PH Pädagogische Hochschule Wien

SOLAR THERMIC APPLICATION

I.Hantschk/H.Fibi 2009

IP EFEU LLP/AT-230/22/08

Solar Thermic Application

ΓΔ Εκπαίδευση και πολιτισμός

GD Bildung und Kultur

Updated for LLP/AT-230/22/08

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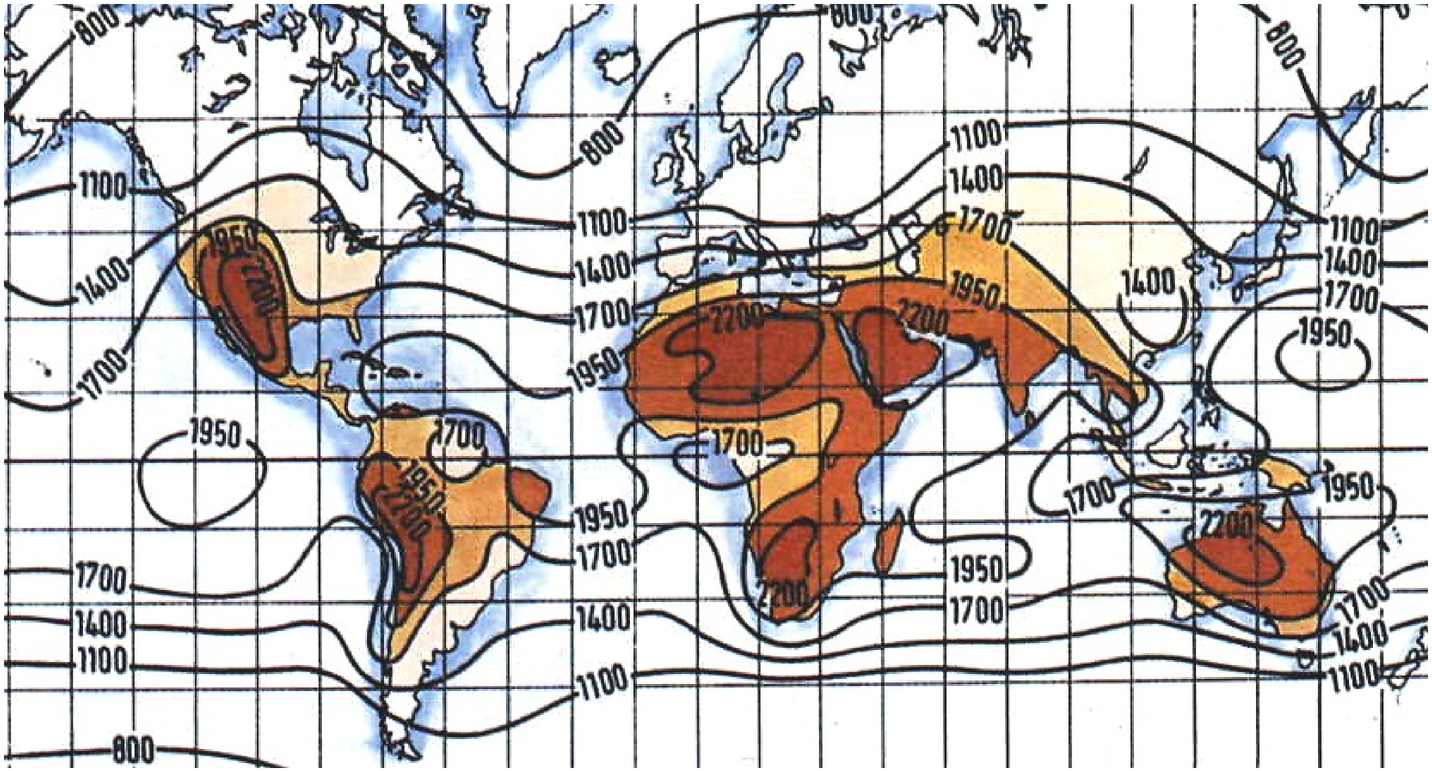
Irradiated Energy



AUSTRIA:

P = 1 kW/m² (maximum)

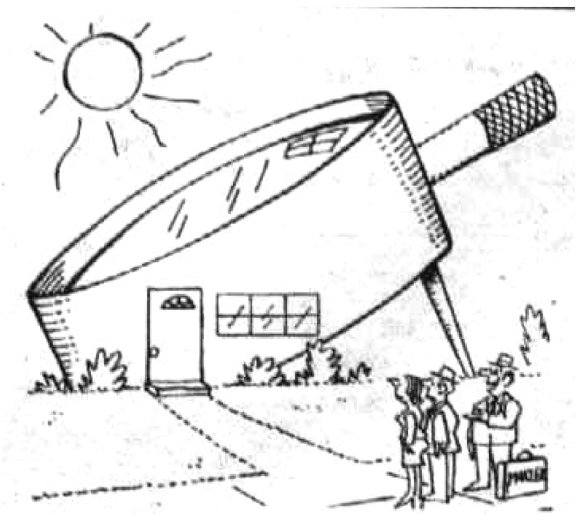
Irradiated Energy:

W = 1 000 kWh/m² per year

Energy irradiated from the Sun

By Absorption: the internal energy of the absorber increases

Thermal Energy



Source: Newspaper unknown

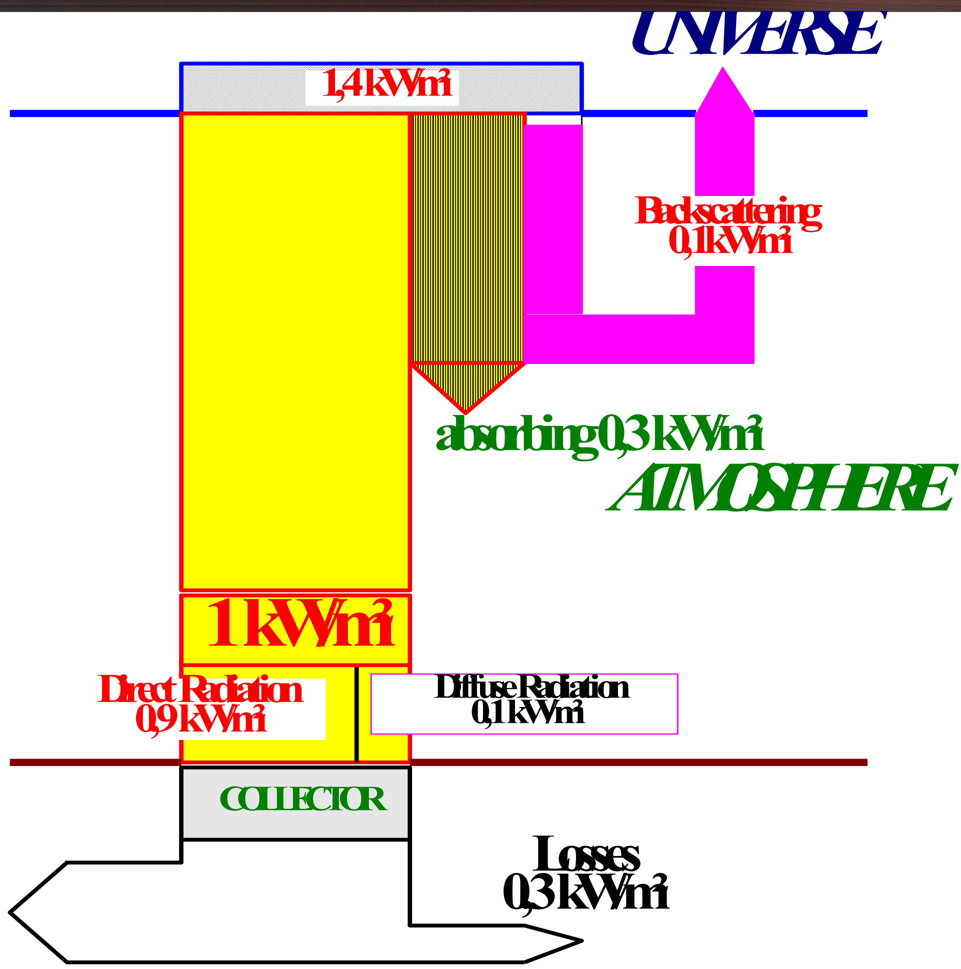
RANGE OF LOW TEMPERATURE:

Liquid (carrier of thermal energy) is warmed up.

RANGE OF HIGH TEMPERATURE:

radiation energy ➔ electric energy
melting metals
attainment of high temperaturs
process warmth

Solar Panel-Energetic Flux



max. power of the solar panel about 0,7 kW/m²

Efficiency about 40 %, the higher, the smaller the difference to the outside temperature and the higher the irradiated power.

History

1767:

Heat box made of glass: built by the Swiss man de Saussure (greenhouse-effect)

1866:

Principle of concentrating radiation by concave mirror - concentrating collectors invented by Augustin Mouchot, France

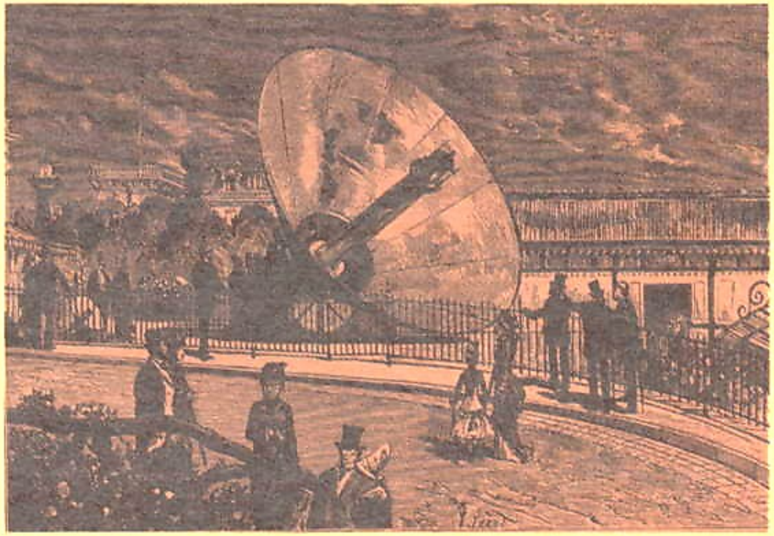
water → vapour → steam engine

1866:

First Solar - Steam - Engine

1878:

World Fair in Paris: the second model was presented. Belonging to economic aspects the france government considered this model as not sufficient.



Solarer Dampferzeuger von A. Mouchot auf der Pariser Weltausstellung 1878.

Well known just for a long time....

„Schrebergartensystem”:

„Barrel on the Roof”

Water is warmed up by solar irradiance in barrels standing on the roofs.
Application especially as showers.

„Tube in the Sun”

Tubes and pipes exposed to solar radiation contain hot water.

Tube System used in Open Air Swimming-Pools:

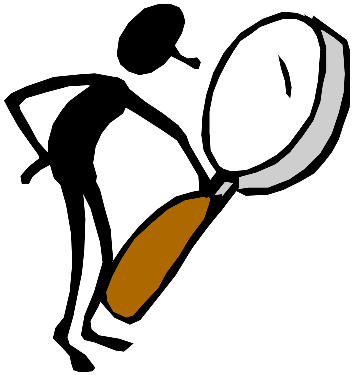
Tube-System in form of plastic mats.
Only for the Low-Temperature-Range:

18 - 21 ^{o}C
$\eta \rightarrow$ 40%

No Glass-Cover, because otherwise the missing infrared let h fall to zero.

Greenhouse-Effect

Low Outside-Temperature and high difference of temperature:
Solar Panels don t work !

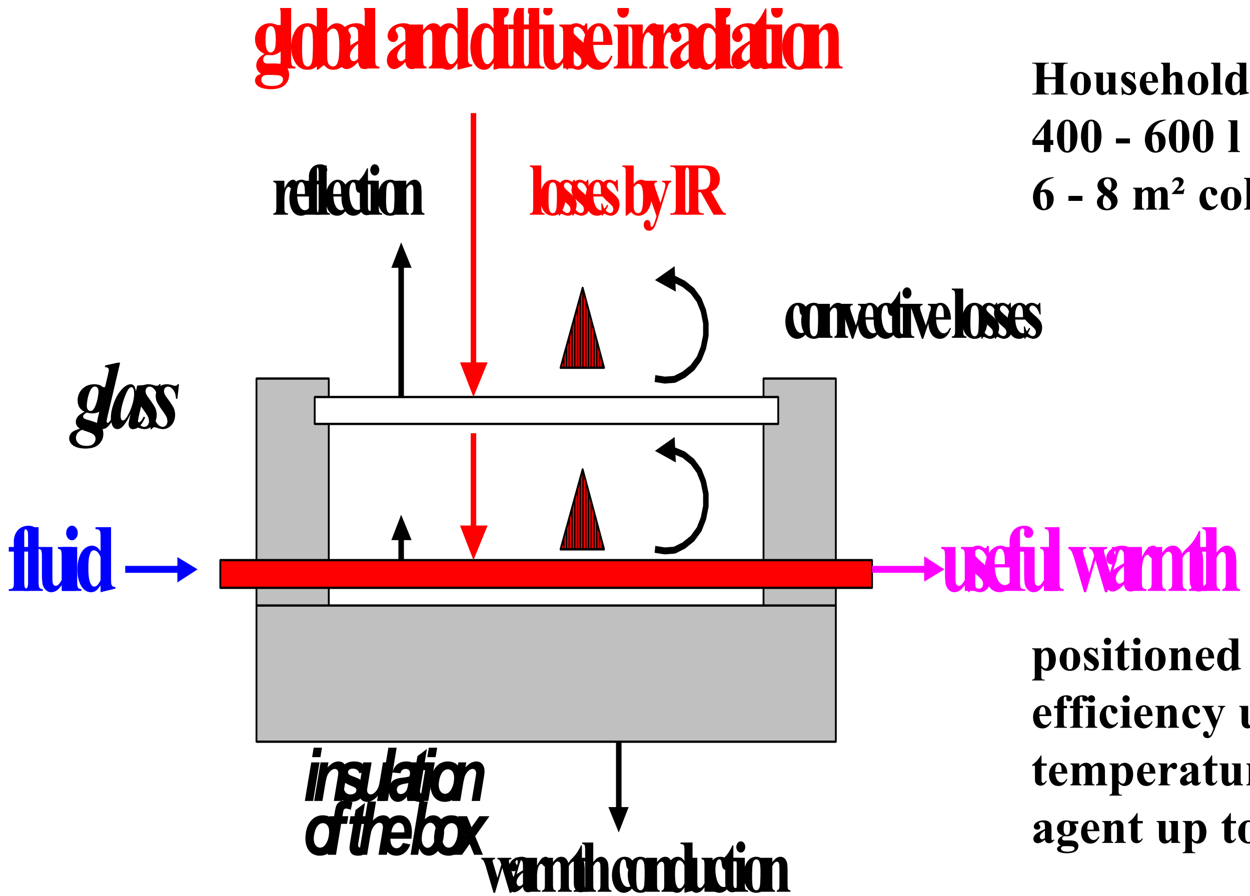


$\eta \rightarrow 0$ because of:

1. Radiation of the absorber
2. Losses by convection

Therefore:
Covering of the absorber by a glass-layer, a plastic foil...

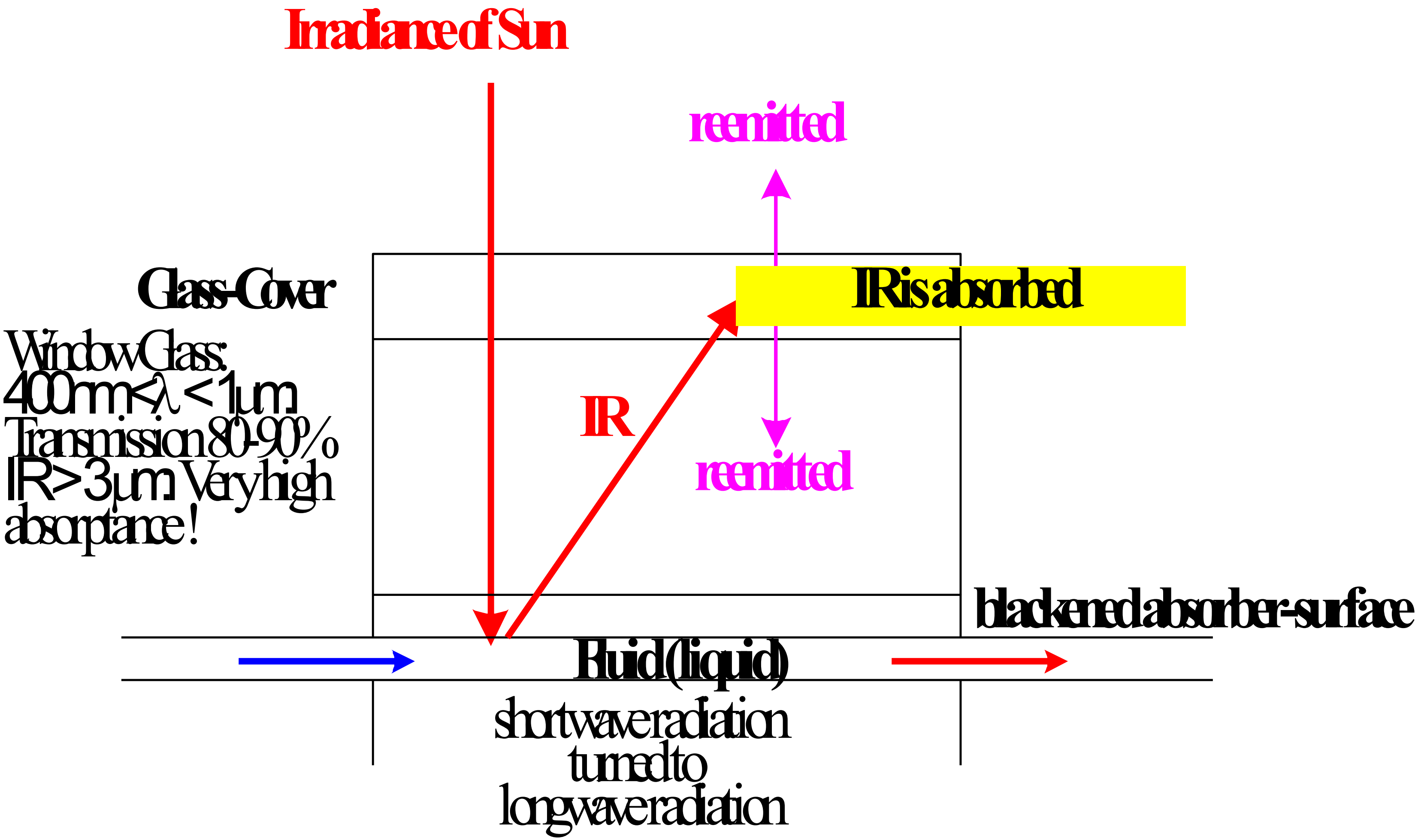
Use the Greenhouse-Effect !
Infrared (IR) is reemitted by the covering glass-layer.
Reduction of losses of warmth by convection (esp. vacuum)



Household / 4 persons:
400 - 600 l - storage
6 - 8 m^2 collector s area

positioned on the roof (inclined) efficiency up to 40%possible, temperatures to be reached in the agent up to 300 ^{o}C.

Water temperature from 40 ^{o}C to 80 ^{o}C available


Irradiance of Sun
reemitted
Glass-Cover
Window Glass:
400nm<λ<1µm
Transmission 80-90%
IR>3µm Very high
absorptance!
IR is absorbed
IR
reemitted
blackened absorber-surface
Fluid (liquid)
short wave radiation
turned to
long wave radiation

Flat Panel

SOLAR PANEL:

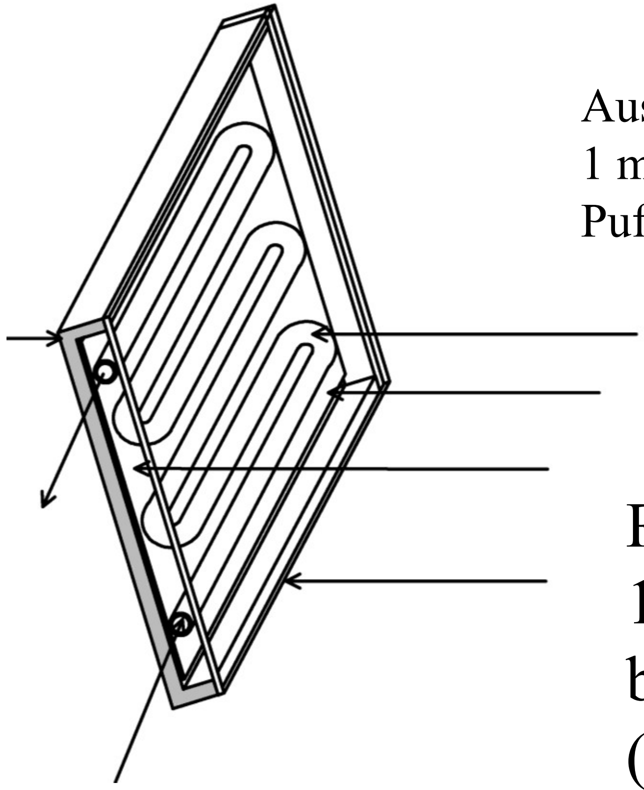
Low-Temperature-Range - Provision of Warm Water

Absorber:

physically black surface- transformer to thermic energy with η about 35 - 40%

Mostly out of order !

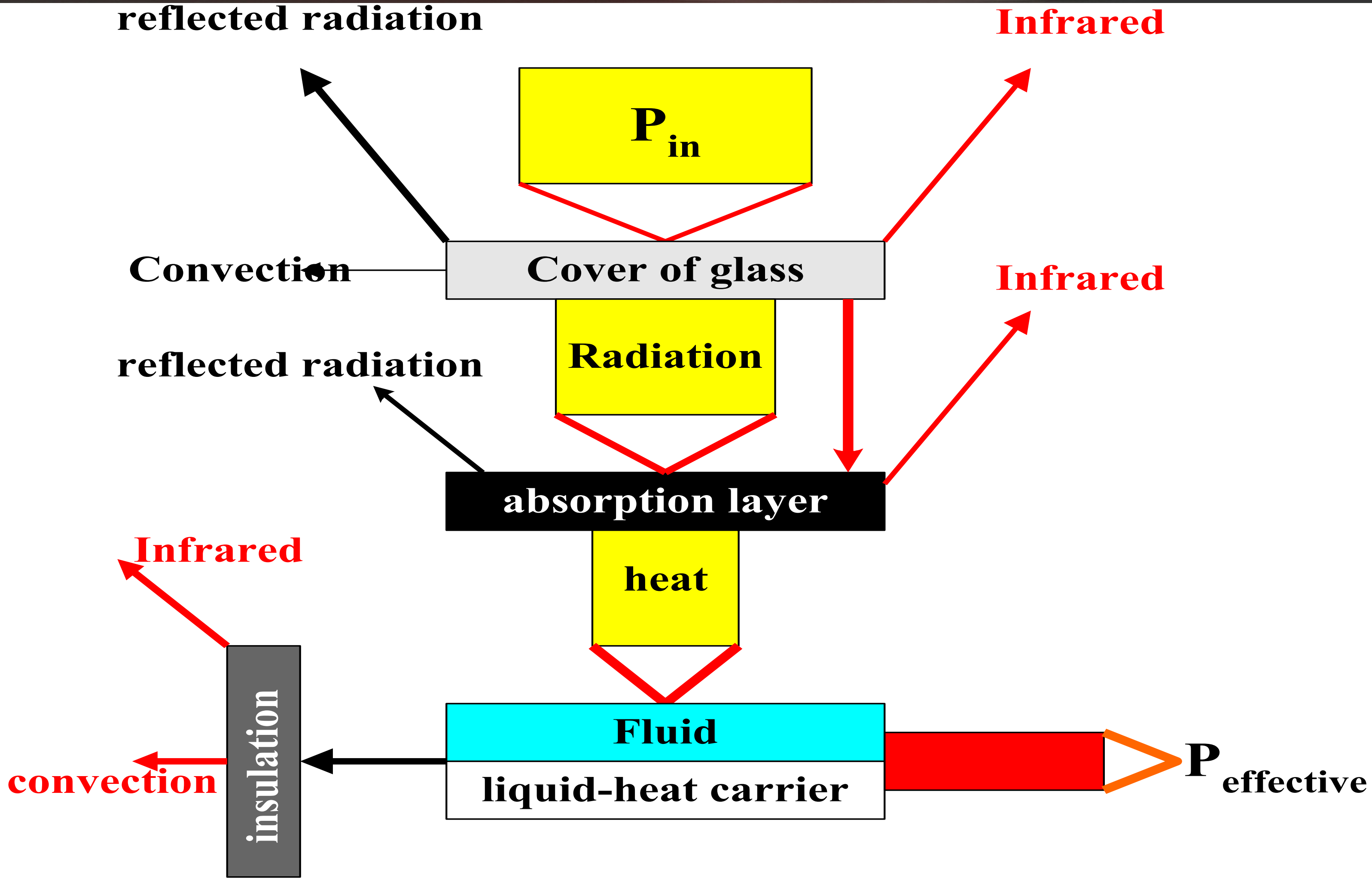
Flat Panel



Auslegungsregeln:
1 m² Kollektor pro 70 l bei 60 °C pro Tag
Pufferspeicher: 50 l pro m² (70 l bei Schwachlasttagen)

Rules for mounting:
1 m² Collector Aerea for 70 l at 60 °C a day
buffer (storage): 50 l per m²
(70 l with respect to days of low irradiance)

Efficiency


reflected radiation
Infrared
P_{in}
Convection
Cover of glass
Infrared
Radiation
reflected radiation
absorption layer
Infrared
heat
Fluid
convection
insulation
liquid-heat carrier
$P_{effective}$

Efficiency

$$\frac{dQ}{dt} = \alpha \cdot \tau \cdot P_{in} - k \cdot (\delta_{fluid} - \delta_{air})$$

power of the
solar panel
in W/m²

temperature of the air

average temperature of the fluid

absorptance of
the absorber

k -value in W/m².K

rate of transmission of the cover

irradiated power
in W/m²

$$\frac{dW_{effective}}{dW_{irradiated}} = \frac{P_{effective}}{P_{irradiated}} \quad \text{with respec}$$

$$P_{irradiated} = A \cdot S$$

$$A \ldots \text{surface of the panel in } m^2$$

$$S \ldots \text{irradiated power in } kW/m^2$$

$$S_{\max} = \mathbf{1370}\, W/m^2$$

$$(S_{\max} = \mathbf{1}\, kW/m^2)$$

$$P_{effective} = P_{irradiated} - P_{losses}$$

$$P_{losses} = P_{optical} - P_{thermal}$$

Efiiciency

$$P_{absorbed} = \alpha_{opt} \,.\, \tau_{opt} \,.\, P_{input}$$

$$P_{absorbed} = \alpha_{opt} \,.\, \tau_{opt} \,.\, A \,.\, S$$

absorptance transmissivity

$$P_{opt} = P_{irradiated} - P_{absorbed}$$

$$P_{therm} = k_T \,.\, dT \,.\, A$$

thermal conductivity in W/m².K, is a function of T_{Coll}

$$P_{effective} = \alpha.\tau.A.S - k_T.dT.A$$

$$P_{irradiated} = A.S$$

$$\eta = \frac{\alpha \cdot \tau \cdot A \cdot S - k_T \cdot A \cdot dT}{A \cdot S}$$

$$\eta = \alpha \cdot \tau - k_T \cdot \frac{dT}{S}$$

Efficieny

$$\eta = \alpha \cdot \tau - k_T \cdot \frac{d' |}{S}$$

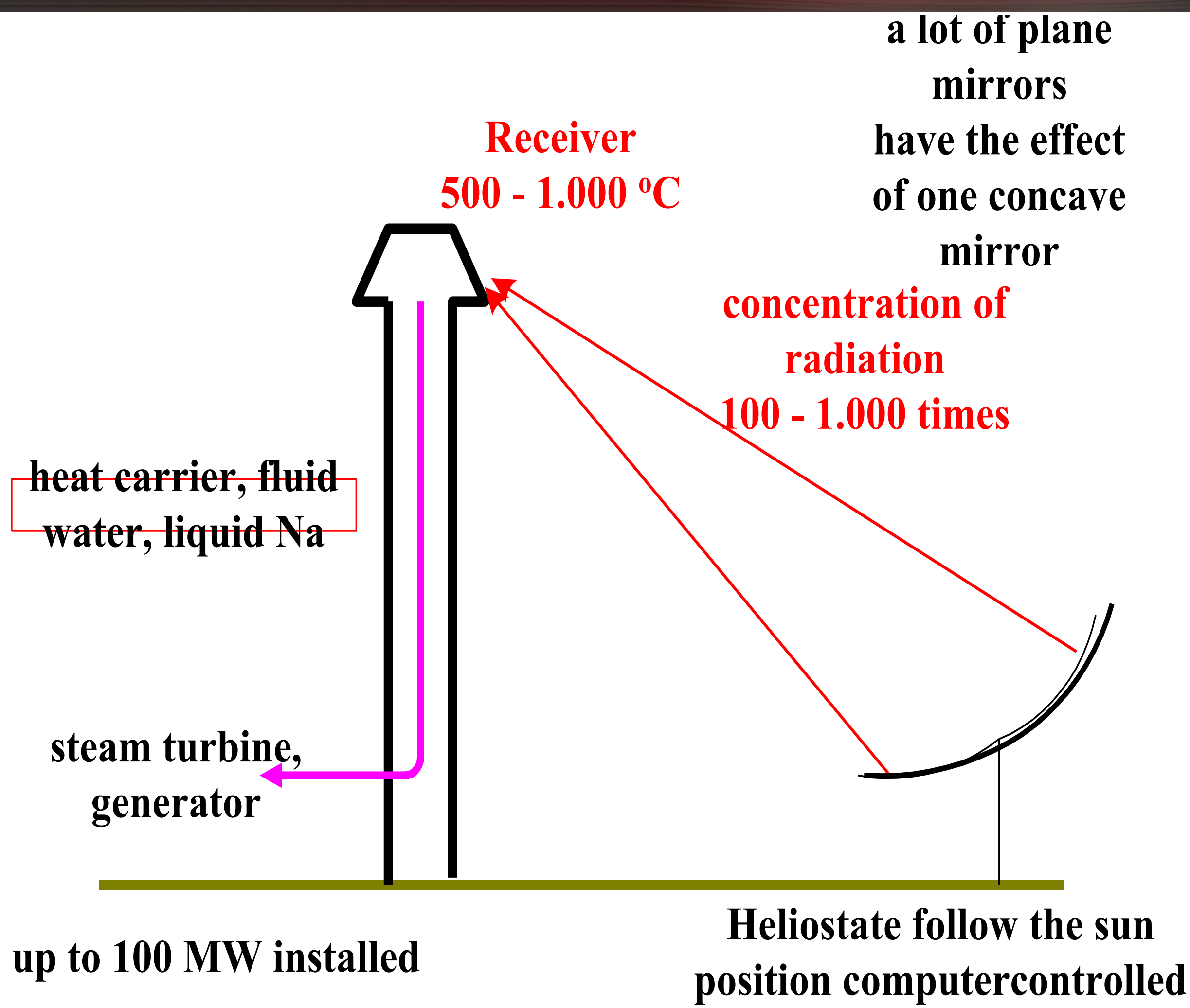
constant optical distribution variable thermal distribution

η_{max}, **if only a little difference of temperature is necessary for gaining effective warmth**

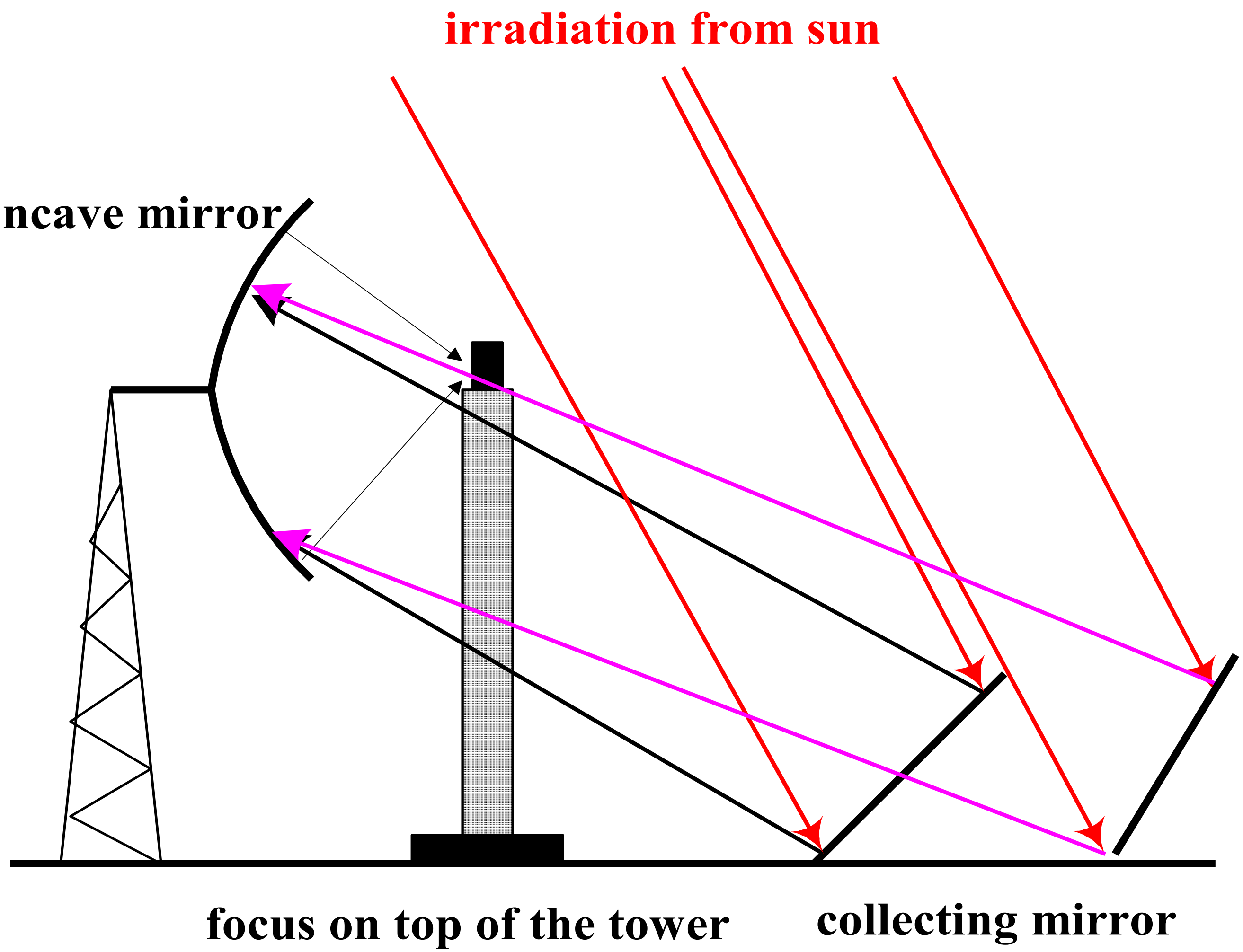
Data:

single-glass-layer k = 7 W/m².K, α.τ = 0,85
double-glass-layer k = 3,2 W/m².K, α.τ = 0,73
vacuum-insulated k = 2,4 W/m².K, α.τ = 0,86.

Tower with Heliostates



Tower with Heliostates



Tower Power Plant

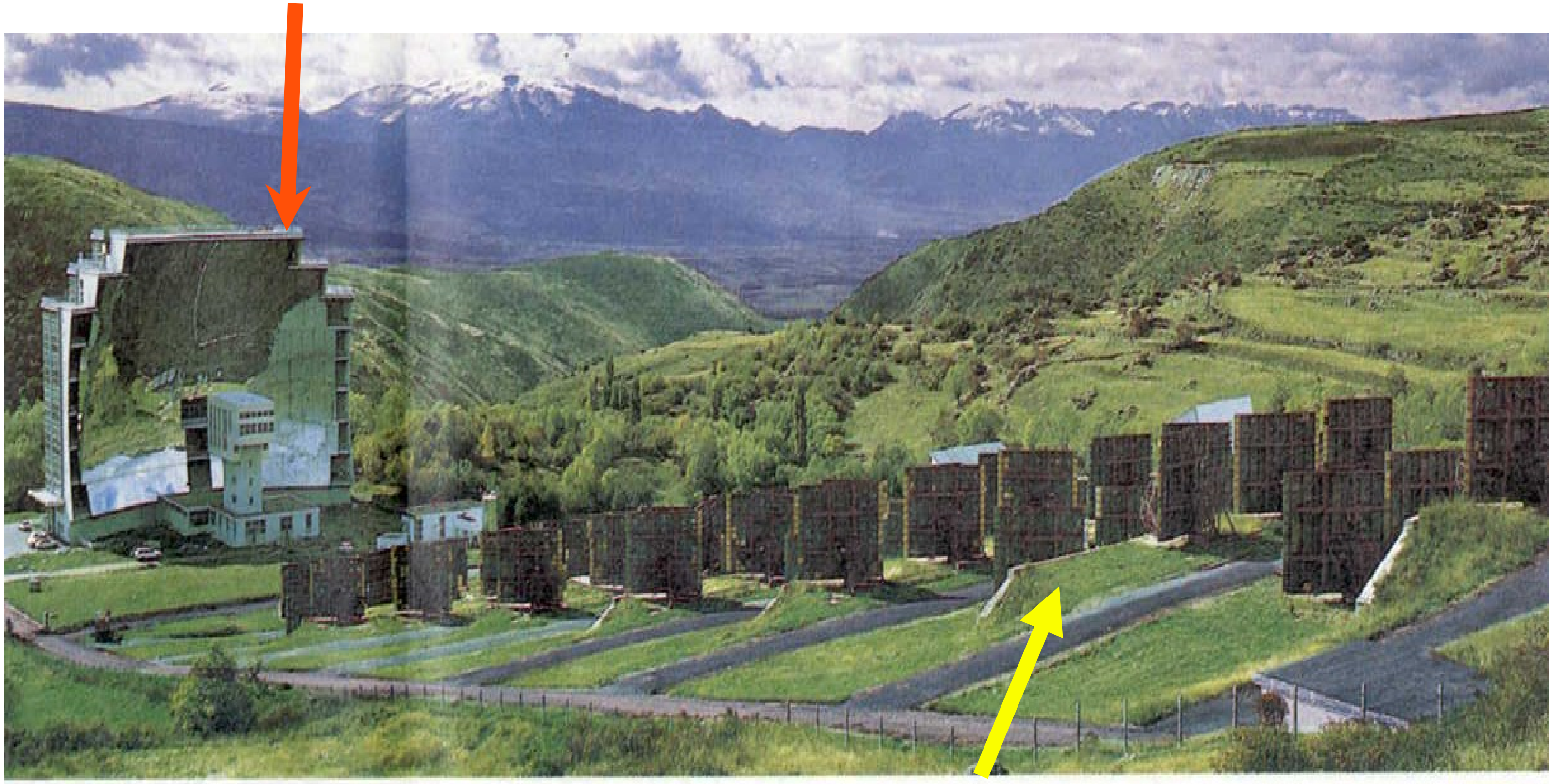
Almeria, Spain P = 1 MW resp. 0,5 MW

Almeria

A row of plane mirrors concentrate sun s energy to a little focal spot in the tower.
About 1 000 ^{o}C available.
Cooling agent:
Air, salt melt, water, vapour.

Odeillo

The concave mirror concentrates the radiation to the focal spot on top of the tower.



Plane mirrors reflect the sun s radiation to the concave mirror.

Sun´s Oven of Odeillo - France Pyrenees

PH Wien

63 collecting mirrors

concave mirror: A = 2 000 m²

consists of 950 single mirrors, focal width f = 18 m

optical concentration 3780 : 1

because of scattering and absorption: 2000 : 1

temperature in the focal spot of the tower: T = 4 000 °C

Power installed: P = 1 Megawatt

EURELIOS
Ätna/Sizilien

- 112 Heliostates, each of them 23 m²;
- 70 mirrors, each of them 51,8 m²
- tower:
  height: h = 55 m
- concentration
  to d = 4,5 m
- optical ratio of concentration:
  440:1

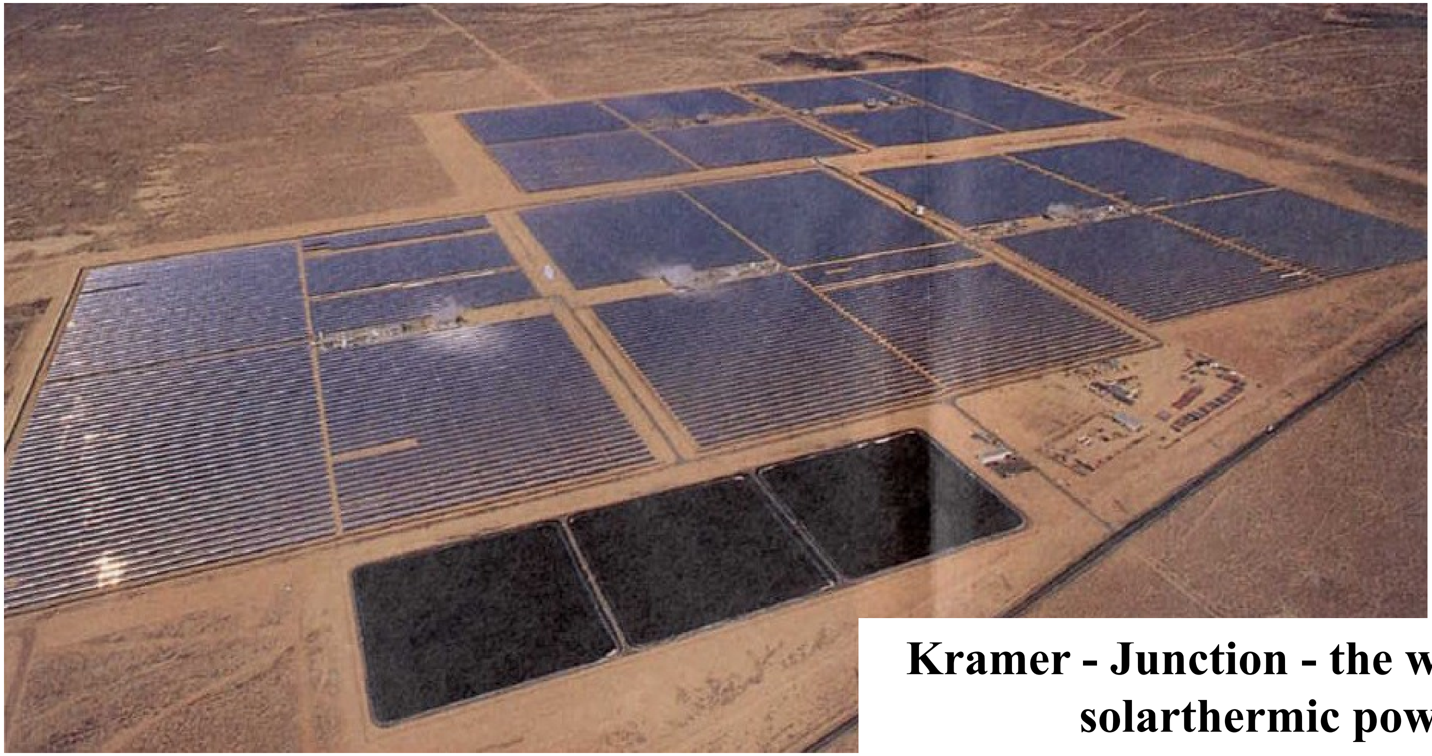
- P_{therm} = 4,8 MW
- Vapour s temperature:
  500 °C
- If 1 kW/m² irradiated:
  η = 16 %
- Aerial gain: 6,2 m²/kW
  To avoid shadowing:
  30 m²/kW

Other Ones (example)

- **Phöbos, Almeria, Spain:**
  100 mirrors, concentration onto receiver with d = 3,5 m
  air is heated up to 700 ^{o}C.
  Installed power P = 2,5 MW. Vapour Creation.
  Ceramic heat reservoir compensates fluctuations in the primary circuit.
- **Solar One, California, USA:**
  1818 Heliostaten, 39 m² each one
  Installed power: P = 10 MW
- **New Mexico, USA:**
  16 kW installed.
- **Rehovot, Israel:**
  16 kW installed.
- **Taschkent, Russia:**
  1 MW installed.

Turmkraftwerk Daggett, USA

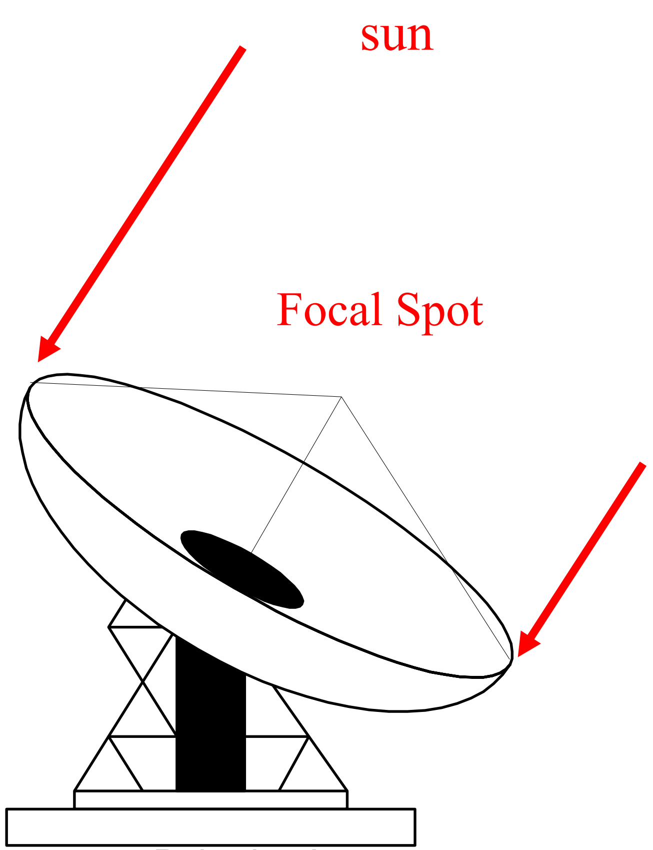
Sun s Farm



Kramer - Junction - the worldwide largest solarthermic power plant in the desert of Las Vegas between Los Angeles and Las Vegas (USA). 5 farms, each of them producing up to P = 30 MW.

Parabolic Mirror Constructions

Dish-System



characteristic values of the construction:
diameter of the concave mirror: d = 17 m

power to be gained: $P = 50\ kW_{electric}$

application:
Stirling-Engine situated in the focus
driving of an electric generator

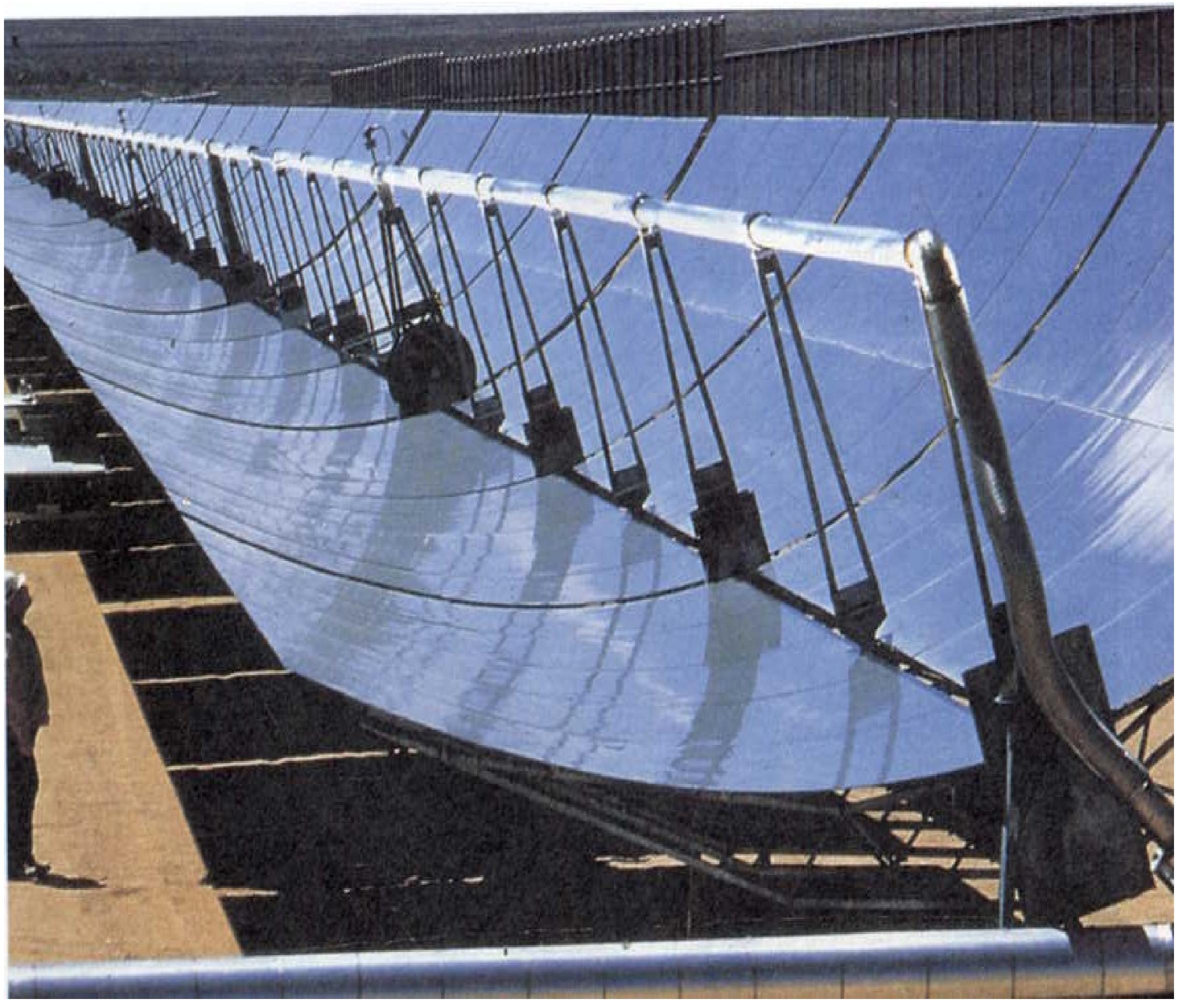
Parabolic-mirror-construction
Concentration: 500 - 2.000 times

Dish System

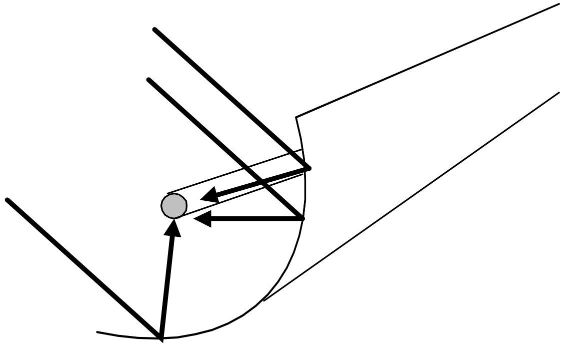
Dish System

Stirling-engines are positioned in the focal spot of the parabolic mirror.
They directly turn concentrated Infrared without using any energetic carrier or fuel to electric energy.
Power to be gained: P = 50 kW.

Cylindric Collector – Focal Line



Concentration: 50 - 80 times



Parabolrinnenkollektor

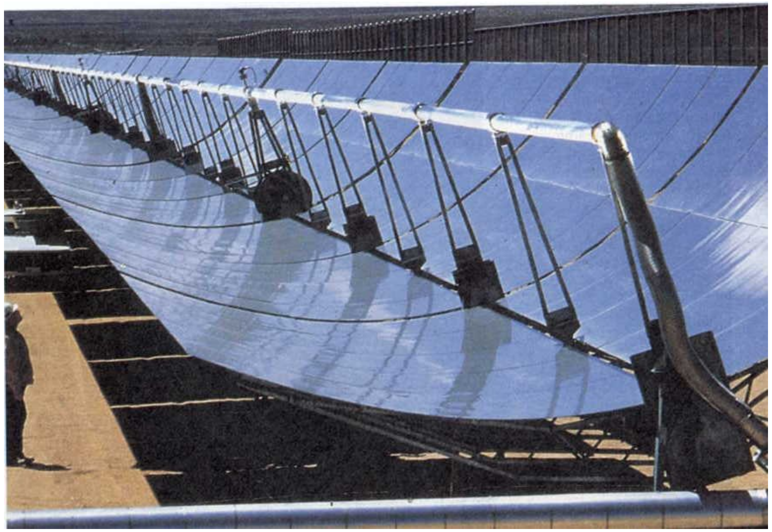
Cylindric Collectors are similar to gutters reflecting on their inside.
Within the focal line: T = 400 °C.

$P_{thermic}$: 0,1 - 10 MW
$P_{electric}$: 50 kW - 1 MW

On the example of California:
Onto an area of 464 000 m² the power of P = 80 MW has been installed !!

Energy in USA 2008

Usable area in California (desert): 650.000 km²
Irradiation2500 kWh/m².a equalling 8 kWh/m²d
Calculated yield 5000 EJ/a
System: Parabolrinnenkraftwerk Cylindric Collector
Generation of Compressed Air (85 bar ~ 85.000 hPa)
Stored in Cavities (former natural gas store), etc.)
Heating of Compressed Air ➔ Rising Pressure
Running of High-Pressure-and Low Pressure Turbines
Power Mains-DCV-Lines
HVDC-LINES
To be improved: energetic carrier salt melt (~ 300 °C)



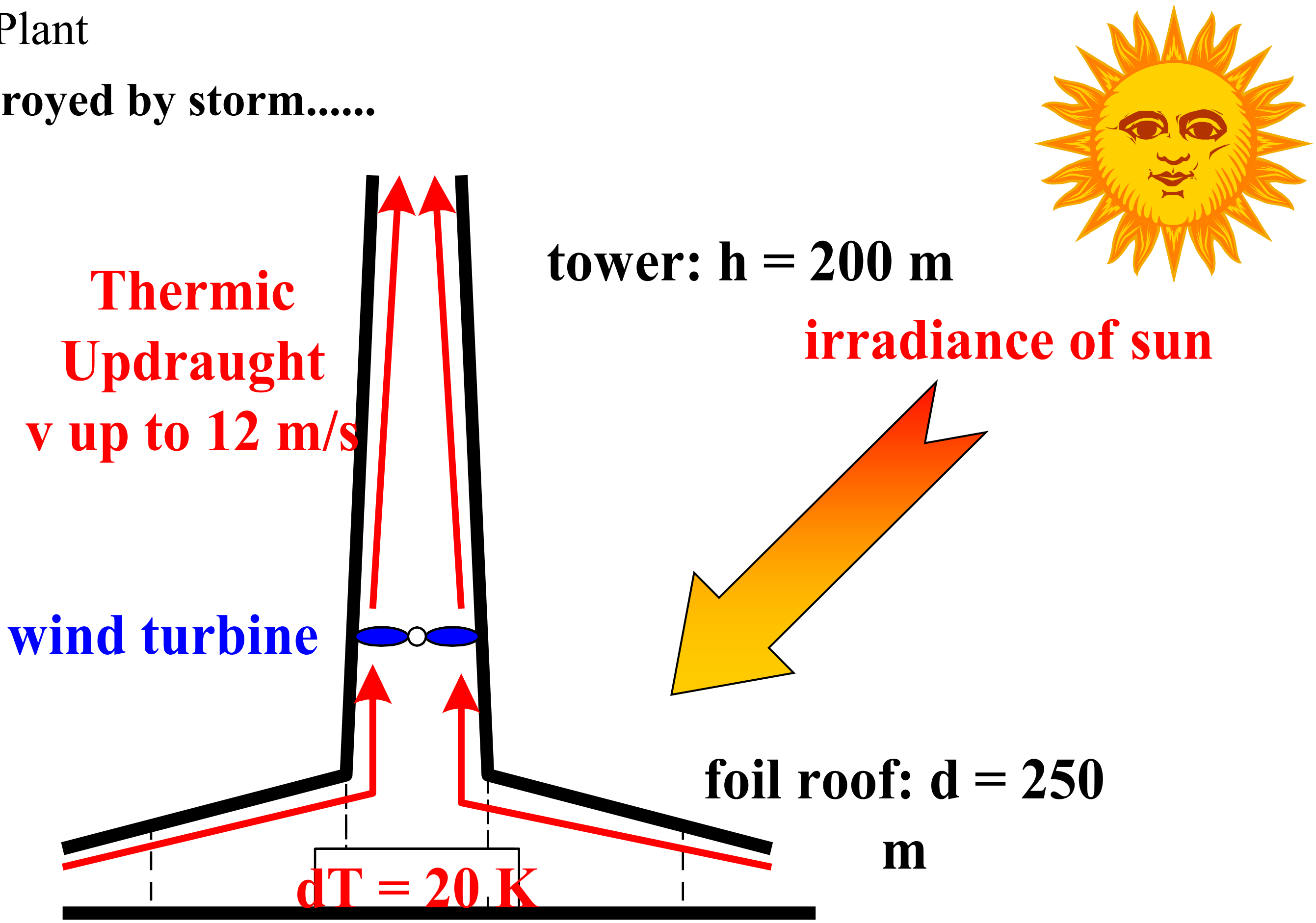
line focus

Compare::
World: 478,7 EJ
USA: 98 EJ
DE: 14 EJ
AT: 1 EJ

Source: Spektrum der Wissenschaft März 2008

Tower Power Plant

destroyed by storm......



Updraught Power Station La Mancha /Spanien

The Updraught-Power-Station was destroyed by storm (tower blown down).

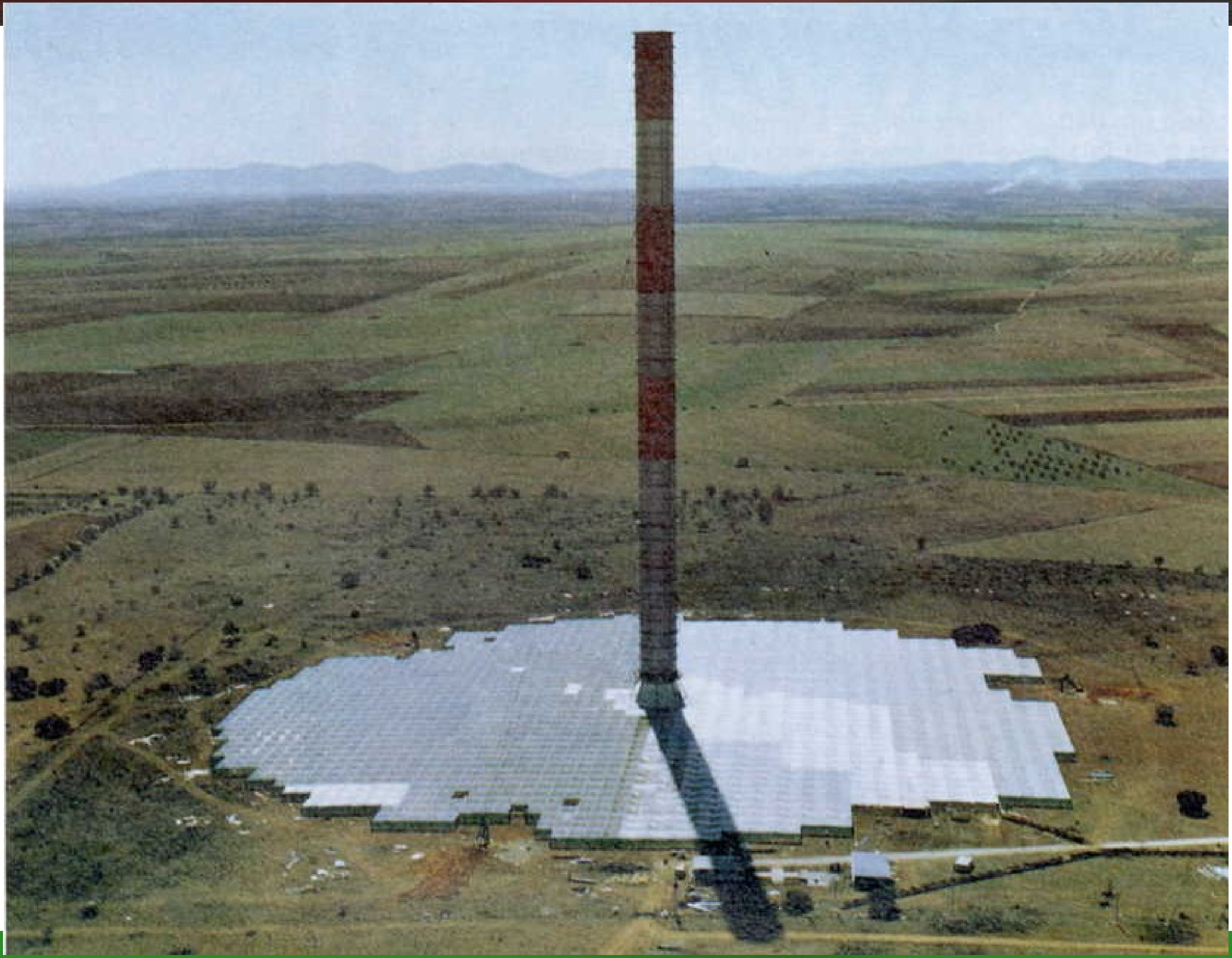
Wheel (Wind-Turbine-Generator) starts(-ed) revolutions at 4 m/s.

$P_{electric}$ (max) was about 50 kW

$\eta \sim 1$ %

To reach senseful orders of magnitude: height of the tower = 450 m, diameter of the “tent” = 1,1 km

Updraught Power Station La Mancha /Spanien



Almeria