Repetition

Werner Weiss

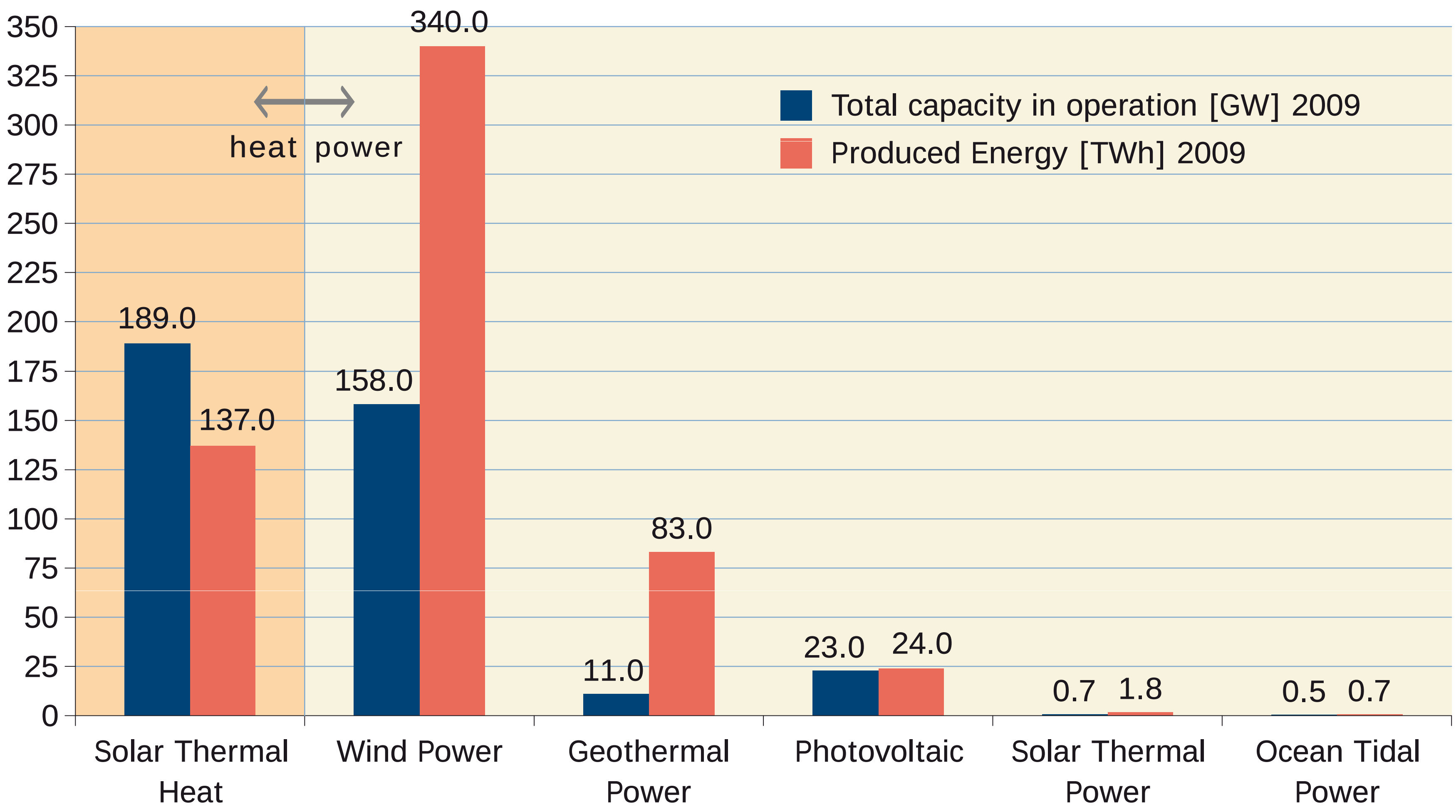
AEE - Institute for Sustainable Technologies
A-8200 Gleisdorf, Feldgasse 2
AUSTRIA

financed by
Austrian
Development Cooperation

Achievements - 2009

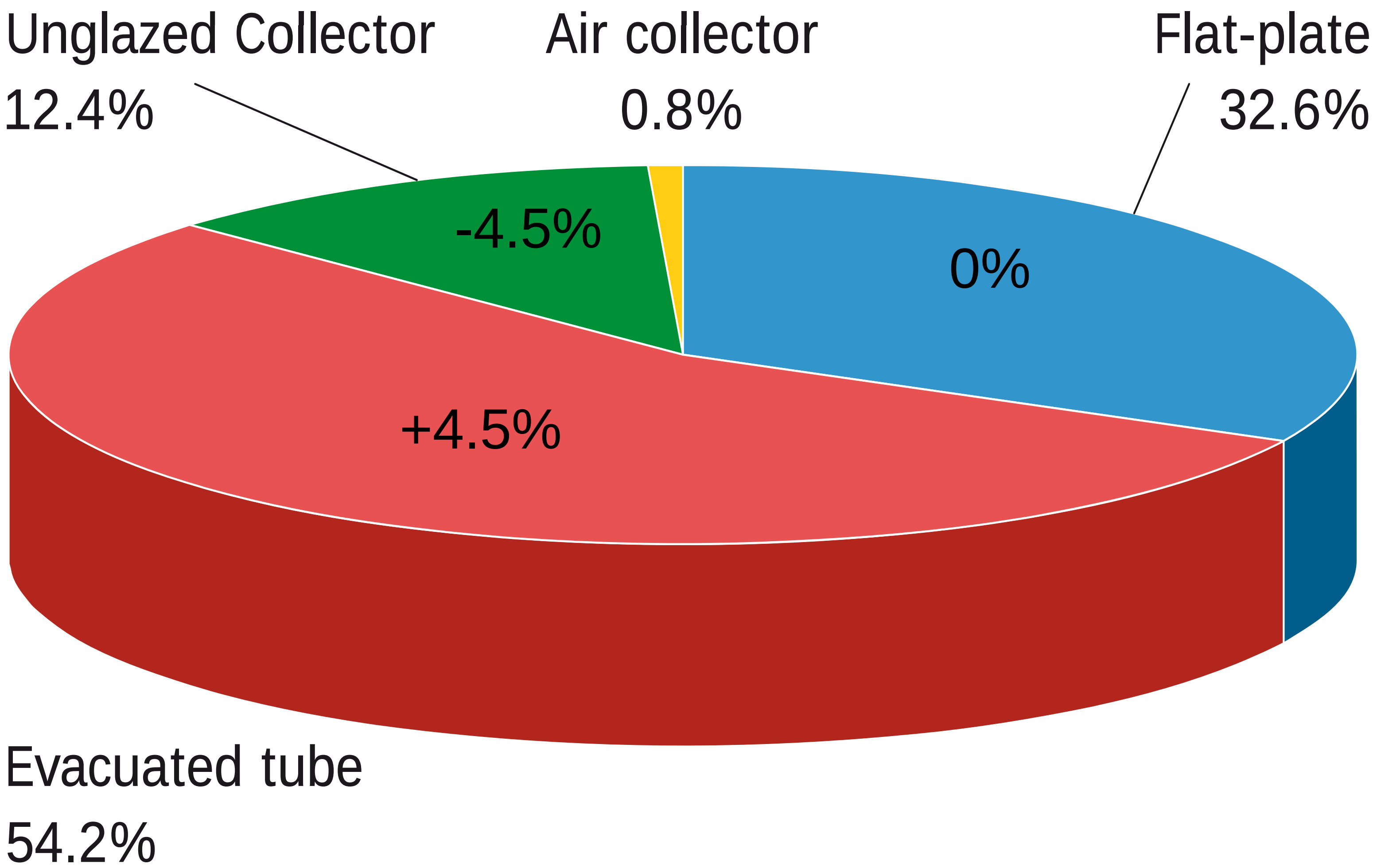
financed by
Austrian Development Cooperation

Total Capacity in Operation [GW_{el}], [GW_{th}] and Produced Energy [TWh_{el}], [TWh_{th}],



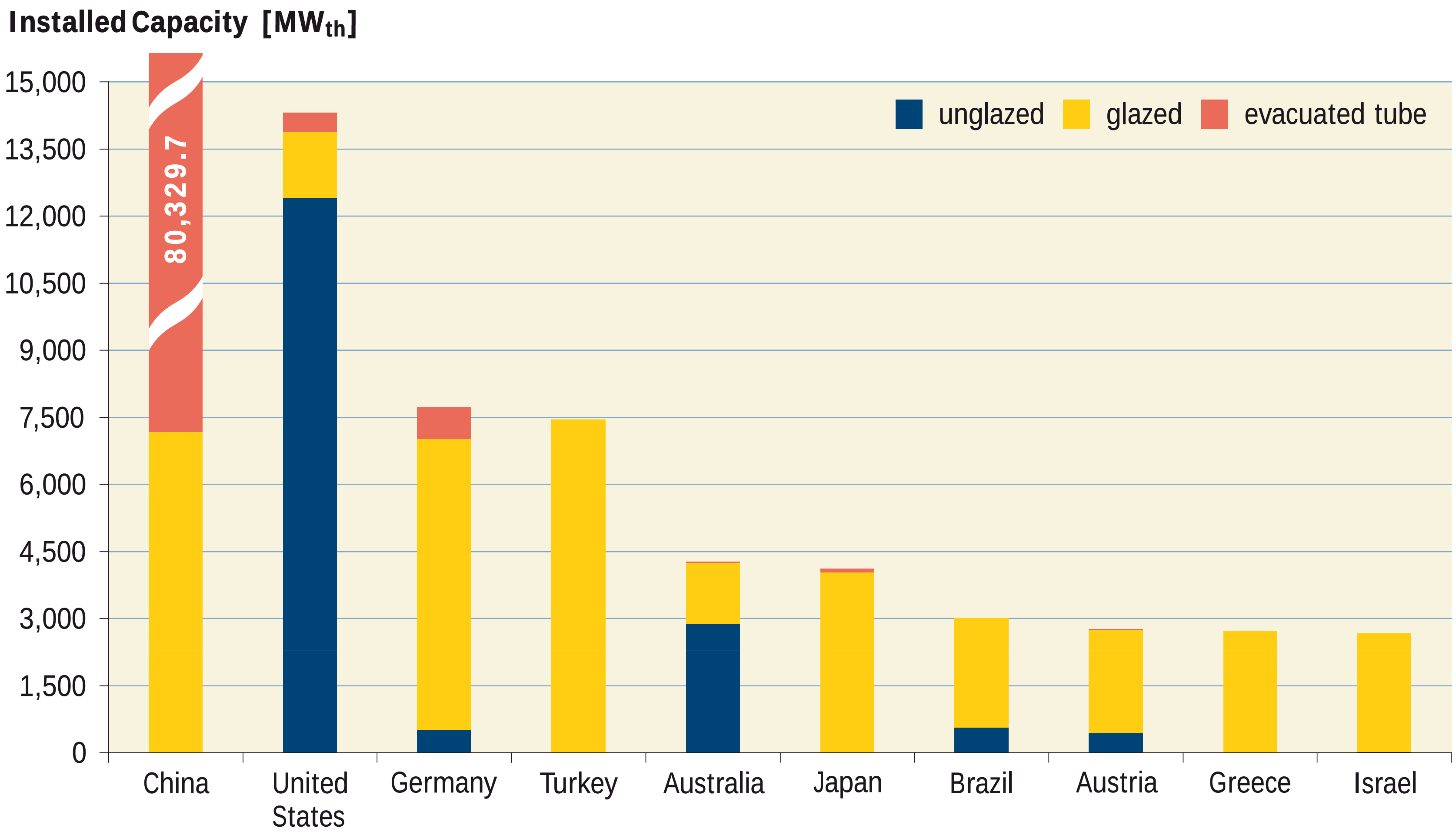
Distribution of Collectors

financed by Austrian Development Cooperation



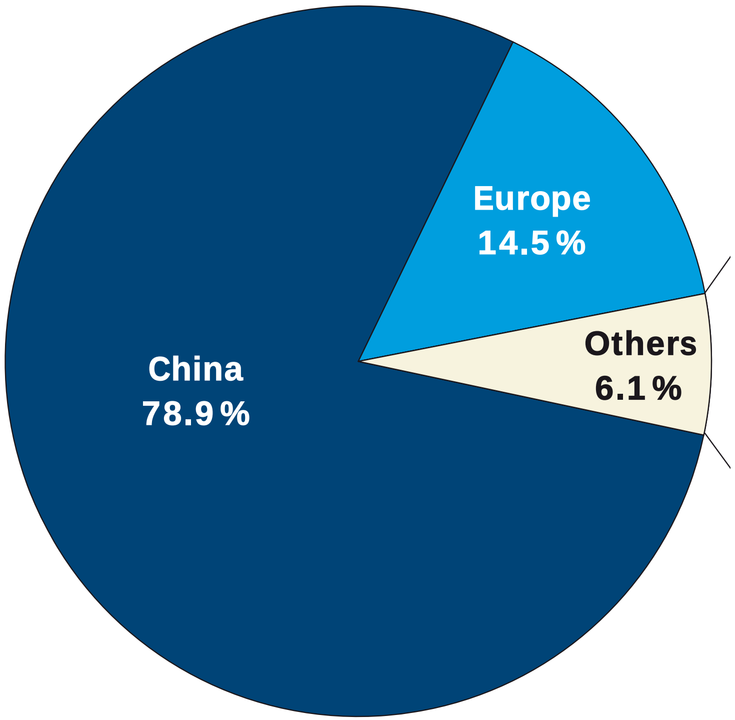
Solar Heat Worldwide - 2008

financed by
Austrian
Development Cooperation



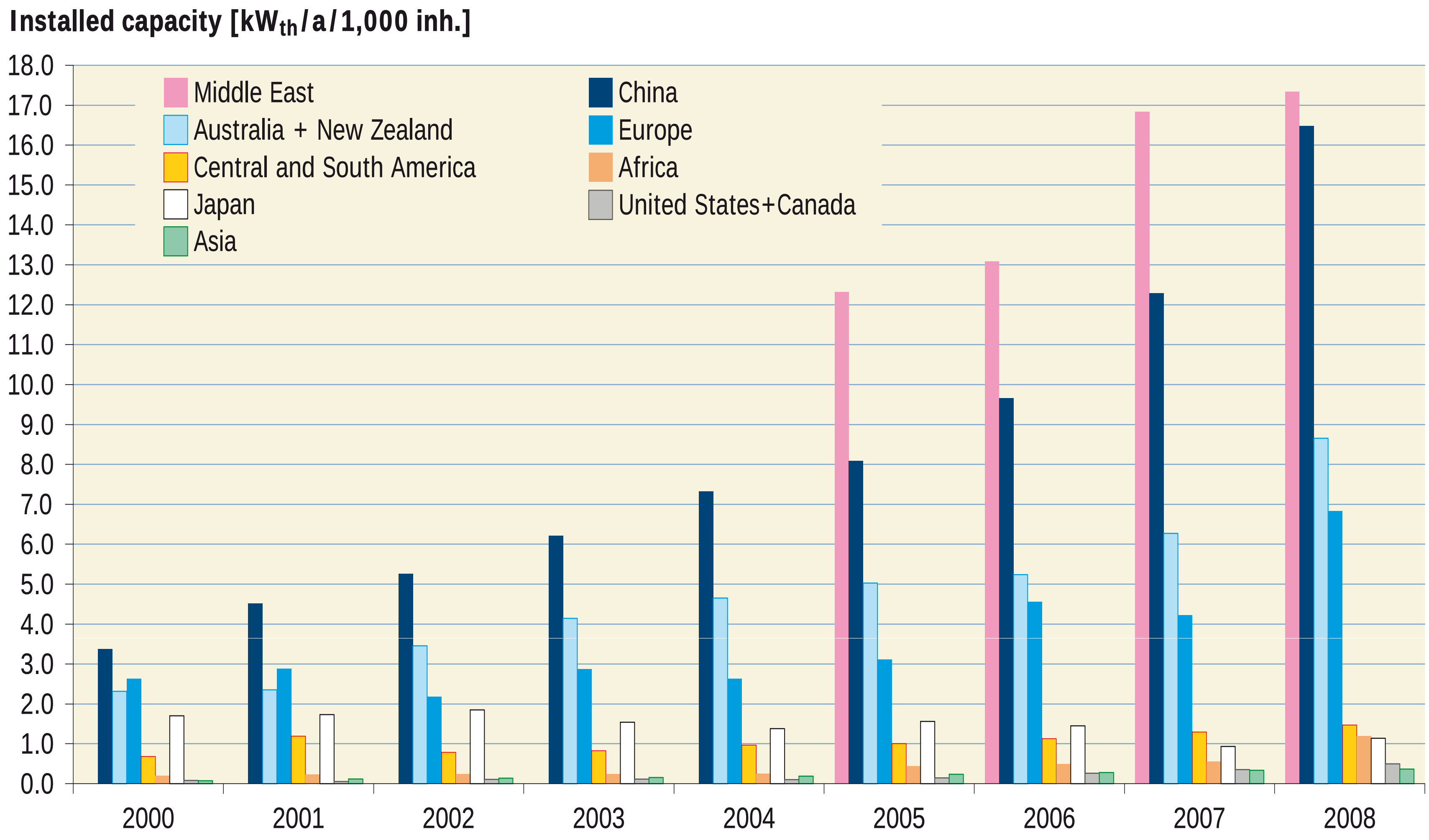
Installations by Economic Region 2008
Flat-plate and Evacuated Collectors

financed by
Austrian
Development Cooperation



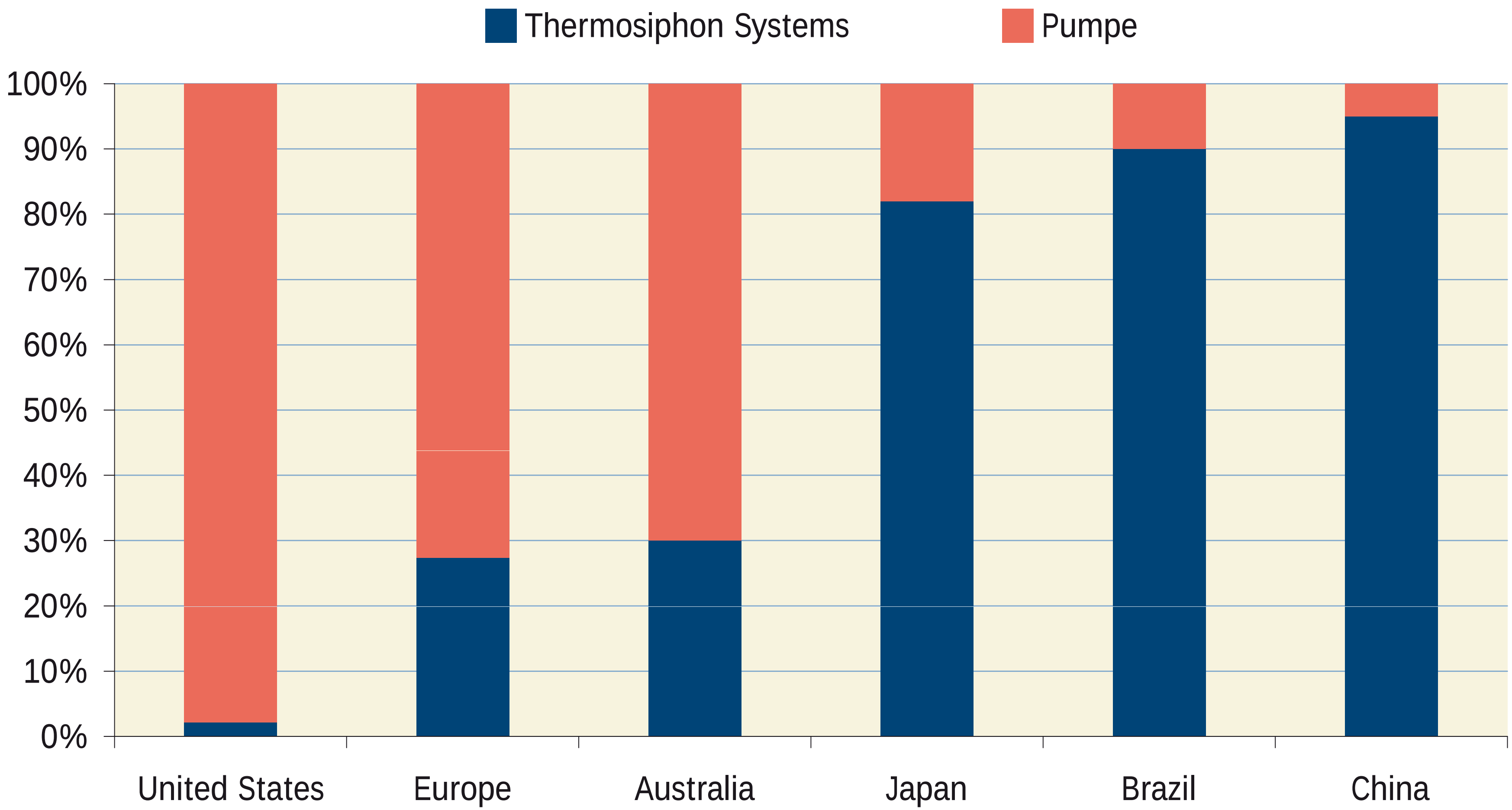
Annually installed capacity of flat-plate and evacuated tube collectors

financed by Austrian Development Cooperation



Distribution of different solar thermal systems by economic region

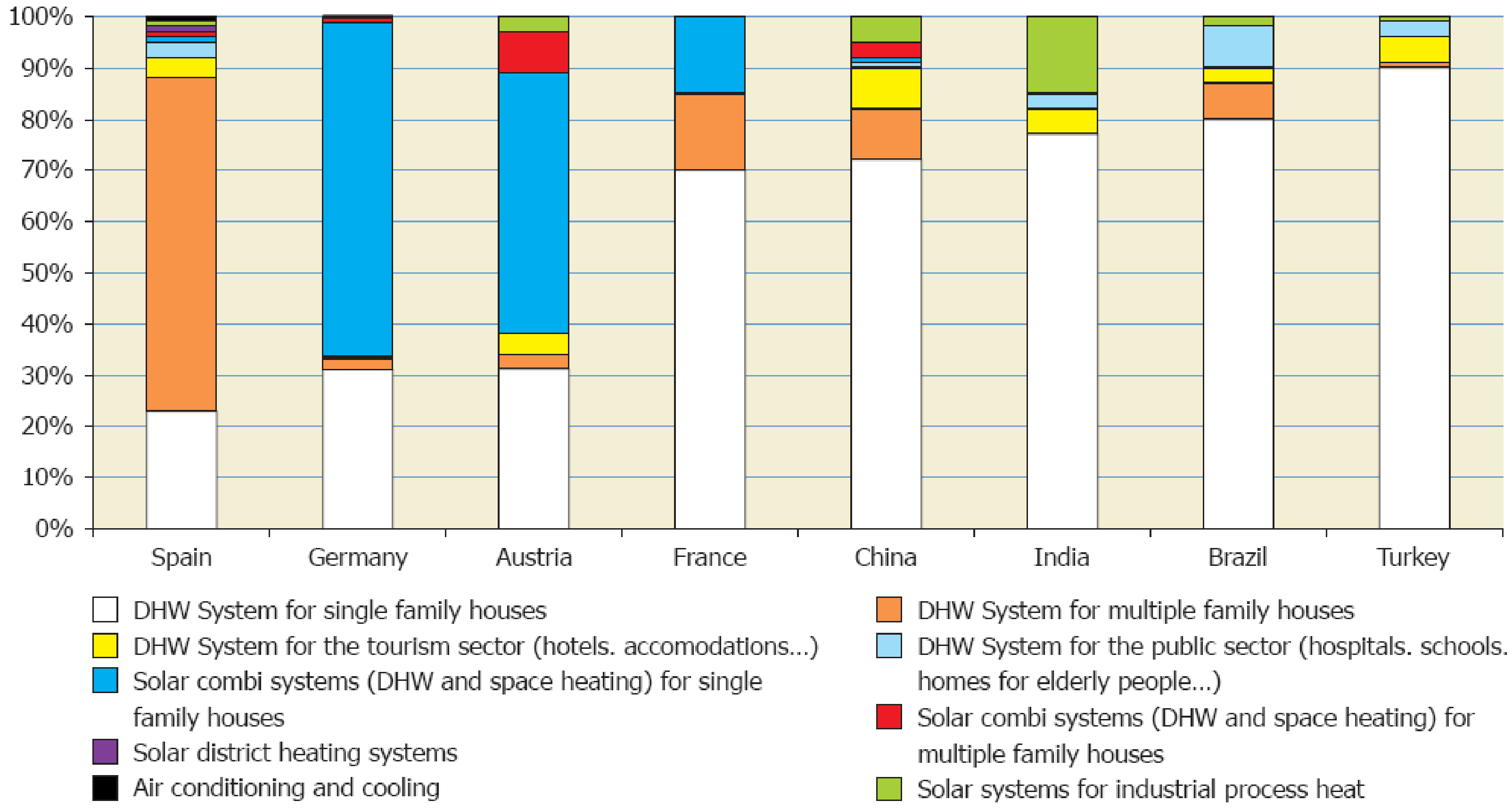
AEE INTEC
financed by Austrian Development Cooperation



financed by
Austrian
Development Cooperation

Distribution by Application

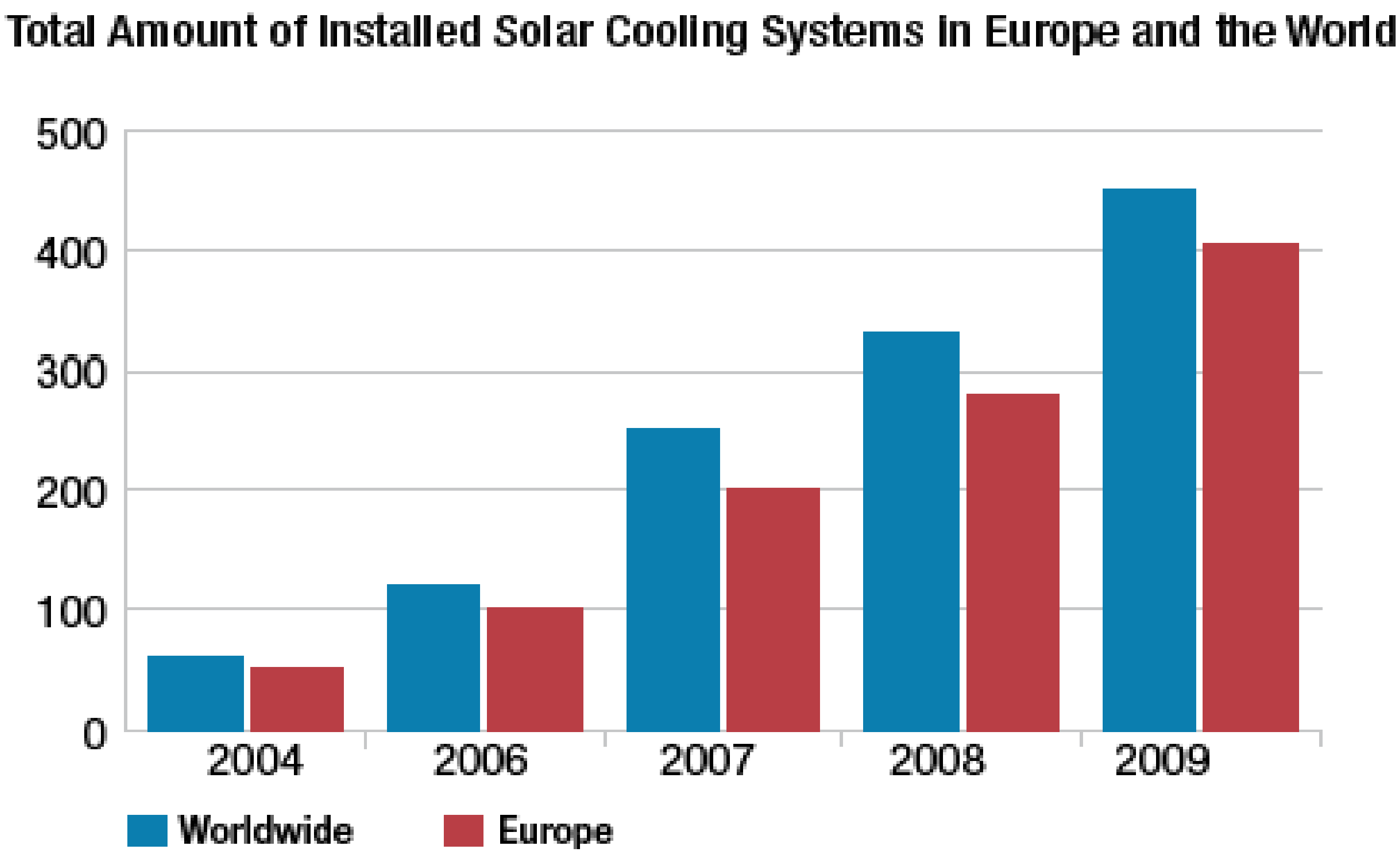
World's Top 8 Countries / Related to newly installed capacity in 2008



Source: Weiss, W., Mauthner, F.: Solar Heat Worldwide, IEA SHC 2010

Cooling Systems 2009

financed by
Austrian Development Cooperation



Source:www.greenchiller.eu.

AEE INTEC

Applications

financed by
Austrian
Development Cooperation

financed by
Austrian
Development Cooperation

AEE INTEC

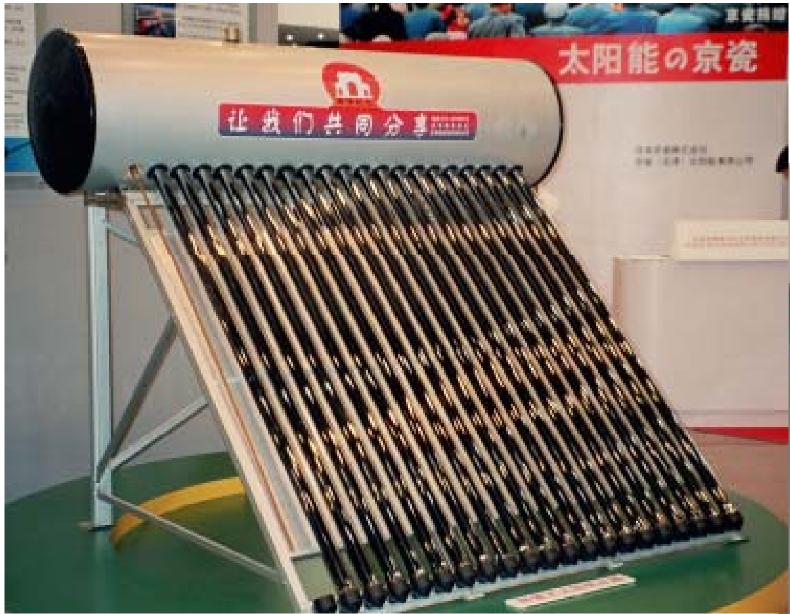
Solar Water Heating Systems

financed by
Austrian
Development Cooperation

AEE INTEC

Solar Water Heating Systems

financed by
Austrian
Development Cooperation

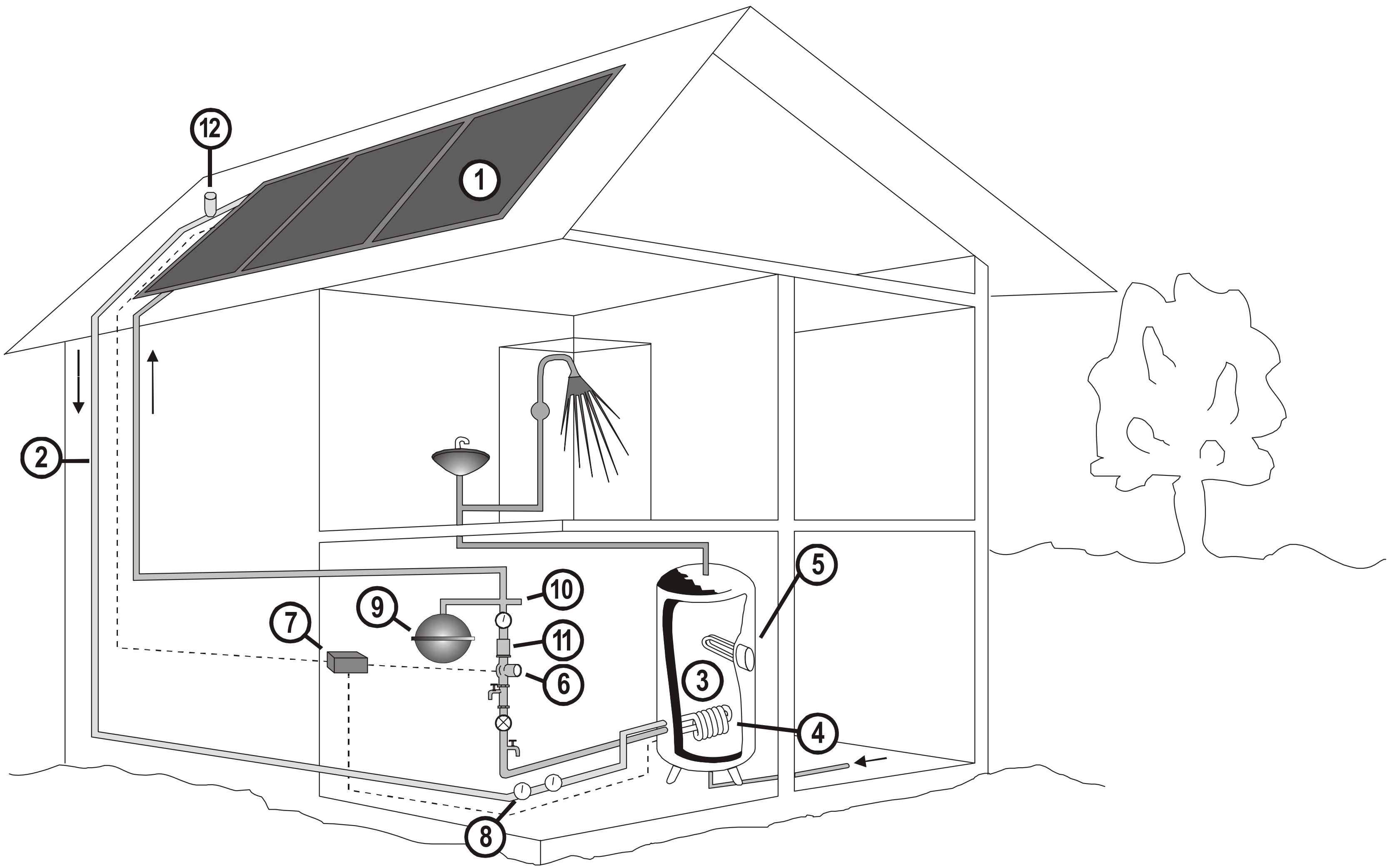


Three different types of evacuated tube collectors:

all-glass
U-tube
heat-pipe

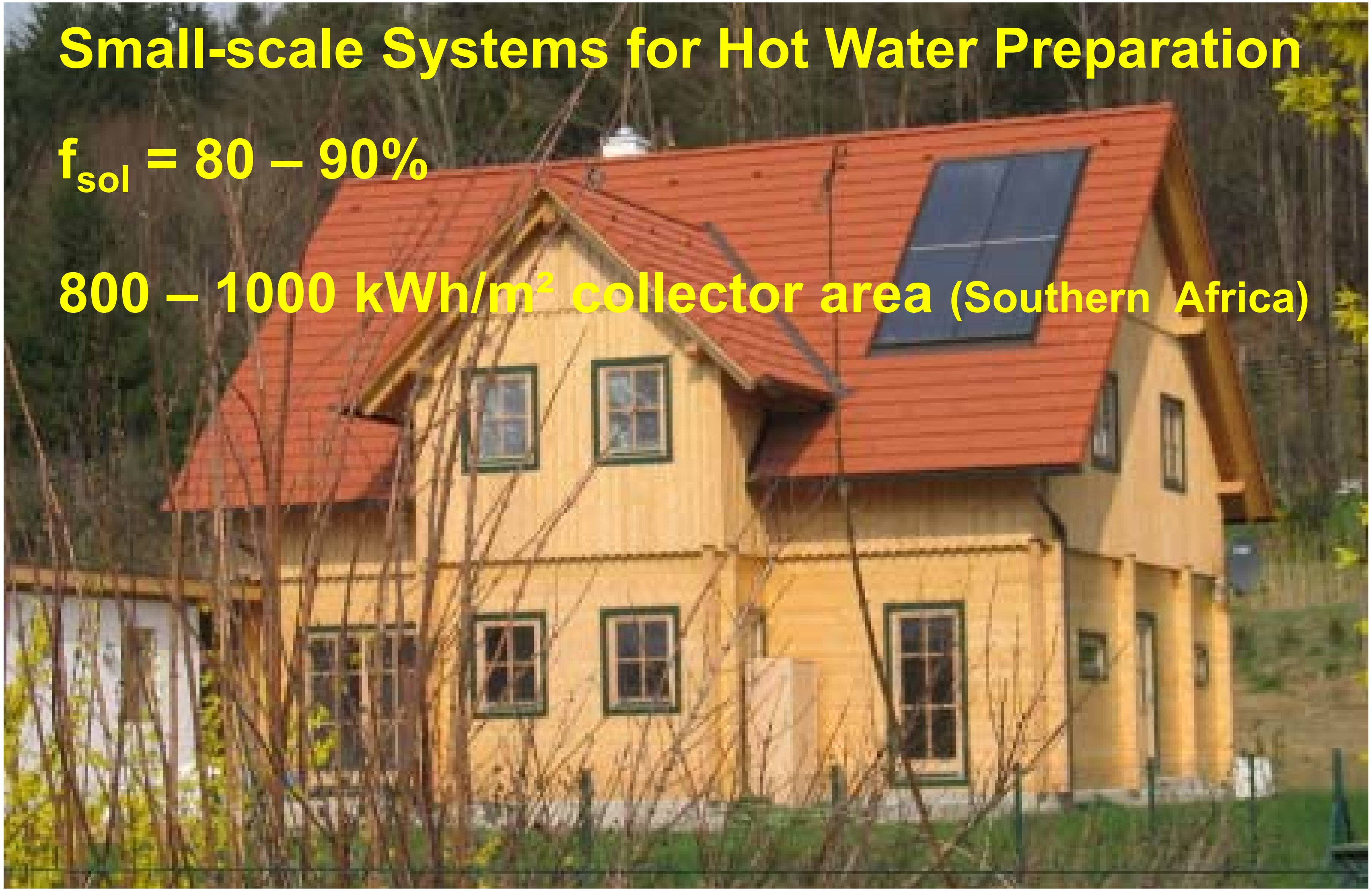
Pumped SWH Systems

financed by
Austrian
Development Cooperation



AEE INTEC

financed by
Austrian
Development Cooperation

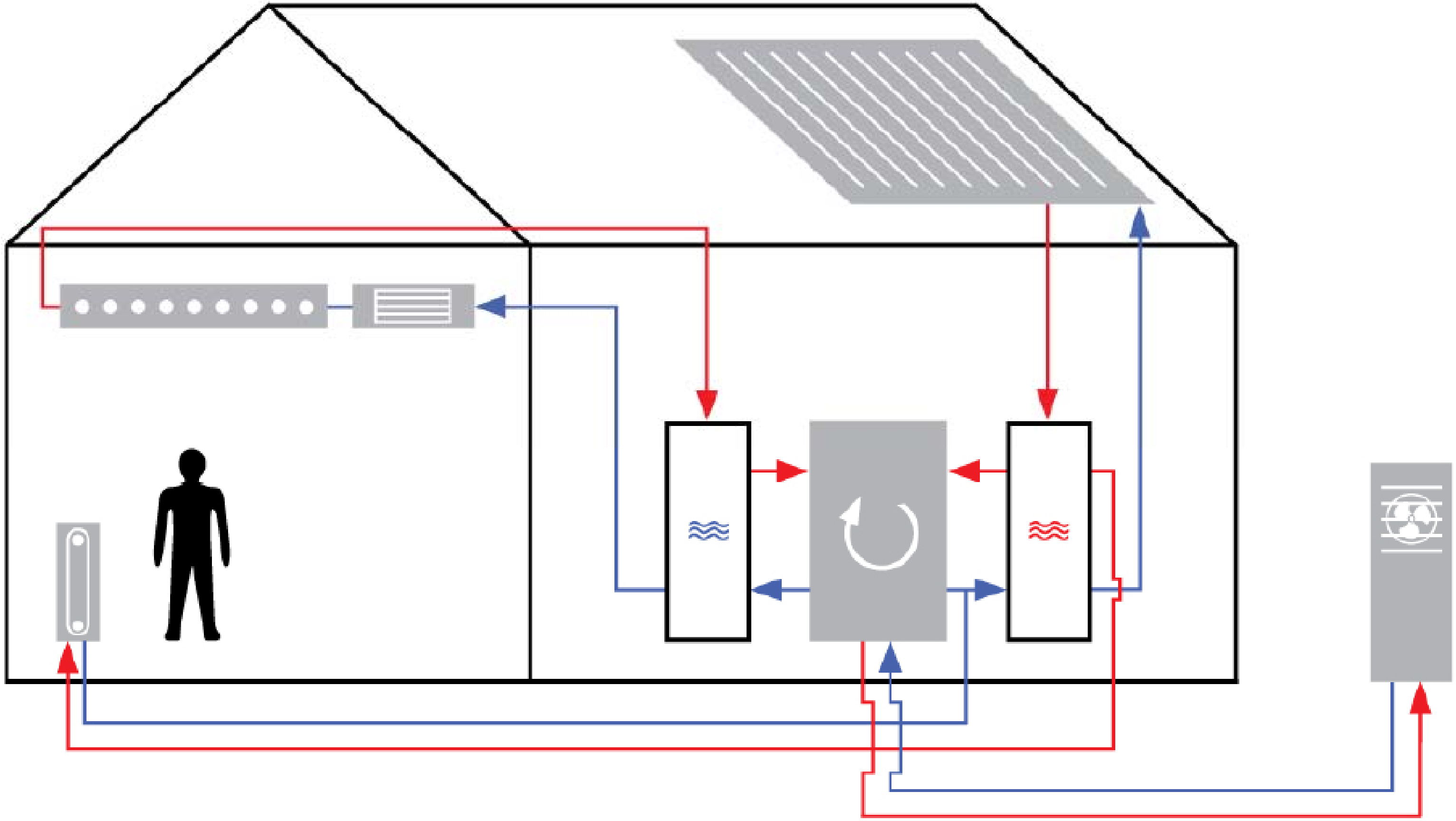


Combined SWH and Cooling

financed by Austrian Development Cooperation

Solar Air Conditioning and Cooling

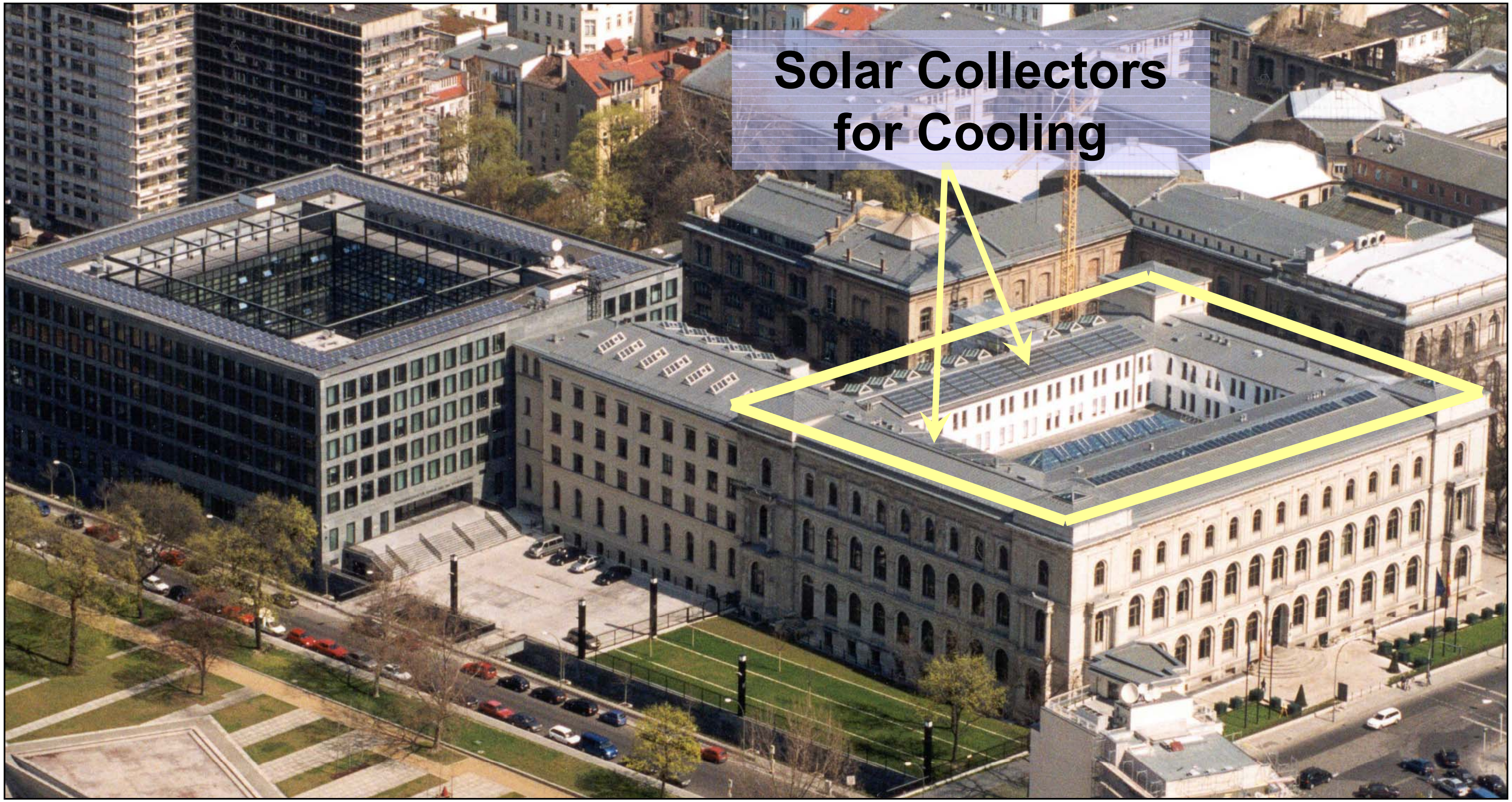
financed by
Austrian
Development Cooperation



Source : Fraunhofer ISE, Solarnext

financed by
Austrian Development Cooperation

Solar Cooling System for the German BMVBW



Source: Jan Albers, IMBE, TU Berlin

financed by
Austrian
Development Cooperation

Solar Combi Systems for SFH

f_{sol} = 50 – 90%

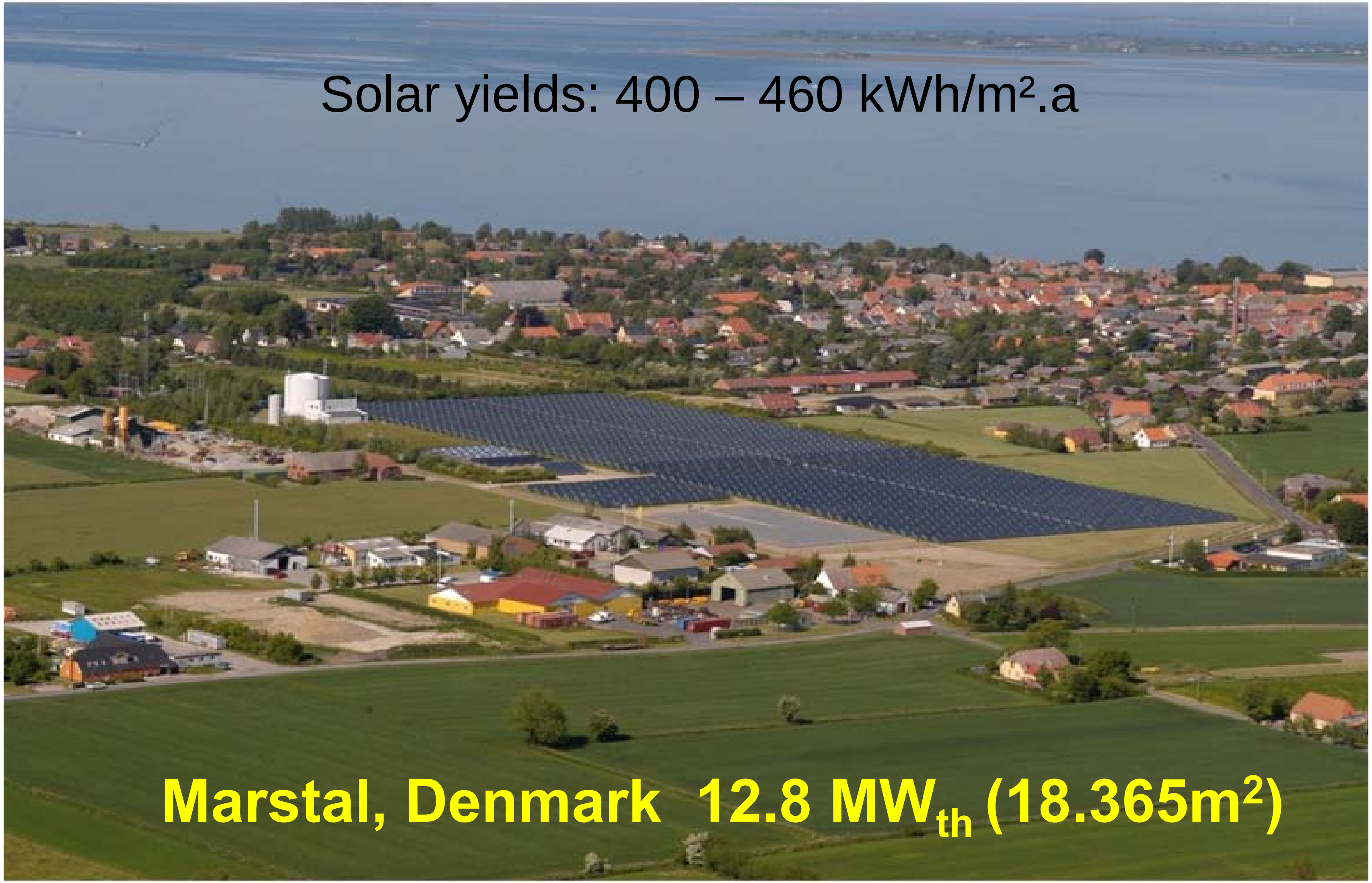
500 – 600 kWh/m² (Southern Africa)

financed by
Austrian
Development Cooperation

Large-scale solar heating systems

Solar District Heating

financed by
Austrian
Development Cooperation



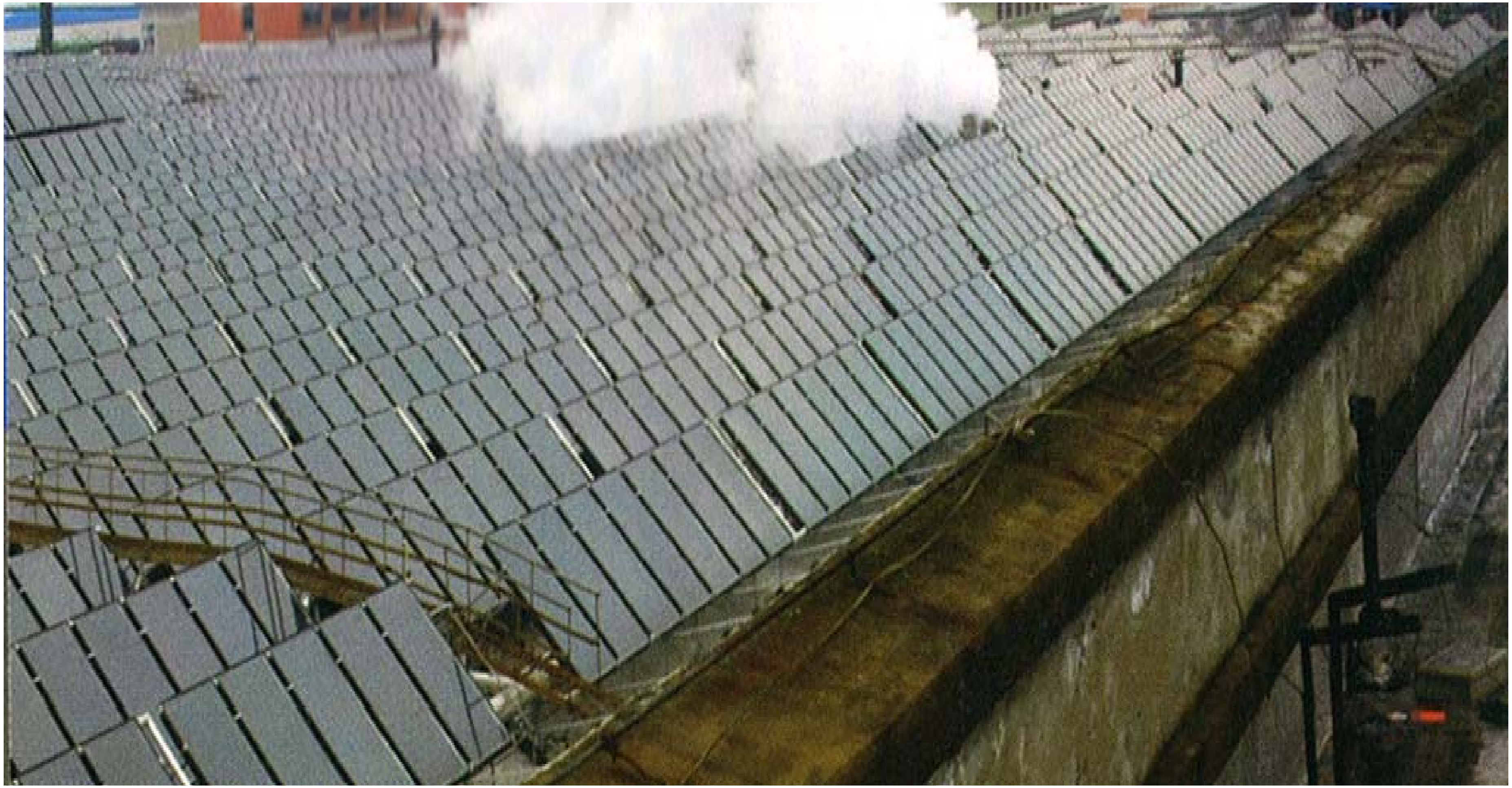
AEE INTEC

Tyras Dairy, Trikala, Greece

financed by
Austrian
Development Cooperation

financed by
Austrian
Development Cooperation

Textile Industry Hangzhou China 13000㎡ (9 MW_{th})



SEA WATER DESALINATION

financed by
Austrian
Development Cooperation

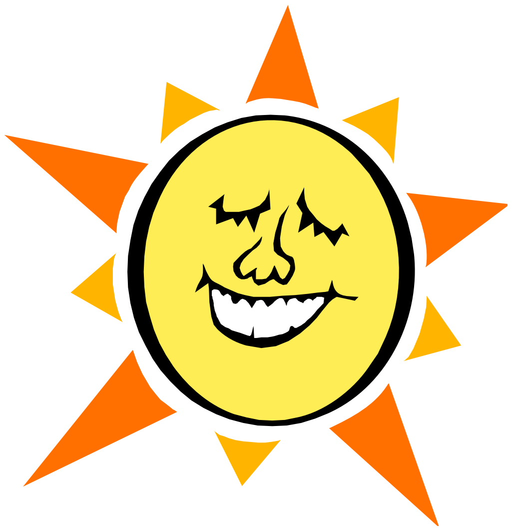
AEE INTEC

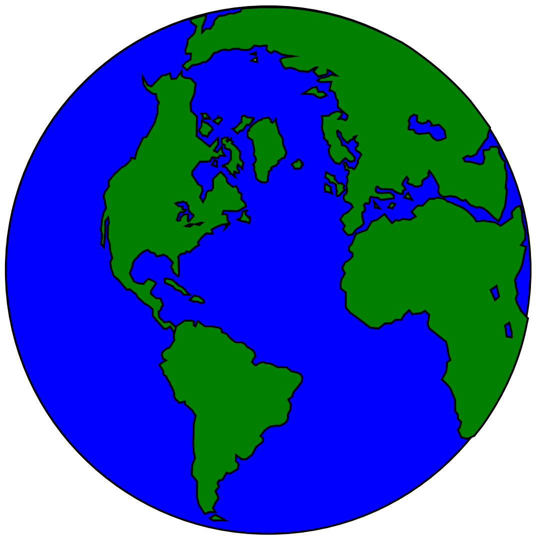
SOLAR RADIATION - 1

financed by
Austrian
Development Cooperation

SOLAR CONSTANT

1360 W/m²





GLOBAL IRRADIATION

800 - 1000 W/m²

AEE INTEC

SOLAR RADIATION - 2

financed by
Austrian
Development Cooperation

	Clear, blue sky	Scattered clouds	Overcast sky
Solar irradiance [W/m²]	600 - 1000	200 - 400	50 - 150
Diffuse fraction [%]	10 - 20	20 - 80	80 - 100

Global irradiance and diffuse fraction, depending on the cloud conditions

SOLAR RADIATION - 7

financed by
Austrian
Development Cooperation

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Year	Lat
Vienna, Austria	25.2	43	81.4	118.9	149.8	160.7	164.9	139.7	100.6	59.8	26.3	19.9	**1090**	48.2 N
Kampala, UG	174	164	170	153	151	142	141	151	155	163	154	164	**1882**	00.2 N
Johannesburg	215	185	183	144	135	119	132	158	189	200	197	218	**2076**	26.1 S

Average monthly and yearly values of global solar radiation on a horizontal surface in kWh/m²

Depending on the geographic location the yearly global insolation on a horizontal surface may vary between 1000 and 2200 kWh/m^2

ANGLE OF TILT

financed by
Austrian Development Cooperation

Latitude [degree]	Best collector tilt in:					
	June	Orientation	**Sept./March**	Orientation	**December**	Orientation
50 N	26.5	S	50	S	73.5	S
40 N	16.5	S	40	S	63.5	S
30 N	6.5	S	30	S	53.5	S
20 N	3.5	N	20	S	43.5	S
15 N	8.5	N	15	S	38.5	S
10 N	13.5	N	10	S	33.5	S
Equator = 0	**23.5**	**N**	**0**	**-**	**23.5**	**S**
10 S	33.5	N	10	N	13.5	S
15 S	38.5	N	15	N	8.5	S
20 S	43.5	N	20	N	3.5	S
30 S	53.5	N	30	N	6.5	N
40 S	63.5	N	40	N	16.5	N
50 S	73.5	N	50	N	26.5	N

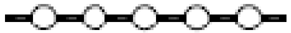
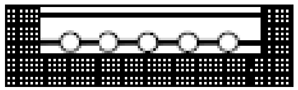
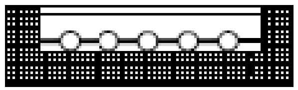
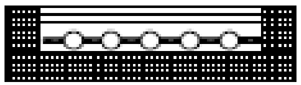
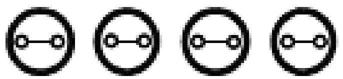
Maputo: Latitude -25.9

Cape Town: Latitude - 34

As a general rule, the optimum angle of tilt is equal to the degree of latitude of the site

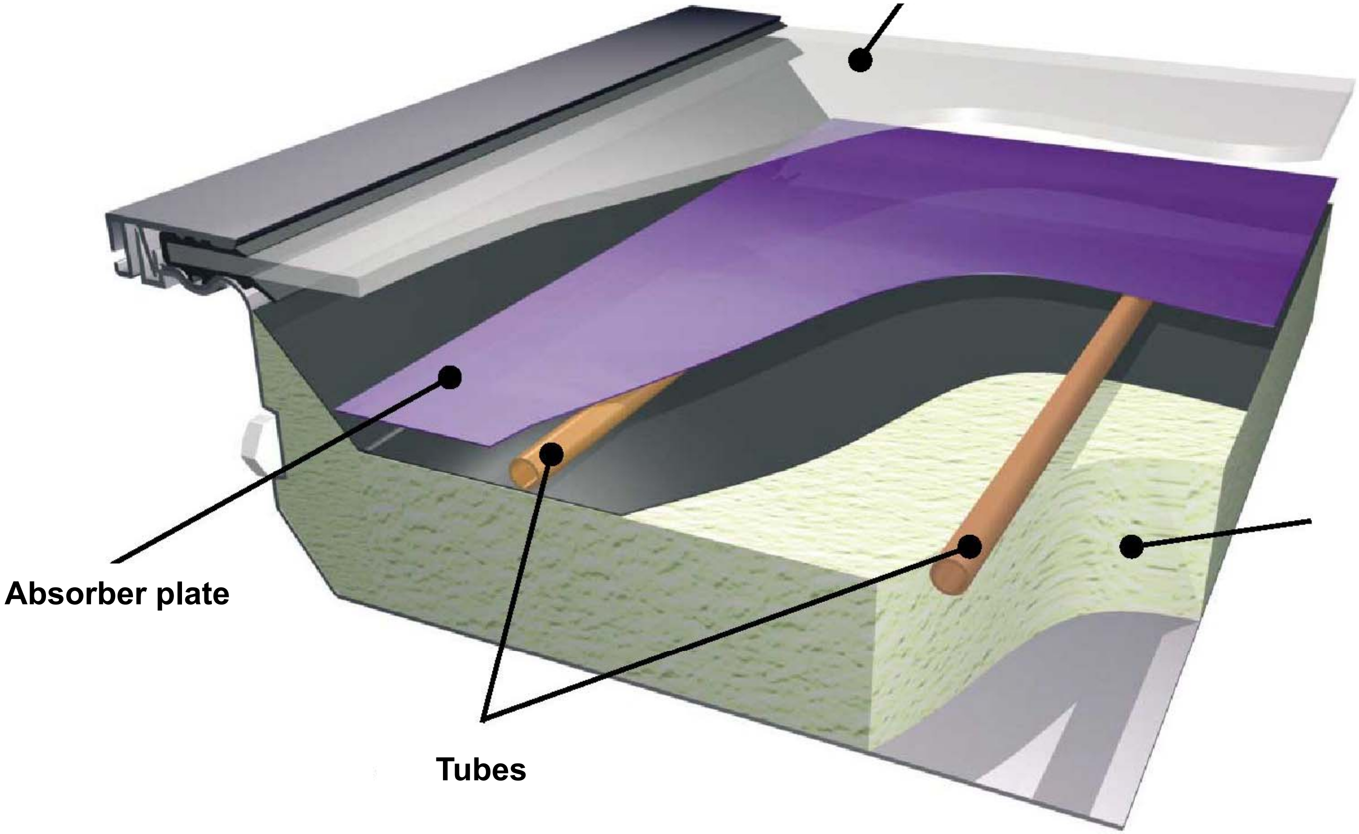
financed by
Austrian
Development Cooperation

TYPES OF COLLECTORS

	principle	η_0 [ ]	U [W/m² K]	collector working temp.	appropriate application areas
simple absorber		0.90	20	15 – 30 °C	swimming pool
simple flat-plate collector with glass cover (FP)		0.80	4	30 – 80 °C	hot water
FP with selective surface (SS)		0.80	3	40 – 90 °C	hot water space heating
FP with double anti-reflective coated glazing and gas filling		0.80	2.5	50 – 100 °C	hot water space heating cooling
evacuated tube collector with SS (ETC)		0.65	2	90 – 130 °C	space heating cooling process heat
ETC with compound parabolic concentrator (CPC)		0.60	1	110 – 200 °C	space heating cooling process heat

FLAT-PLATE COLLECTOR

financed by
Austrian Development Cooperation



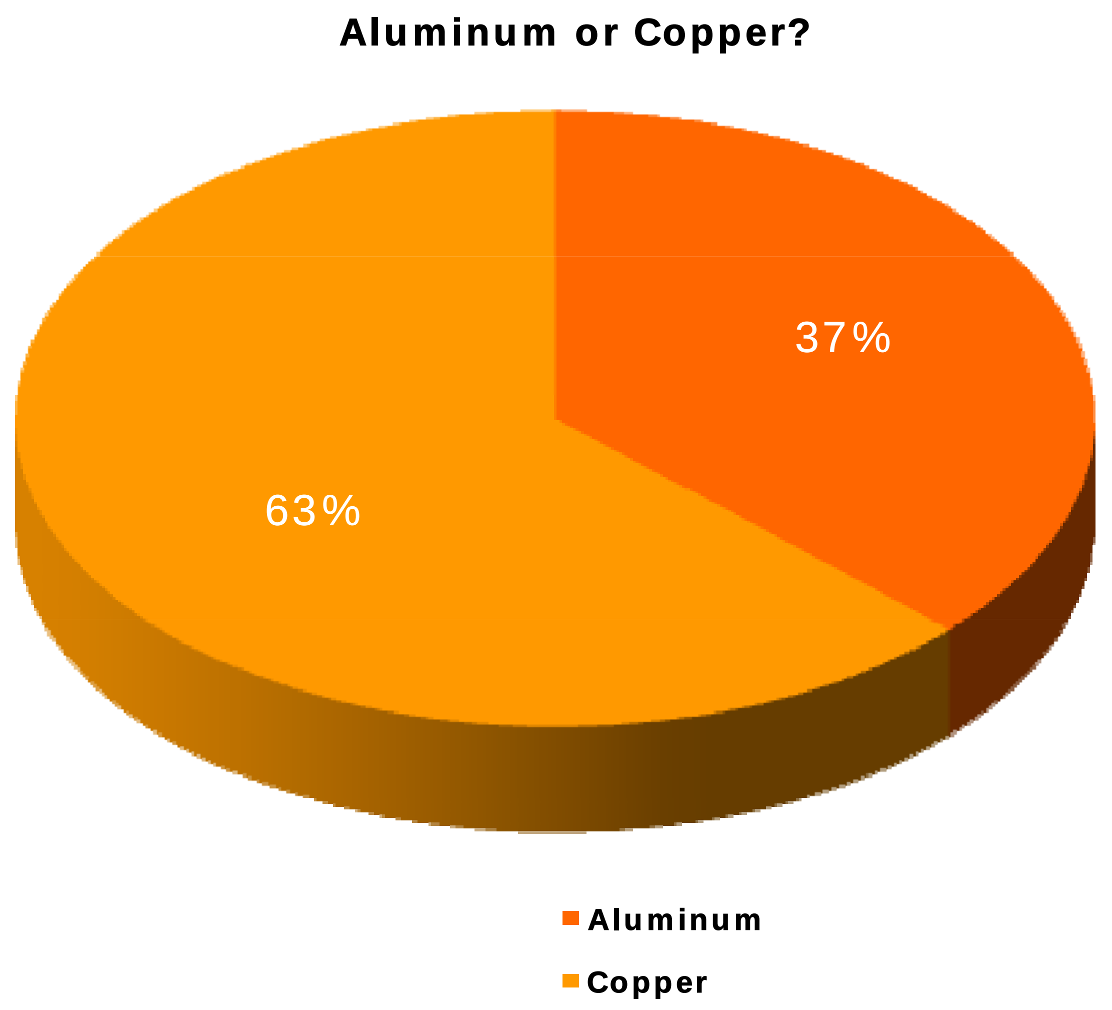
Source: Consolar

Evacuated Tube Collectors – Heat Pipe

financed by
Austrian Development Cooperation

Absorber Material

financed by
Austrian
Development Cooperation



Source: Sonne, Wind und Wärme, 2009

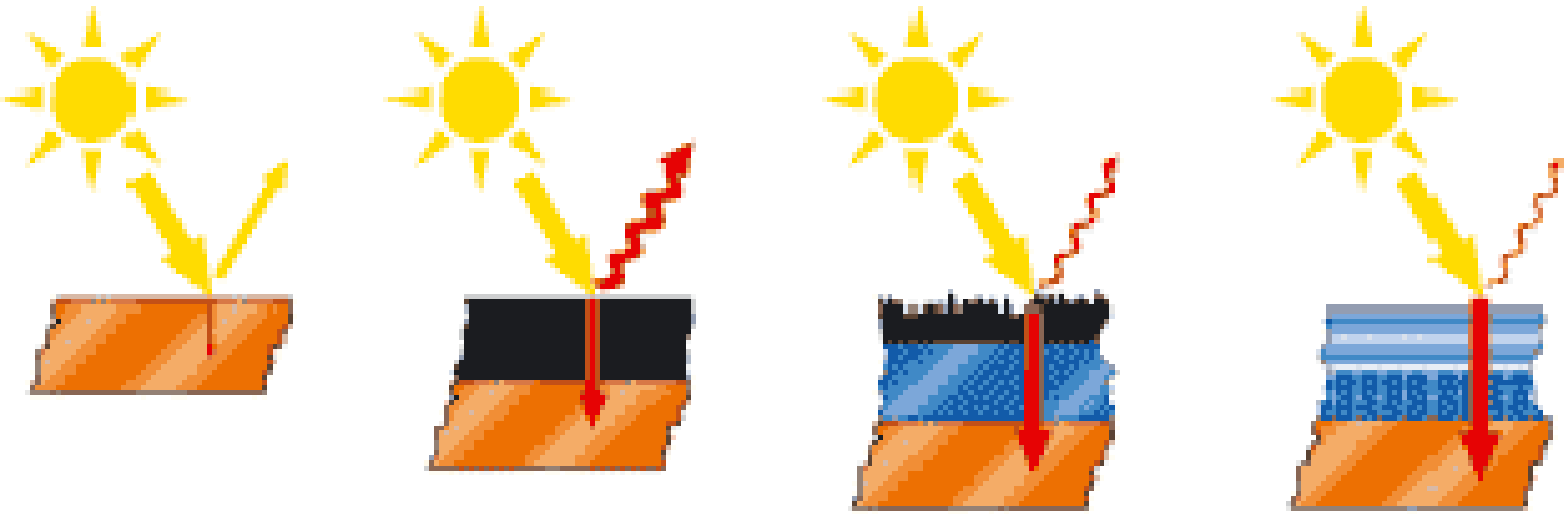
financed by
Austrian
Development Cooperation

ABSORBER COATING

Selective coating: $0 \leq \varepsilon < 0.2$, $\alpha > 0.9$

Partially selective coating: $0.2 \leq \varepsilon < 0.5$, $\alpha > 0.9$

Non selective coating: $0.5 \leq \varepsilon < 1.0$, $\alpha > 0.9$



Plain copper | *black paint* | *galvanic coating* | *physical vapour deposition or sputtering*

COLLECTOR MATERIALS

financed by
Austrian
Development Cooperation

ABSORBER MATERIALS
THERMAL CONDUCTIVITY

financed by
Austrian
Development Cooperation

absorber material	thermal conductivity [W/mK]
steel	50
aluminium	210
copper	380

TRANSPARENT COVER MATERIALS

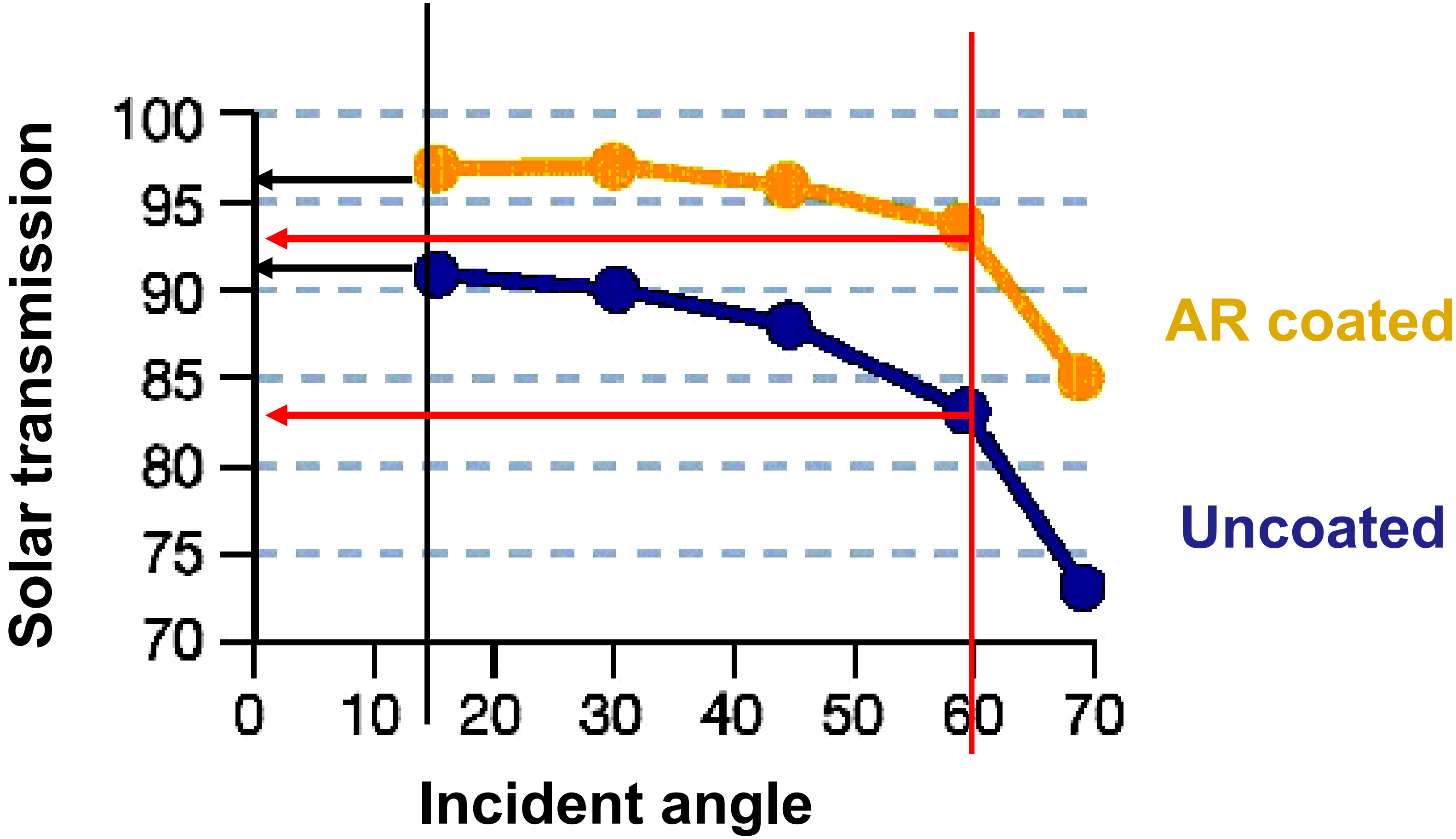
financed by
Austrian
Development Cooperation

cover	thickness [mm]	weight [kg/m²]	solar transmittance
Standard glass *)	4	10	0.84
Standard glass, tempered	4	10	0.84
Iron free glass, tempered	4	10	0.91
Antireflective coated glass	4	10	0.95
PMMA, ducted plate	16	5.0	0.77
PMMA, double ducted plate	16	5.6	0.72

*) danger of breaking determined by high collector temperatures

TRANSPARENT COVER MATERIALS

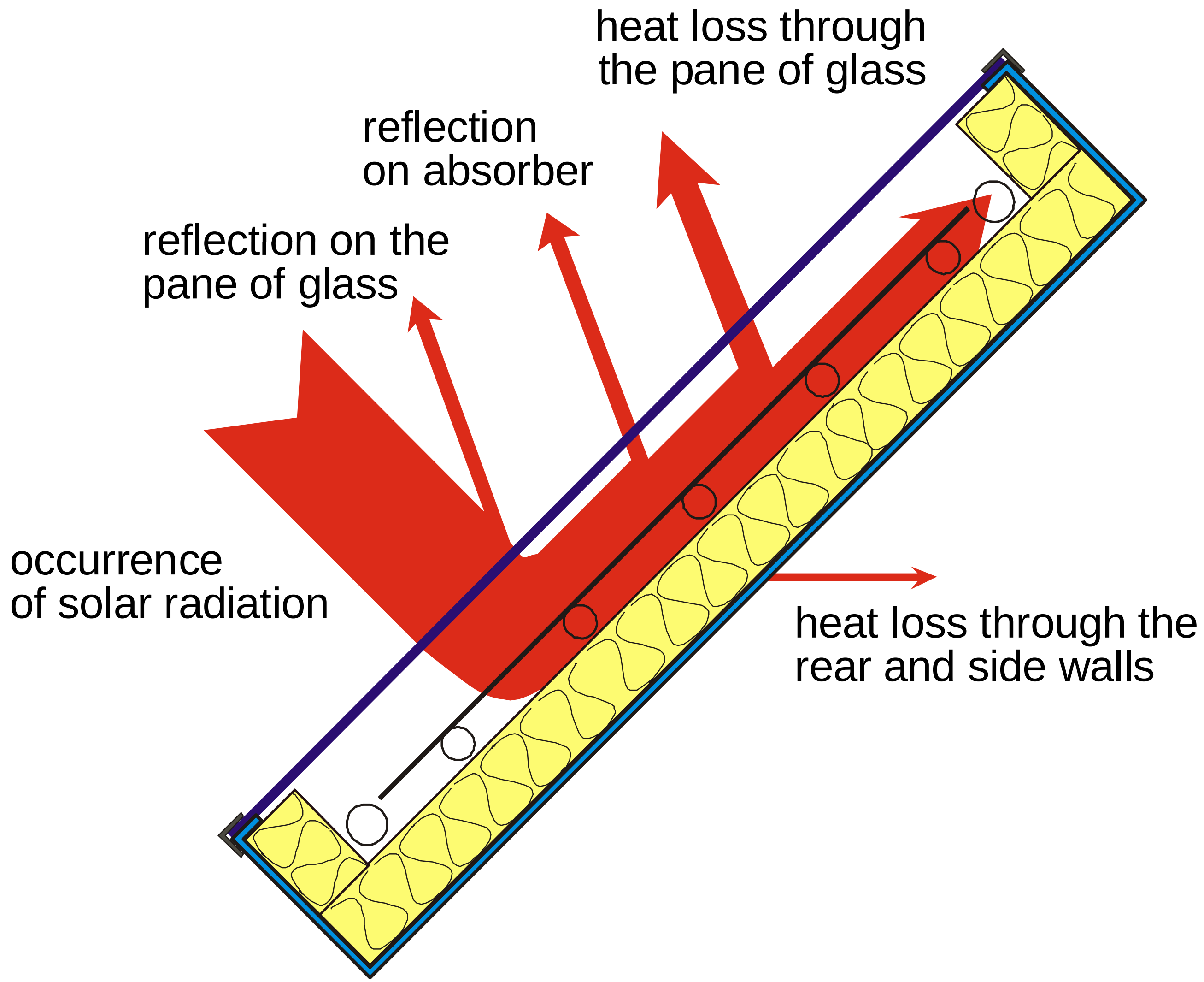
financed by
Austrian
Development Cooperation



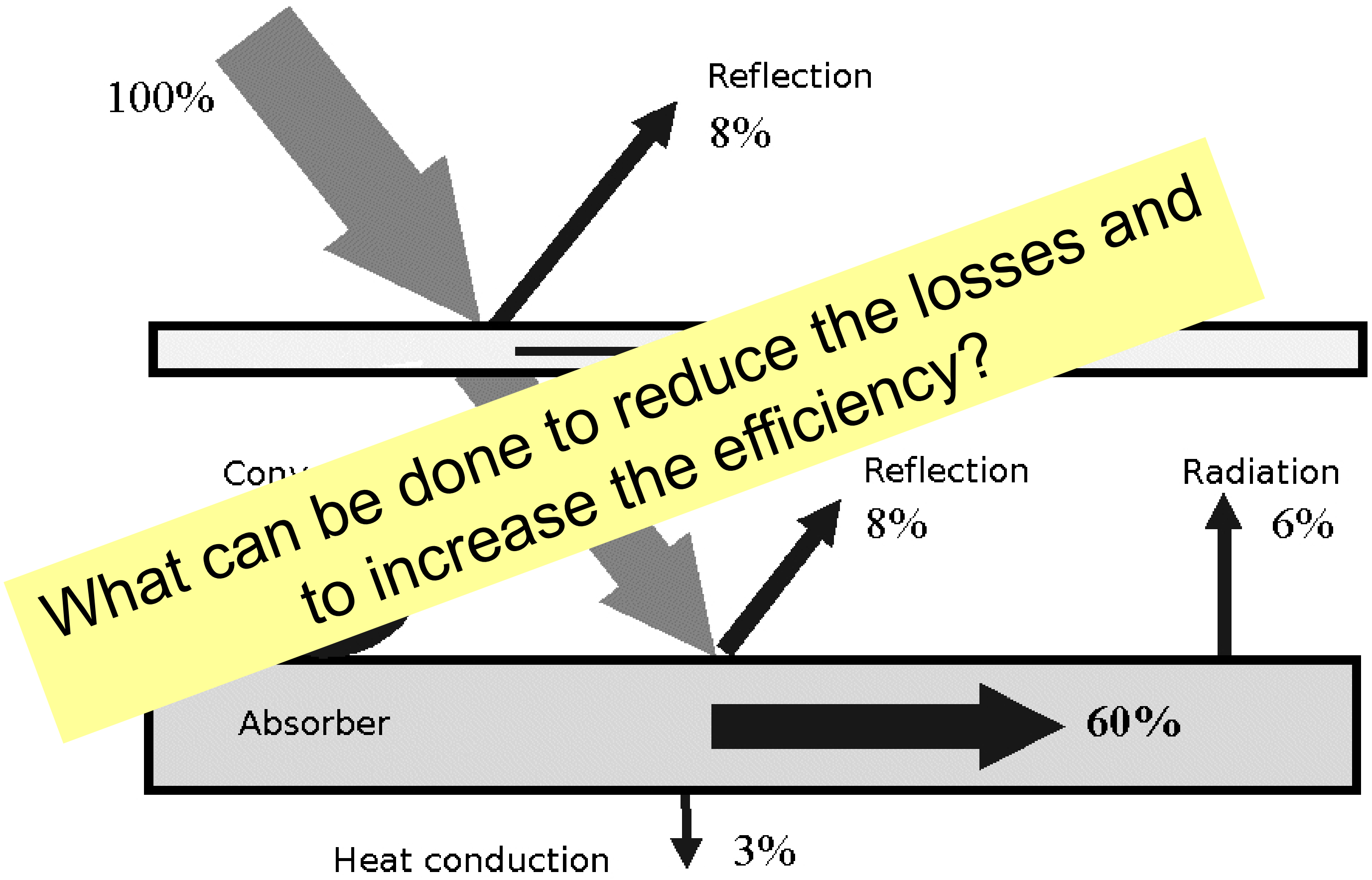
(42)

Physical Processes inside a Flat-Plate Collector

financed by
Austrian
Development Cooperation



Losses of a basic Flat-plate Collector



What can be done to reduce the losses and to increase the efficiency?

Source: Source: Wagner & Co.

Characteristic Values of Flat-plate and Evacuated Tube Collectors

financed by Austrian Development Cooperation

$$\dot{Q}_{coll} = F_R(\tau\alpha)G - F_R U_L \Delta T$$

Q_{coll} is the energy collected per unit collector area per unit time

FR is the collector's heat removal factor

τ is the transmittance of the cover

α is the shortwave absorptivity of the absorber

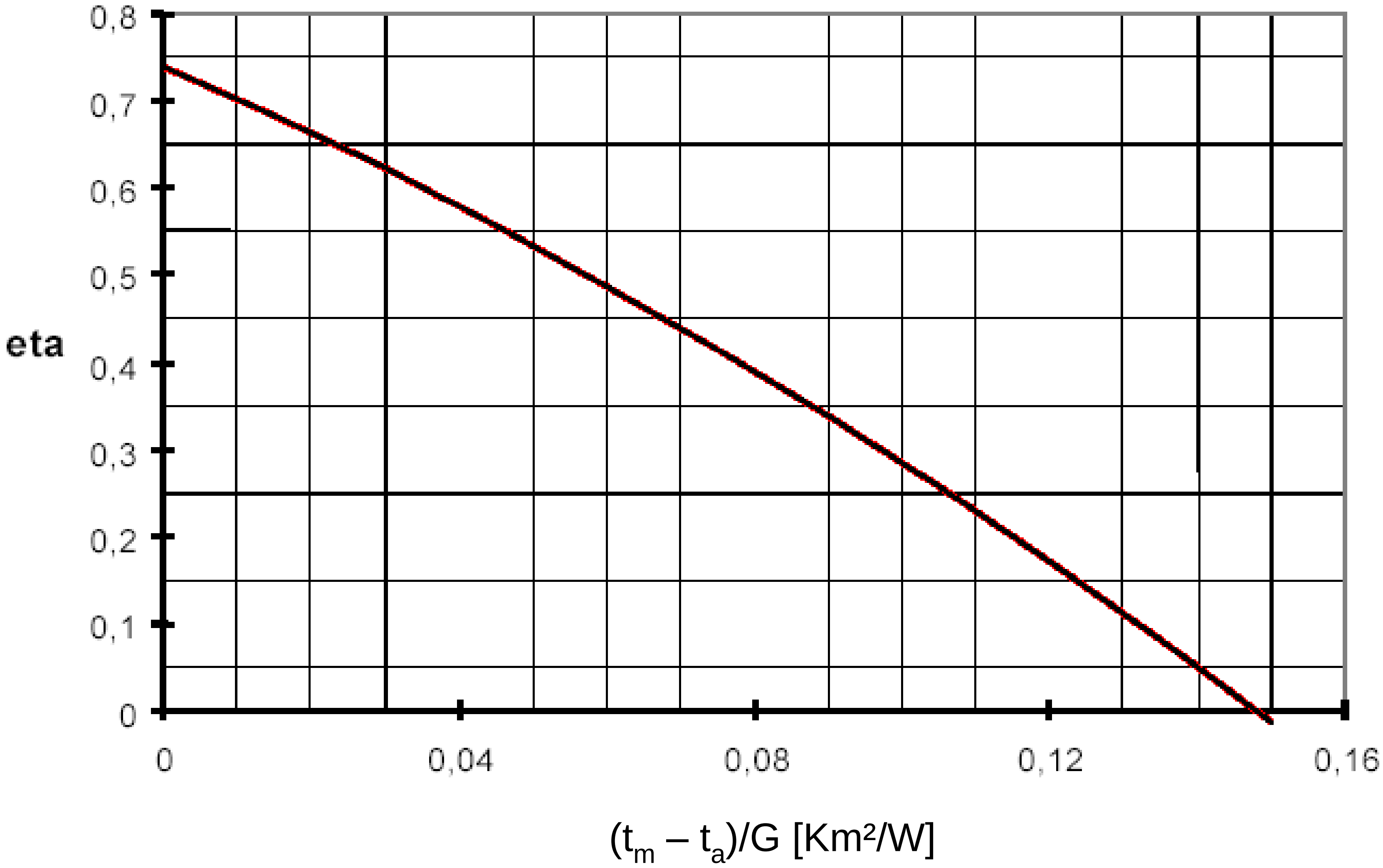
G is the global incident solar radiation on the collector

U_L is the overall heat loss coefficient of the collector

ΔT is the temperature differential between the heat transfer fluid entering the collector and the ambient temperature outside the collector.

Collector Efficiency Curve

financed by
Austrian Development Cooperation



Collector Efficiency

financed by
Austrian Development Cooperation

$$\eta = \frac{useful\ energy}{solar\ energy}$$

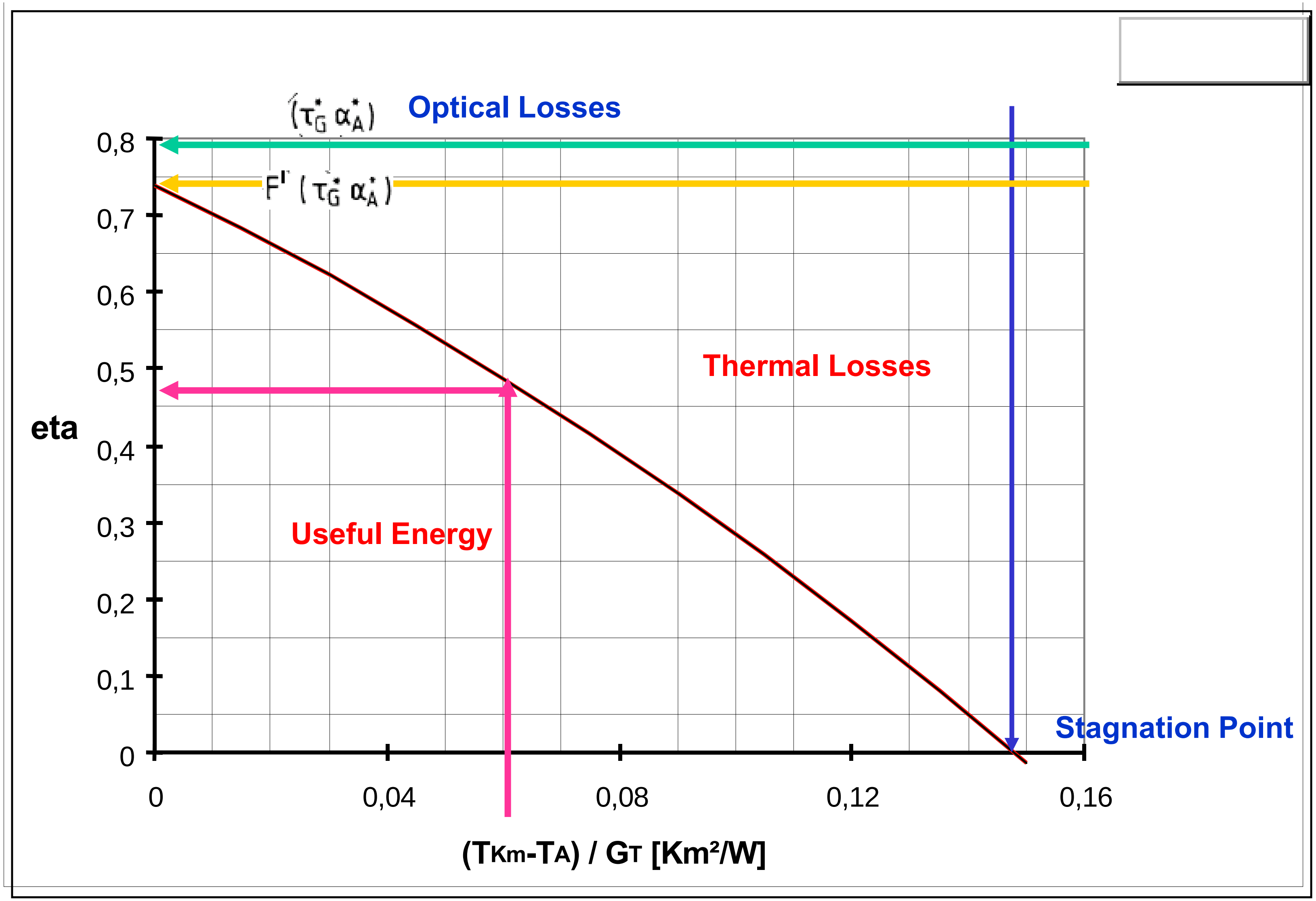
$$\eta = \eta_0 - a_1 \cdot \frac{(t_m - t_a)}{G} - a_2 \cdot \frac{(t_m - t_a)^2}{G}$$

Collector Efficiency

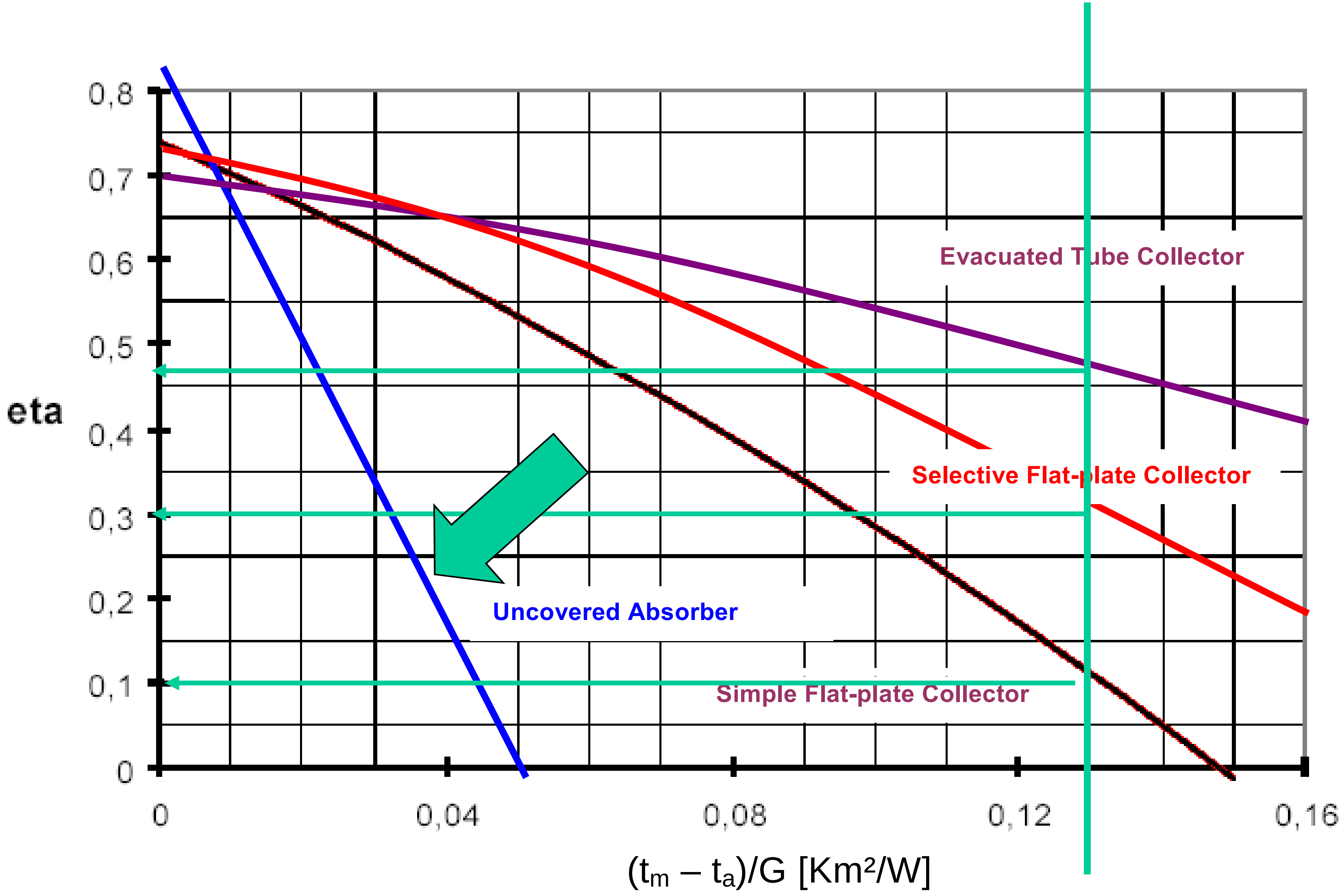
financed by
Austrian
Development Cooperation

η_0	maximum efficiency (= efficiency at $t_m = t_a$)	
a_1	linear heat loss coefficient	$\frac{W}{m^2 \cdot K}$
	s. T-Sol Collector data	
a_2	quadratic heat loss coefficient	$\frac{W}{m^2 \cdot K^2}$
t_m	average temperature of the heat transfer fluid	°C
t_a	ambient temperature	°C
G	incident radiant energy (global radiation)	$\frac{W}{m^2}$

Collector efficiency curve



Efficiency of different collector types (calc)



Capacity of a Water Storage (calc)

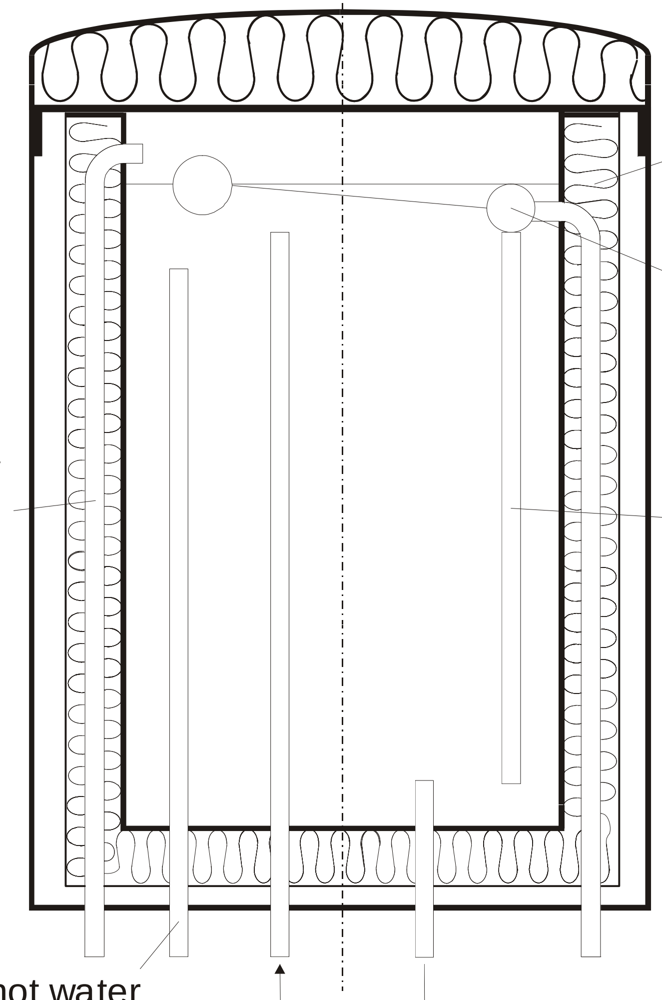
financed by
Austrian Development Cooperation

$$Q_s = (m\ C_p)\ \Delta T$$

Q_s	total heat capacity of the storage tank	[kWh]
m	volume of the storage tank	[m³]
C_p	heat capacity of water	[1.16 kWh/m³K]
ΔT	temperature difference - hot water temperature and cold water temperature	[K]

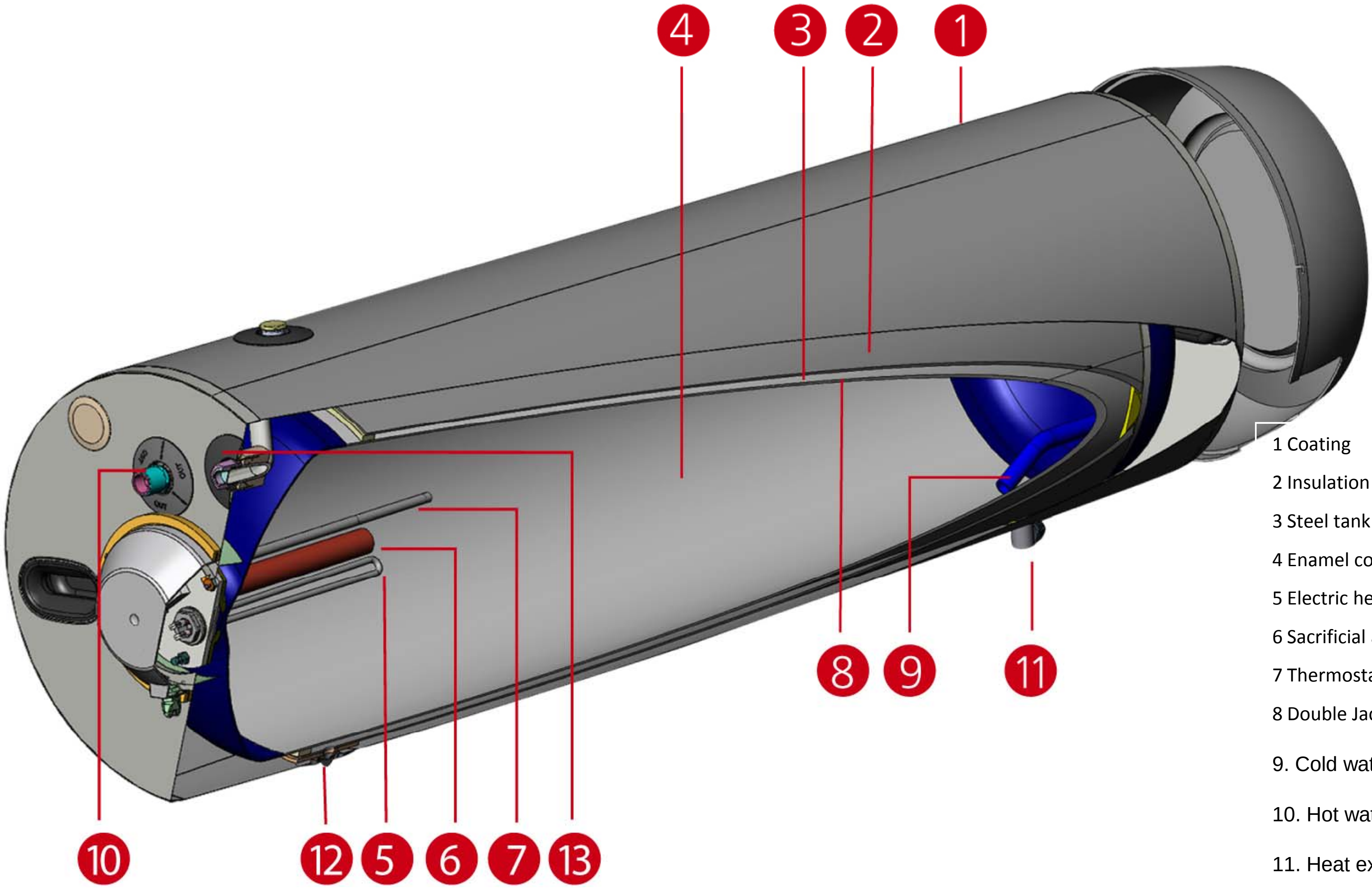
THERMOSYPHON SYSTEMS

financed by
Austrian
Development Cooperation



Hot water storage for a thermosyphon system

financed by
Austrian Development Cooperation



1 Coating
2 Insulation
3 Steel tank
4 Enamel coating
5 Electric heating element
6 Sacrificial anode
7 Thermostat
8 Double Jacket Heat Exchanger
9. Cold water inlet
10. Hot water to user
11. Heat exchanger inlet
12. Heat exchanger outlet
13. Heat Exchanger Safety Valve

Source: Chromagen

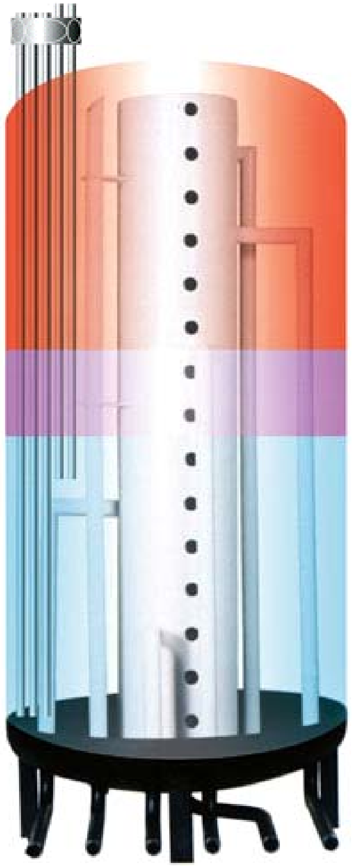
financed by
Austrian
Development Cooperation

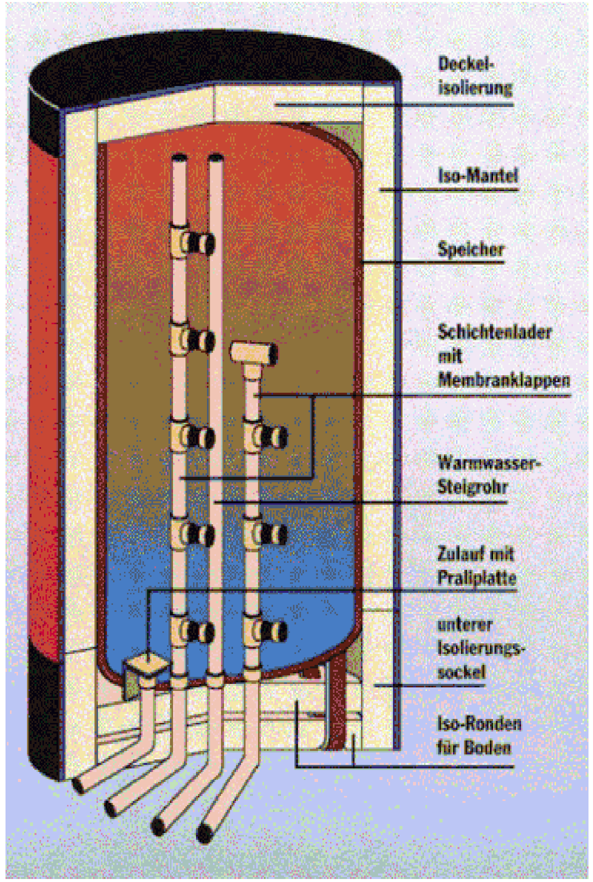
Domestic Hot Water Tank

AEE INTEC

financed by
Austrian
Development Cooperation

Hot water tanks with stratification devices





Sources from left to right: Solarklar, TiSun and Solvis