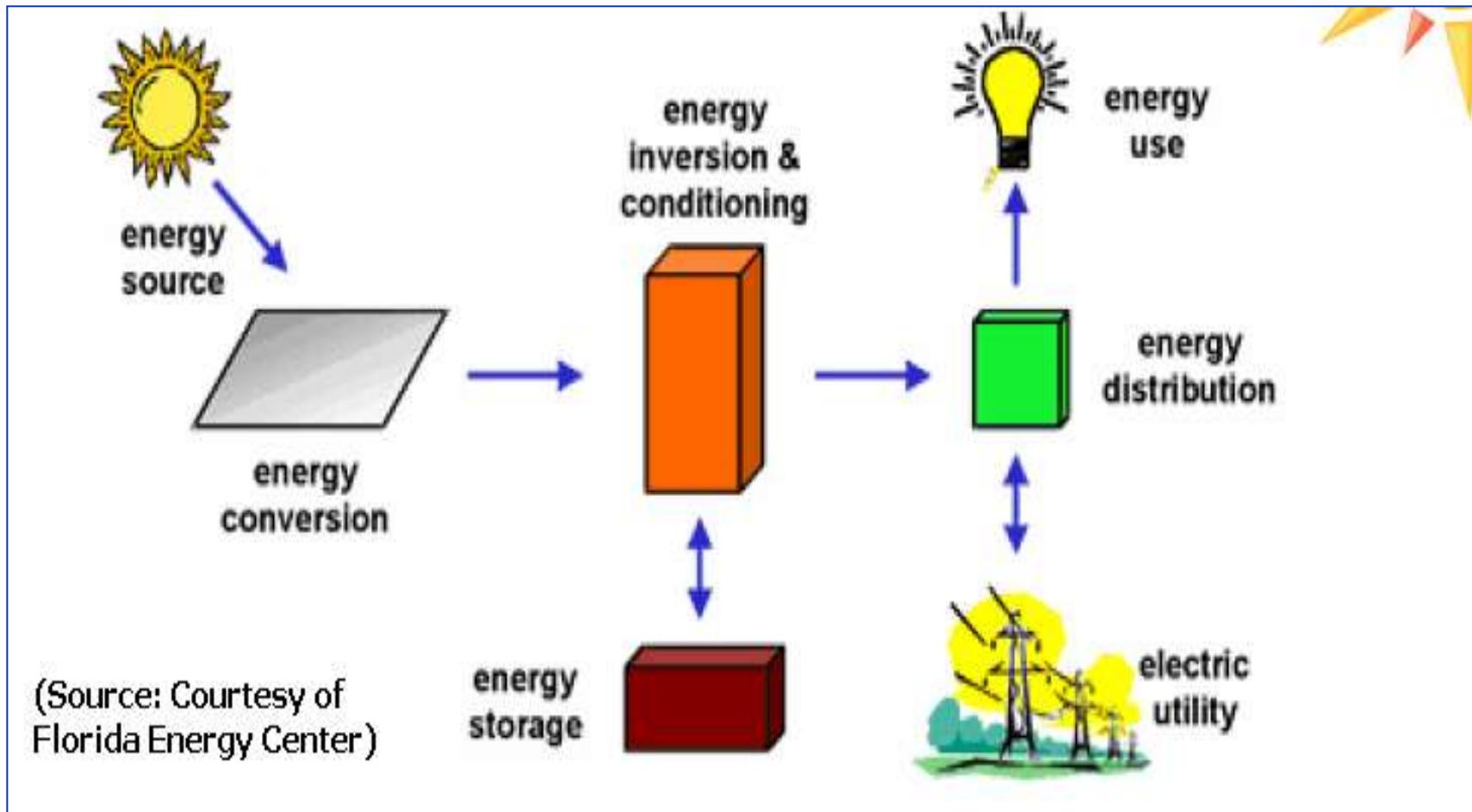
# PV panel's Performance factor



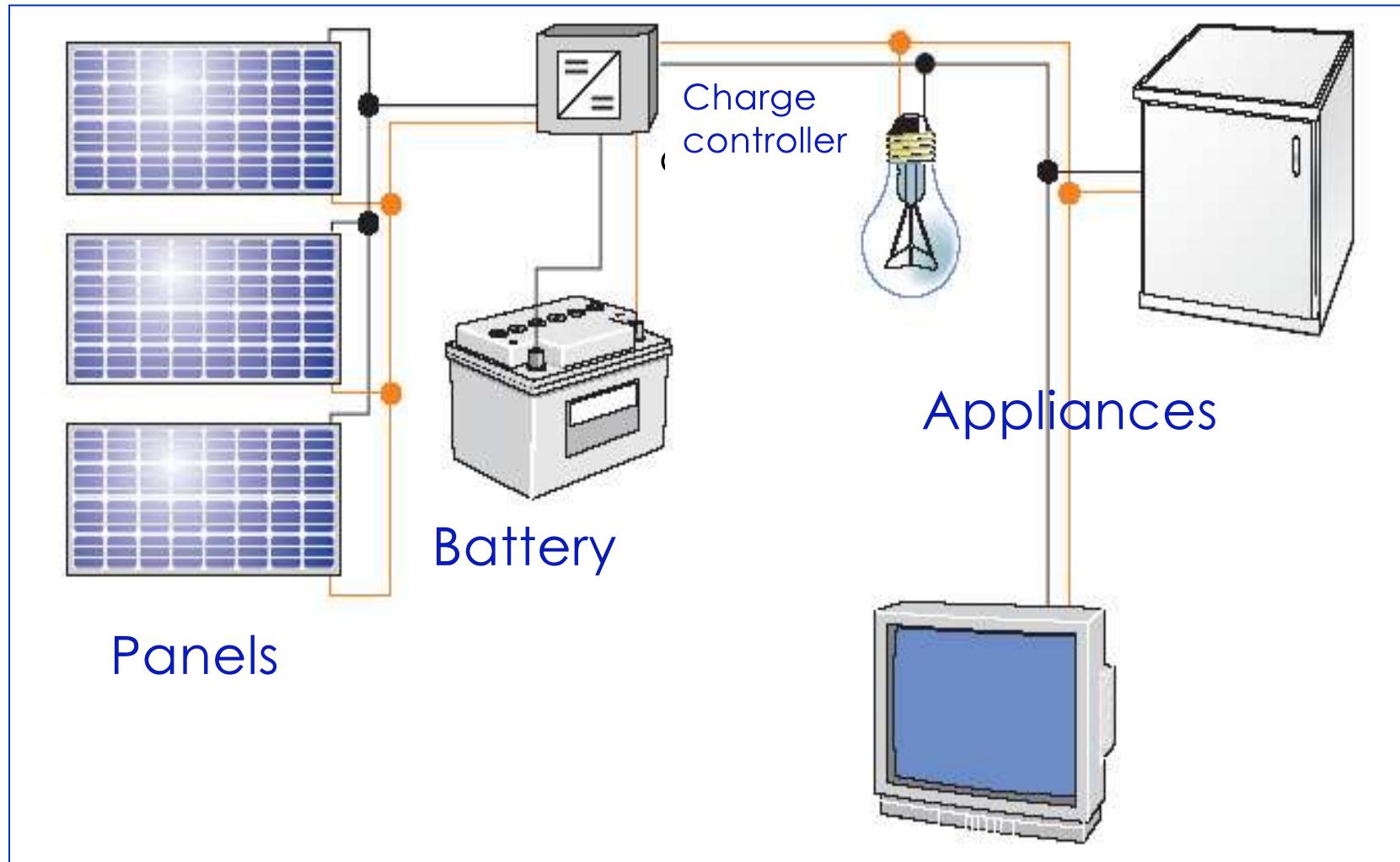
# Photovoltaic electricity generation- estimates

	Unit	Low	High
Daily Solar irradiance,	MJ/sq.m/day	13	19
	kWh/sq.m/day	3.6	5.3
Annual irradiance,	kWh/sq.m/year	1,318	1,926
Overall Conversion efficiency	%	10%	10%
Annual electricity production,	kWhe/sq.m/year	135	184
Electricity consumption in Laos (2010)	GWh	2,441.00	2,441.00
PV area required: Consumption	sq.m	18,081,481.48	13,266,304.35
Square Size	m x m	4252 x 4252	3642 x 3642
	km x km	4.25 x 4.25	3.64 x 3.64

# Principle of Solar PV Application



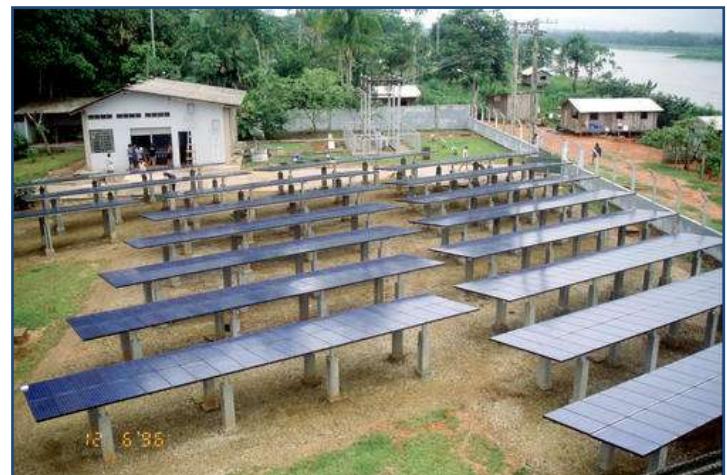
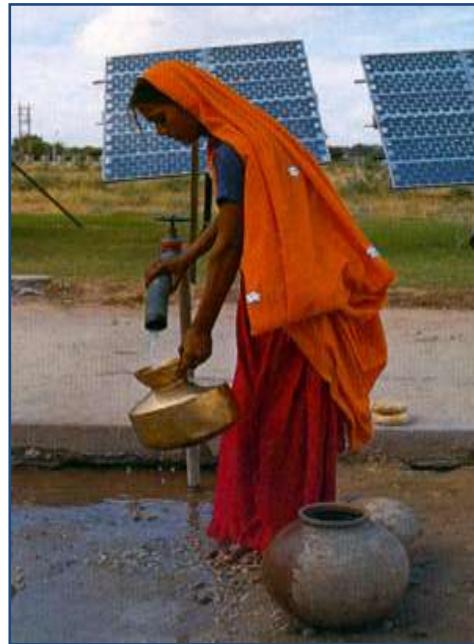
# Stand alone system



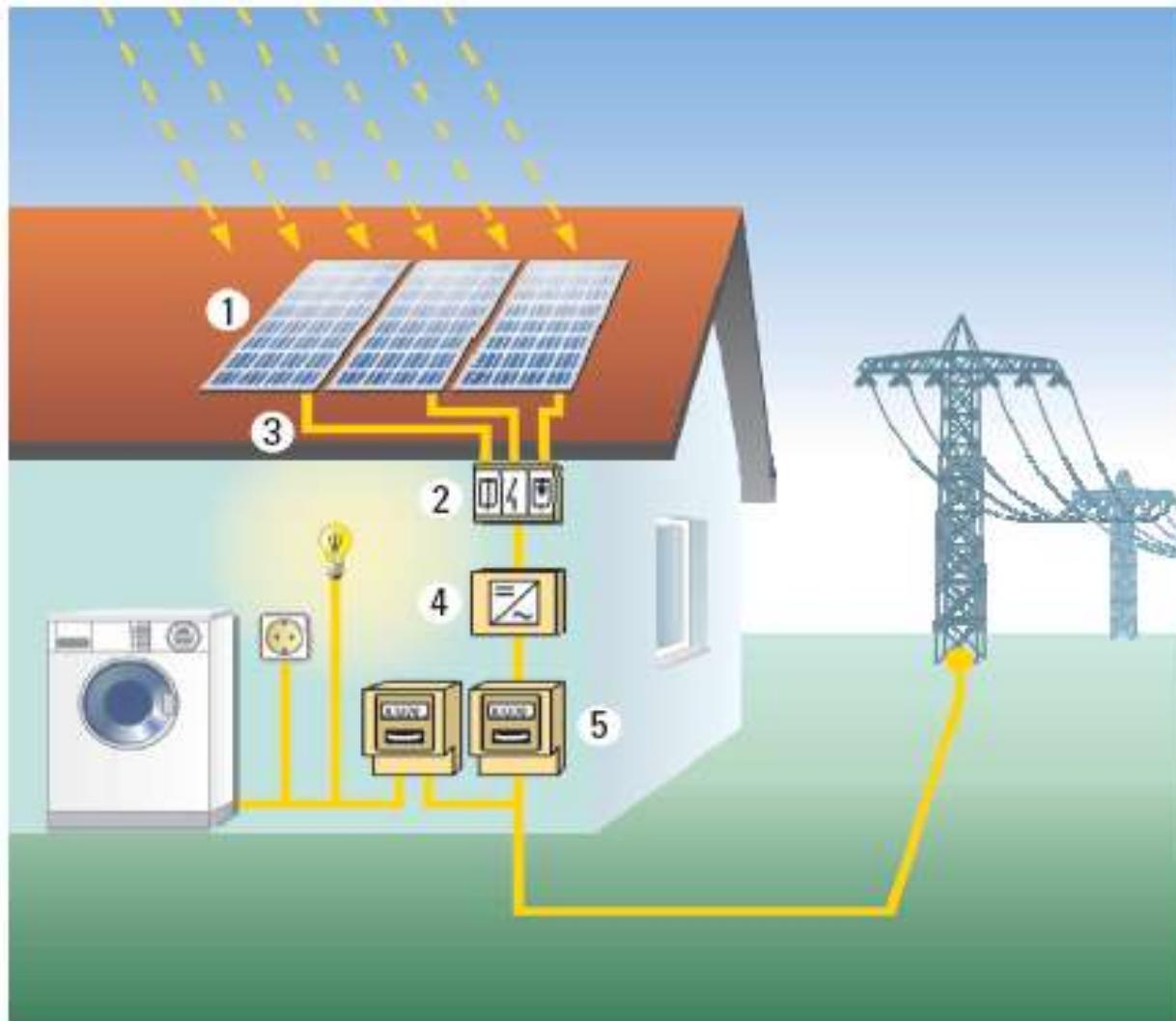
# Stand alone system: applications



# Stand alone system: applications



# Grid connected PV system



1. PV array
2. DC connection box
3. Panels cables
4. Inverter
5. Watts Meters

# Grid-connected Solar home

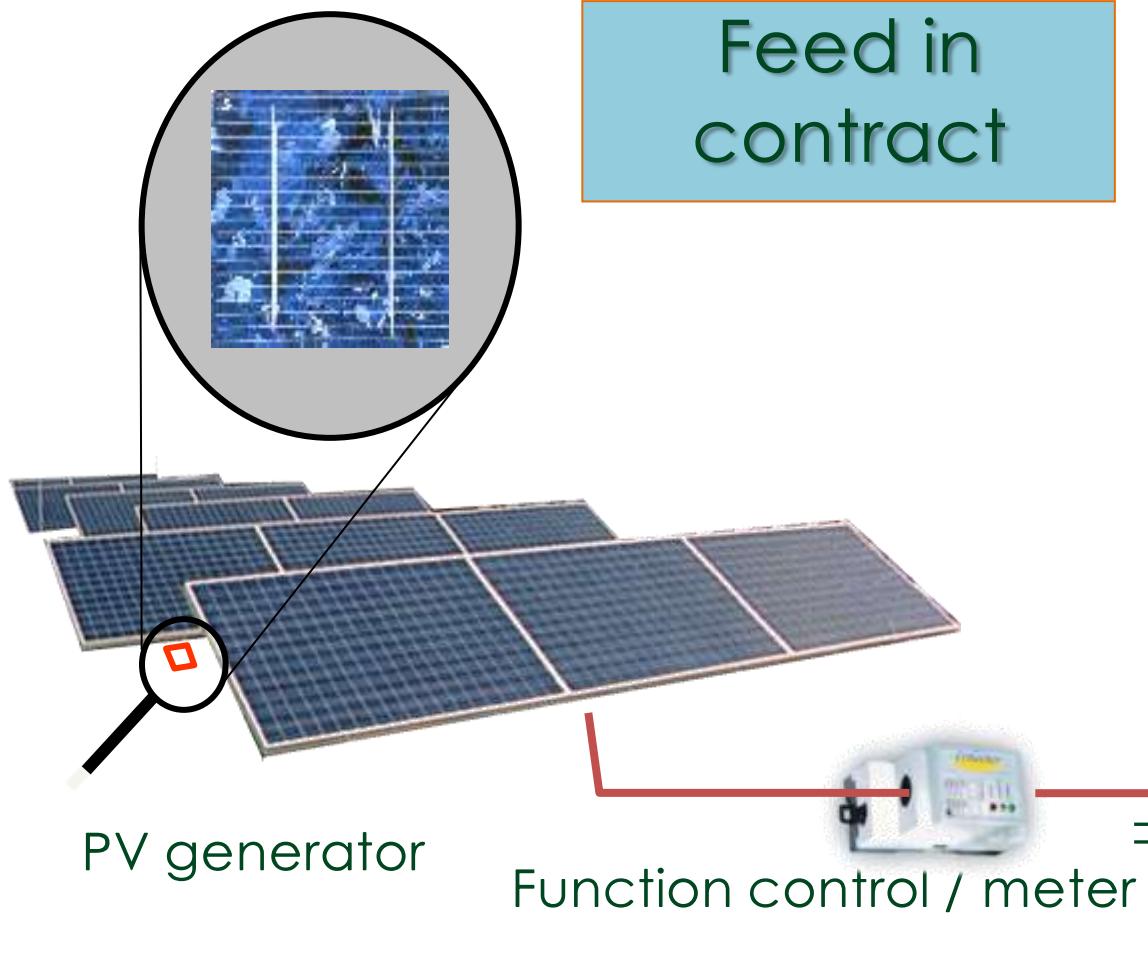


Thin-film a-Si PV array



Inverter and power distribution panels

# Grid-connected systems



# Grid-connected PV power plant



Crystalline silicon array in flat roof mounting

# Grid-connected PV power plant



[Nellis Solar Power Plant](#) at Nellis Air Force Base in the USA.  
These panels track the sun in one axis.



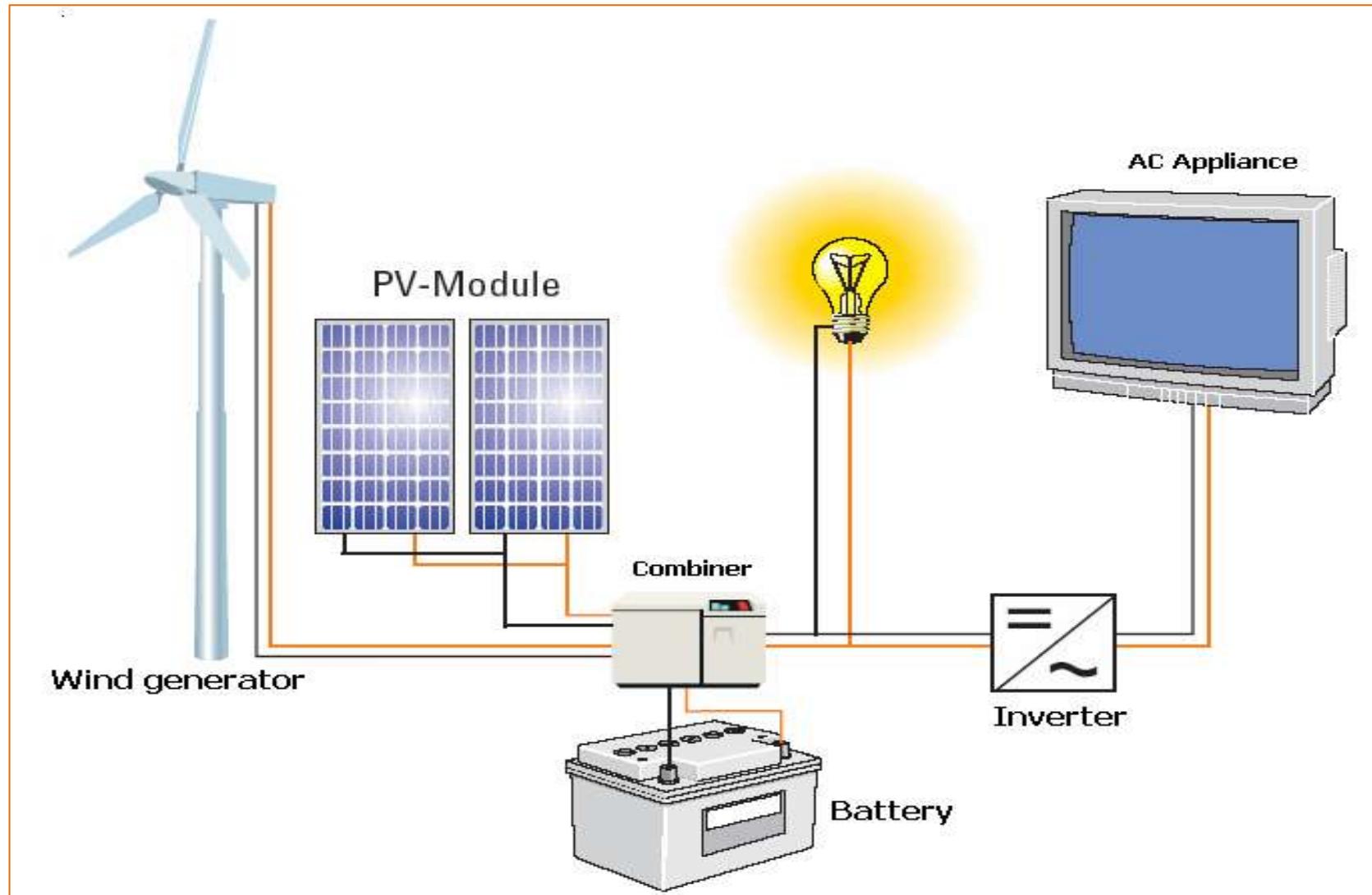
## 19 MW solar park in Germany

# Grid-connected PV power plant

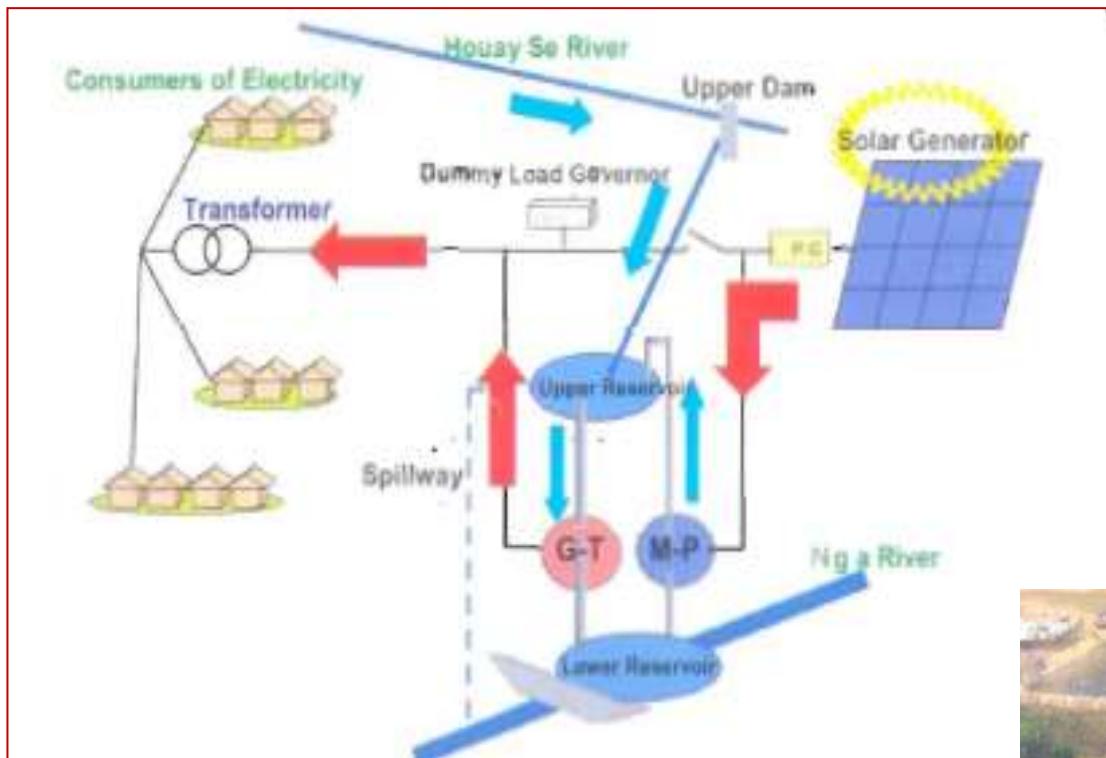


Photovoltaic wall at MNACTEC Terrassa in Spain

# Hybrid grid system



# Hybrid grid system:



Solar PV Panel 100 kW



Micro hydropower (80kW)  
+ PV (100kW)

# Hybrid system:

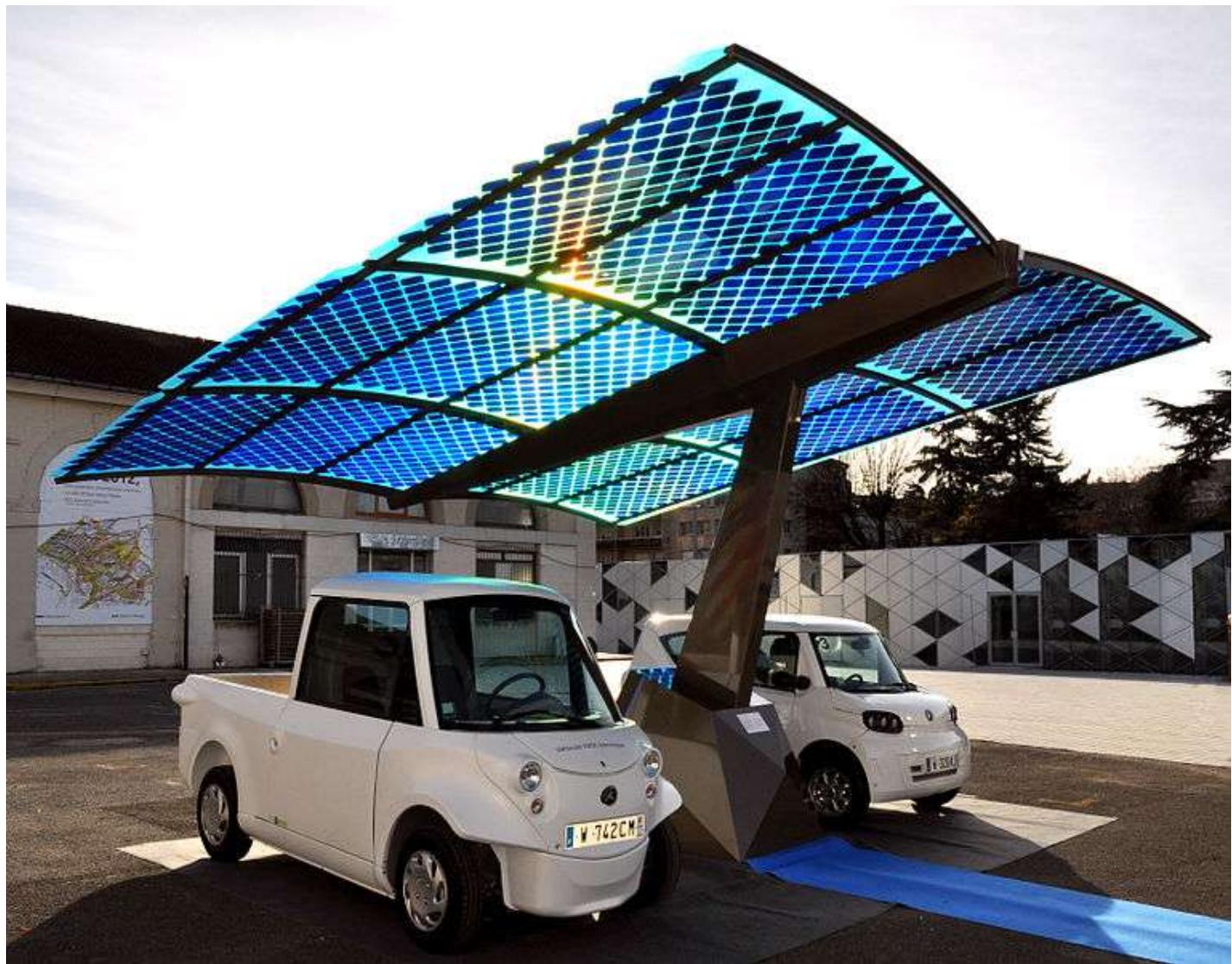
Mini hydro (110kW)

+ PV(40kW)

+ Capacitor ( $\pm 40$  kW)



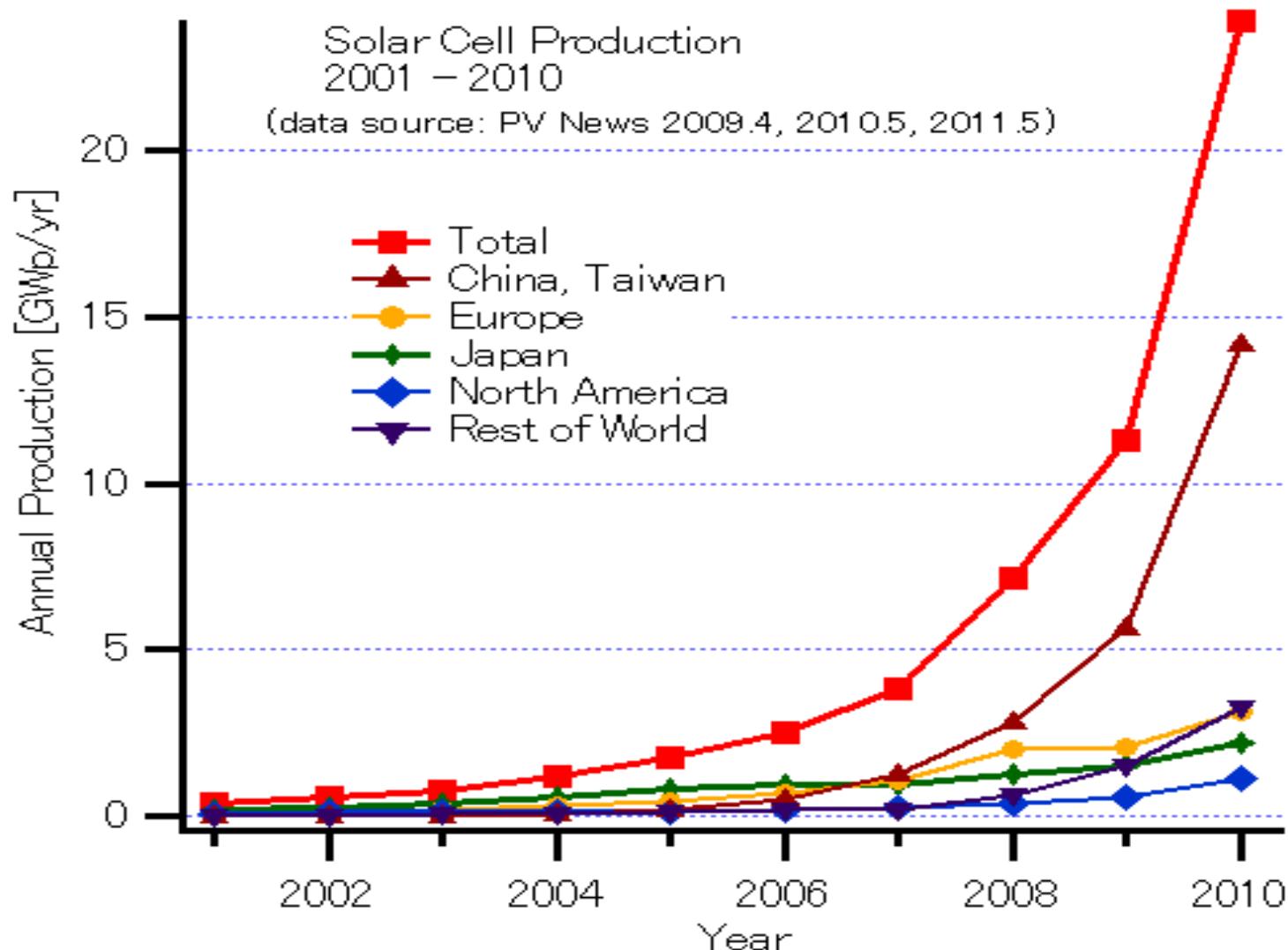
# Other Applications



# Other Applications

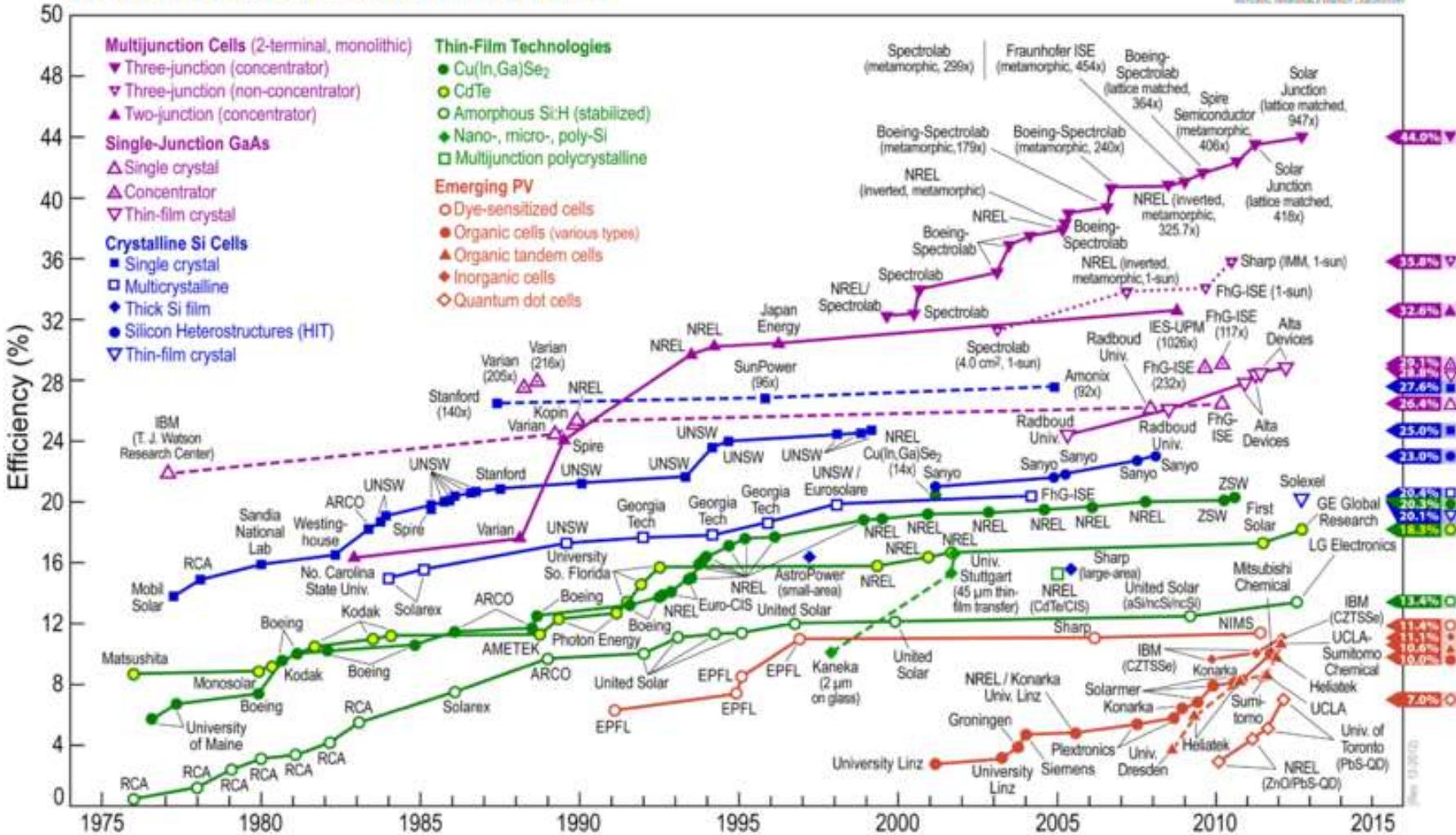


# Other Matters



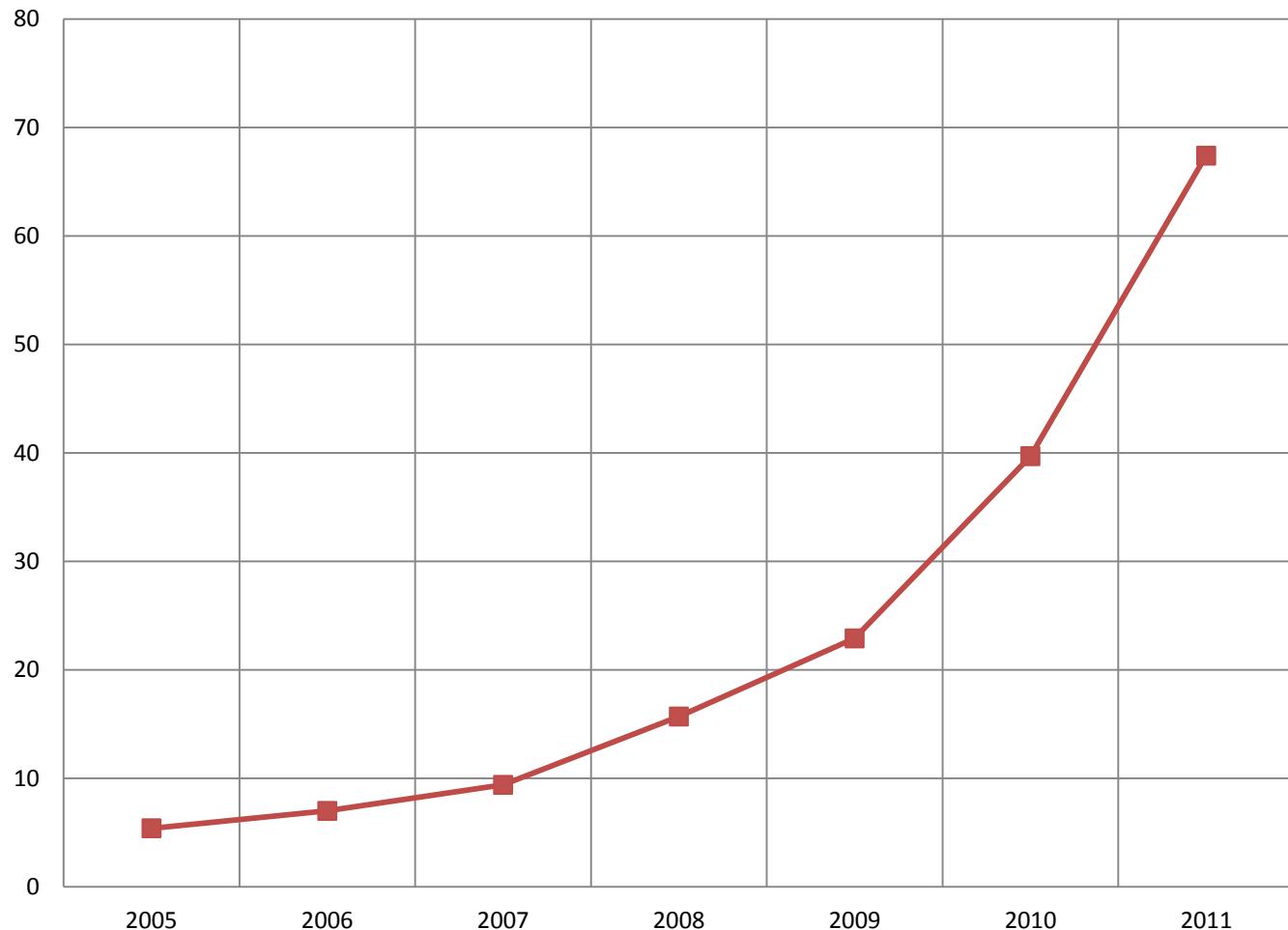
# Other Matters

## Best Research-Cell Efficiencies



# Other Matters

**Photovoltaic worldwide, GWp**



# End of Solar energy