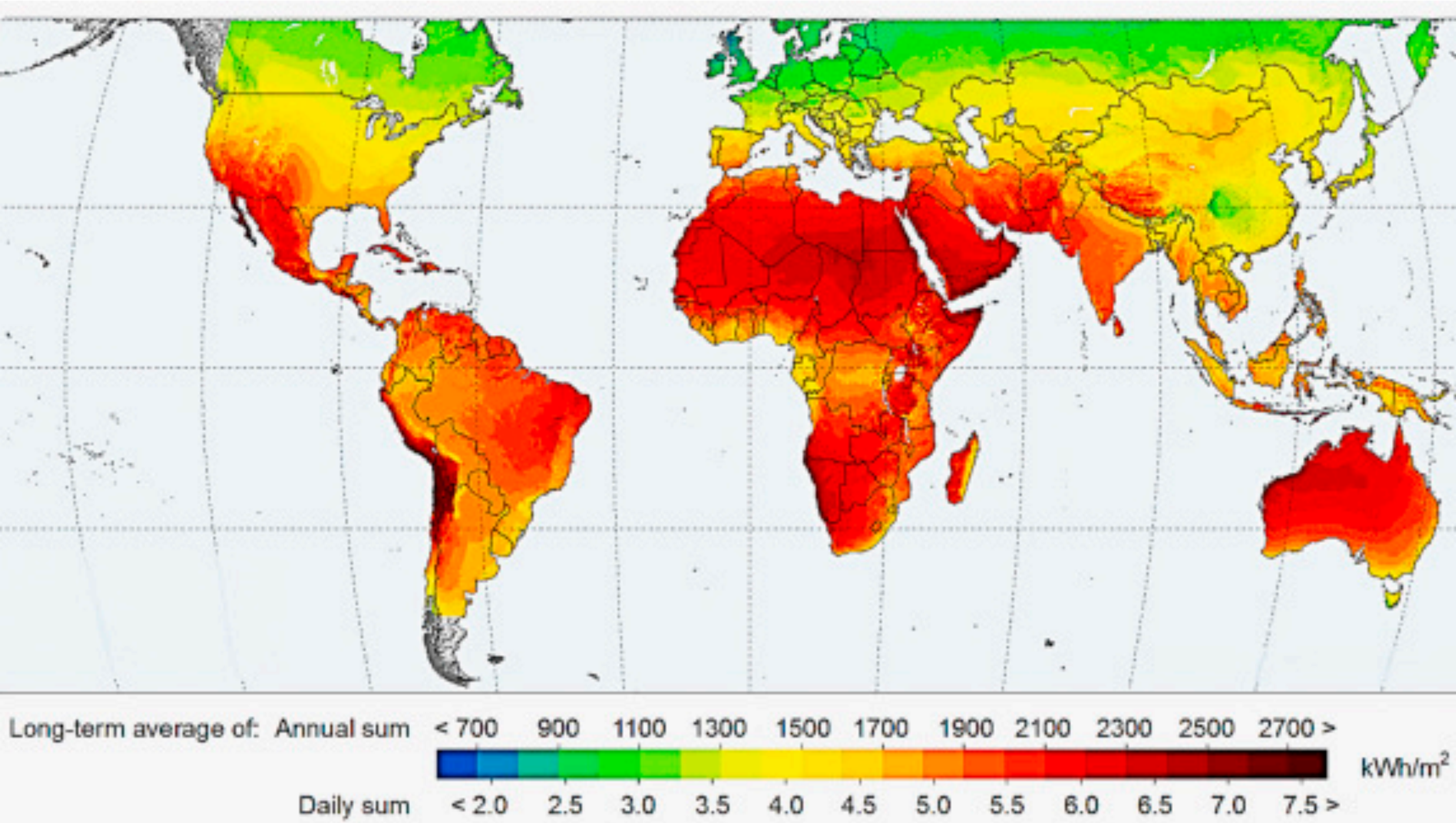
Direct forms of solar energy

annual Sun's radiation



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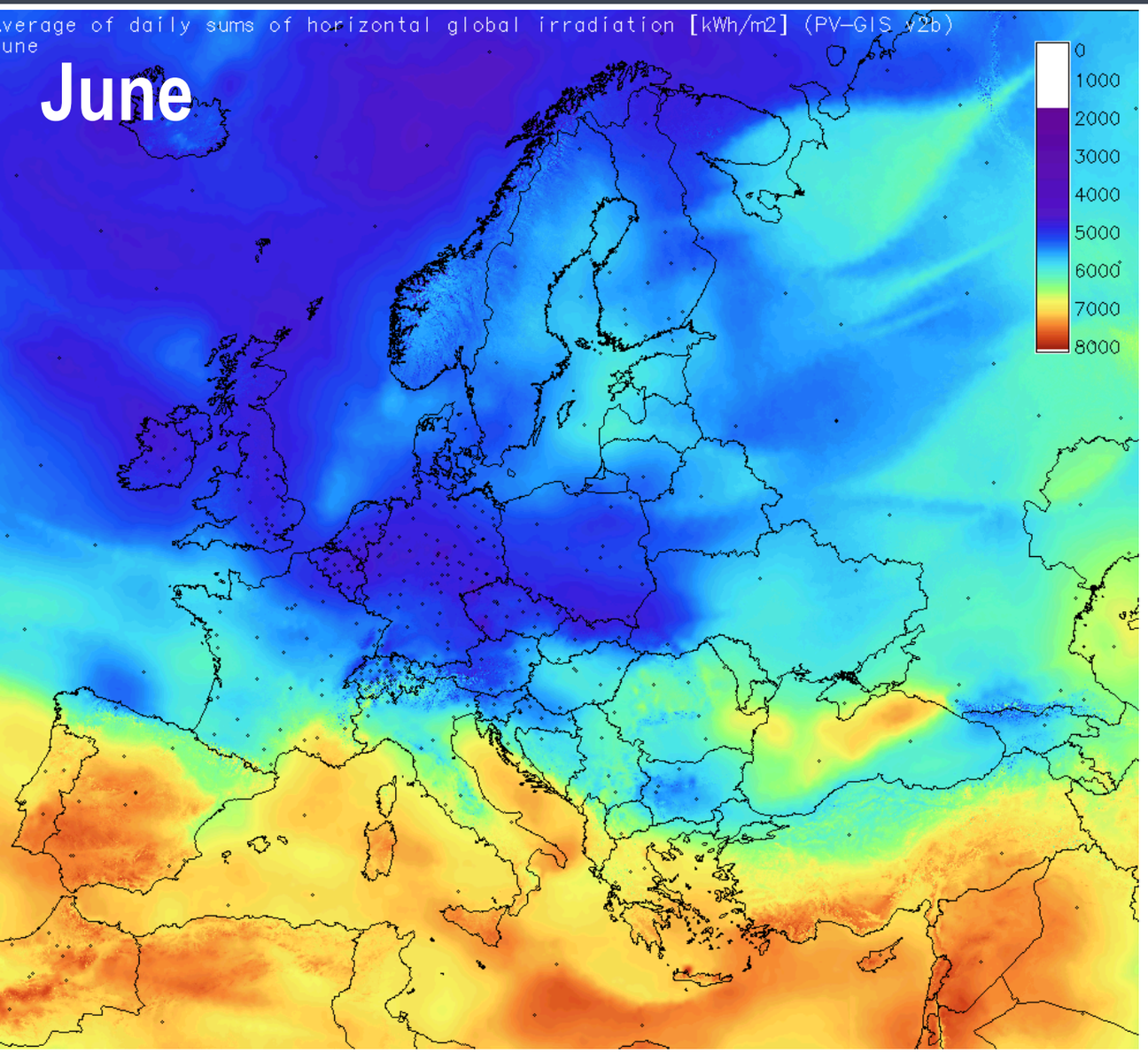
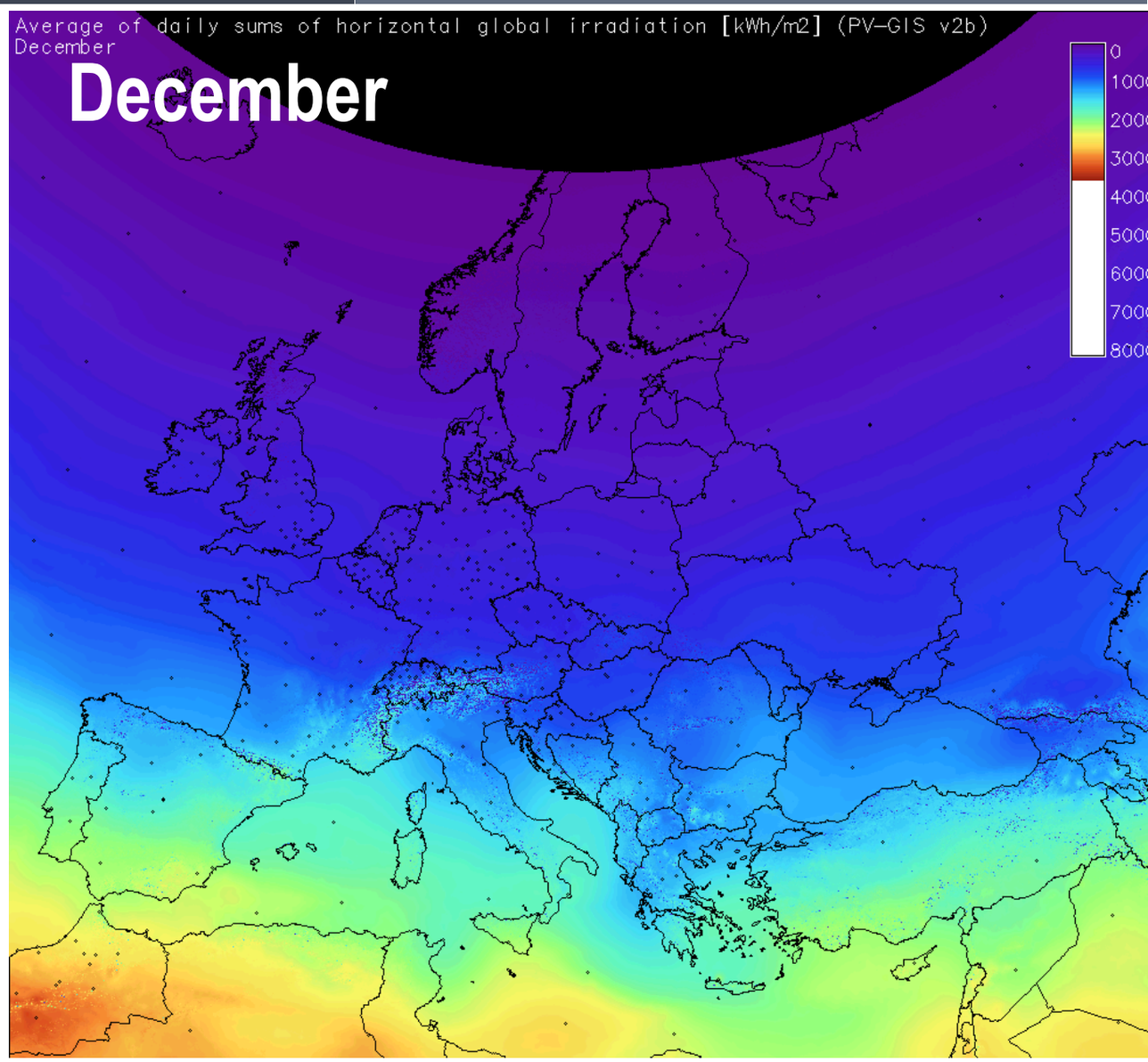
Source: https://doi.org/10.1016/j.rser.2016.05.022

annual Sun's radiation





Source: PVGIS © European Communities, 2001-2008

Portugal: 7 - 7.6 kWh/m²

+30% central Europe

Portugal: 1.6 - 2.2 kWh/m²

2 times central Europe

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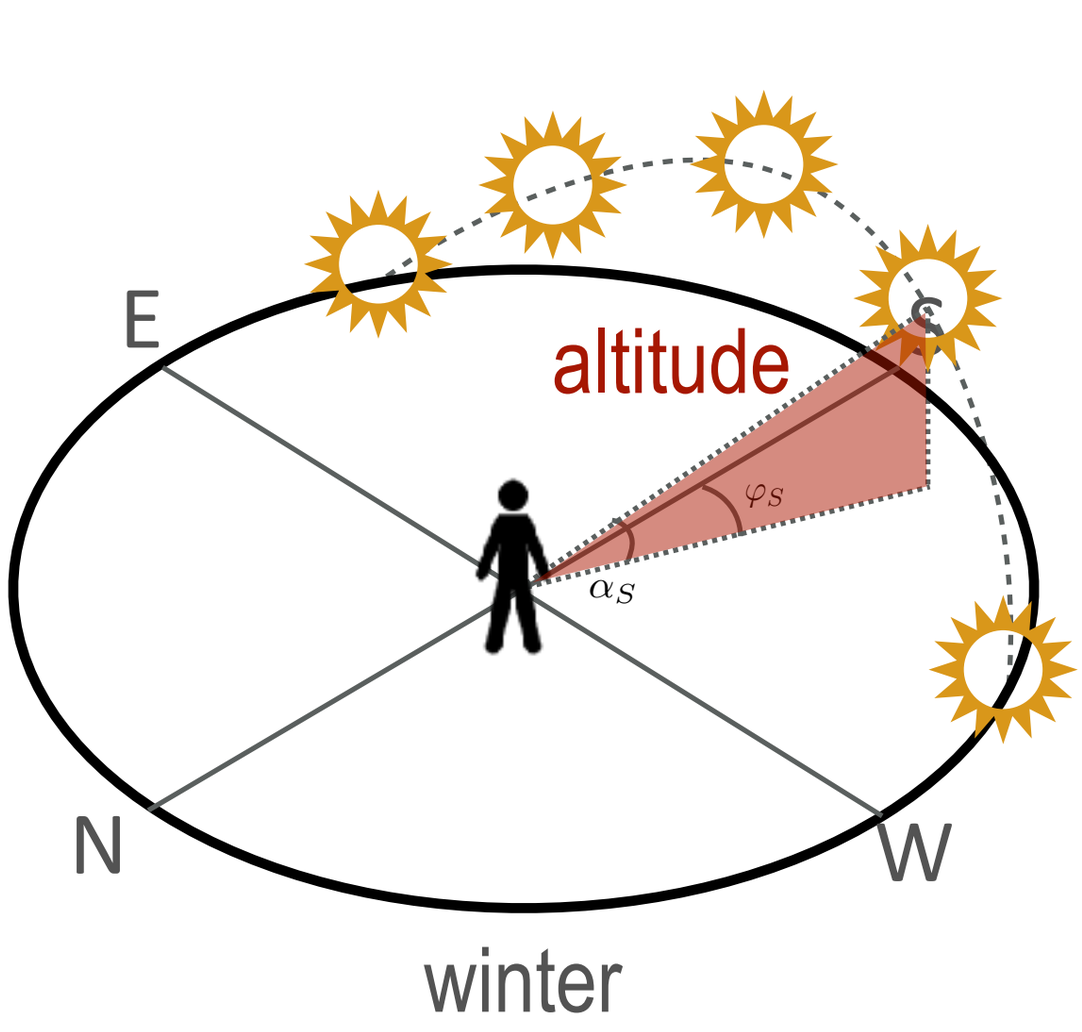
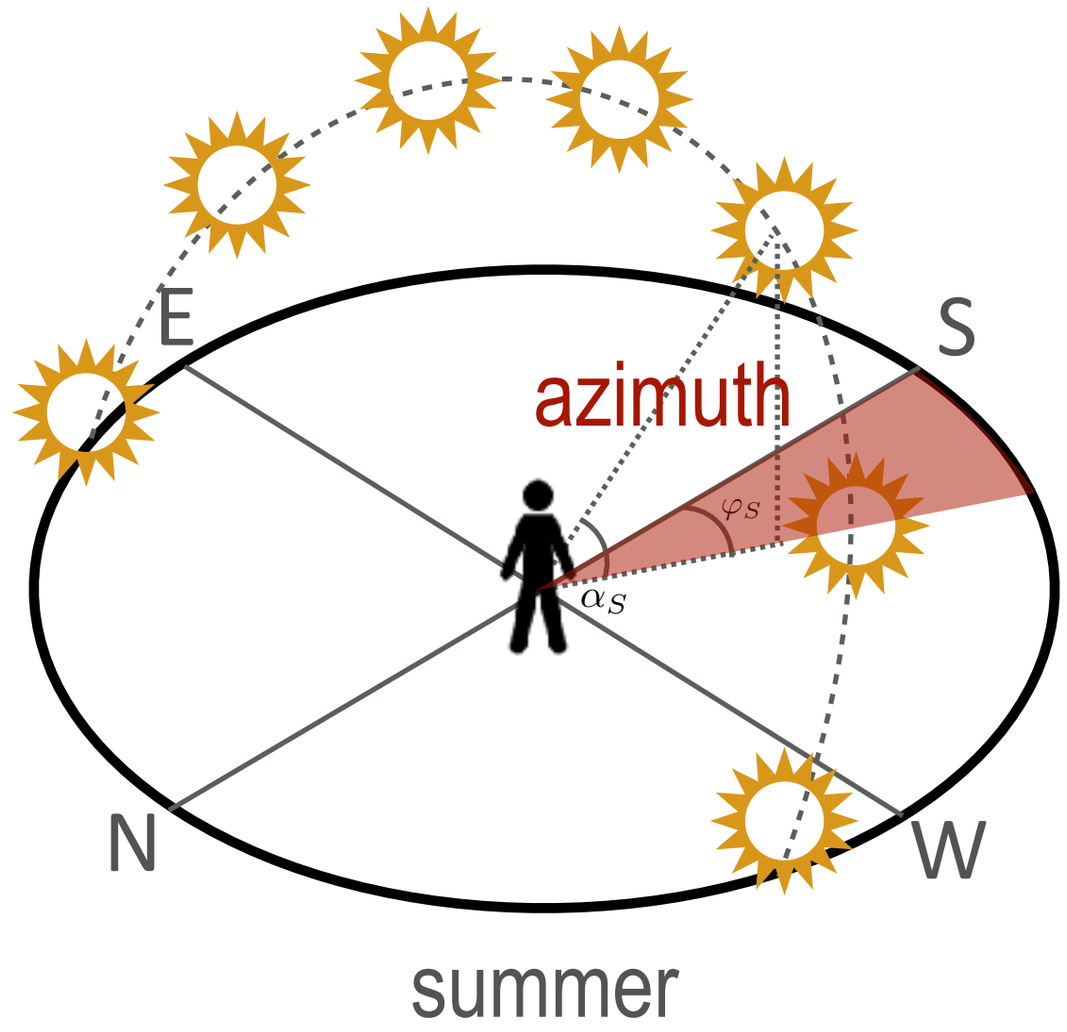
mid latitude at North hemisphere



winter



summer

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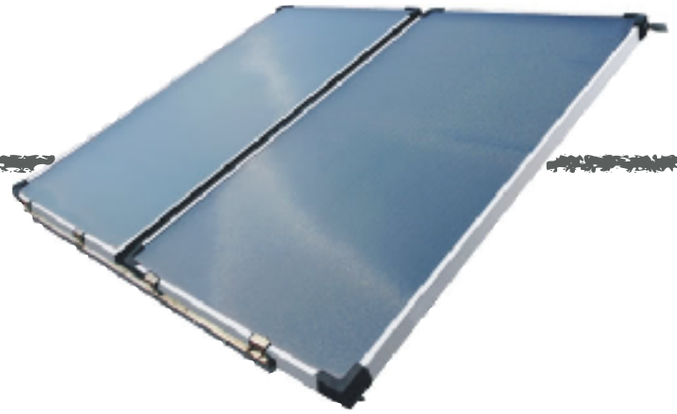
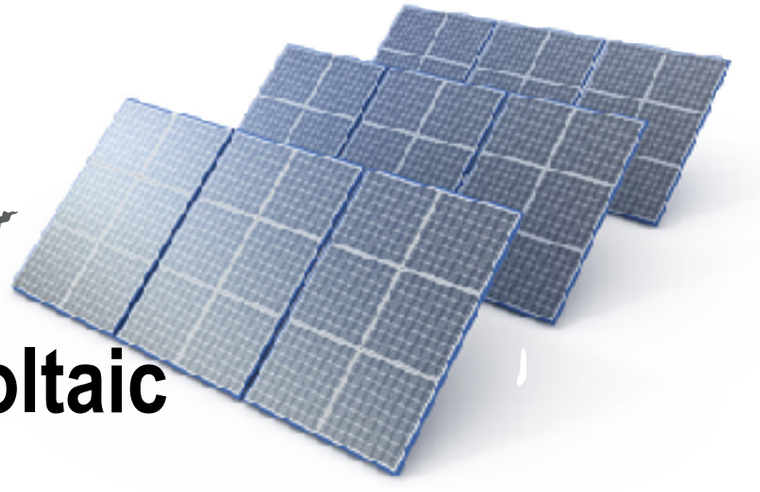
low temperature solar collectors



concentration solar power

solar photovoltaic



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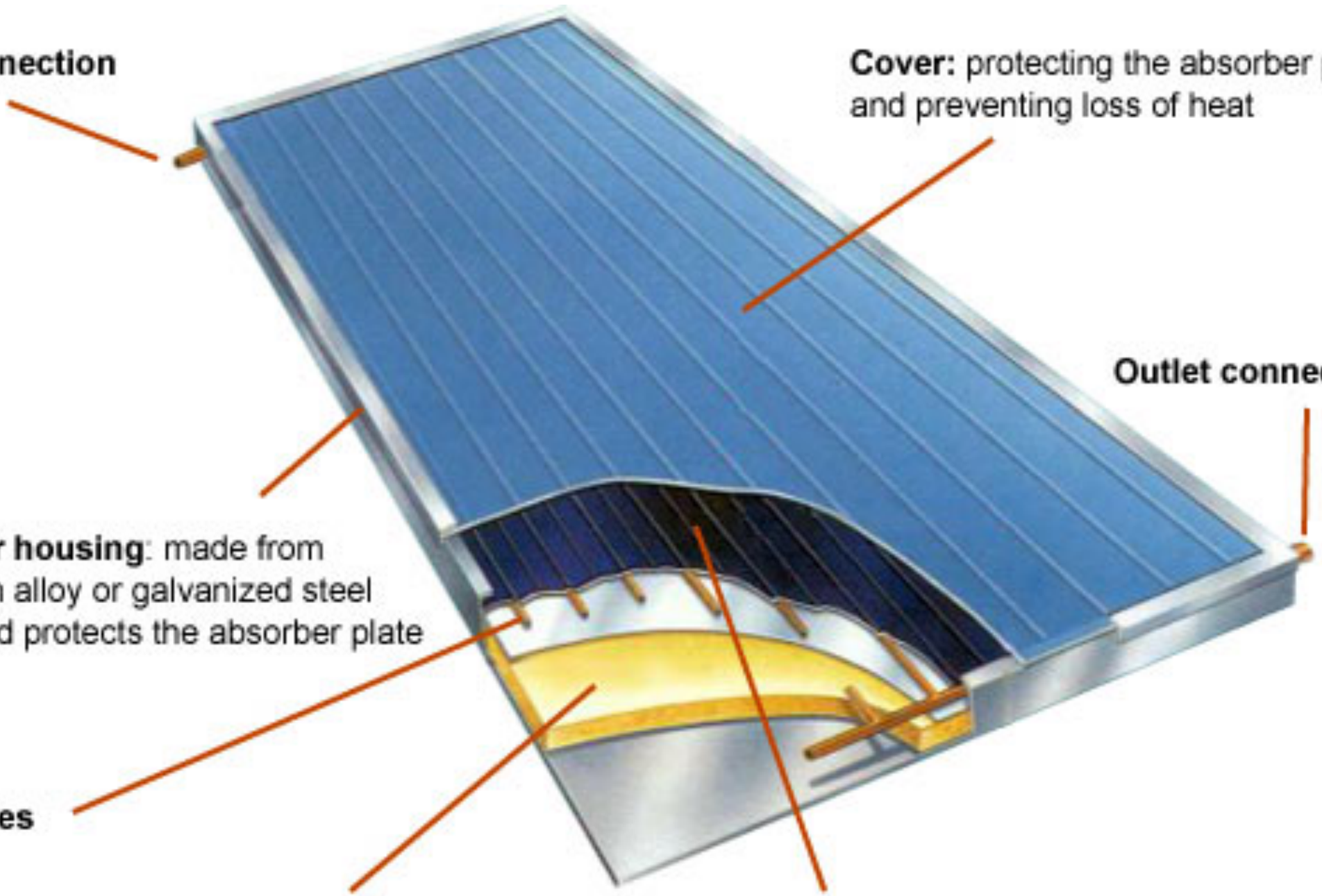
Low temperature solar collectors



Inlet connection

Cover: protecting the absorber plate and preventing loss of heat

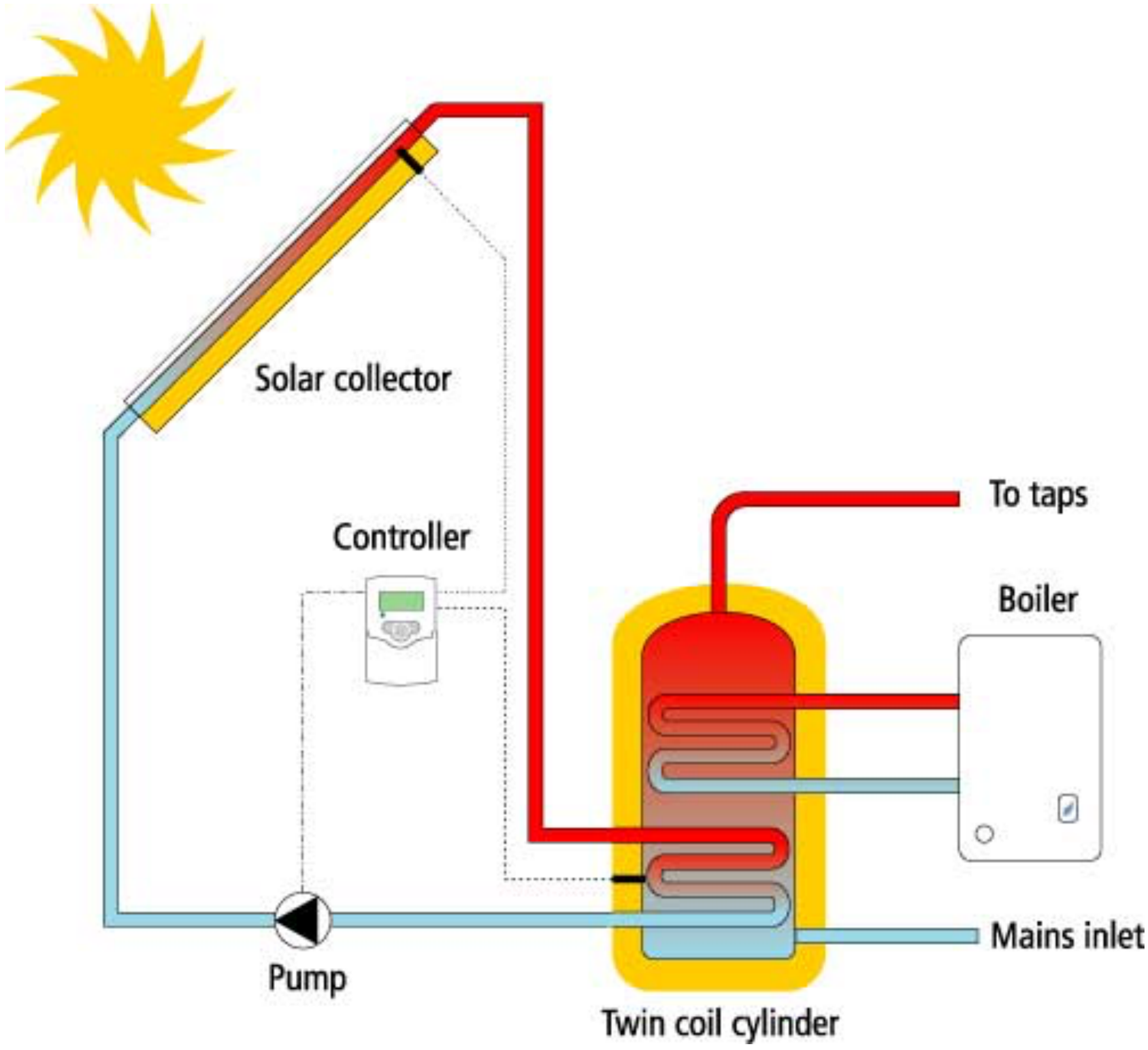
Outlet connection

Collector housing: made from alumnium alloy or galvanized steel - fixes and protects the absorber plate

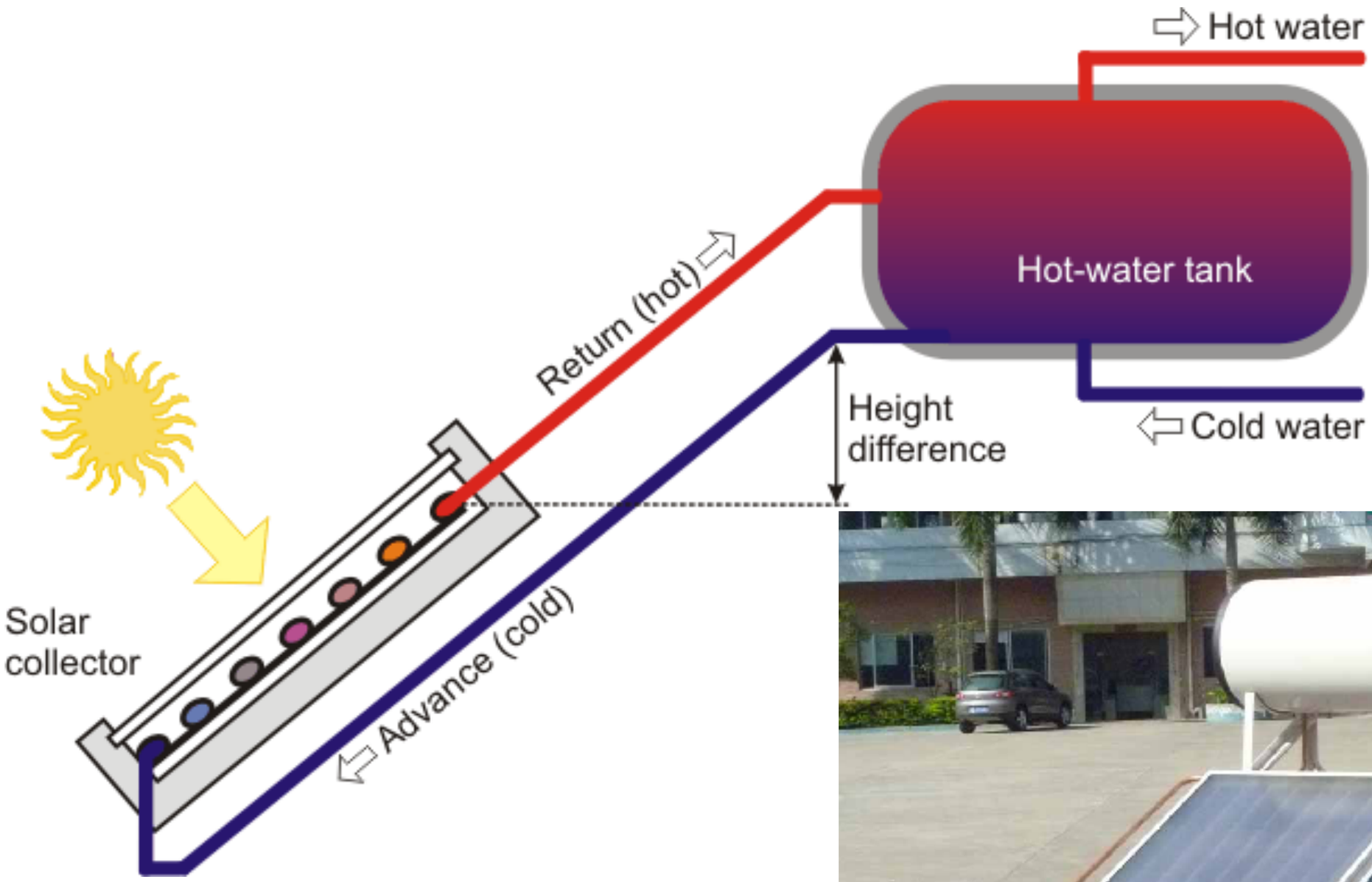
Flow tubes

Insulation: to the bottom and sides of the collector to reduce the loss of heat

Absorber plate: usually black chrome absorbing coating to maximise heat collecting efficiency

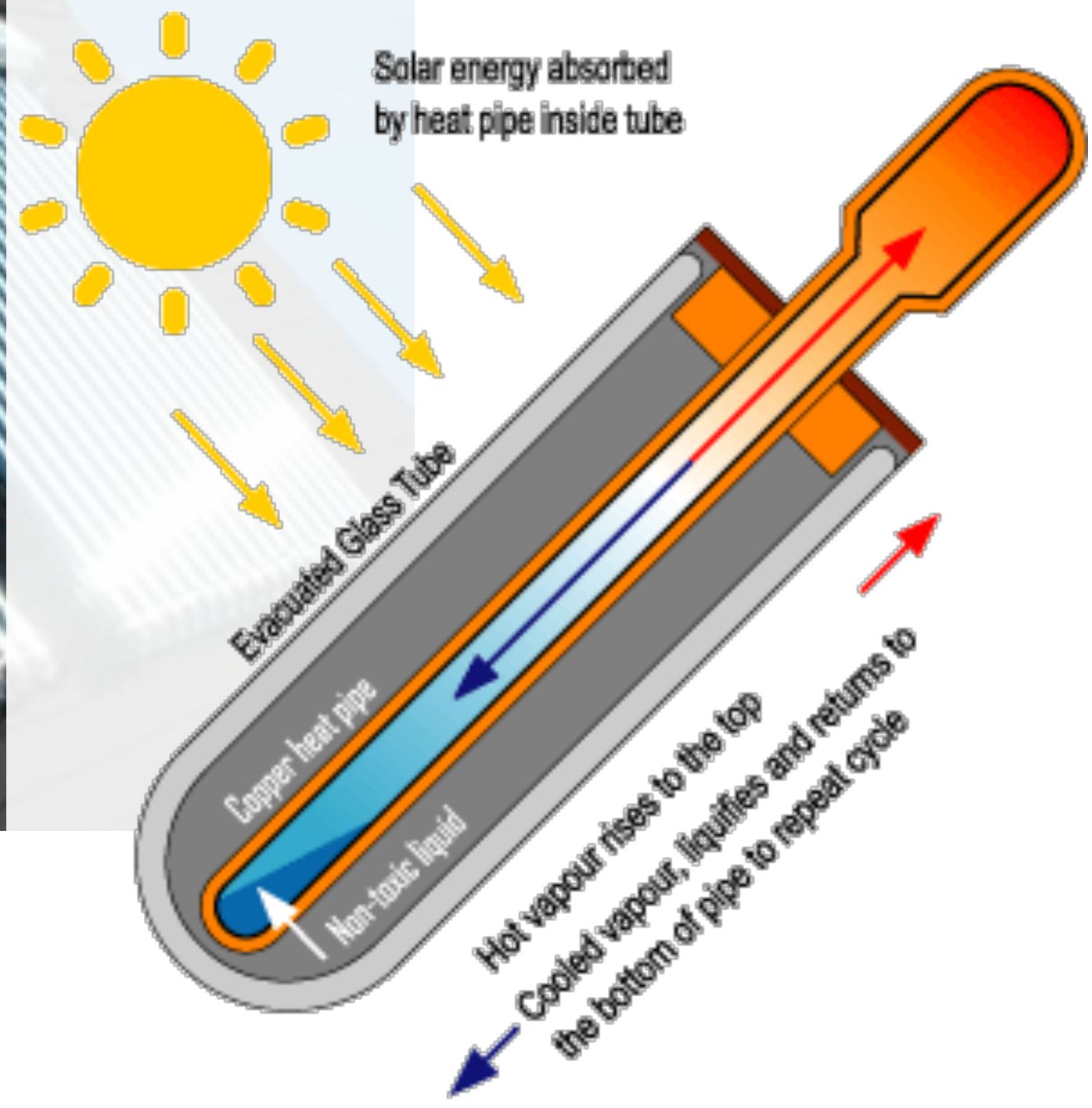

Solar collector
Controller
To taps
Boiler
Mains inlet
Pump
Twin coil cylinder

thermosiphon solar system

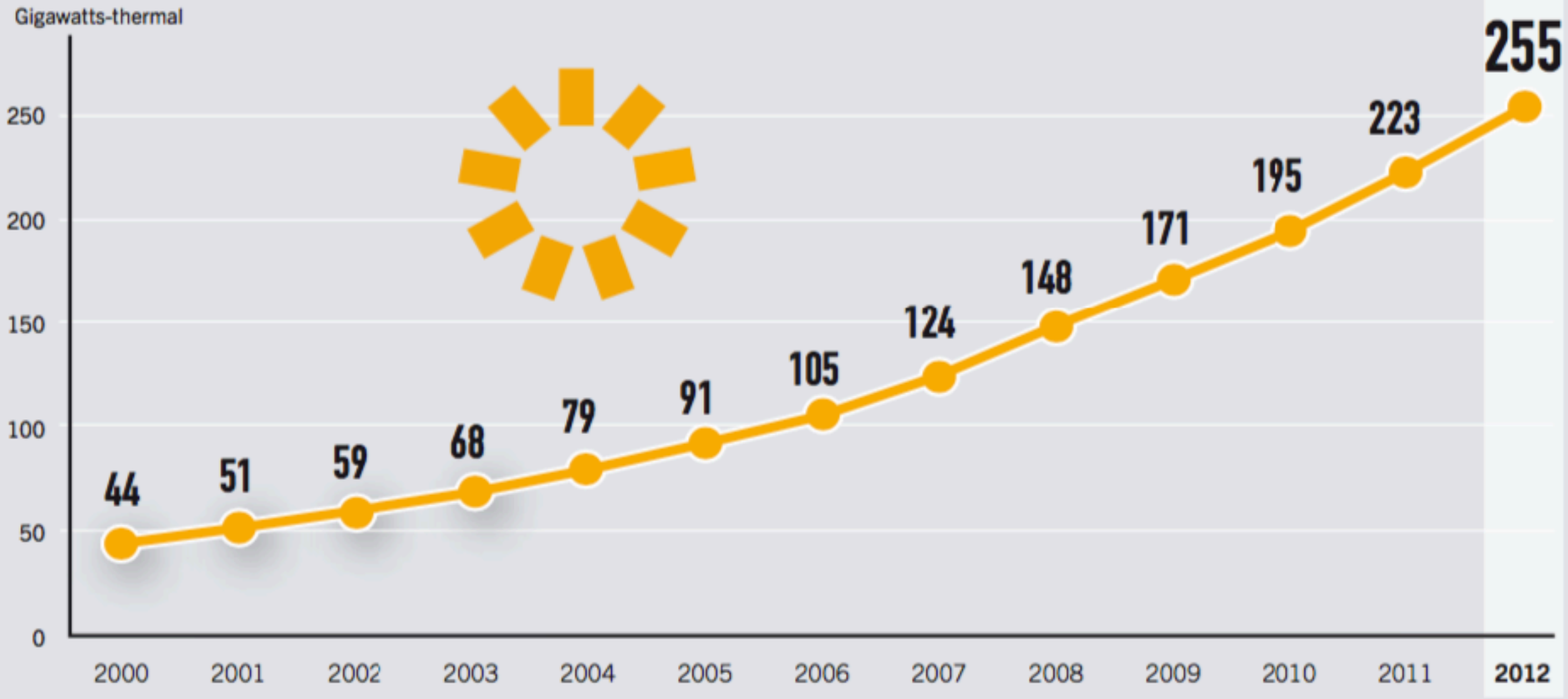


Ciências ULisboa

evacuated solar tubes

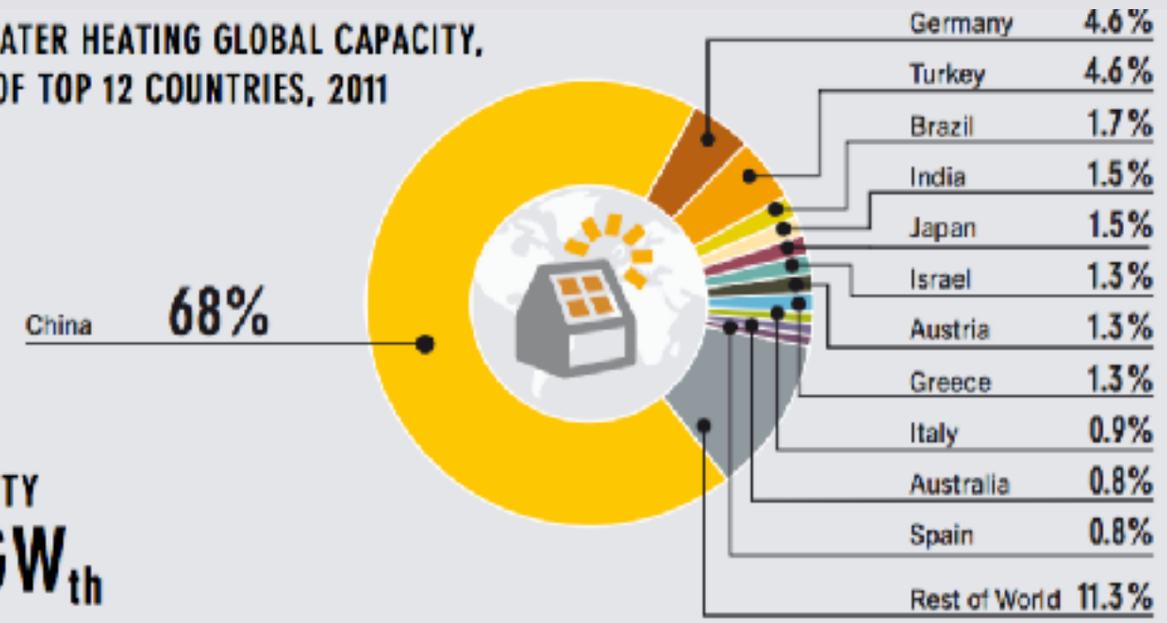


Ciências
ULisboa



Note: Data are for glazed water collectors only.

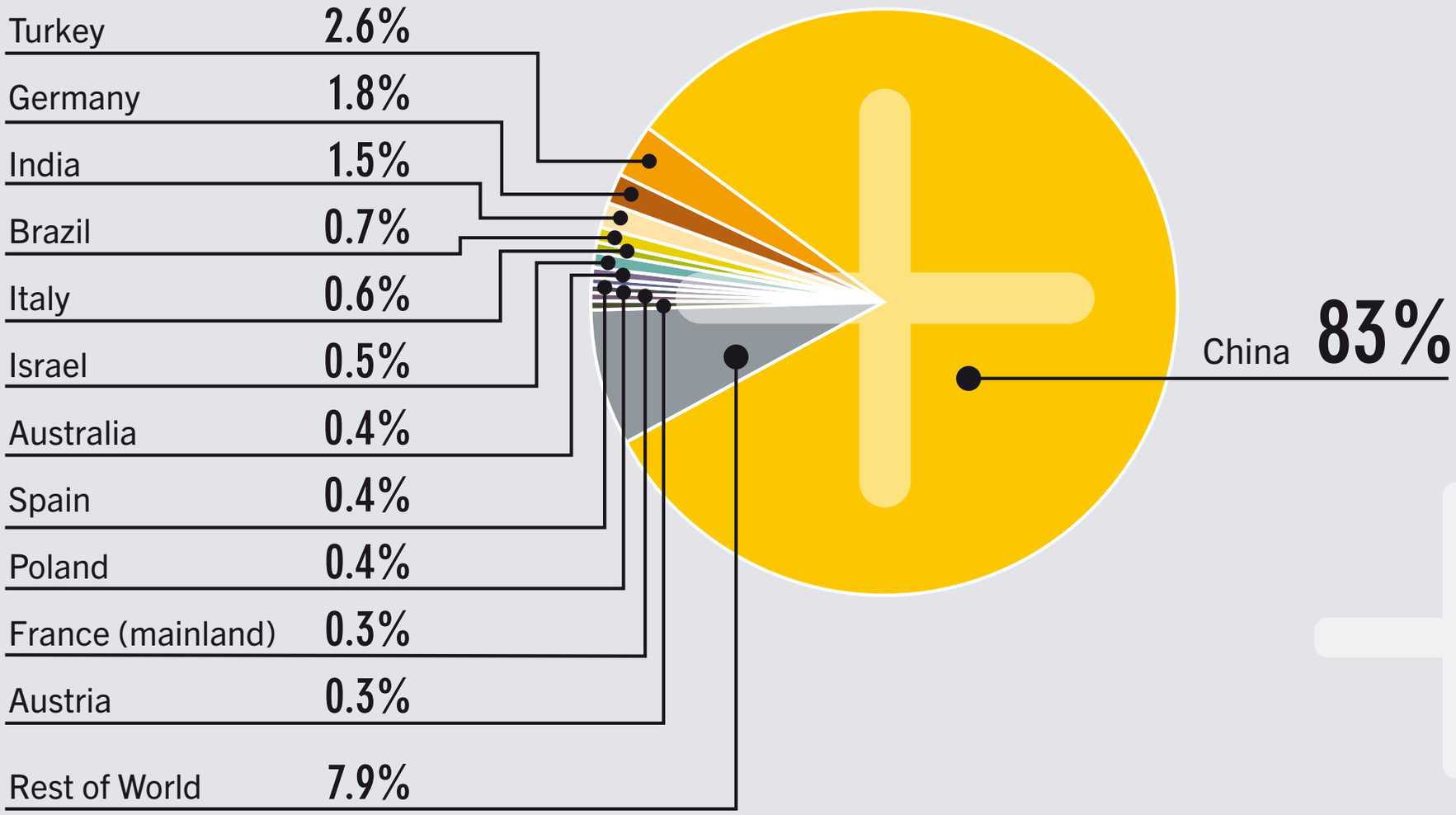
FIGURE 16. SOLAR WATER HEATING GLOBAL CAPACITY, SHARES OF TOP 12 COUNTRIES, 2011



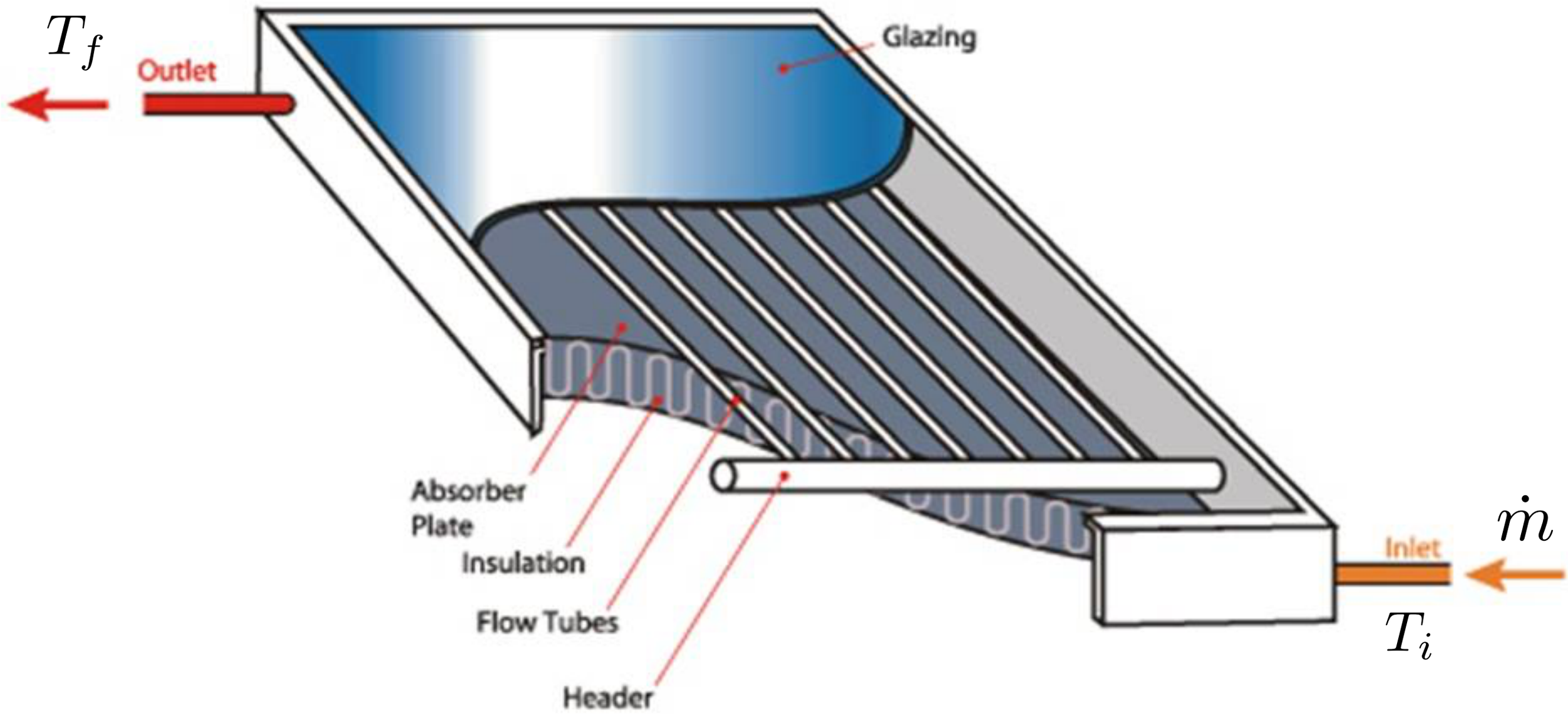
TOTAL CAPACITY
~ 223 GW_{th}

Ciências ULisboa

FIGURE 15. SOLAR WATER HEATING GLOBAL CAPACITY ADDITIONS, SHARES OF TOP 12 COUNTRIES, 2011



Area: 70 x 10^6 m^2



Ciências ULisboa

$$Q = mc(T_f - T_i)\ \text{[J]} \qquad \dot{Q} = \dot{m}c(T_f - T_i)\ \text{[W]}$$

m mass [kg]

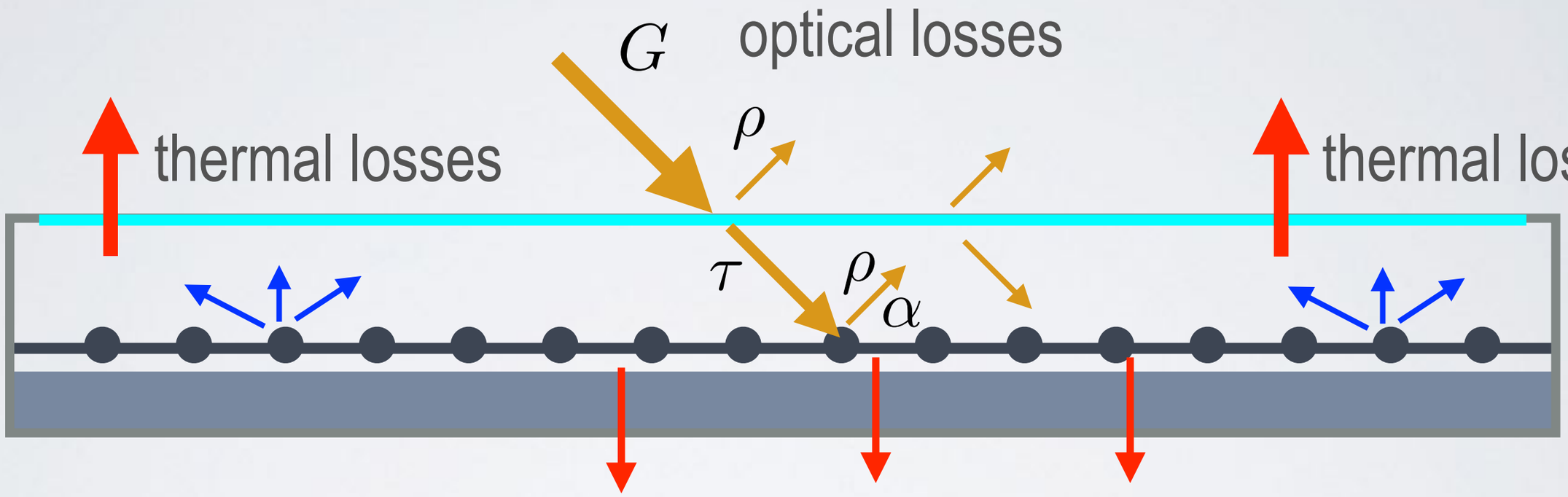
$\dot{m}$ mass flow [kg/s]

c fluid thermal capacity [J/(kgK)]

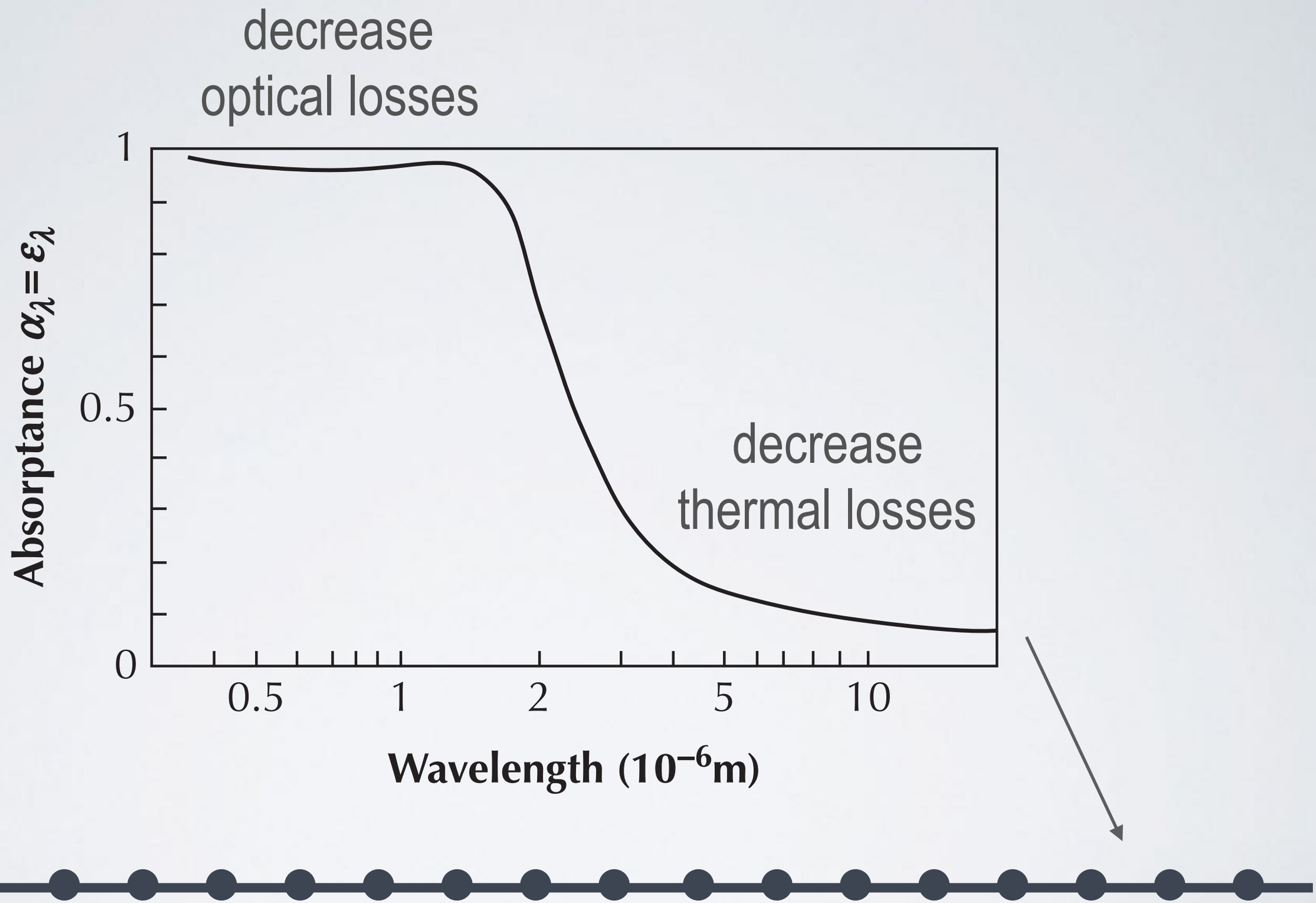
T_f output temperature [K]

T_i input temperature [K]

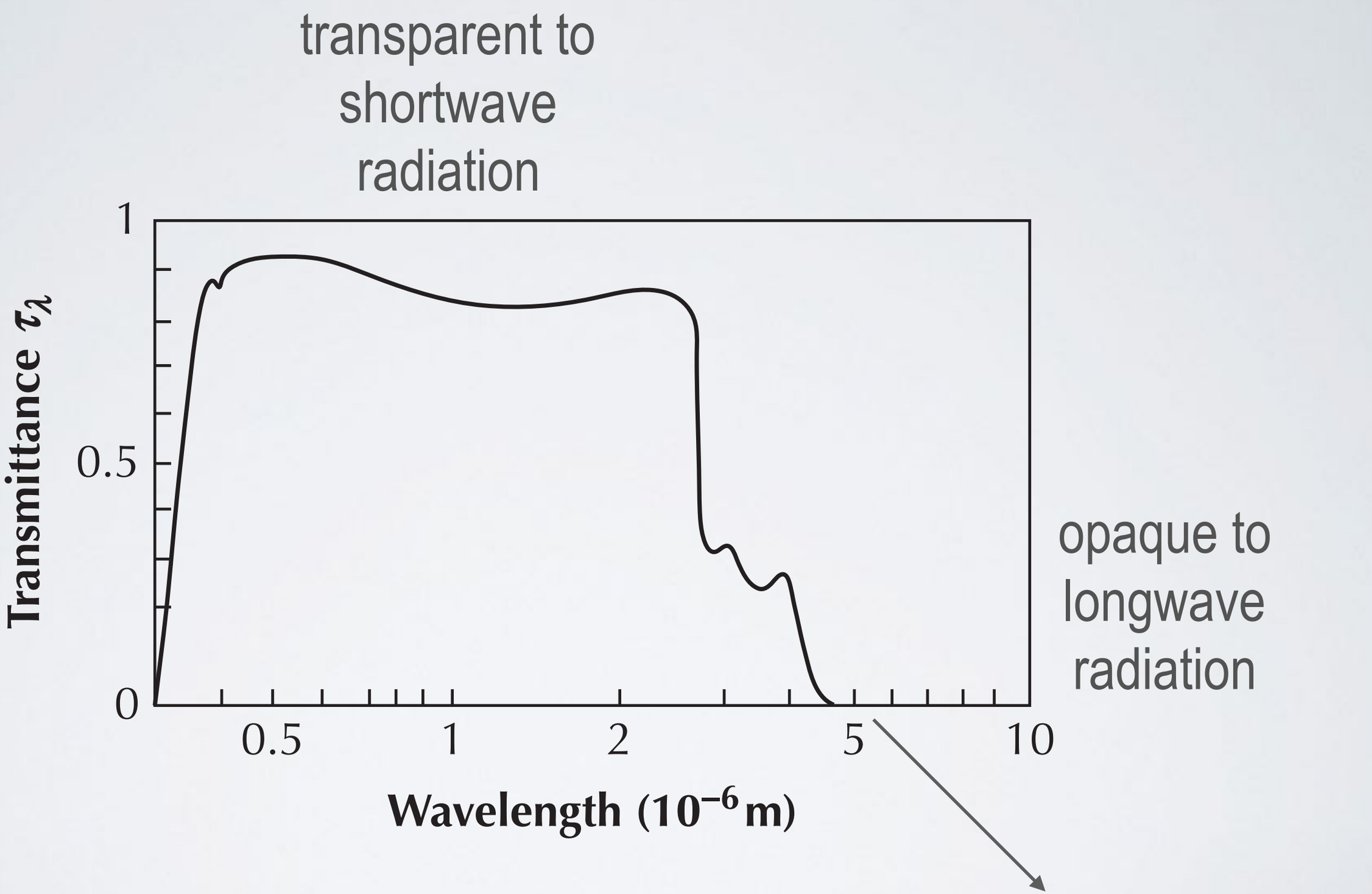
Ciências ULisboa

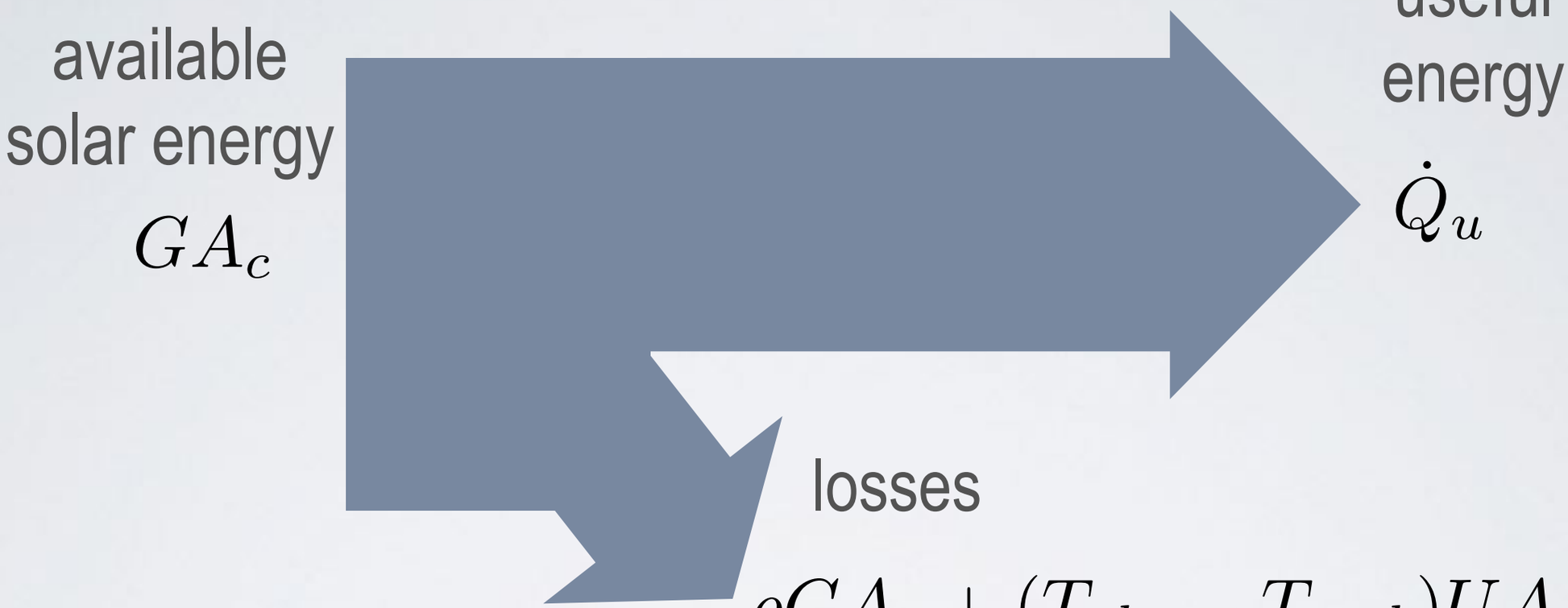


Ciências ULisboa



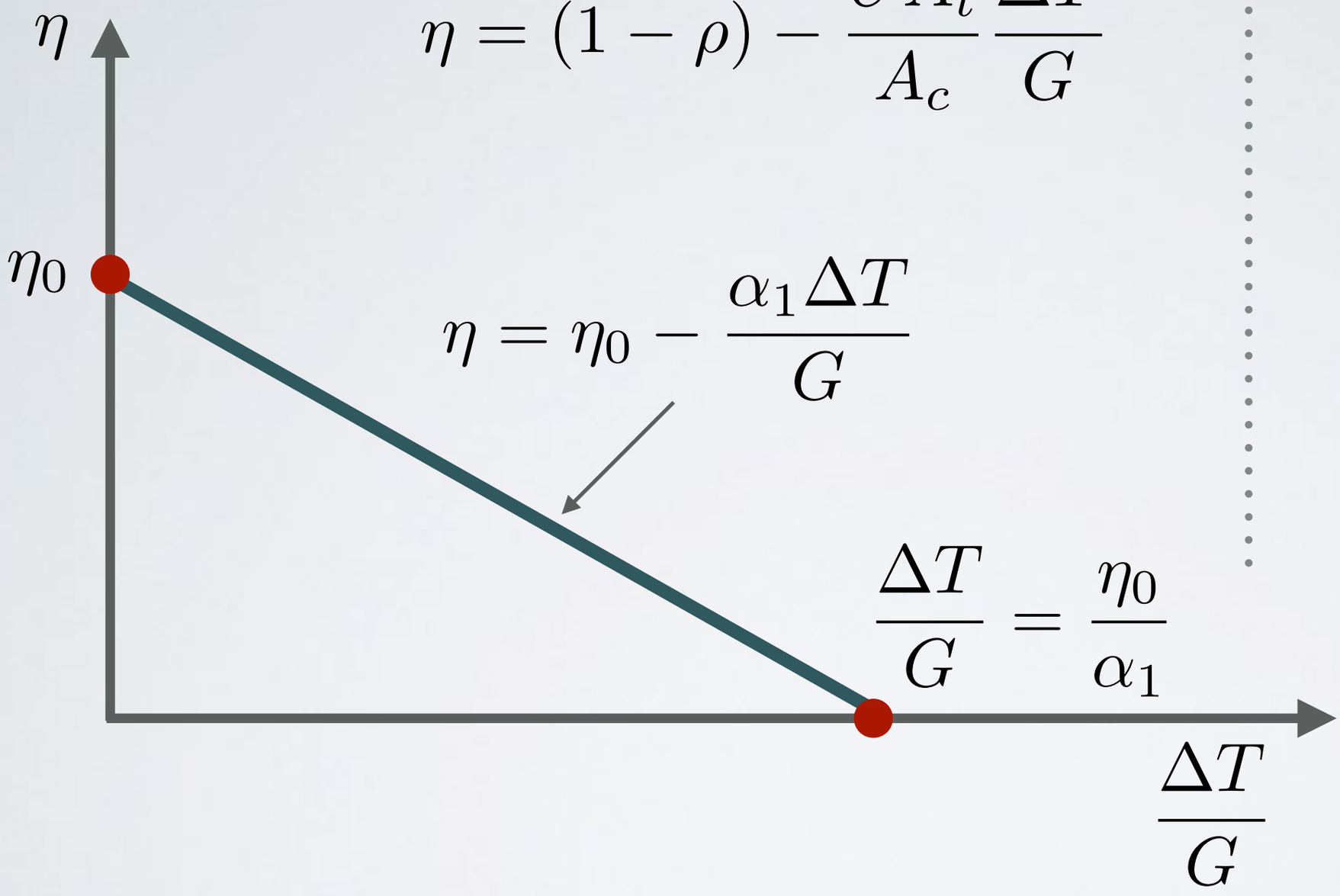
Ciências ULisboa


transparent to
shortwave
radiation
1
0.5
0
Transmittance τ_λ
0.5
1
2
5
10
Wavelength (10^{-6} m)
opaque to
longwave
radiation



$$\dot{Q}_u = GA_c - \rho GA_c - (T_{abs} - T_{amb}) U A_t$$

Ciências ULisboa



$$\eta = (1 - \rho) - \frac{U A_t}{A_c} \frac{\Delta T}{G}$$

$$\eta = \eta_0 - \frac{\alpha_1 \Delta T}{G}$$

Assumptions

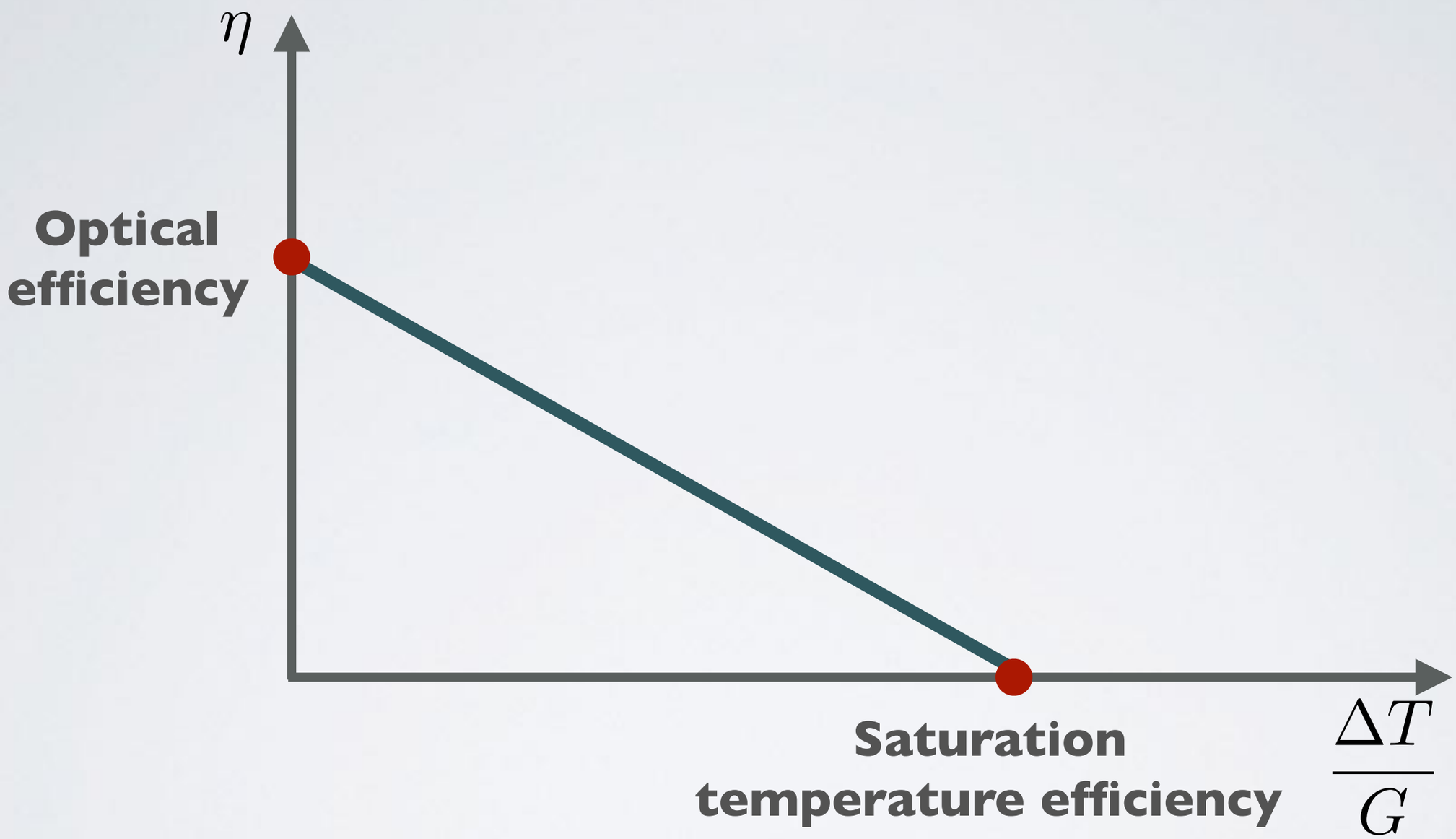
$$T_{abs} \simeq T_f$$

$$T_{amb} \simeq T_i$$

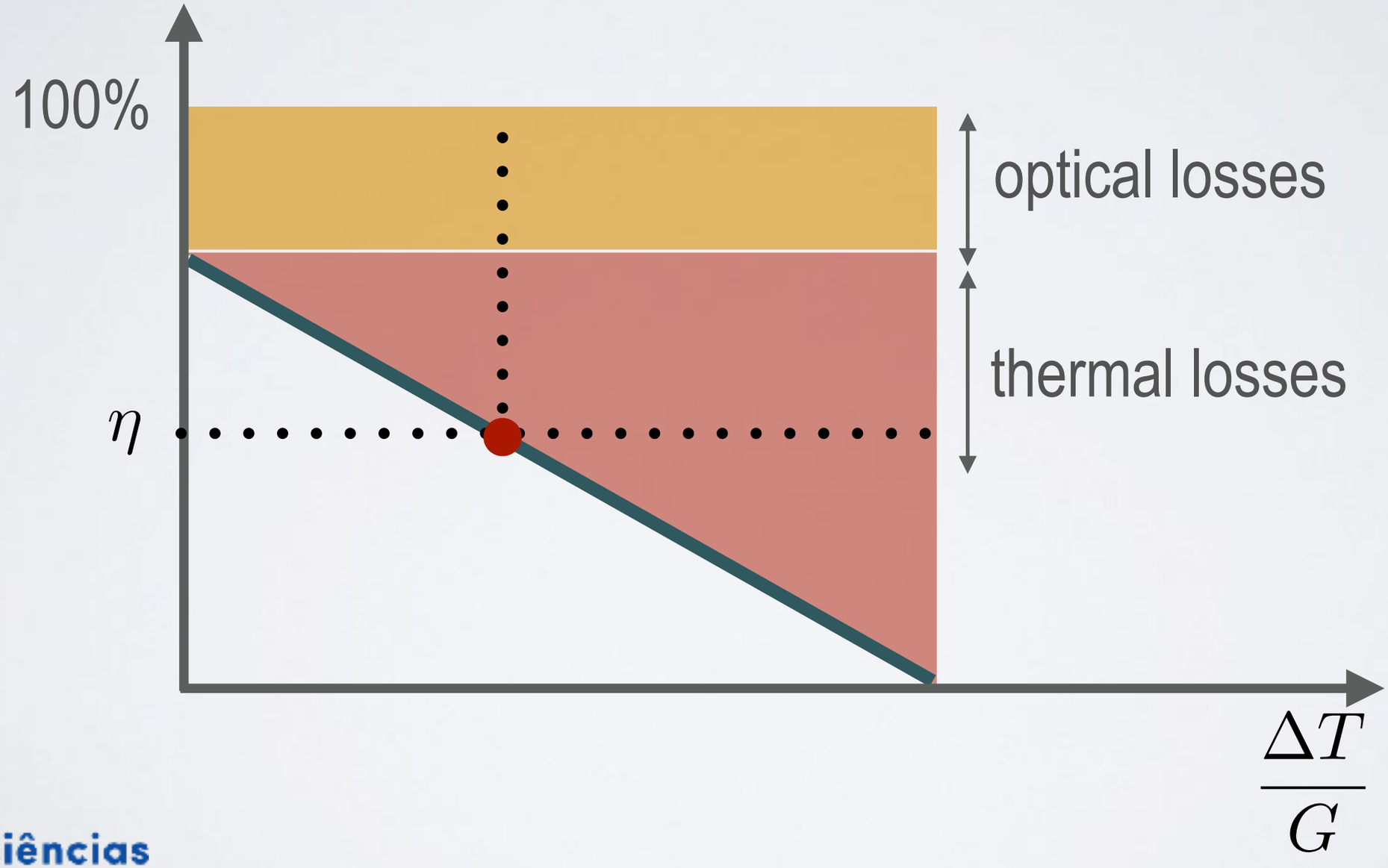
$$\Delta T = T_f - T_i$$

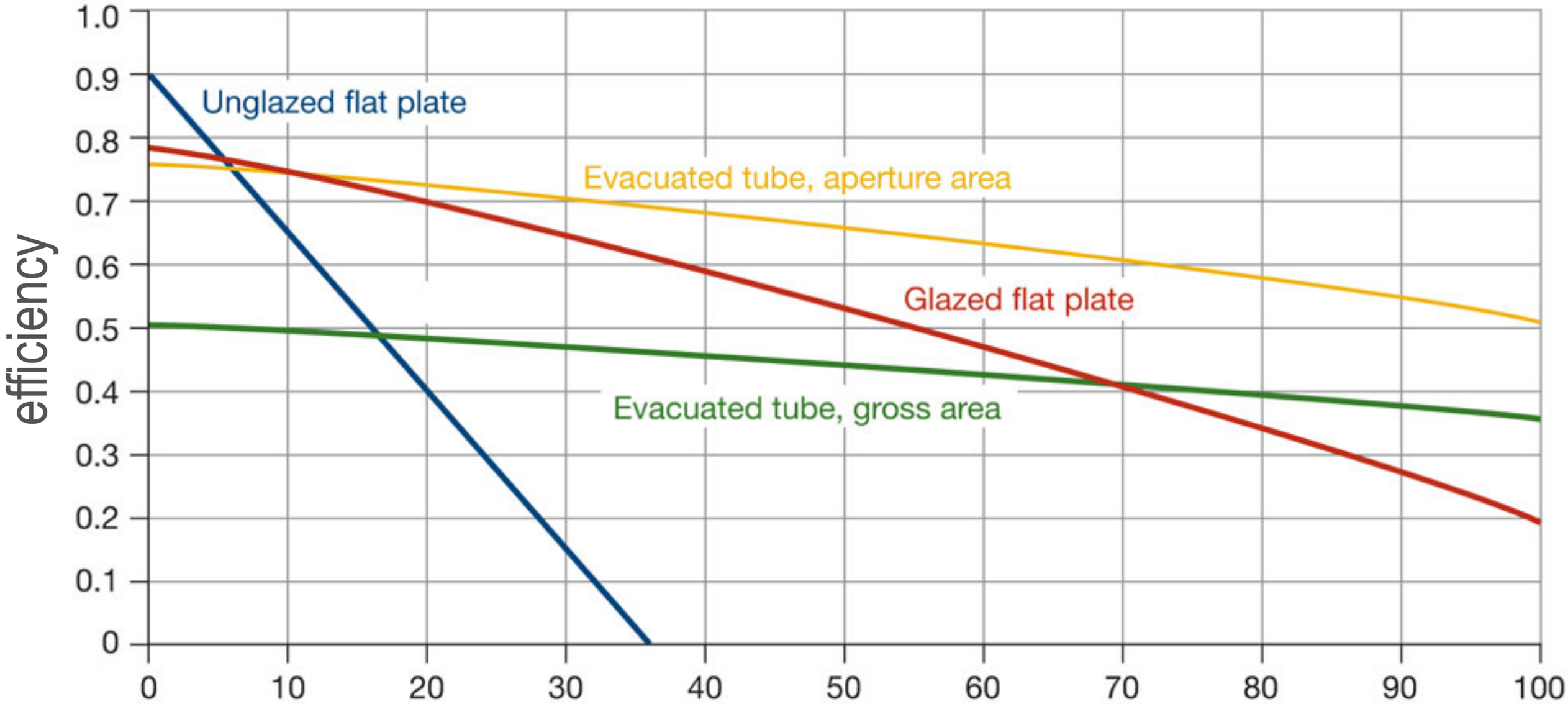
$$\frac{dU}{dT} = 0$$

Ciências ULisboa



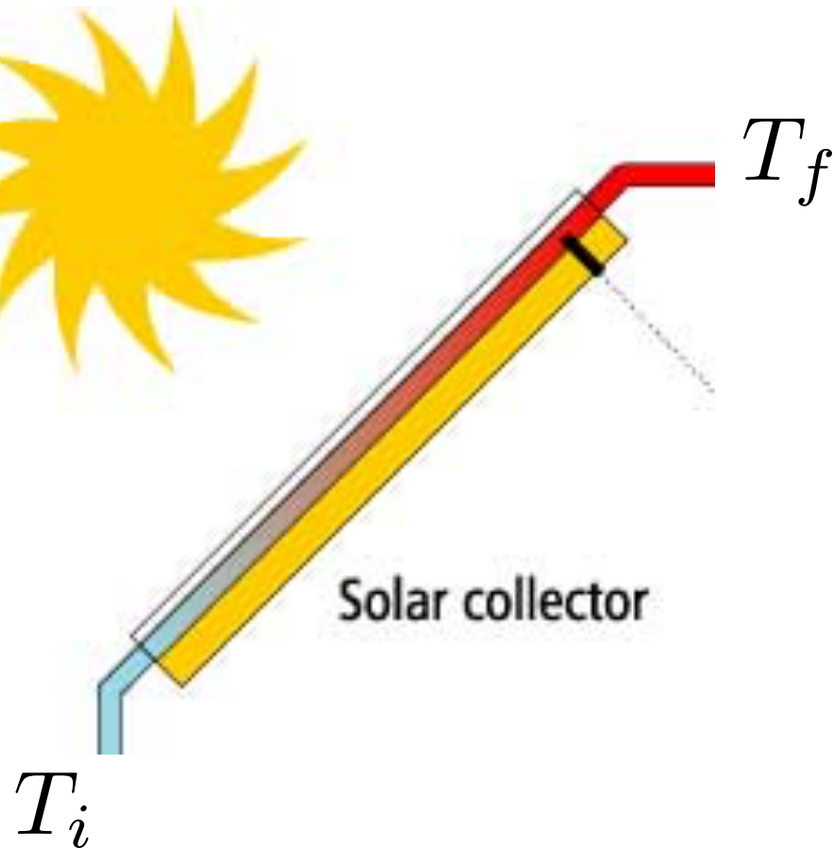
Ciências ULisboa


100%
optical losses
thermal losses
η
$\frac{\Delta T}{G}$



Ciências ULisboa

$$\eta = \eta_0 - \alpha_1 \Delta T/G - \alpha_2 \Delta T^2/G$$

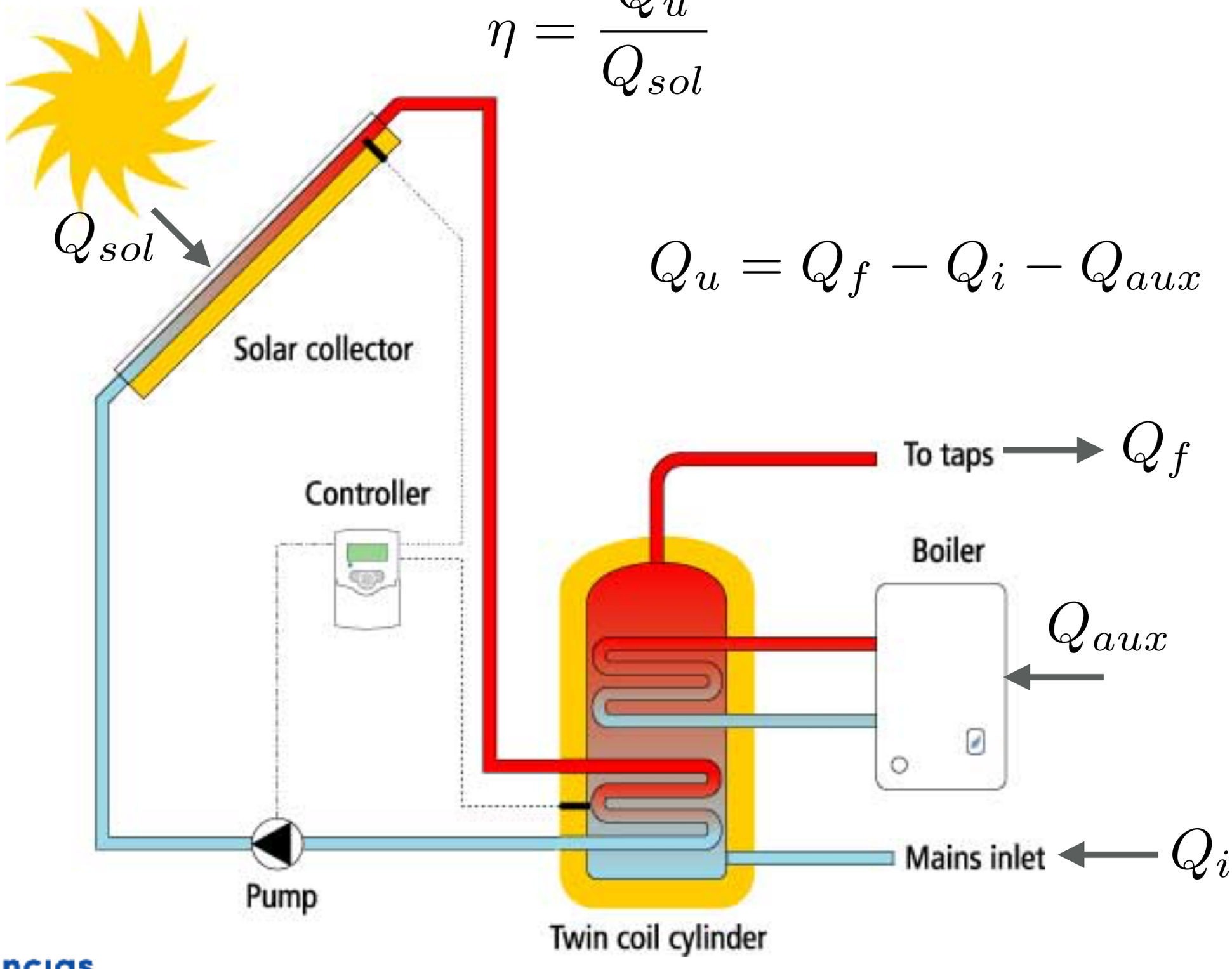


$\dot{Q}_u$
useful energy

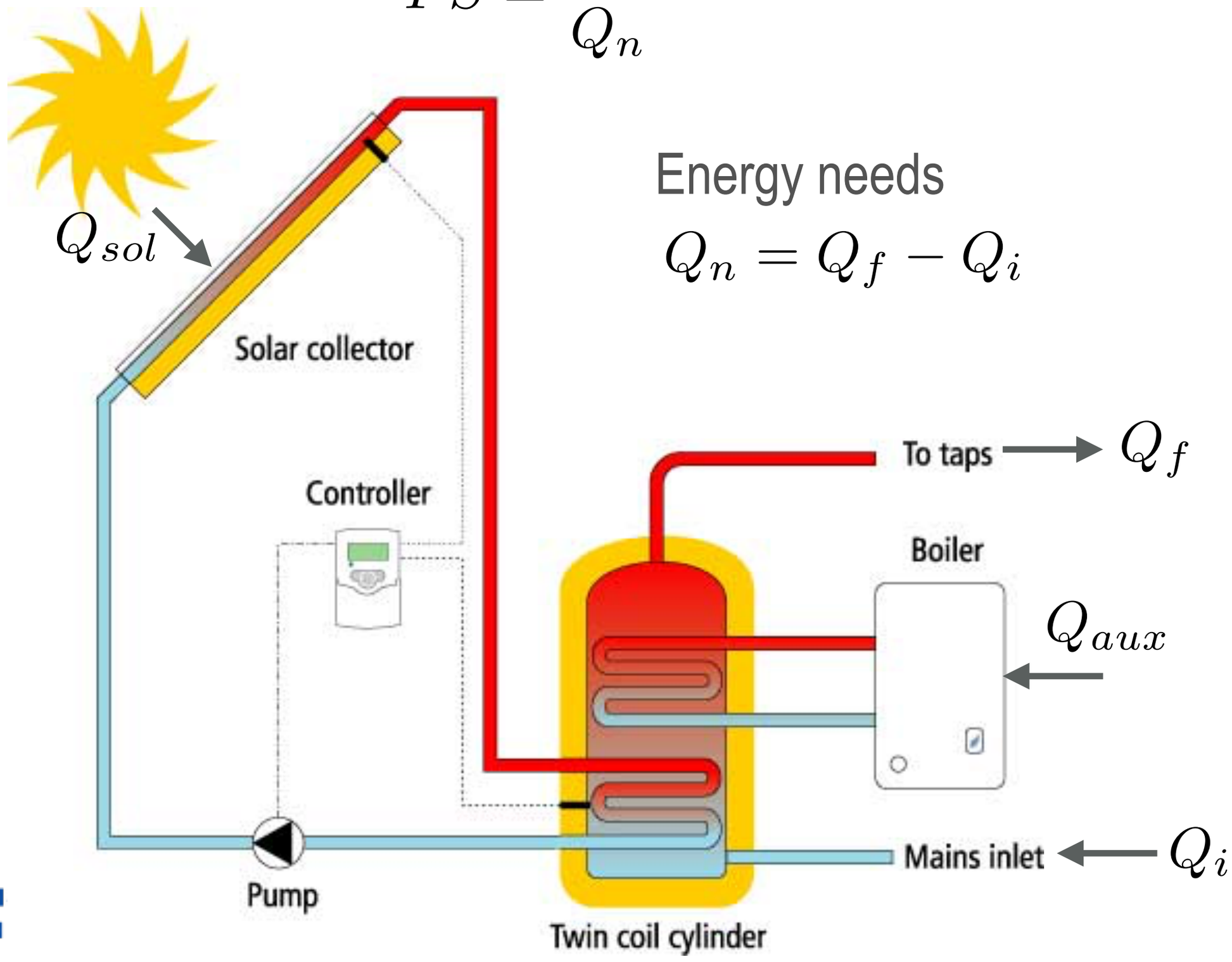
- solar collector efficiency
- pipes thermal losses
- storage tank thermal losses

$$\eta = \frac{Q_u}{Q_{sol}}$$

$$Q_u = Q_f - Q_i - Q_{aux}$$



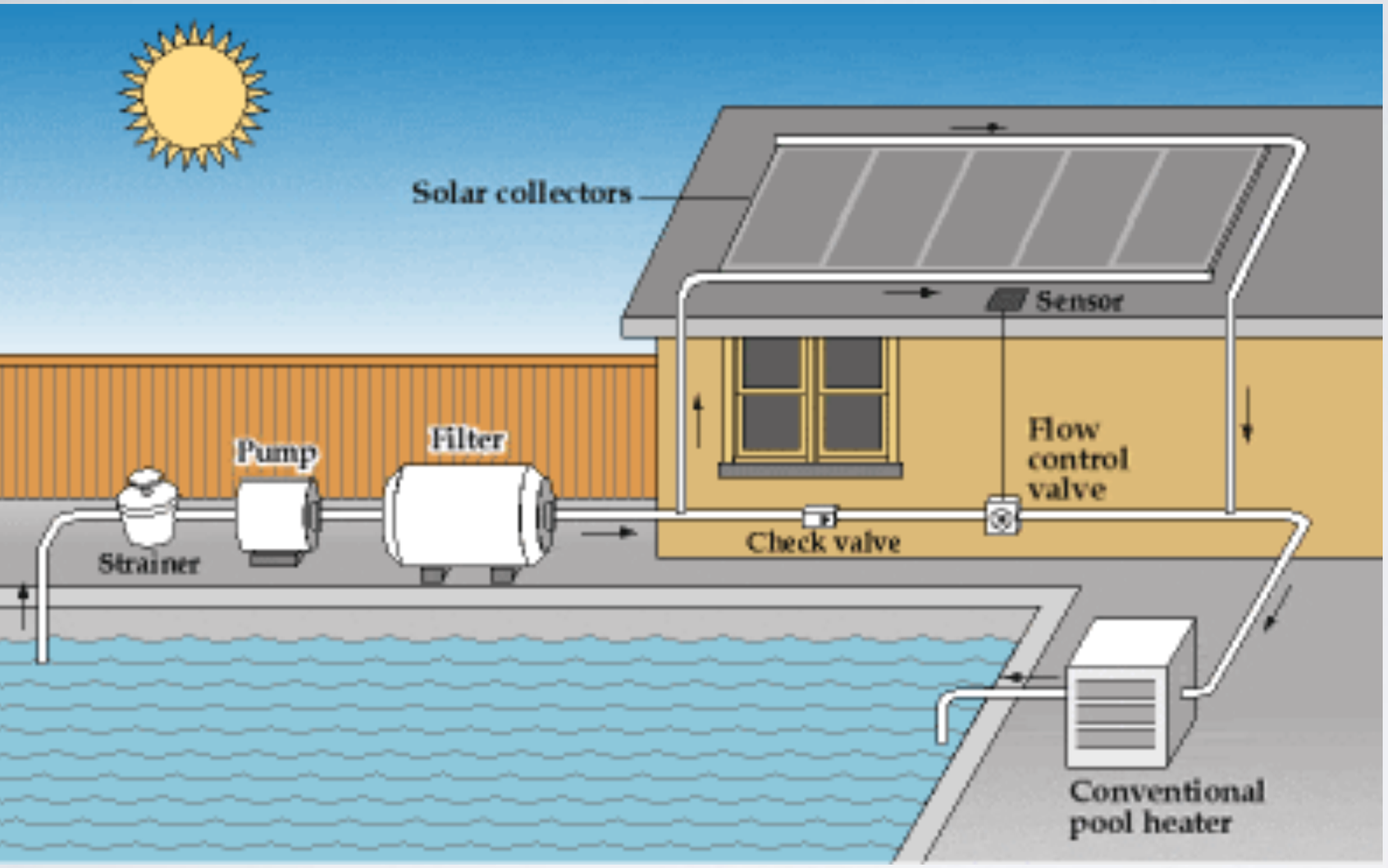
$$FS = \frac{Q_u}{Q_n}$$



Energy needs

$$Q_n = Q_f - Q_i$$

unglazed solar collectors



- low water temperature
- for swimming pools (no storage tank needed)
- evaporator component of heat pump

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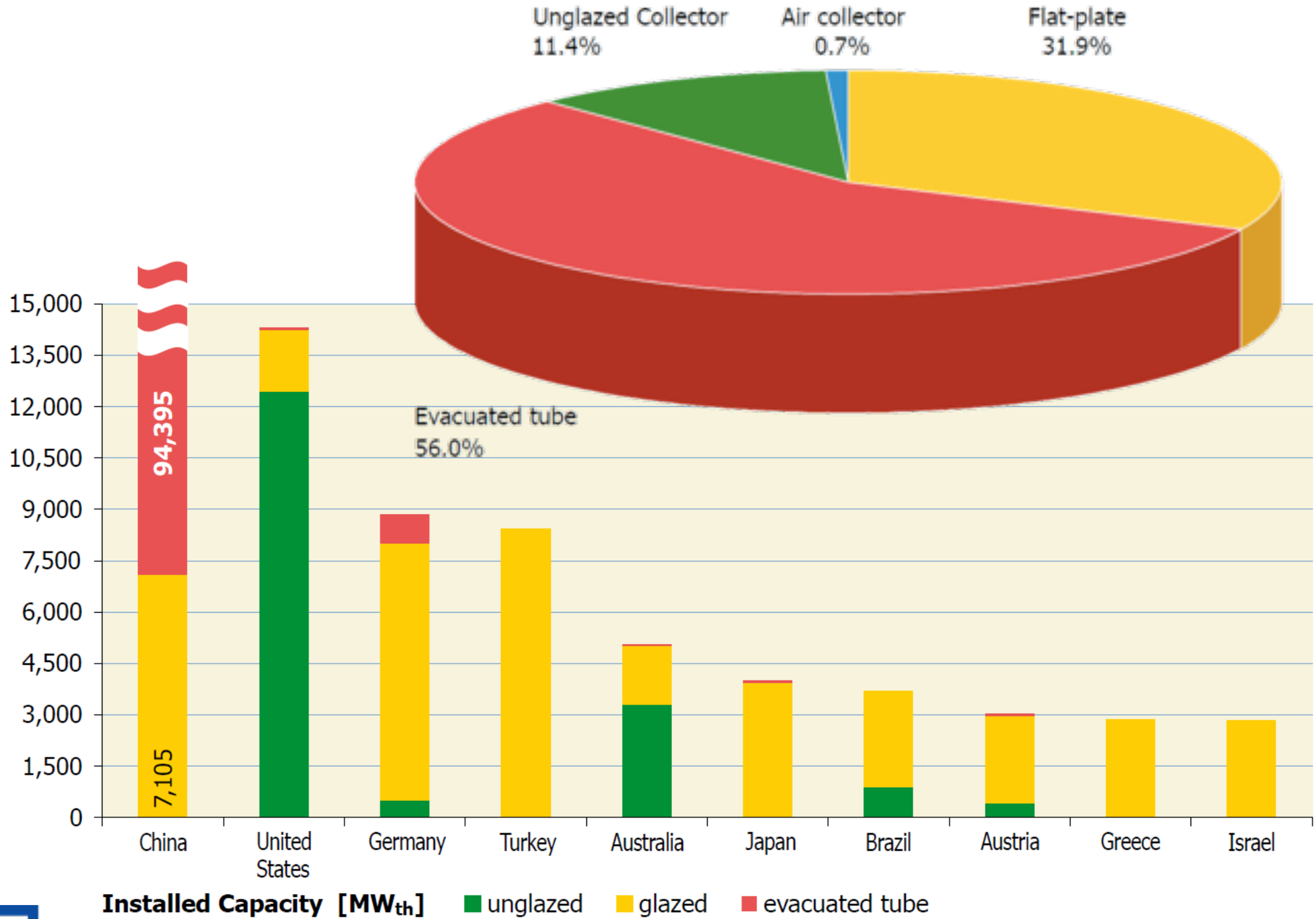
installed solar collectors by type



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Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE – U.S. cents/kWh)
Hot Water/Heating/Cooling (continued)			
Solar thermal: Domestic hot water systems	Collector type: flat-plate, evacuated tube (thermosiphon and pumped systems) Plant size: 2.1–4.2 kW_{th} (single family); 35 kW_{th} (multi-family) Efficiency: 100%	Single-family: 1,100–2,140 (OECD, new build); 1,300–2,200 (OECD, retrofit) 150–635 (China) Multi-family: 950–1,850 (OECD, new build); 1,140–2,050 (OECD, retrofit)	1.5–28 (China)
Solar thermal: Domestic heat and hot water systems (combi)	Collector type: same as water only Plant size: 7–10 kW_{th} (single-family); 70–130 kW_{th} (multi-family); 70–3,500 kW_{th} (district heating); >3,500 kW_{th} (district heat with seasonal storage) Efficiency: 100%	Single-family: same as water only Multi-family: same as water only District heat (Europe): 460–780; with storage: 470–1,060	5–50 (domestic hot water) District heat: 4 and up (Denmark)

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OUTROS SISTEMAS SOLARES

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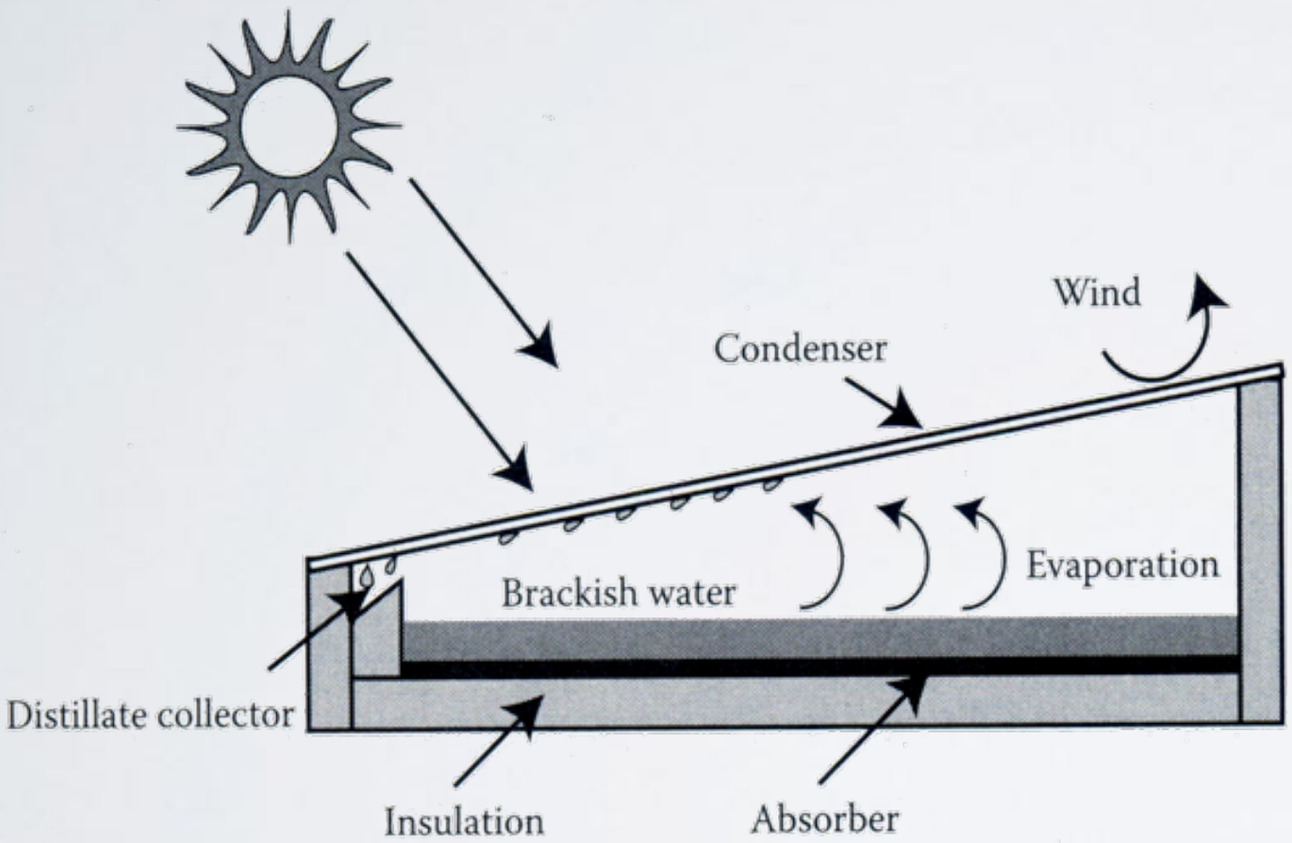
DESTILADOR SOLAR



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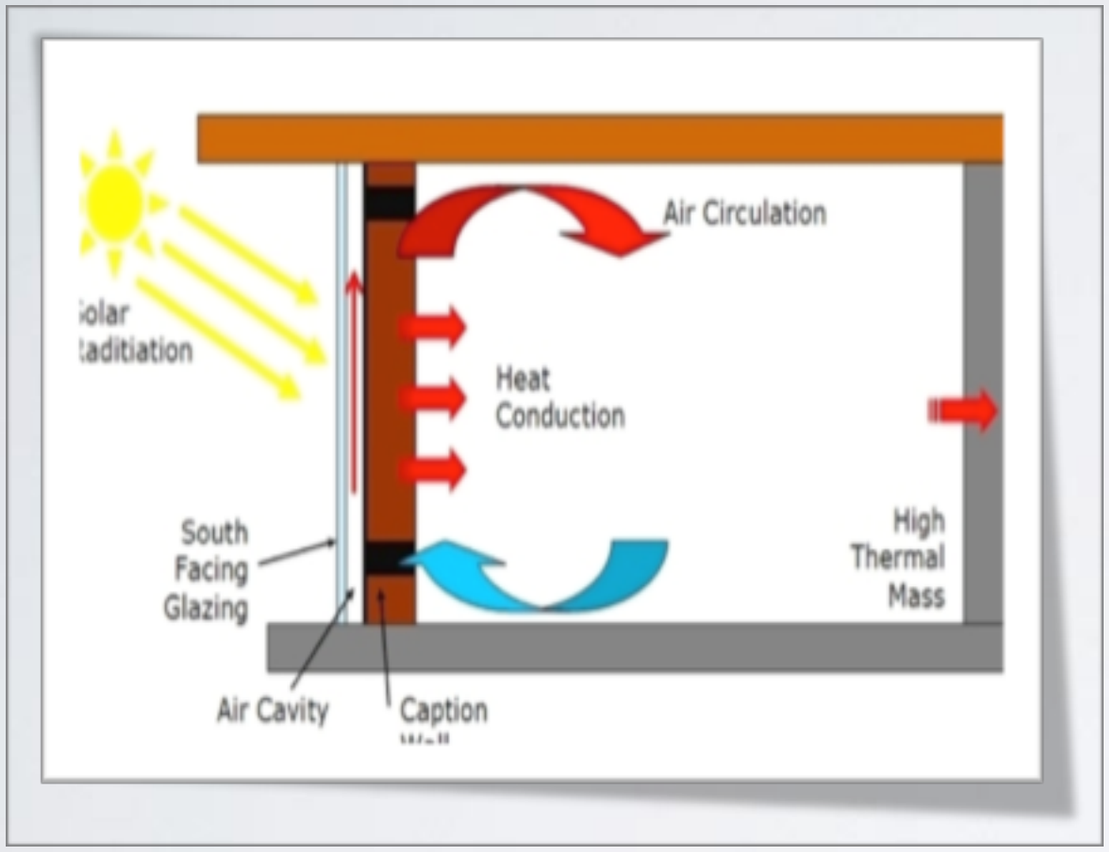
PAREDES DE ACUMULAÇÃO



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FORNO SOLAR

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Solar Thermal Energy (2.6, 2.10)

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