

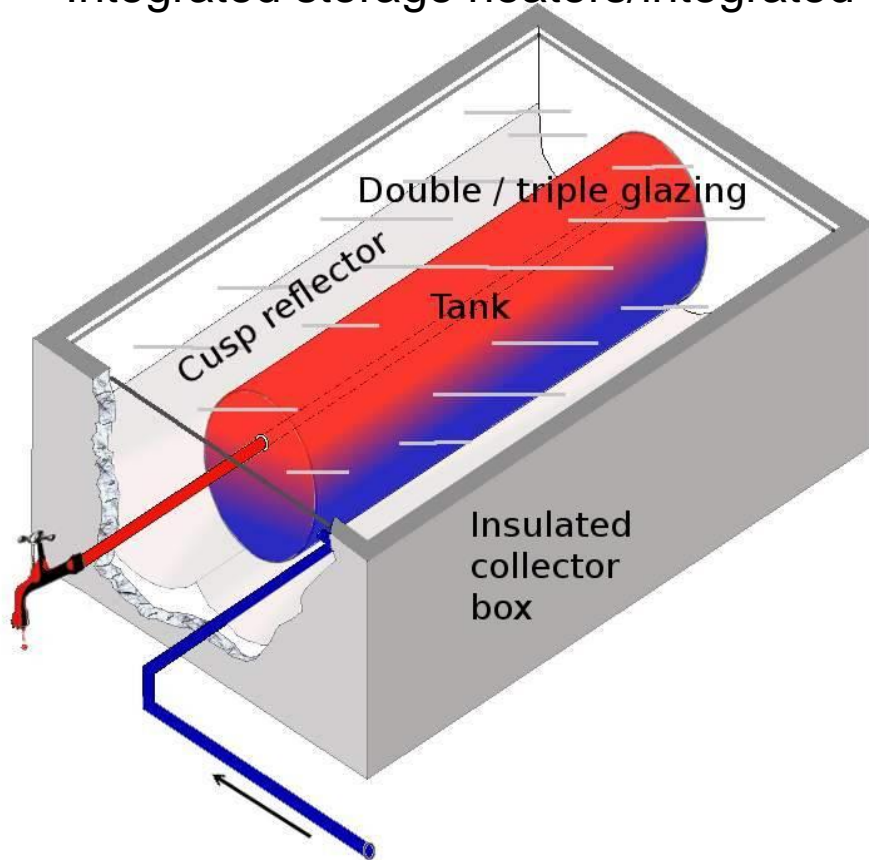


# Solar applications and market

Konstantinos Ninikas  
kninikas@uth.gr

# Other types of solar collectors

Integrated storage heaters/integrated collector storage/ batch collectors



Simple, cheap, heavy losses, low efficiency



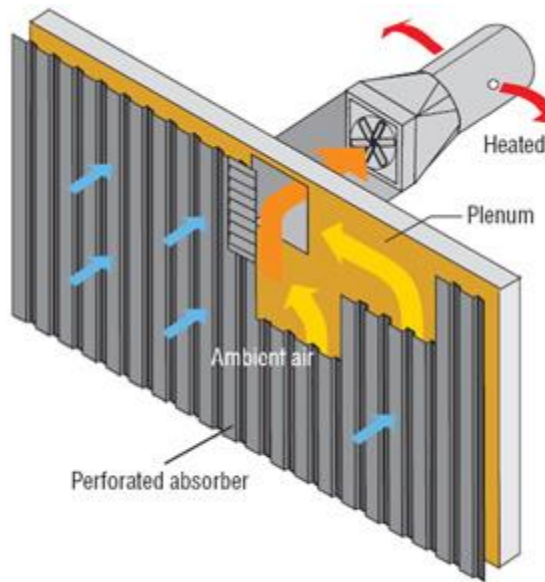
## Pool collectors



Usually from rubbers, low temp rise, low heat gain, increased losses.



# Air collectors



Remember  $Q_u = mc_p(T_o - T_i)$  Cp of water is 4.2, Cp of air is 1

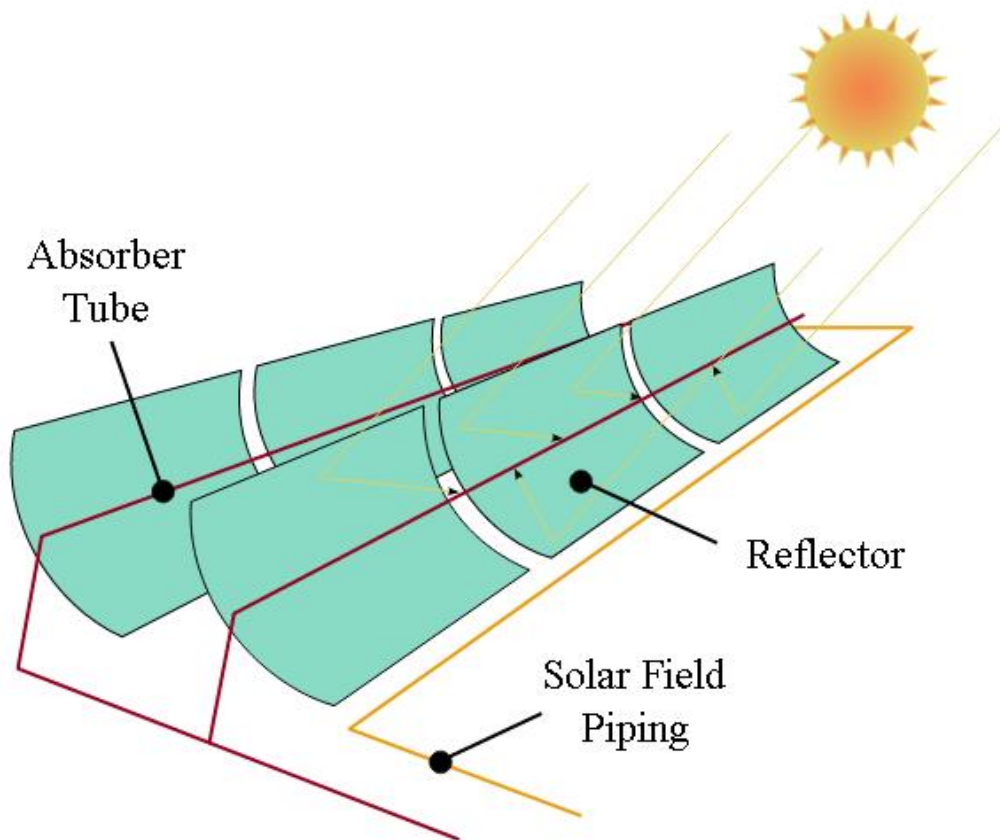
Temperature rise might be big, but heat gain is small

## Solar concentrators (dish system)

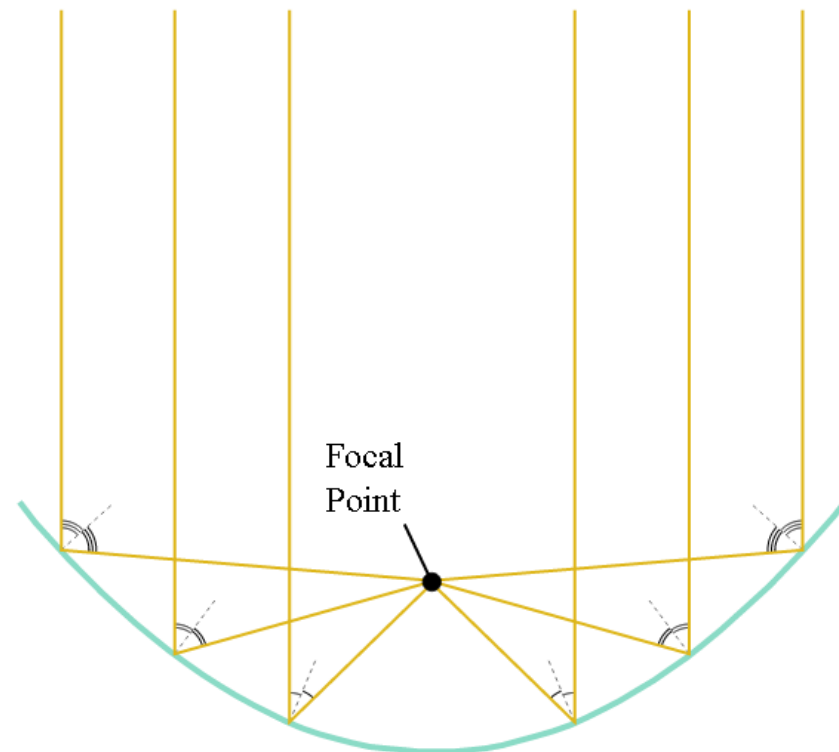


Each dish can produce from 5 to 50 kW of electricity and can be used independently or linked together to increase generating capacity. A 250-kW plant composed of ten 25-kW dish/engine systems requires less than an acre of land

# Parabolic trough



A parabola which has an absorber tube located in its focal point  
Heat transfer fluid (oil or water) flows in the absorber tube  
Fluid absorbs the heat from the tube and then heats steam that powers a steam turbine



Solnova Solar power station, Seville, Spain. 5 units of 50 MWe each



## Solana plant, Arizona, USA



Largest parabolic trough plant in the world using molten salt for heat storage

Keeps generating energy for hours after sundown

280 MW, 7.8 Km<sup>2</sup>

## SEGS plant, California, USA



Second largest solar thermal facility in the world, largest parabolic trough installation

Located in the Mojave desert

354 MW providing 662 GWh annually

6.5 Km<sup>2</sup>

936,384 mirrors in total

Lined up all the mirrors would have a length of 370 km



Noor 1, Morocco  
1<sup>st</sup> phase 160 MW

When the last stage is completed, estimated output 560 MW, 24.6 km<sup>2</sup>



Uses molten salt for storage, can  
run up to 20 hours per day

500,000 mirrors in total



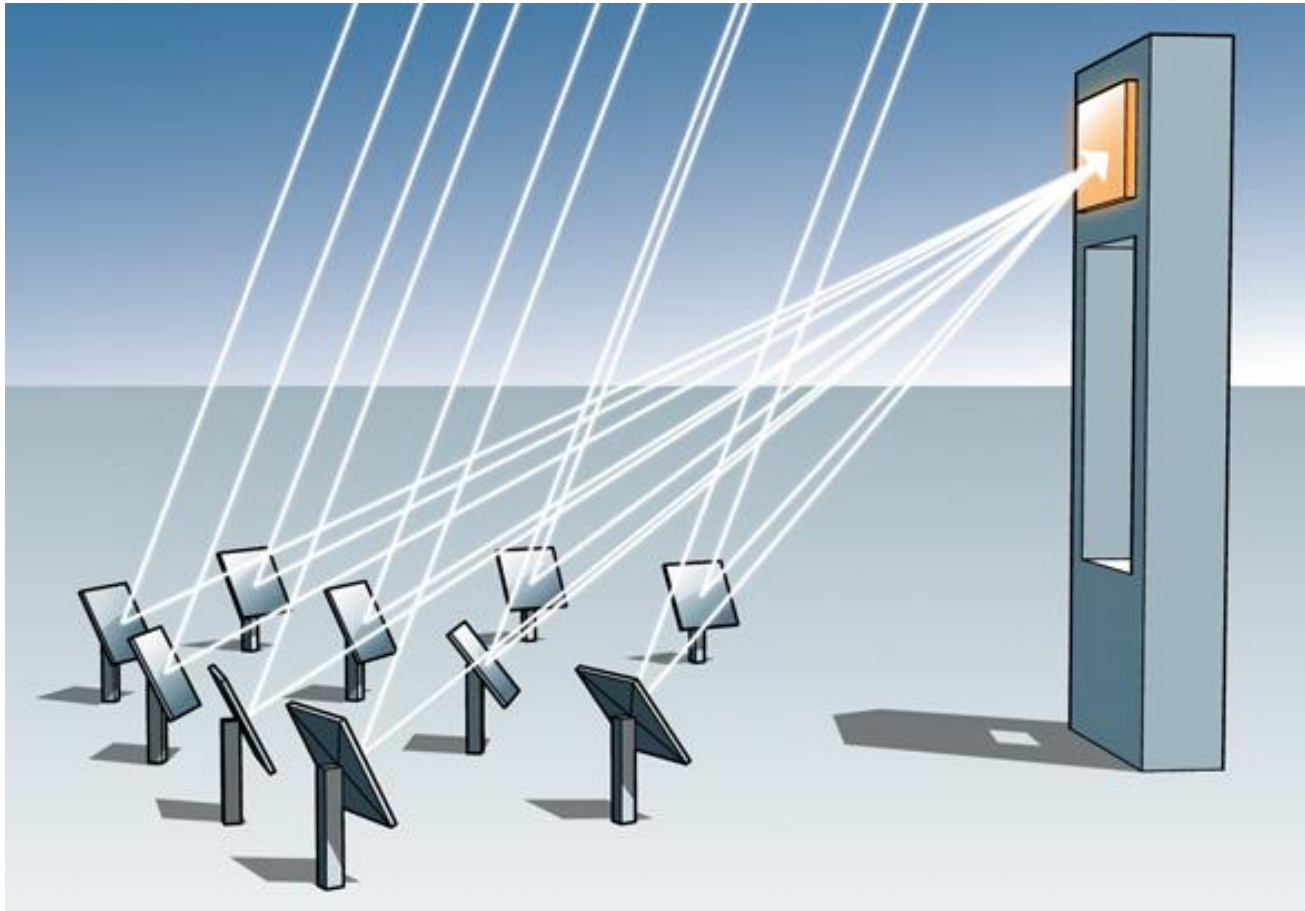


# So...seen Blade runner 2049?

<https://www.youtube.com/watch?v=u9L0pord5jE>

## Solar tower concept

Moving mirrors-heliostats track the sun and point it at a point in the tower.



Ivanpah solar power plant Mojave desert, California, US  
392MW, 173.500 mirrors, 14 km<sup>2</sup>





PS10 solar power plant in Seville,  
Spain

The plant produces steam at 275  
degrees

11MW of electricity by a steam turbine.

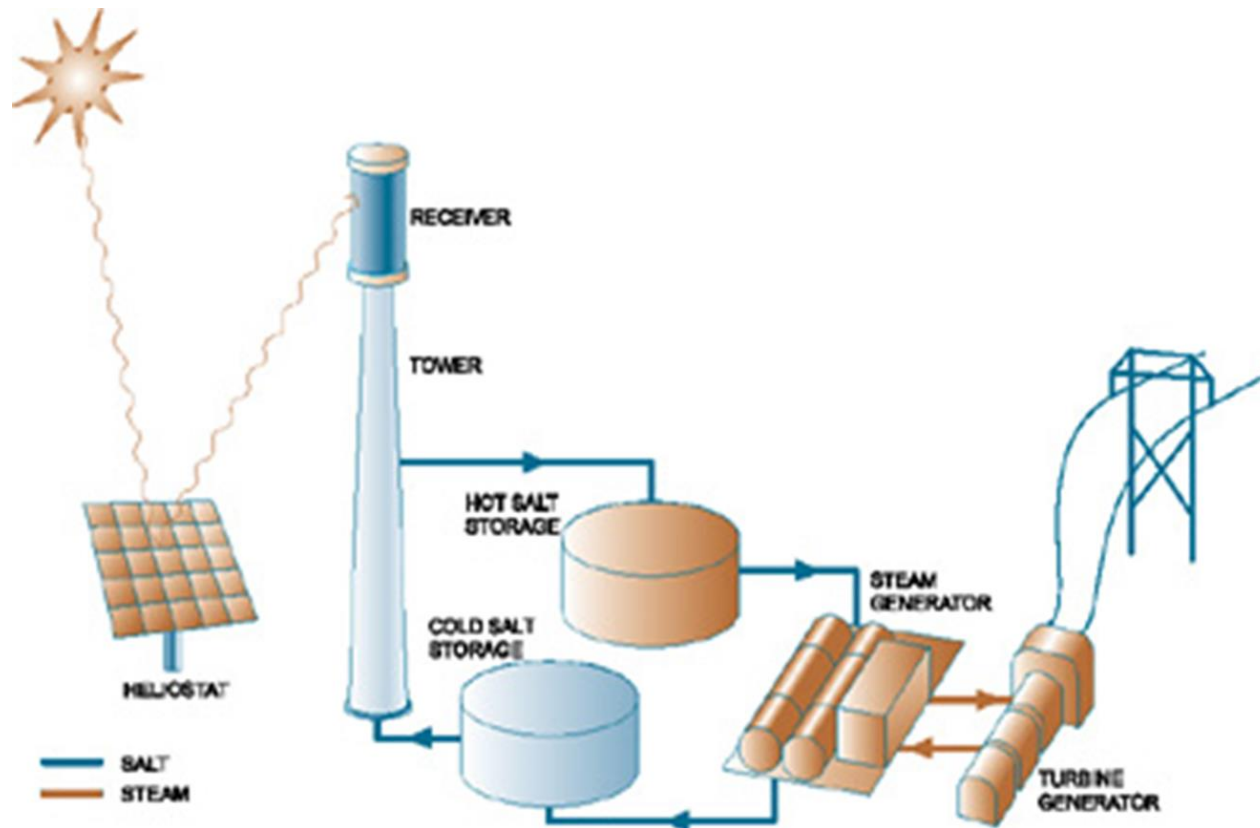




PS20 solar  
power plant  
again in Seville,  
Spain

20MW of  
electricity

# The process of molten salt storage



## Odeillo Solar furnace, France

Parabolic mirrors focus sunlight on a certain points.

Temperatures of over  $3,500^{\circ}$ , focused on an area of a cooking pot.

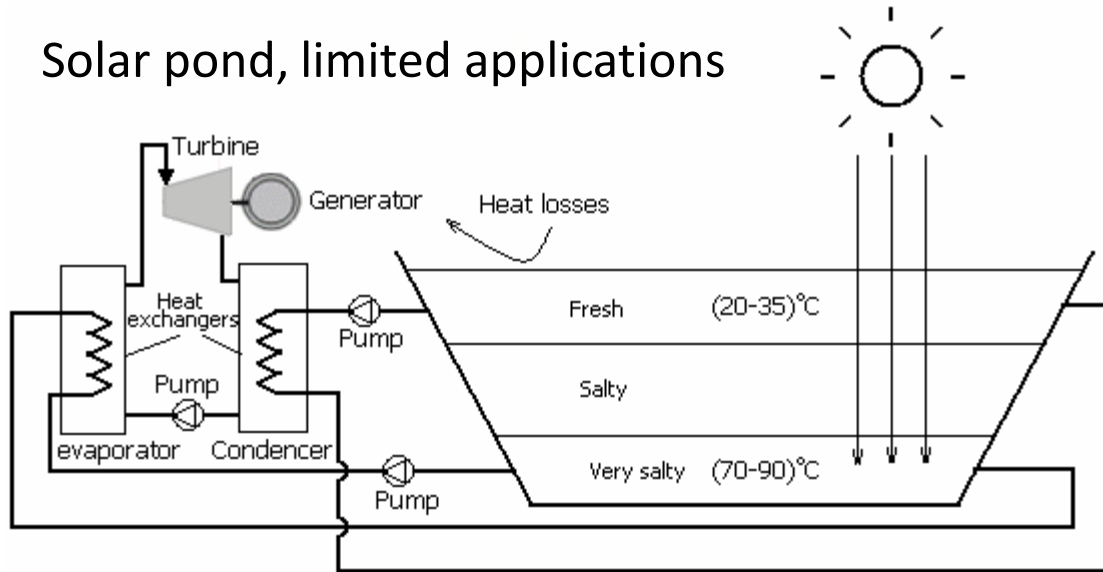


## key features of the three solar technologies

	<b>Parabolic Trough</b>	<b>Dish/Engine</b>	<b>Power Tower</b>
Size	30-320 MW	5-25 kW	10-200 MW
Operating Temperature (°C/°F)	390/734	750/1382	565/1049
Annual Capacity Factor	23-50 %	25 %	20-77 %
Peak Efficiency	20%(d)	29.4%(d)	23%(p)
Net Annual Efficiency	11(d)-16%	12-25%(p)	7(d)-20%
Commercial Status	Commercially Scale-up Prototype	Demonstration	Available Demonstration
Technology Development Risk	Low	High	Medium
Storage Available	Limited	Battery	Yes
Hybrid Designs	Yes	Yes	Yes
Cost USD/W	2,7-4,0	1,3-12,6	2,5-4,4

(p) = predicted; (d) = demonstrated

## Solar pond, limited applications

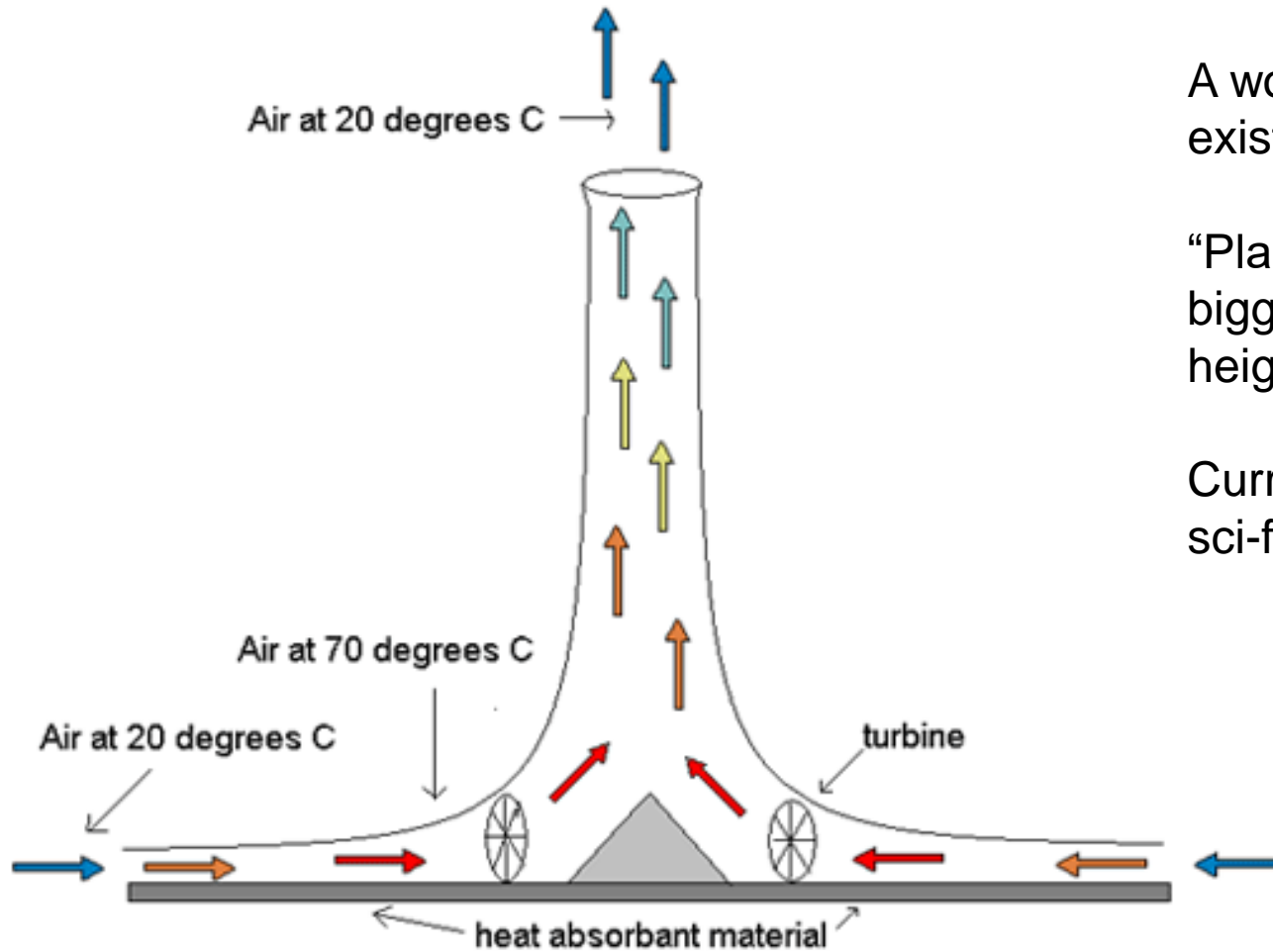


Different concentrations of salt cause a density gradient.

The water on the bottom is more dense, and so despite the temperature difference doesn't rise



Solar “tower”, do not confuse with previous solar towers



A working prototype exists at 50KW

“Planning” to do a bigger one of 1Km height.

Currently in the realm of sci-fi

# Domestic/small scale applications

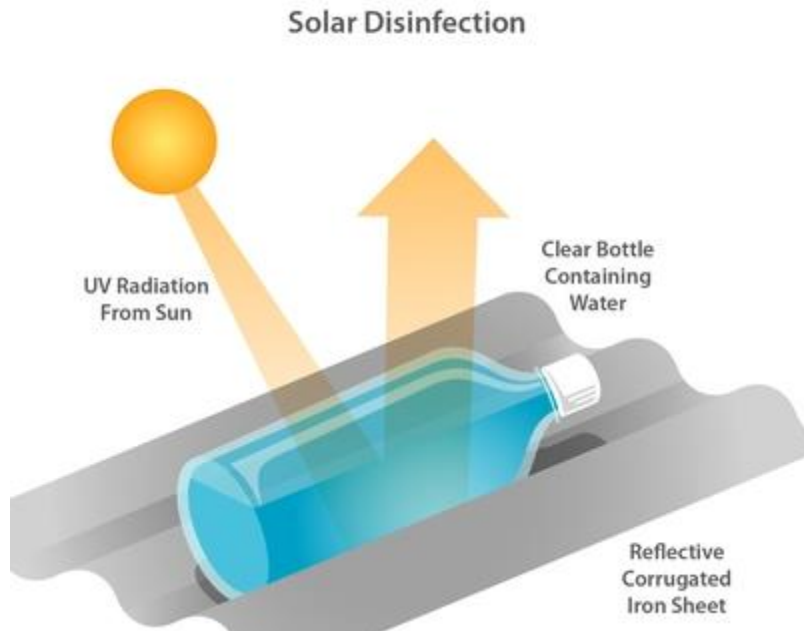
Solar cookers and solar ovens



# Solar showers

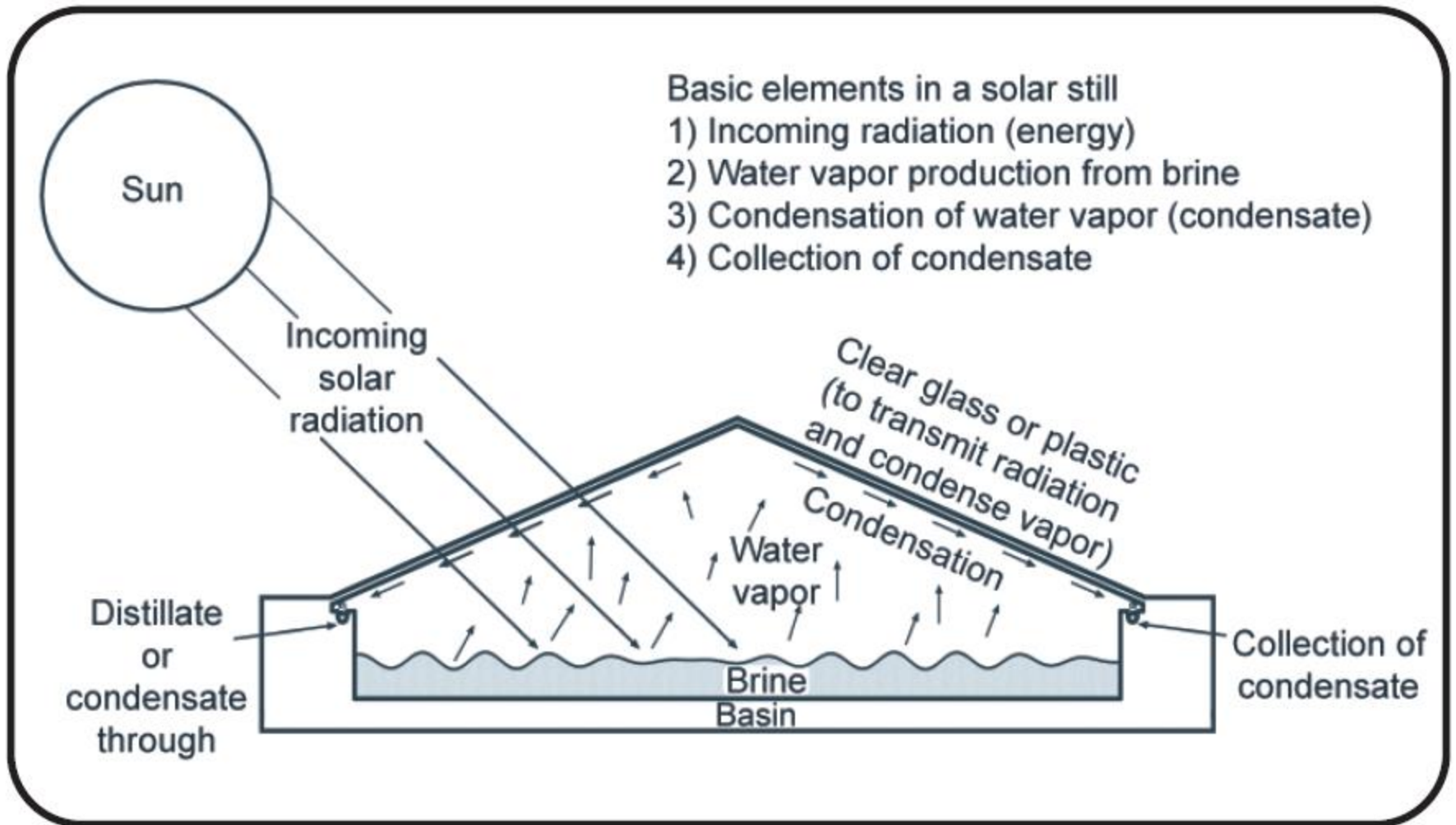


# Solar disinfection – SODIS

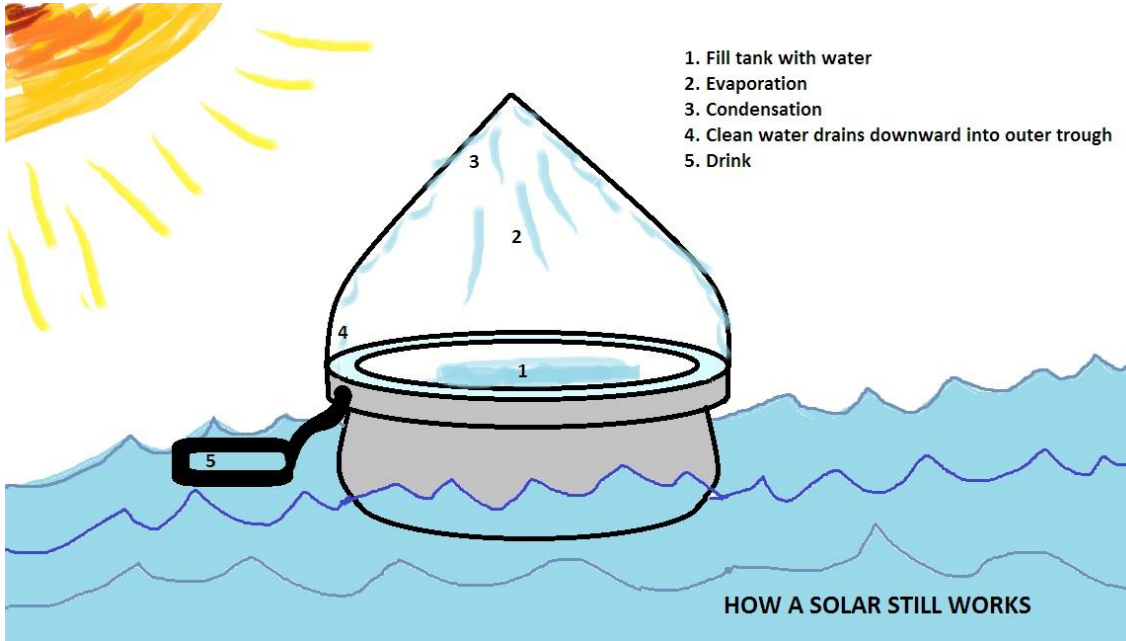


- Solar disinfection using PET bottles and radiation and heat from the Sun
- Recommended by Unicef, WHO and the red cross
- UV-A interferes directly with the metabolism and destroys cell structures of bacteria. Furthermore oxygen free radicals are formed that kill pathogens. After six hours water is safe to drink
- If the water temperatures rises above 50 °C, the disinfection process even faster.

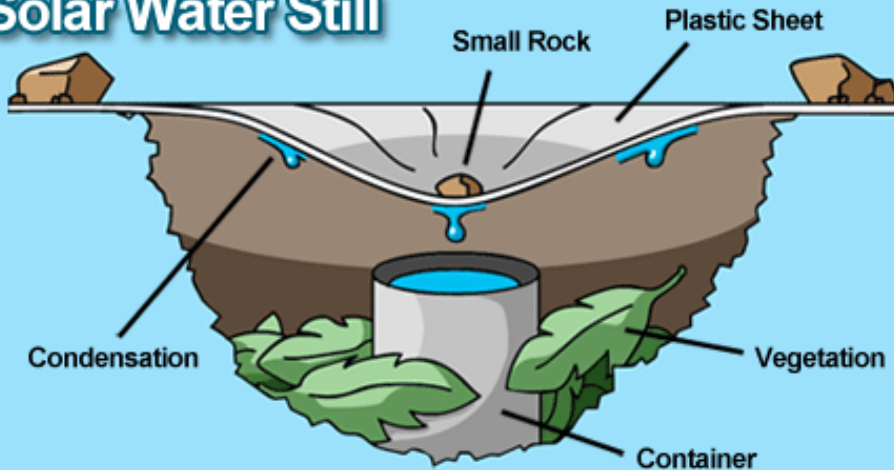
# Solar desalination



# Solar stills



## Solar Water Still



# Evaporation ponds

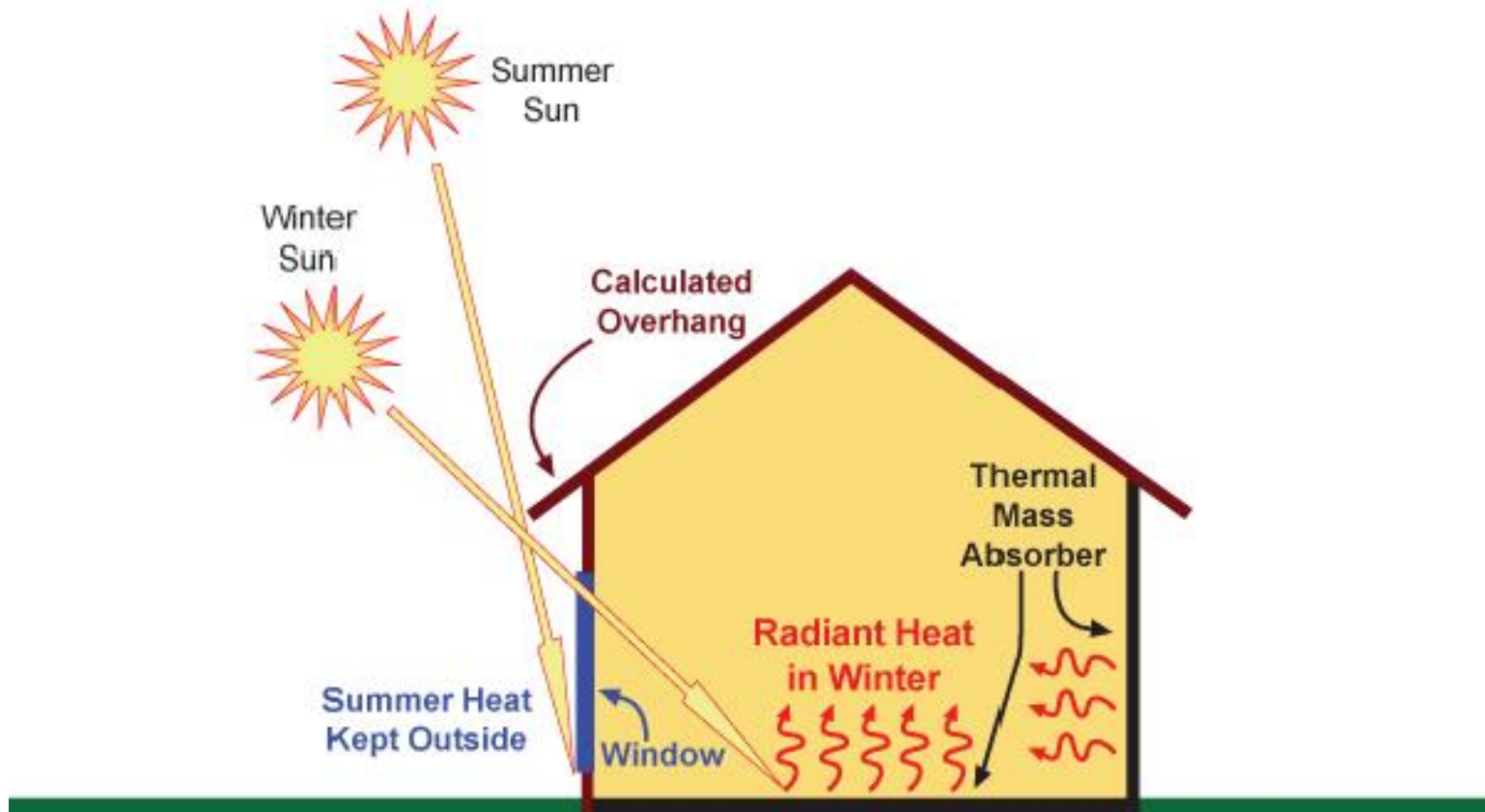




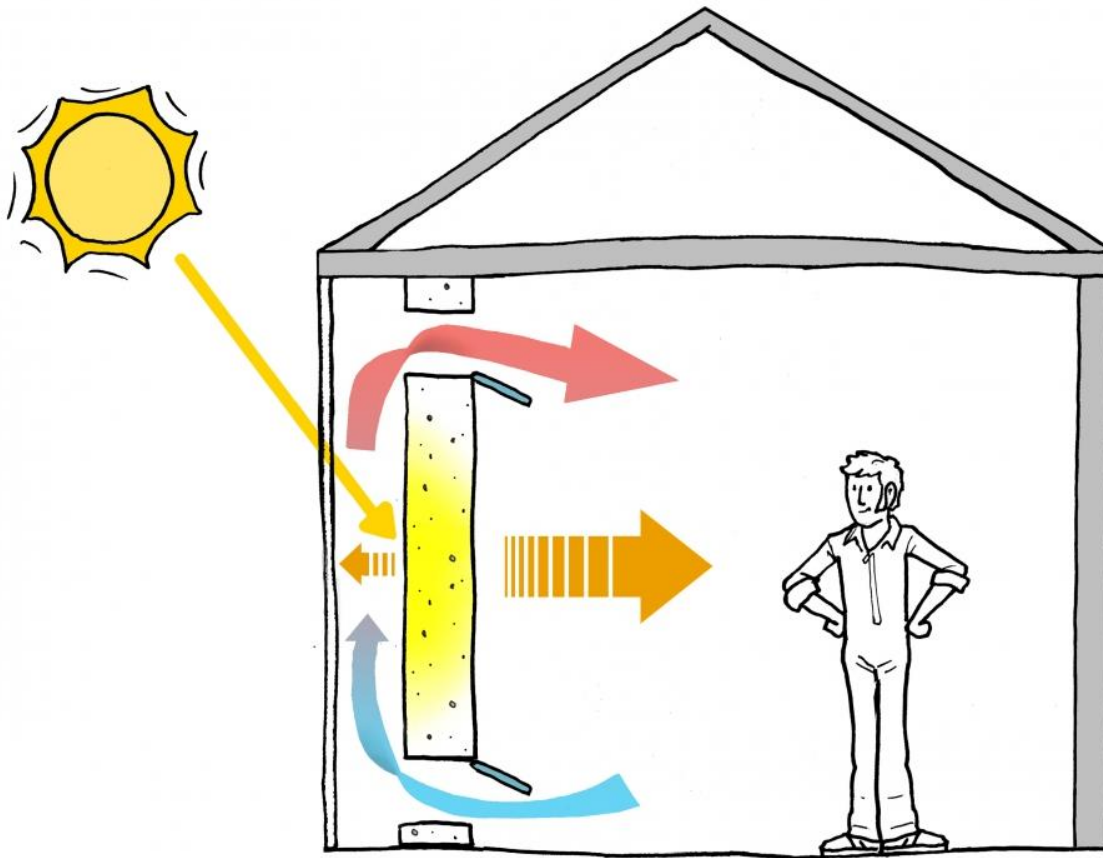
# Building use

- Passive solar design uses windows, walls and floors in order to capture and distribute heat from the sun
- Called passive cause no mechanical means are used.
- Aim is to minimise building energy lost
- Some buildings have even managed net energy gain

# Passive Solar Design



# Trombe walls for heating and cooling



## First mechanism

A wall is built on the winter sun side of a building with a glass external layer and a high heat capacity internal layer

Wall that then re-radiates in the far infrared spectrum

Absorb heat during sunlit hours of winter then slowly release the heat over night.

## Second mechanism

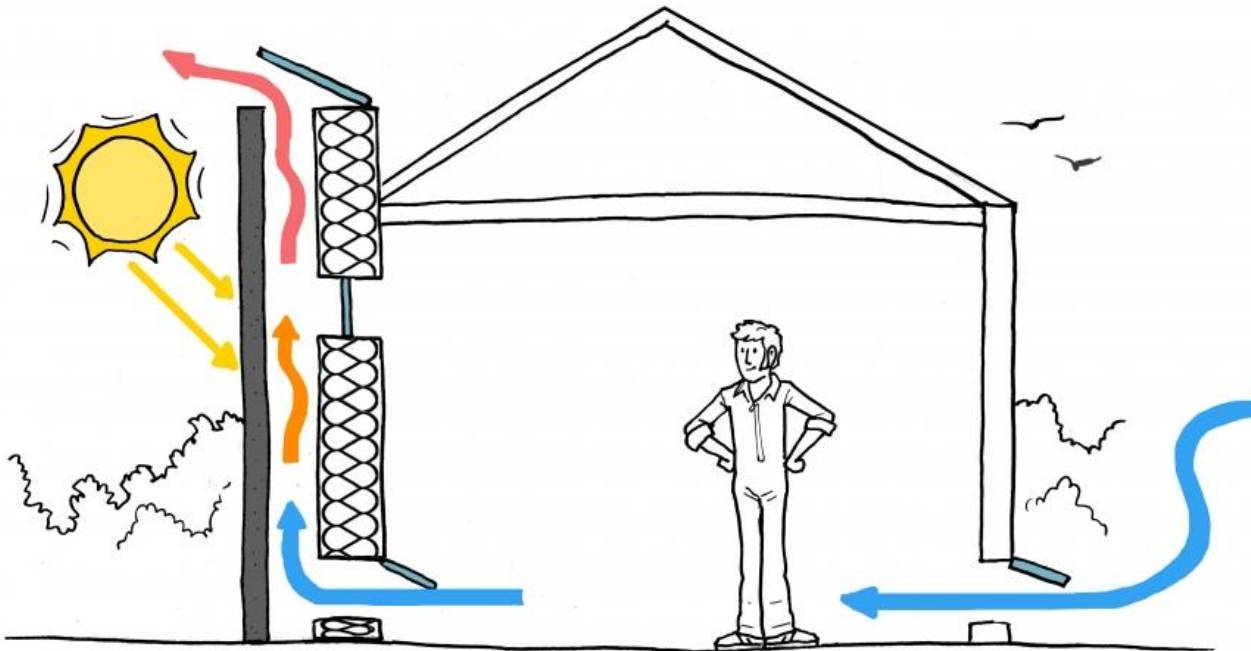
Air is heated because of the heated wall and rises causing a circulation of warm air

# COOLING

Wall absorbs radiation and heats up

Warmed air rises causing a suction of cooler air from the outside

Airflow current helps cool the house



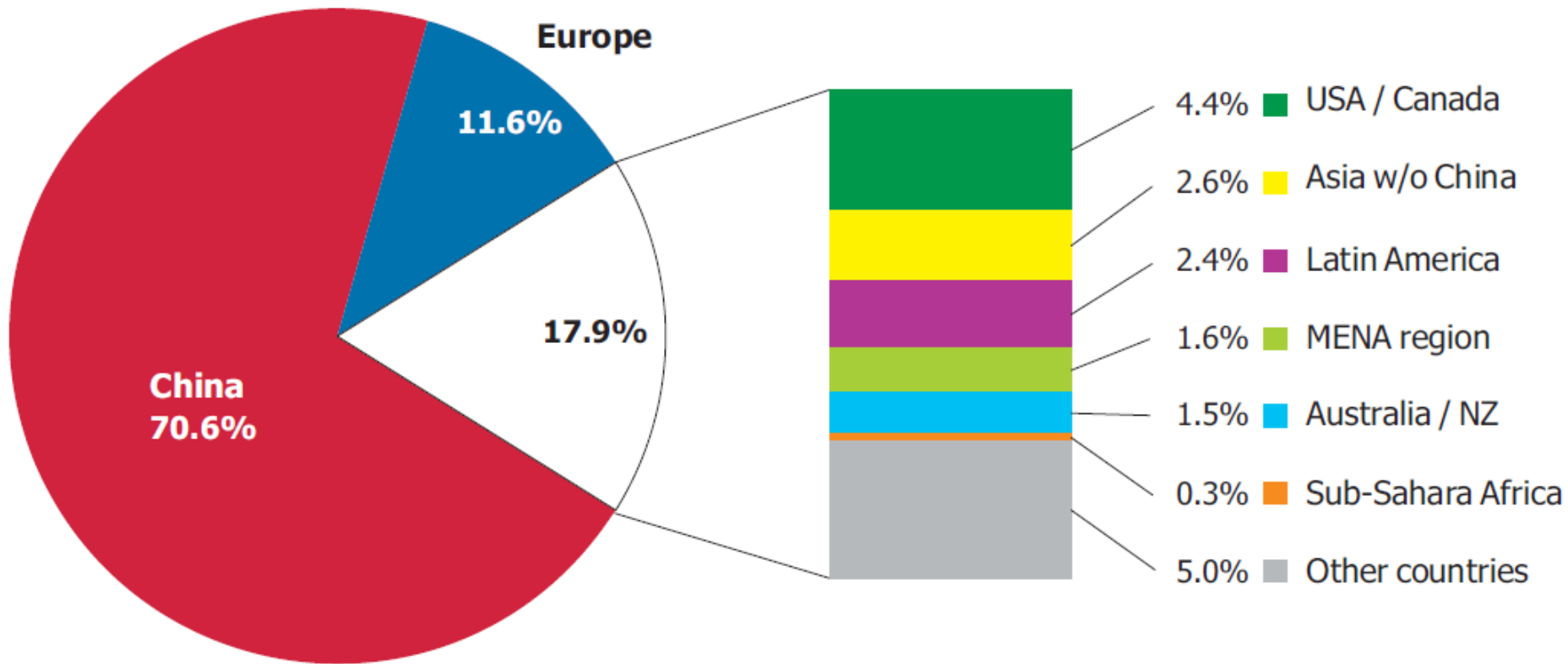


# Renewable heat incentive

Latest domestic and commercial tariffs are (Domestic closed from March 2021)

	<b>Biomass</b>	<b>Solar thermal</b>
<b>Domestic tariff (p/kWh renewable heat)</b>	14.22-5.08(Price for 2021/2022)	21.09
<b>Commercial tariff (p/kWh renewable heat)</b>	10.26-1.16(price from Jan 2017)	Starting from 10.98- depending on date and output

# Total installed capacity in operation



Sub-Sahara Africa:

Asia w/o China:

Latin America:

Europe:

MENA region:

Lesotho, Mauritius, Mozambique, Namibia, South Africa, Zimbabwe

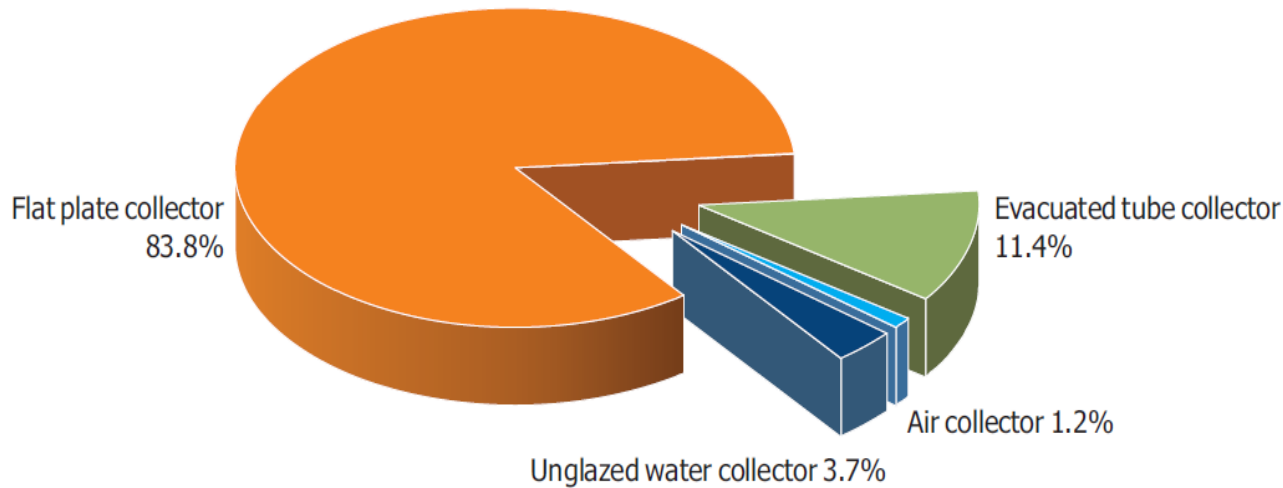
India, Japan, Korea South, Taiwan, Thailand

Barbados, Brazil, Chile, Mexico, Uruguay

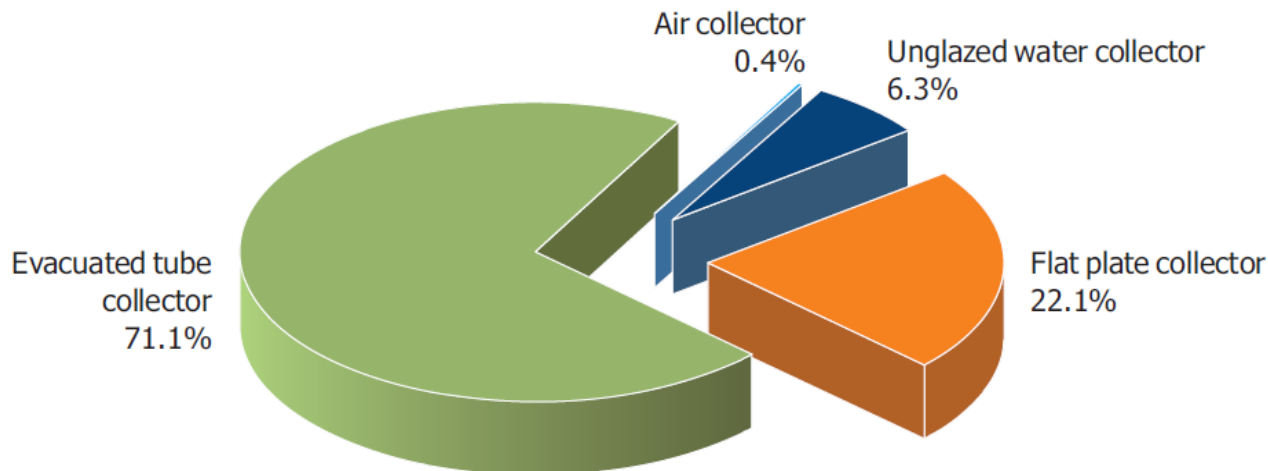
EU 28, Albania, Macedonia, Norway, Russia, Switzerland, Turkey

Israel, Jordan, Lebanon, Morocco, Palestinian Territories, Tunisia

# Installed capacity in Europe vs the rest of the world

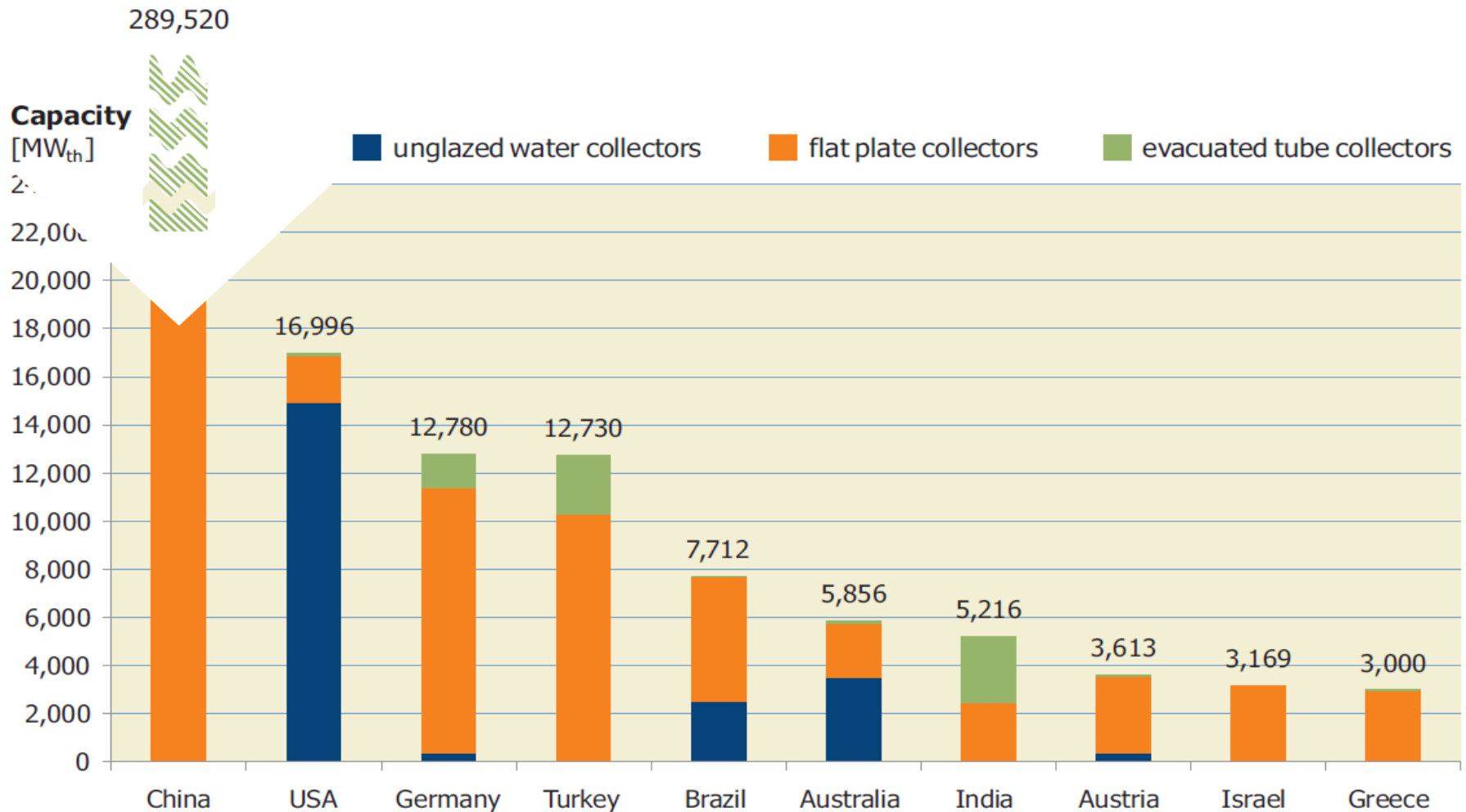


Europe

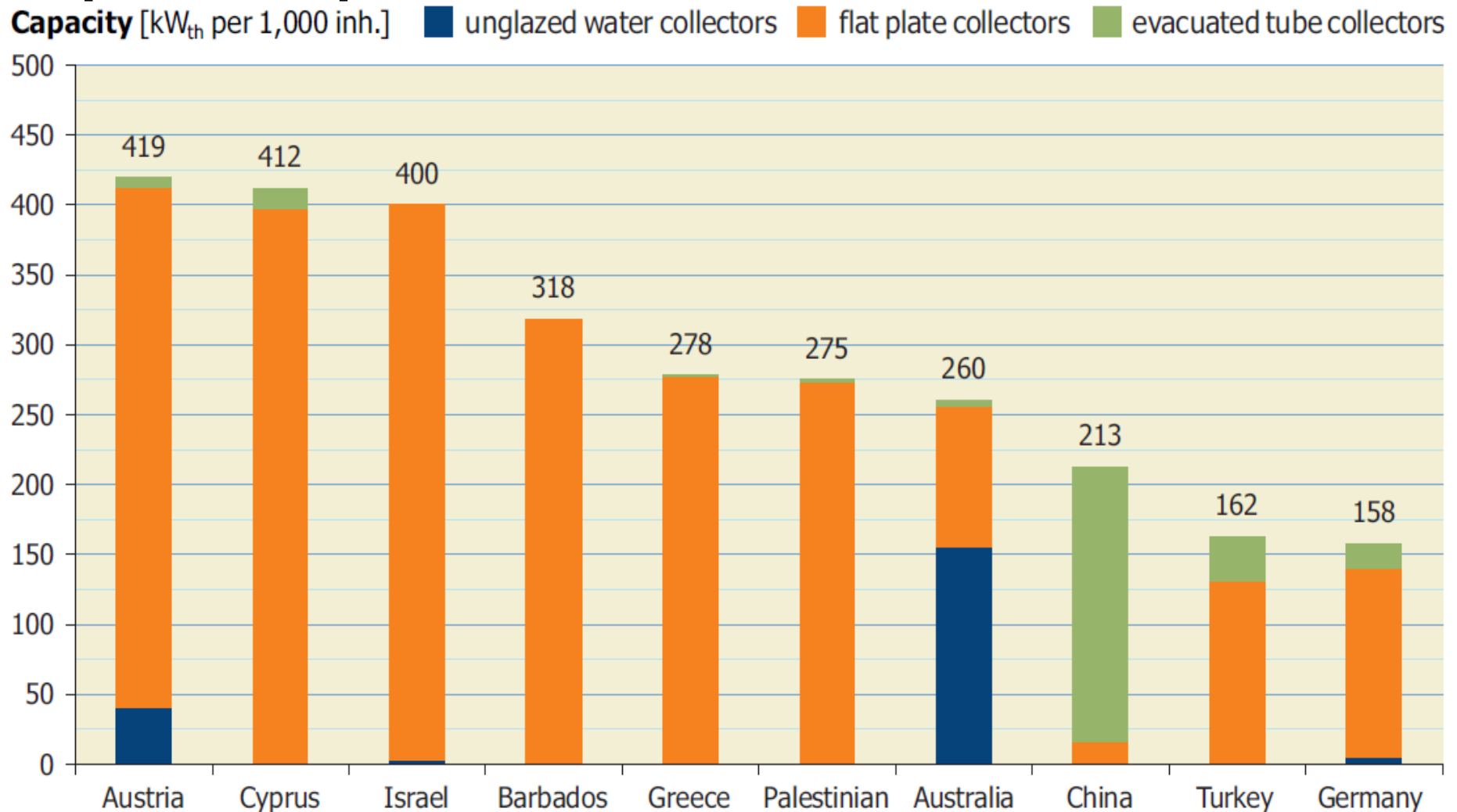


World – why such a big difference?

# Cumulated installed capacity – top 10 countries

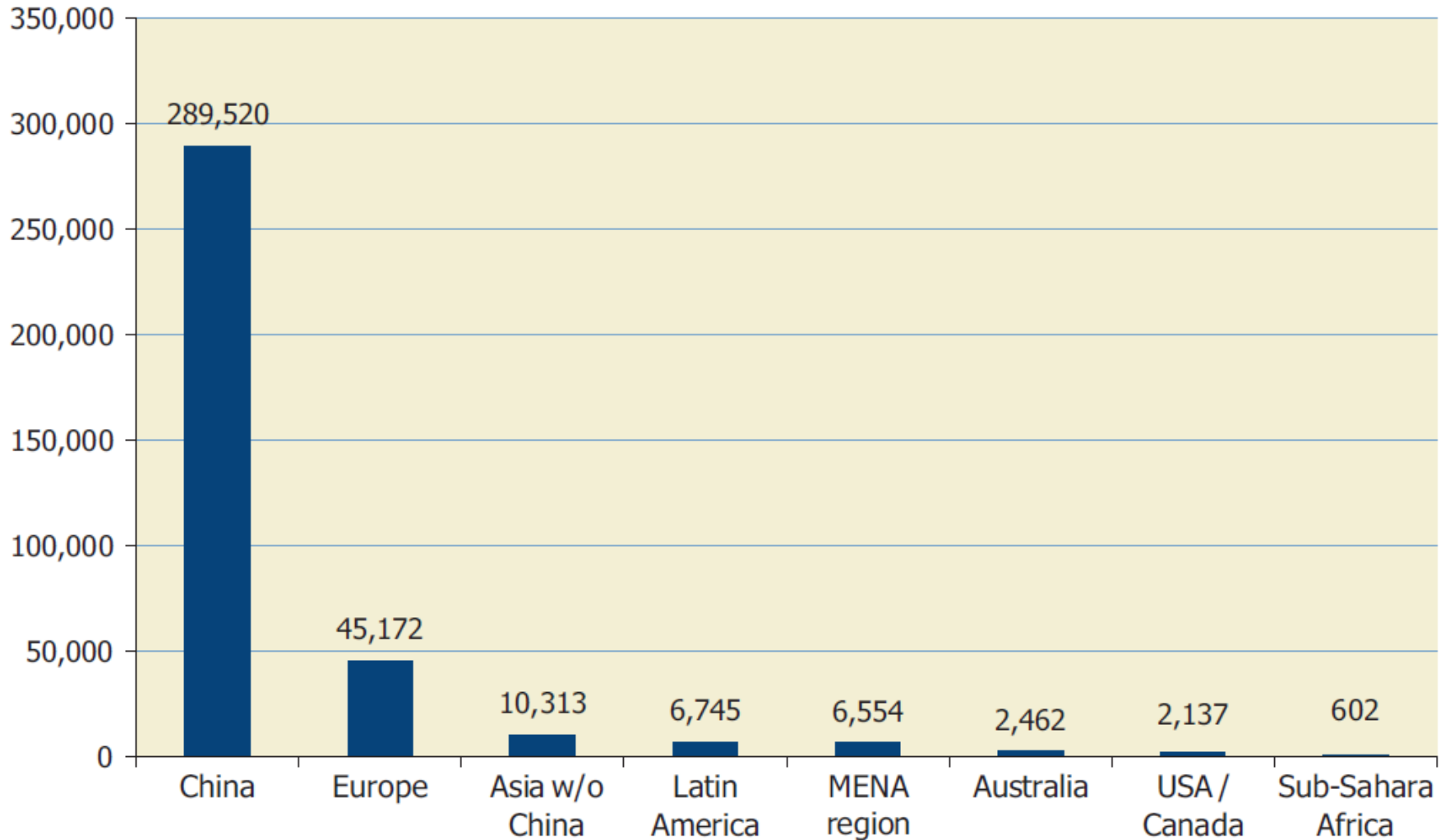


# Cumulated installed capacity per capita.



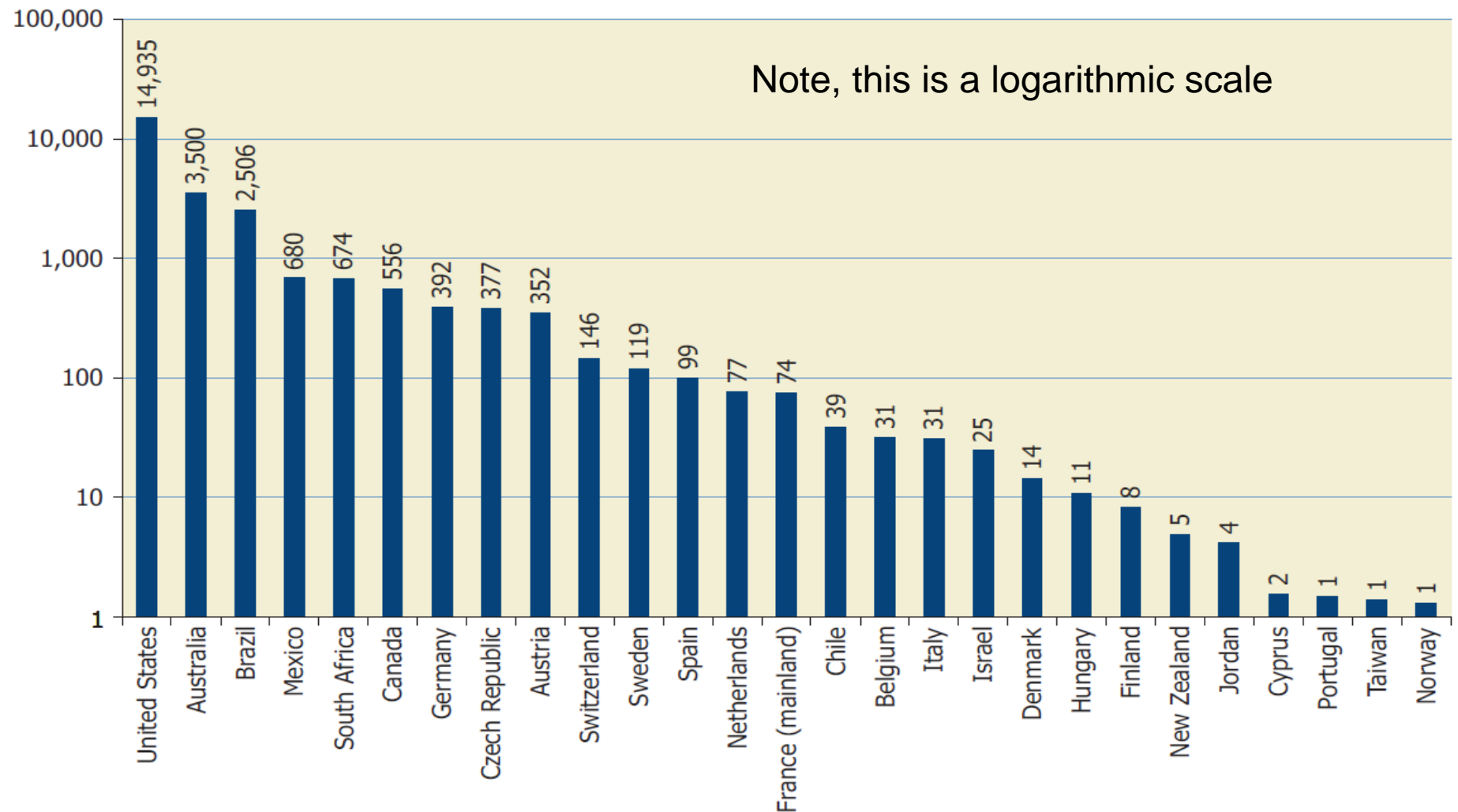
# Glazed collectors

Capacity [ $\text{MW}_{\text{th}}$ ]



# Unglazed collectors

Capacity [MW<sub>th</sub>]





# Economic and Environmental Considerations

The most important factor driving the solar energy system design process is whether the energy it produces is economical.

Although there are factors other than economics that enter into a decision of when to use solar energy; i.e. no pollution, no greenhouse gas generation, security of the energy resource etc., design decisions are almost exclusively dominated by the 'levelised energy cost' (LEC).

This economic parameter, gives the expected cost of the energy produced by the solar energy system, averaged over the lifetime of the system.

Commercial solar plants have achieved levelised energy costs of about 12-15¢/kWh, and the potential for cost reduction are expected to ultimately lead to costs as low as 5¢/kWh