



***First Summer School***  
***Part A: Line-focus Solar Thermal Technologies***  
*September 20-24, 2021*

**Lecture 1:**  
**An Introduction to Concentrating Solar Thermal (CST)**  
**Technologies and Applications**

Lecturer: Eduardo Zarza Moya

Plataforma Solar de Almería – CIEMAT

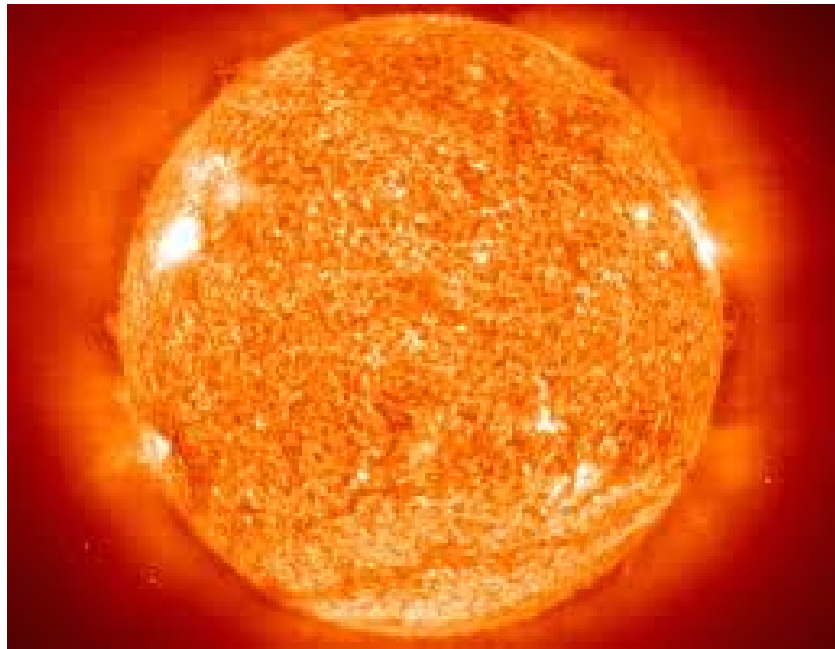
(e-mail: [eduardo.zarza@psa.es](mailto:eduardo.zarza@psa.es))

## Content

- Introduction
- Concentrating Solar Thermal Systems
- Concentrating Solar Thermal Technologies
- Summary

# The Sun and the Solar Radiation

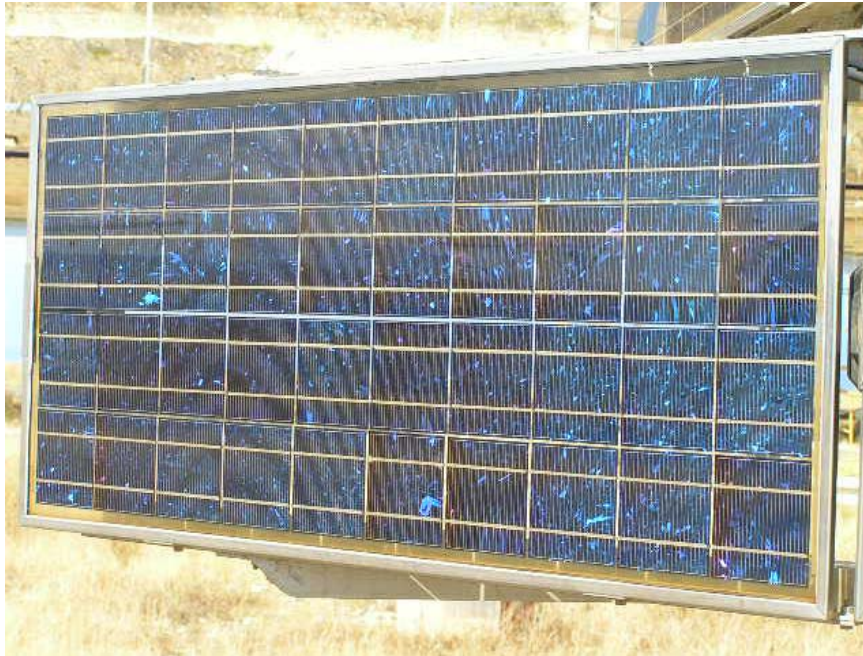
☀ Sun is a huge nuclear reactor ( $7 \times 10^5$  km radius) emitting a great amount of radiant energy ( $3,8 \times 10^{23}$  kW,  $5800^\circ\text{K}$ ), which can be easily converted into thermal energy



☀ The Earth intercepts only  $1,7 \times 10^{14}$  kW of solar radiation (10 days  $\cong$  known fossil fuels resources)

# Commercial Use of Solar Energy

- Photovoltaic solar Plants:
  - Static PV panels



View of a typical PV panel

# Commercial Use of Solar Energy

➤ Photovoltaic solar Plants:

- Static PV panels

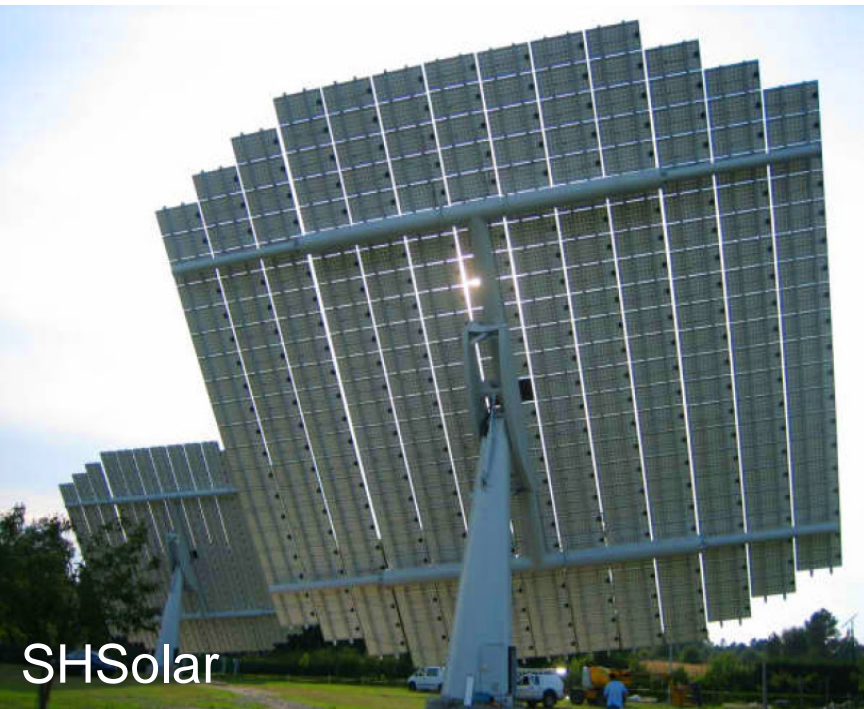


Vistas plantas fotovoltaicas de paneles estáticos

# Commercial Use of Solar Energy

## ➤ Photovoltaic solar Plants:

- Static PV panels
- PV panels with solar tracking



*Vistas de seguidor solar y planta fotovoltaicas con seguimiento solar*

# Commercial Use of Solar Energy

## ➤ Photovoltaic solar Plants:

- Static PV panels
- PV panels with solar tracking
- PV panels with solar concentration



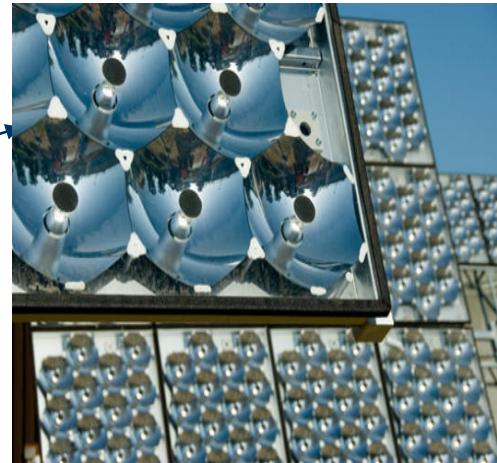
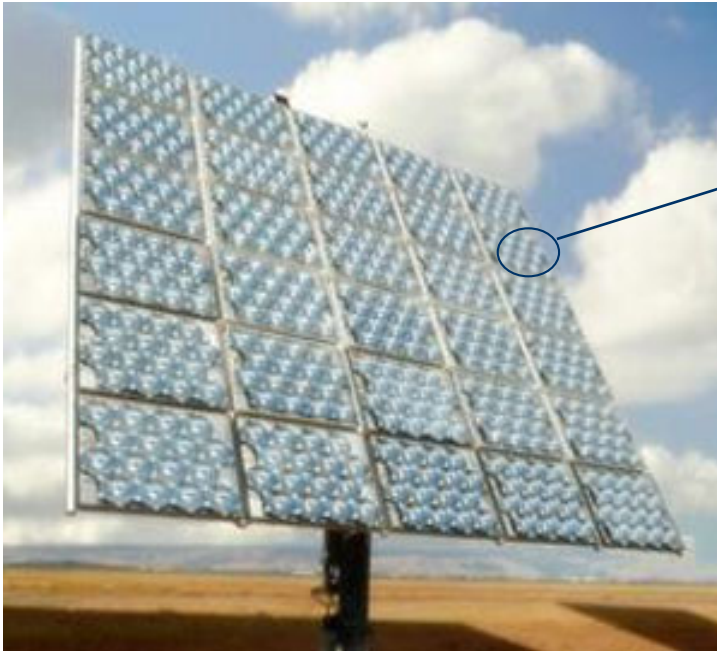
PV panels using flat mirrors for solar concentration



# Commercial Use of Solar Energy

## ➤ Photovoltaic solar Plants:

- Static PV panels
- PV panels with solar tracking
- PV panels with solar concentration



PV panels with curved mirrors  
for solar concentration



# Commercial Use of Solar Energy

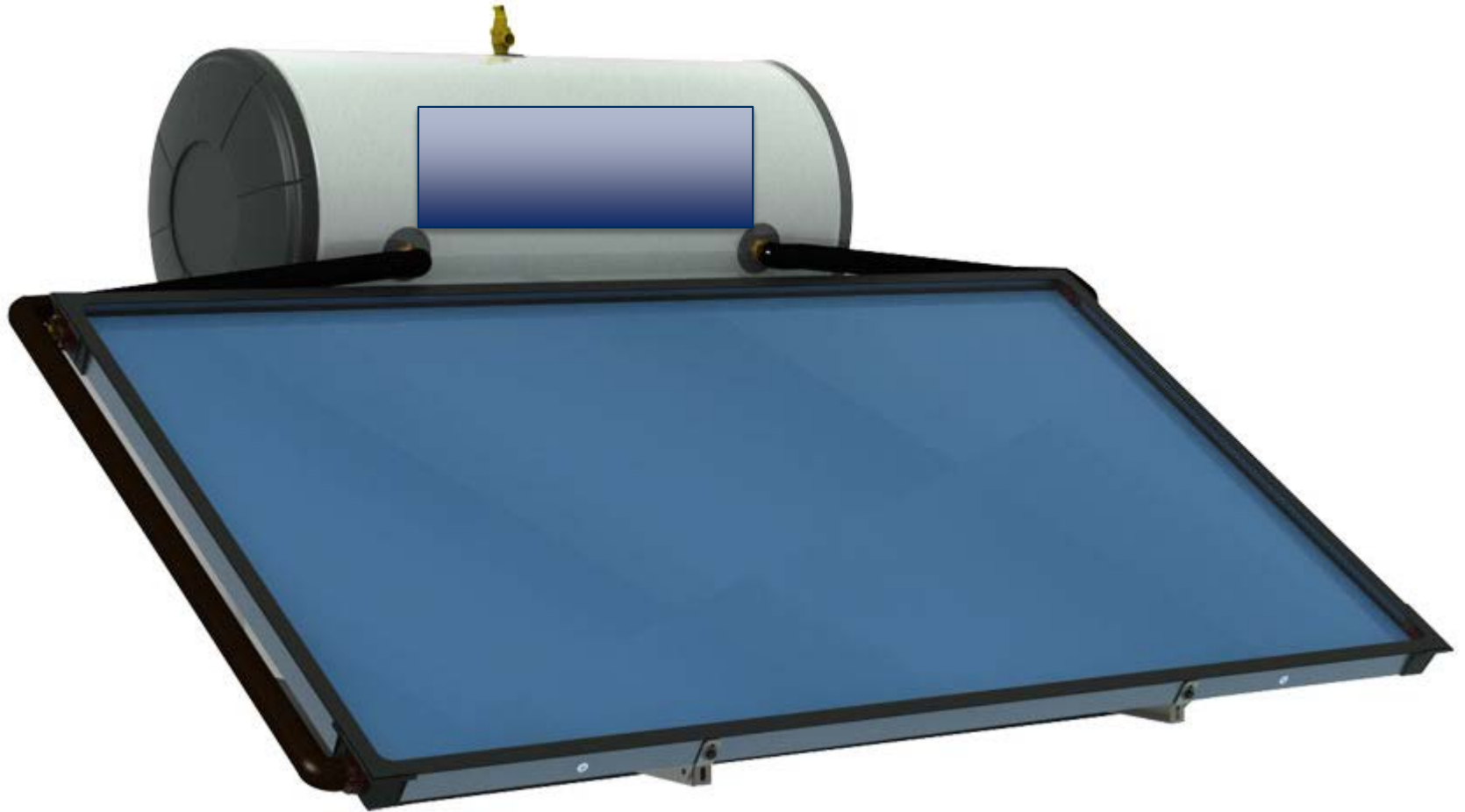
## ➤ Photovoltaic solar Plants:

- Static PV panels
- PV panels with solar tracking
- PV panels with solar concentration

## ➤ Solar Thermal Plants:

- Solar systems for low temperature (125°C)

# Commercial Use of Solar Energy



Domestic solar system for hot water

# Commercial Use of Solar Energy

## ➤ Photovoltaic solar Plants:

- Static PV panels
- PV panels with solar tracking
- PV panels with solar concentration

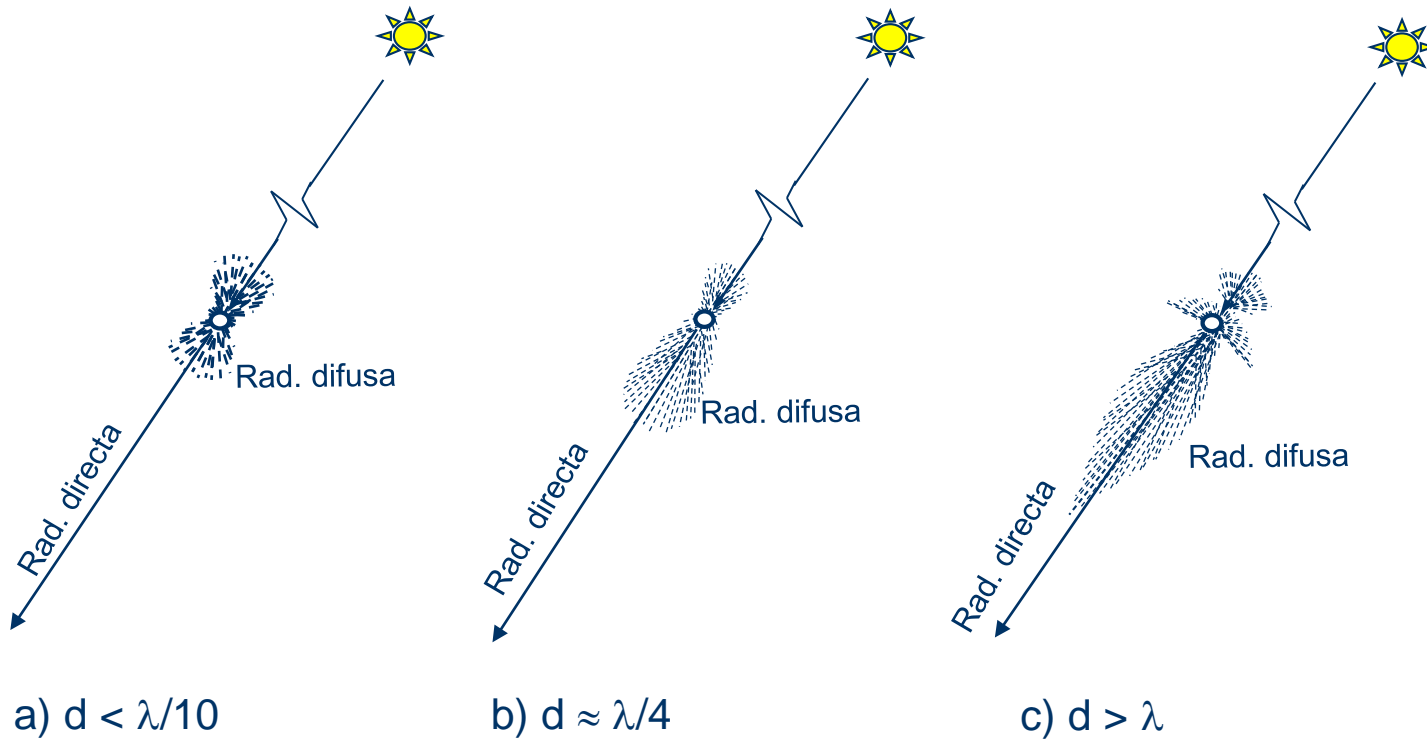
## ➤ Solar Thermal Plants:

- Solar systems for low temperature ( $125^{\circ}\text{C}$ )
- Solar systems for médium temperature ( $125^{\circ}\text{C} < T < 500^{\circ}\text{C}$ )
- Solar systems for high temperature ( $> 500^{\circ}\text{C}$ )

*Concentrating Solar Thermal Systems*

# The Solar Radiation and its concentration

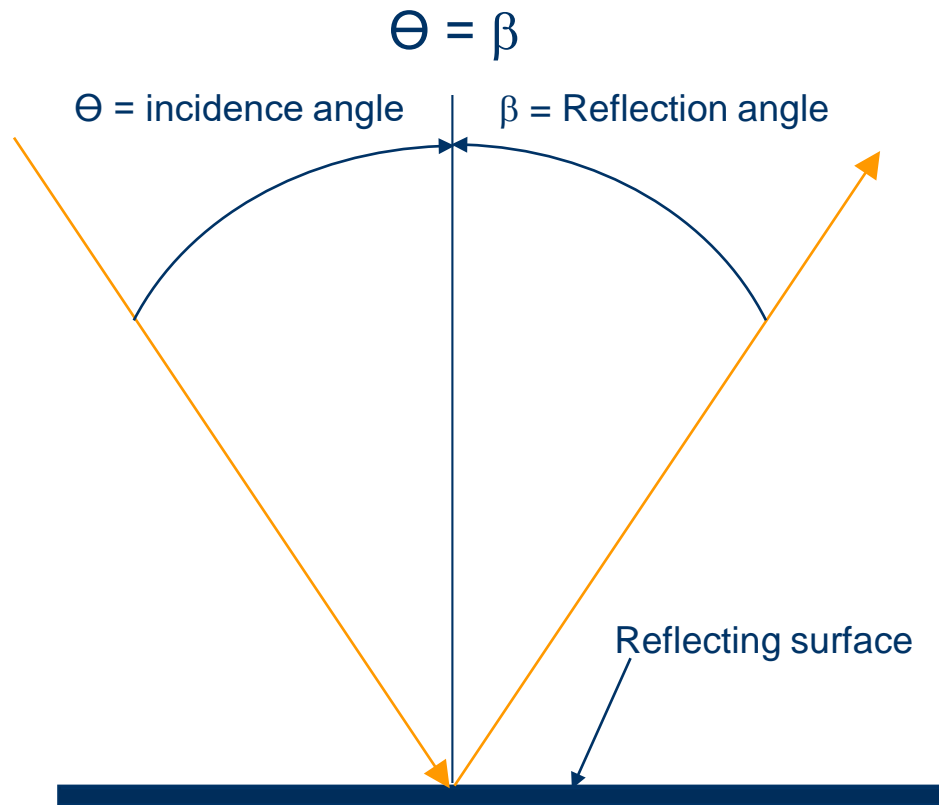
☀ Solar radiation at ground level has two components: *Direct Radiation* and *Diffuse Radiation*. The sum of direct and diffuse radiations onto a plane is called *Global Radiation*



☀ Only *Direct Solar Radiation* can be concentrated !!!, because solar concentrators are optical devices making use of the Specular Reflection Law

# The Solar Radiation and its concentration

## Law of Specular Reflection



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# Concentrating Solar Thermal Systems

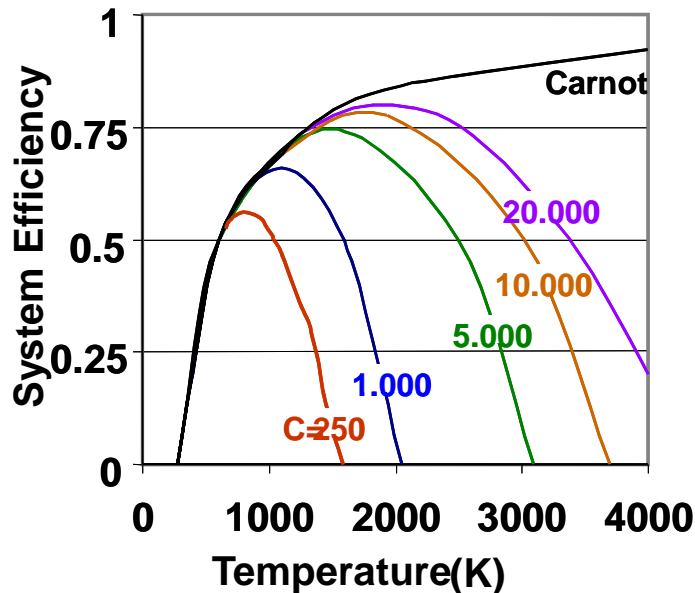
## ➤ What is a Concentrating Solar Thermal System ?

System concentrating the direct solar radiation to increase its flux density ( $\text{kW}/\text{m}^2$ ) and thus achieve higher temperatures when converting the solar radiation into heat (thermal energy).

## ➤ Solar Concentration: Why ?

Solar radiation suffers a significant attenuation in its way to the Earth (from  $63,2 \text{ MW}/\text{m}^2$  to  $1 \text{ kW}/\text{m}^2$ ) and it has to be concentrated to increase its low flux density at the Earth surface to achieve higher temperatures and efficiencies.

$$\eta = f(C, T)$$



Dependence of the *Efficiency* and the *Optimum Working Temperature* on the *Solar Radiation Concentration Factor, C*

# Concentrating Solar Thermal Systems

## ➤ What is a Concentrating Solar Thermal System ?

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## ➤ Theoretical and practical limits for solar concentration

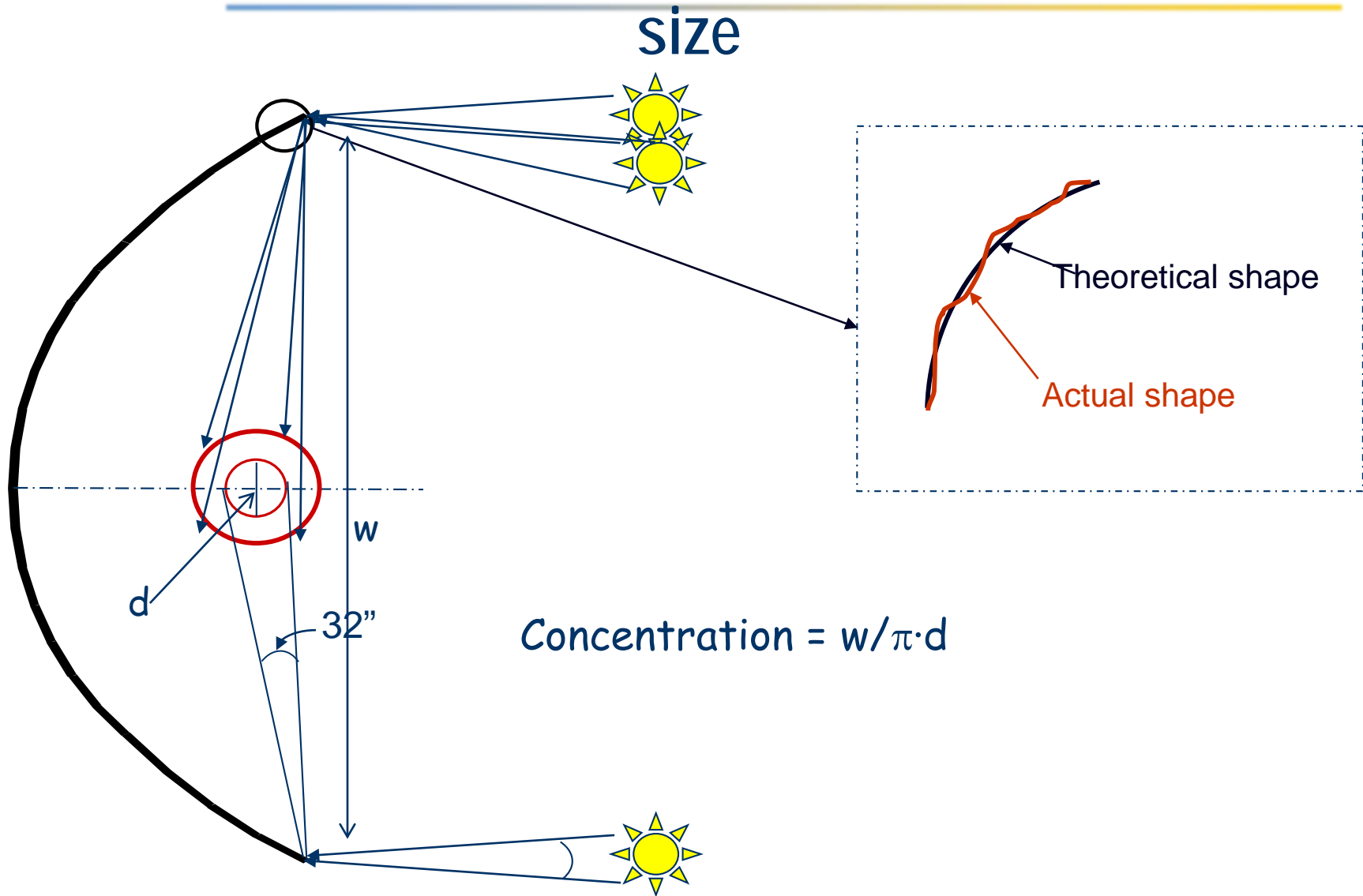
- Point focus concentrators: 46200 (theoretical); 5000 y 10000 (practical)
- Linear focus concentrators: 220, (theoretical); 20 – 80 (practical)

## ➤ Limiting factors for solar concentration

- a) The apparent size of solar sphere is  $32'$  as seen from the Earth
- b) Inaccuracies and optical/geometrical errors of solar concentrators

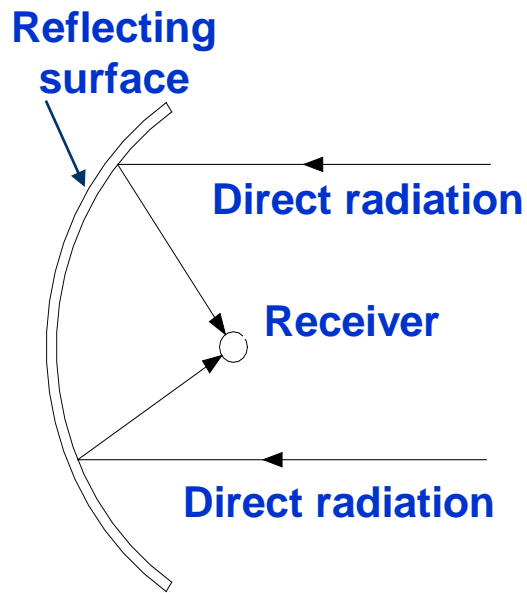


# Concentration limit due to errors and the Sun disk size



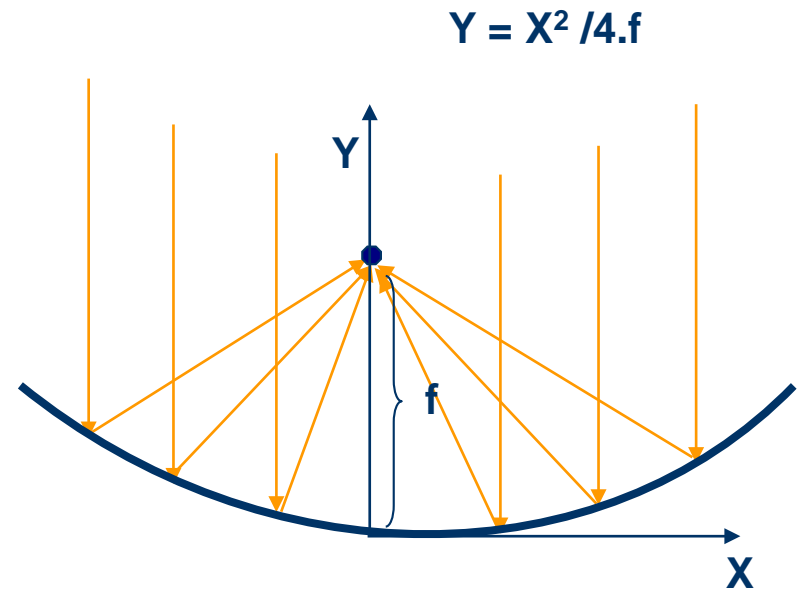
# Sistemas Solares Térmicos de Concentración

- Different ways to concentrate the direct solar radiation



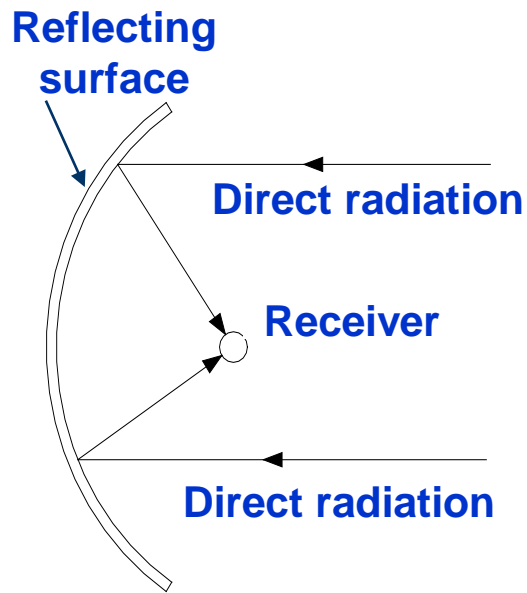
a) by Reflection

## The Parabolic concentrator

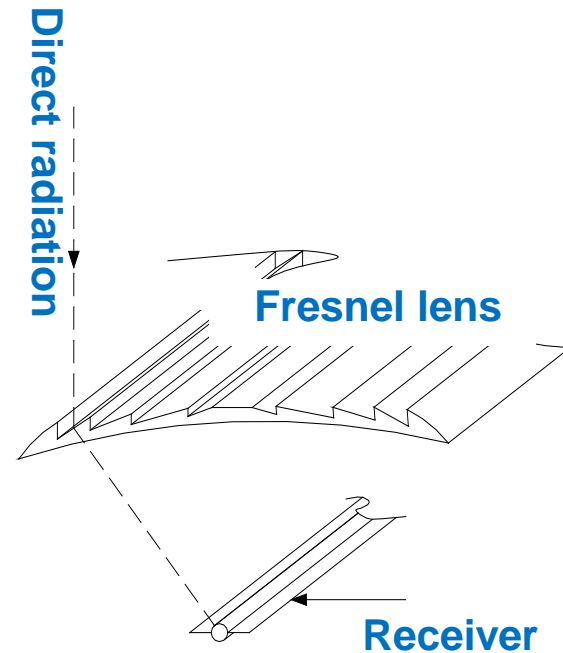


# Sistemas Solares Térmicos de Concentración

- Different ways to concentrate the direct solar radiation



a) by Reflection



b) by Refraction

# Concentrating Solar Thermal Systems

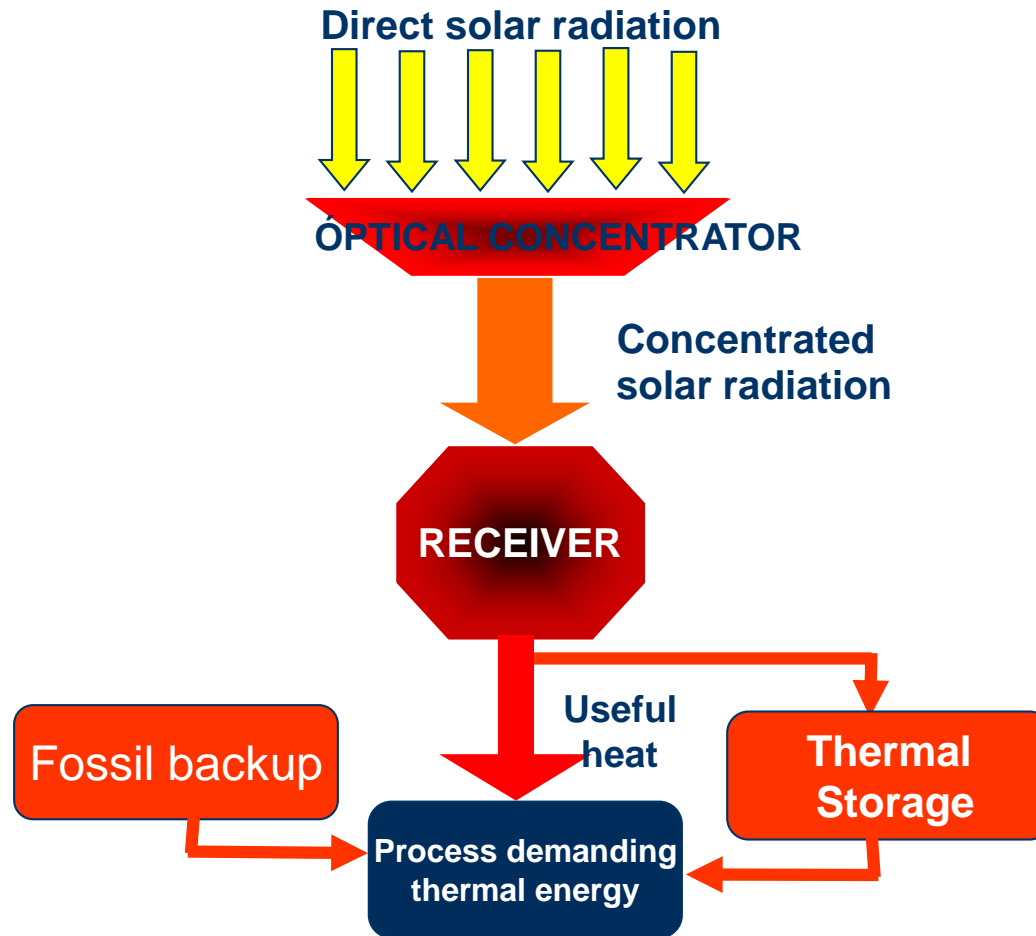
## Main applications for concentrating solar thermal systems

**Industrial process heat:** Concentrated solar radiation is converted into thermal energy, which is then used to feed industrial processes demanding heat within the range  $125^{\circ}\text{C}$  -  $2000^{\circ}\text{C}$

**Electricity Generation:** it is the most important commercial application at present, with more than 5700 MWe currently in operation. These solar systems are called *Solar Thermal Power Plants*, which are systems where direct solar radiation is concentrated and then converted into thermal energy at medium/high temperature ( $300^{\circ}\text{C}$  -  $600^{\circ}\text{C}$ ). This thermal energy is then used in a thermodynamic cycle to produce electricity. The thermodynamic cycles used are: Rankine, Brayton and ORC

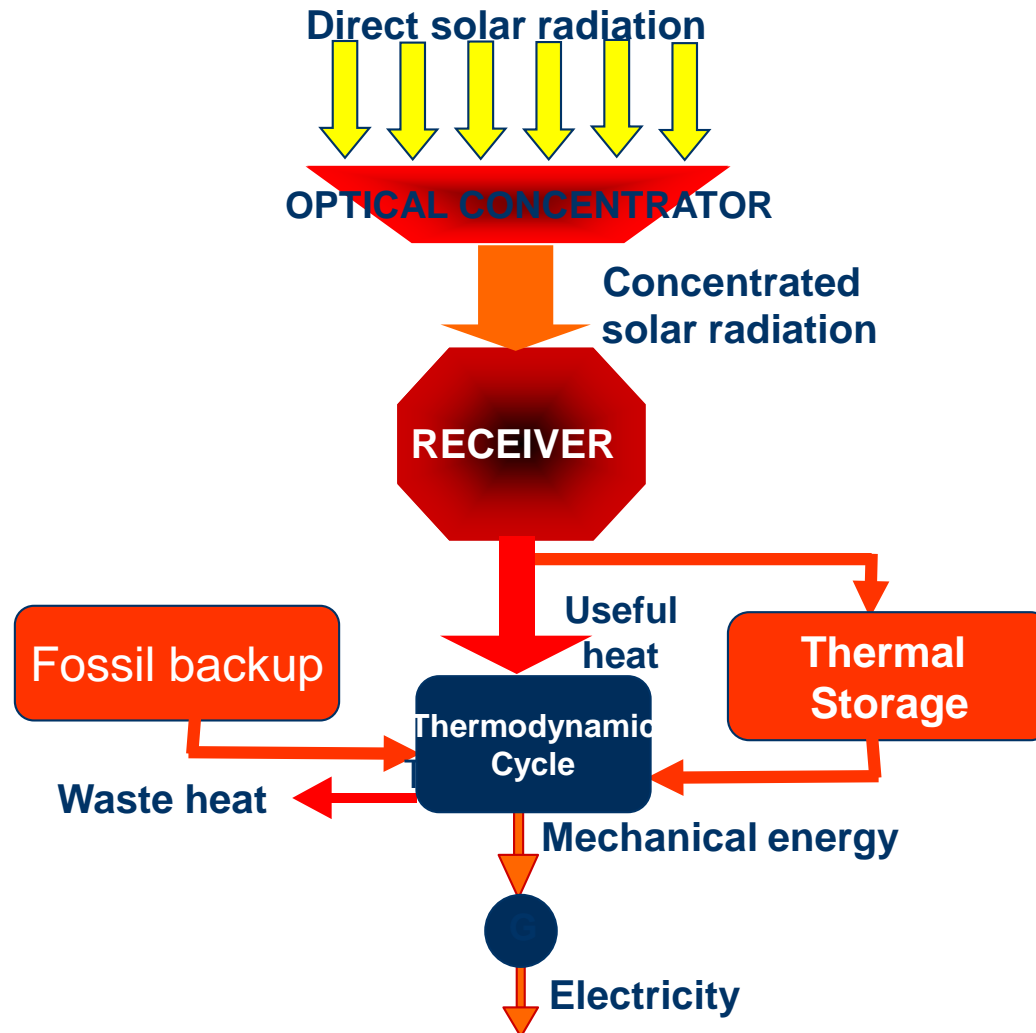
# Concentrating Solar Thermal Systems

## Simplified Scheme for Industrial Process Heat



# Concentrating Solar Thermal Systems

## Simplified Scheme of a Solar Thermal Power Plant



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# Concentrating Solar Thermal Technologies

There are four different concentrating solar thermal technologies:

➤ Parabolic Trough collectors

➤ Lineal Frenel Concentrators

Line-focus technologies

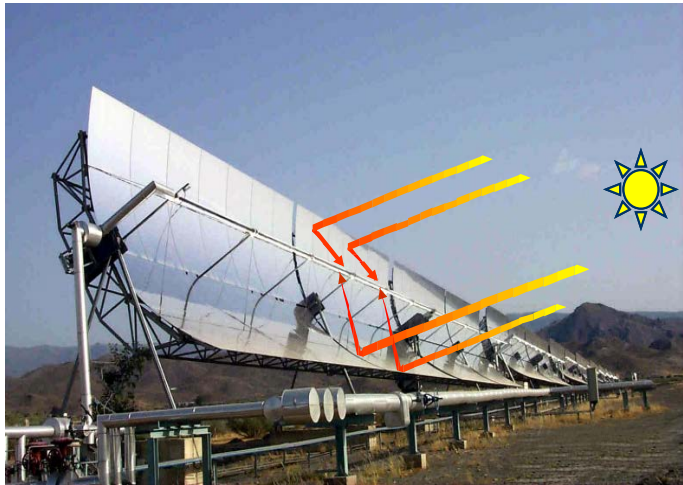
➤ Stirling Parabolic Dishes

➤ Central receiver technology

Point-focus technologies



# Plants with Parabolic-trough Collectors



Parabolic Trough collector

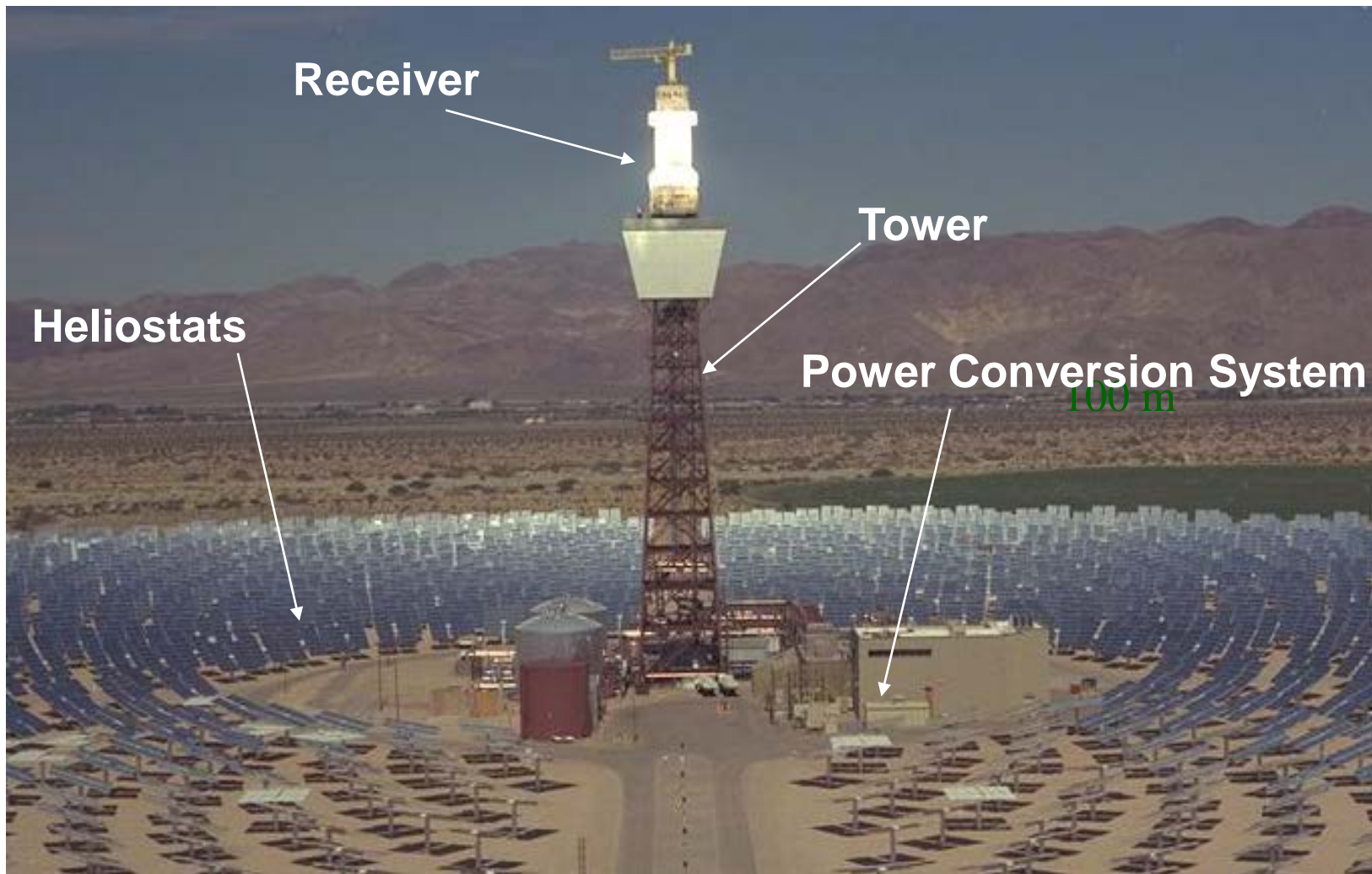


Solar Field

Power Block



# Central Receiver Plant

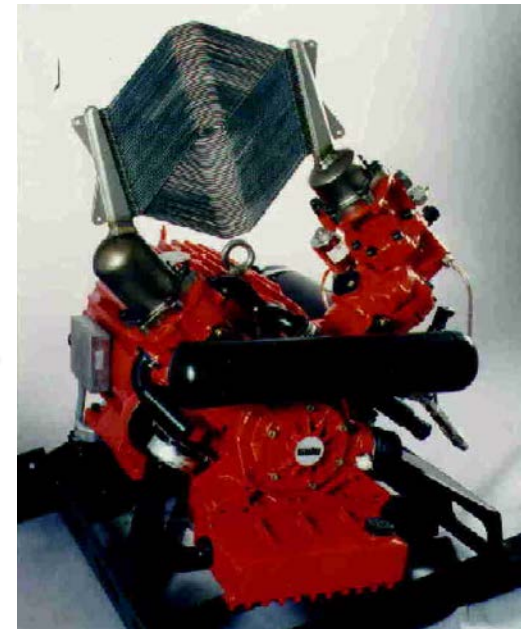
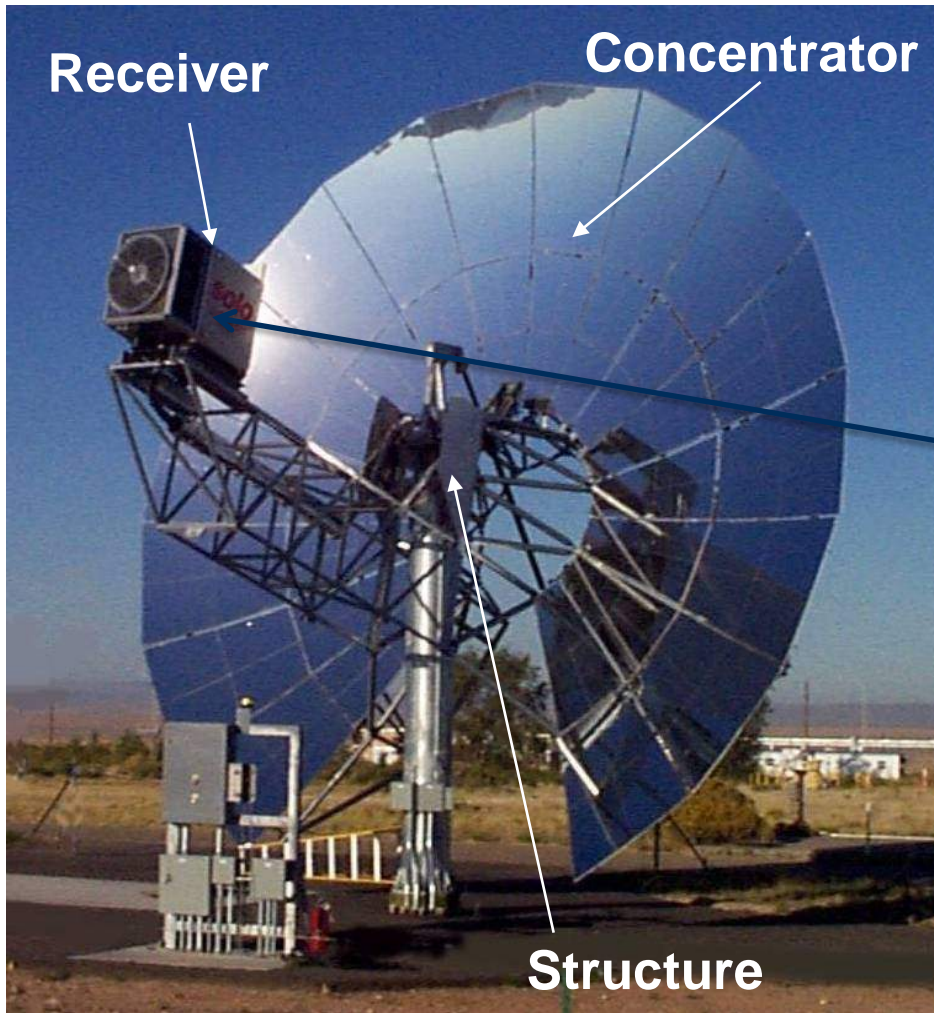


# Heliostats



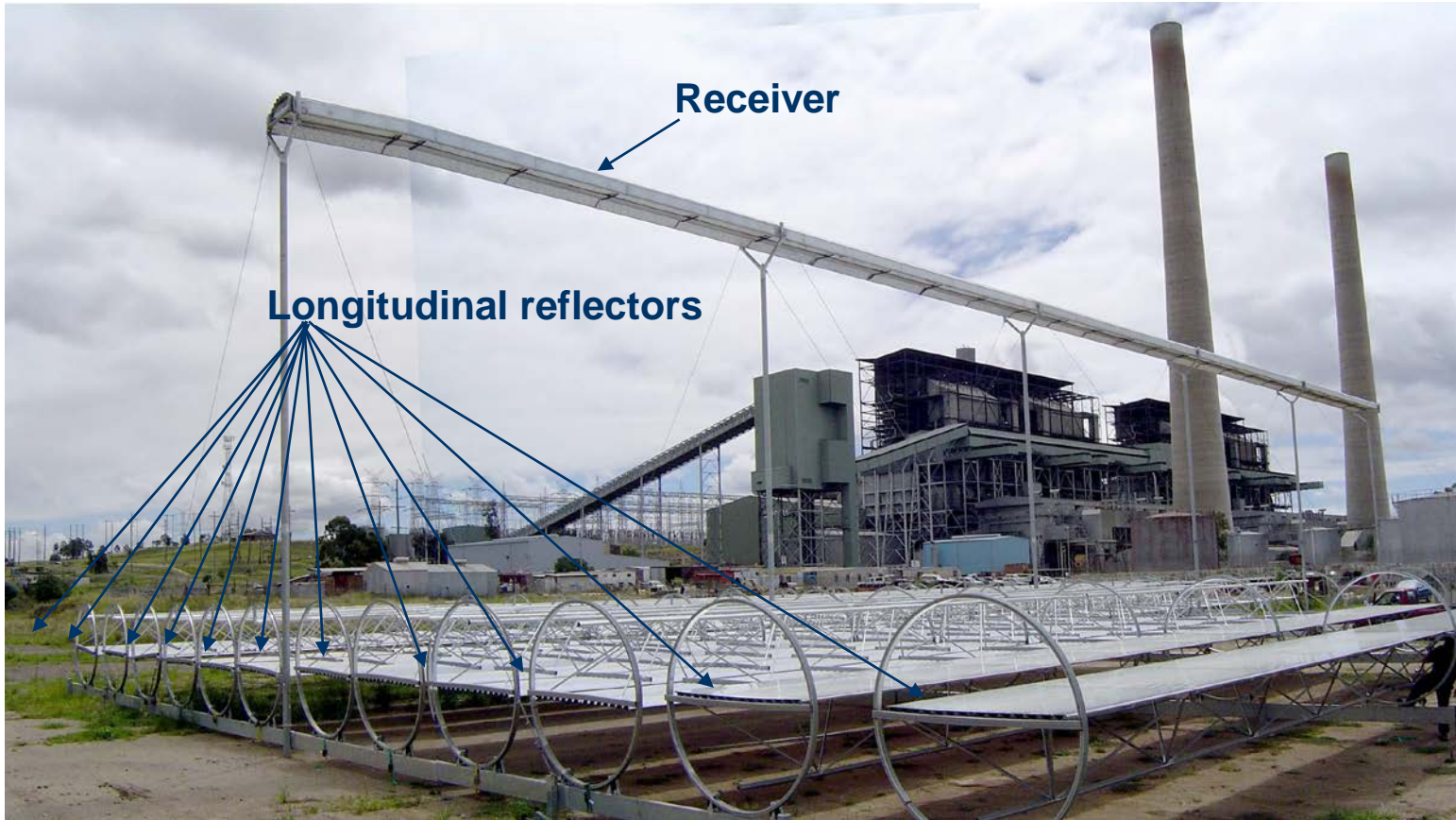
- | The reflecting surface is made of back-silvered glass mirrors
- | Specific cost nowadays is of about 115 €/m<sup>2</sup>
- | New designs will be soon available with a cost of less than 100 €/m<sup>2</sup>

# Stirling Parabolic Dish



Stirling engine

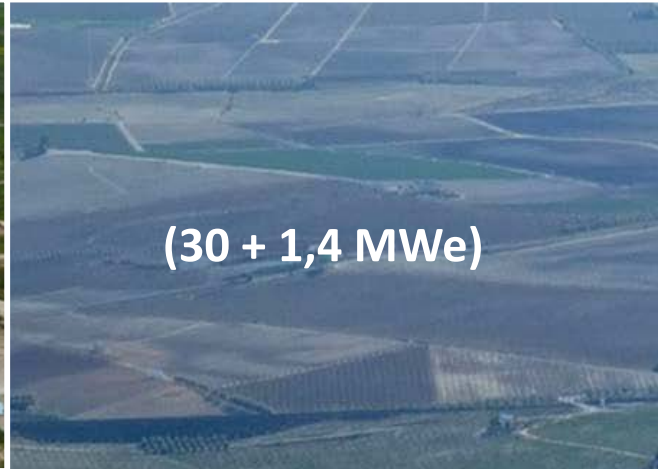
# Lineal Fresnel Concentrator



Lineal Fresnel Concentrator

# Plants with Lineal Fresnel Concentrators

## Puerto Herrado I&II (Murcia, Spain)



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# Basic Concepts and Commercial Potential of solar Thermal Power Plants

## Summary

- Concentrating solar thermal systems can achieve higher temperatures and efficiencies when converting solar radiation into thermal energy
- The two main applications of concentrating solar thermal systems are: *Industrial Process Heat (SHIP)* and *Solar Thermal Electricity (STE)*
- There are 4 concentrating solar thermal technologies: Central Receiver, Parabolic-trough Collectors, Linear Fresnel Concentrators and Parabolic Dishes.



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#### **Lecture 1:**

## **An Introduction to Concentrating Solar Thermal (CST) Technologies and Applications**

- **Thank you very much for your attention**
- **Questions?**

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