

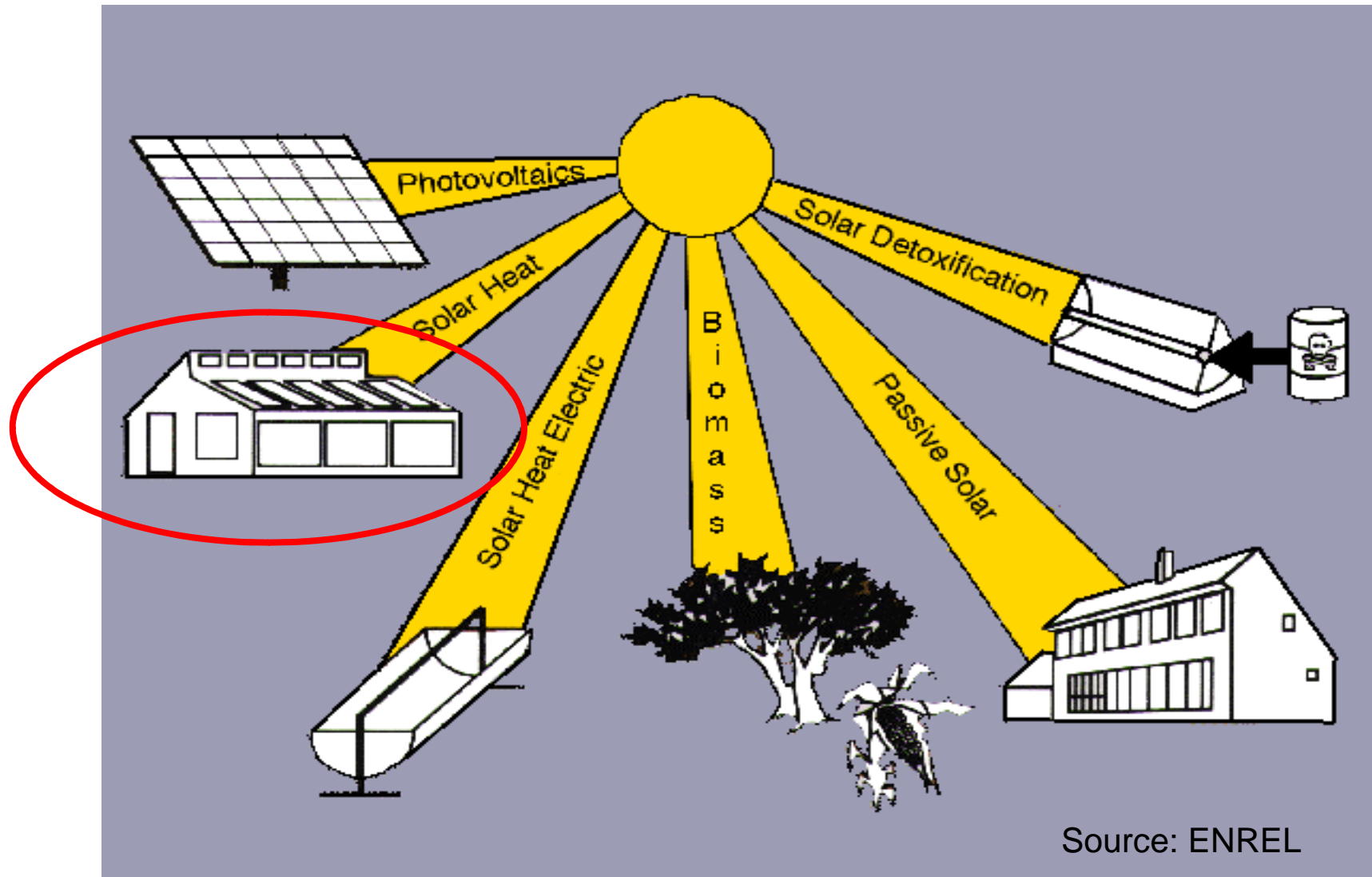


# SOLAR COLLECTORS


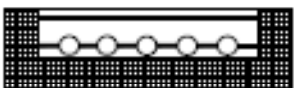
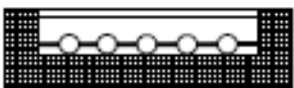
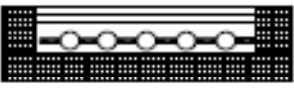


**Werner Weiss**

**AEE - Institute for Sustainable Technologies (AEE INTEC)**  
A-8200 Gleisdorf, Feldgasse 19  
AUSTRIA

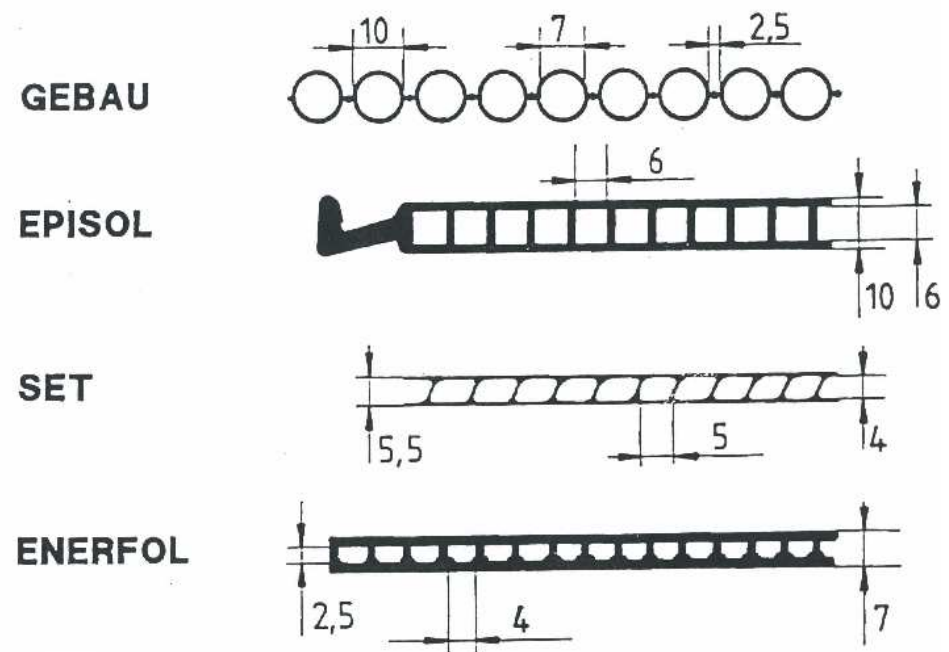
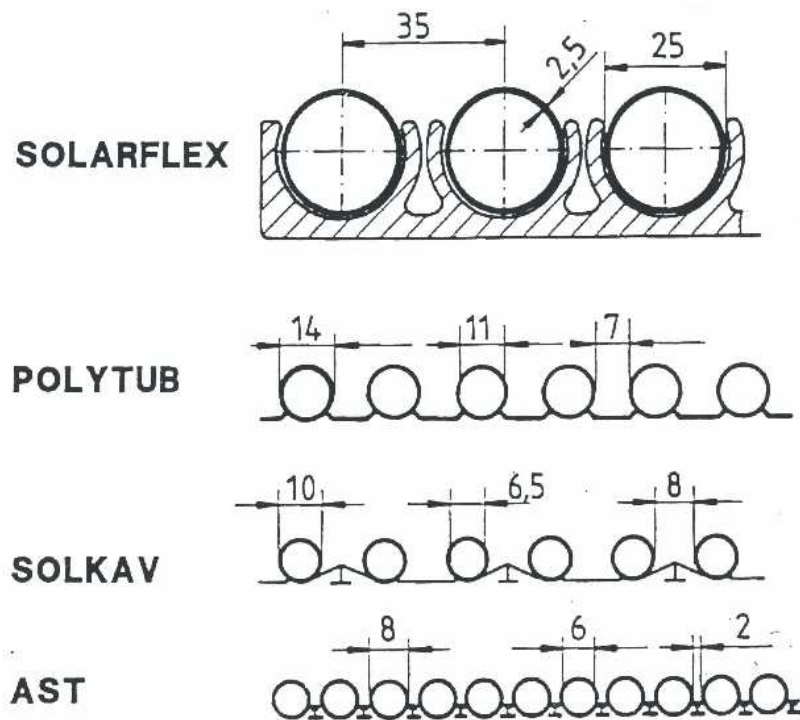
# Conversion of solar radiation energy into other energy forms



# TYPES OF COLLECTORS

	principle	$\eta_0$ [ ]	U [W/m <sup>2</sup> 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

# Plastic Absorber



# Flat plate collectors

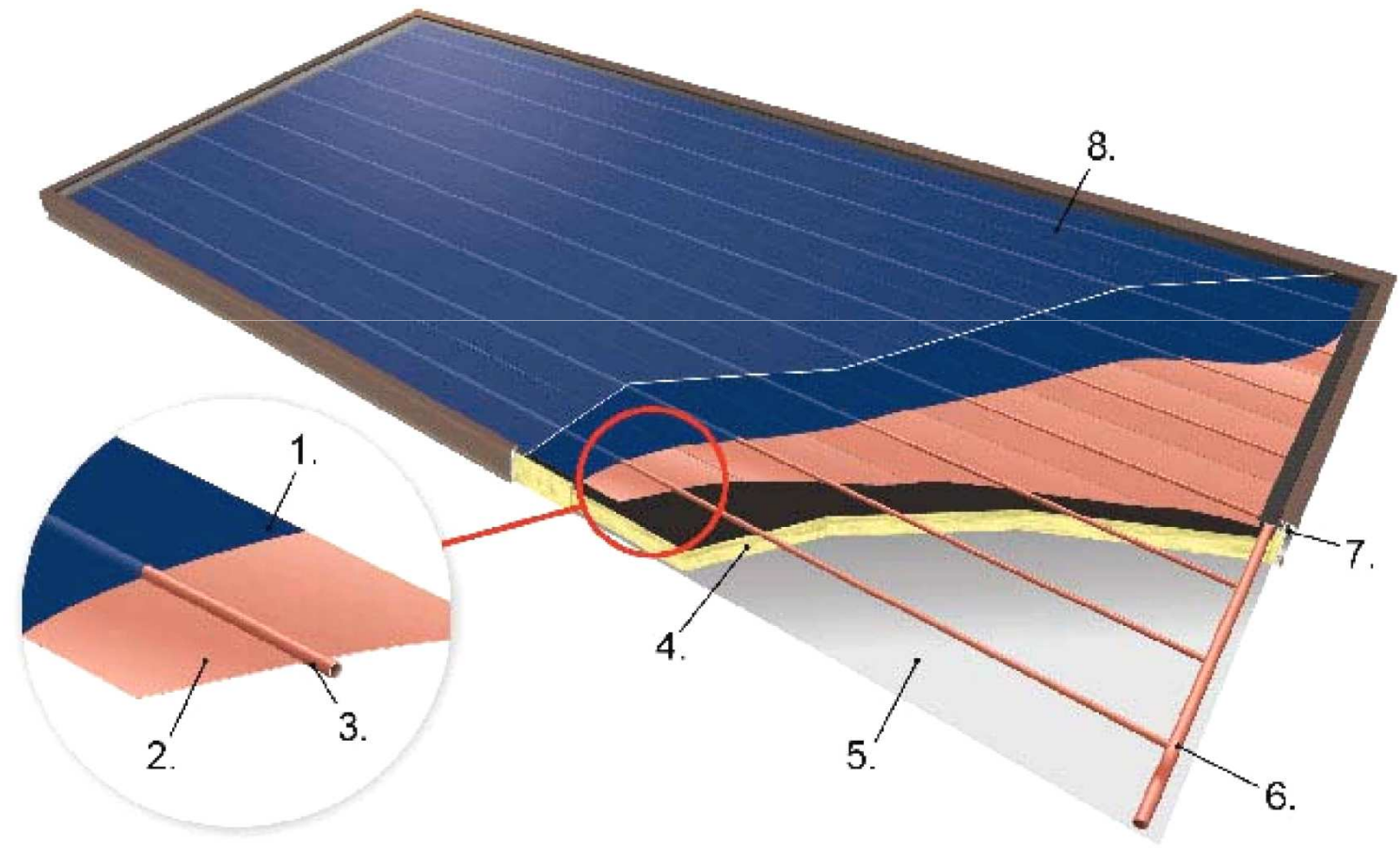
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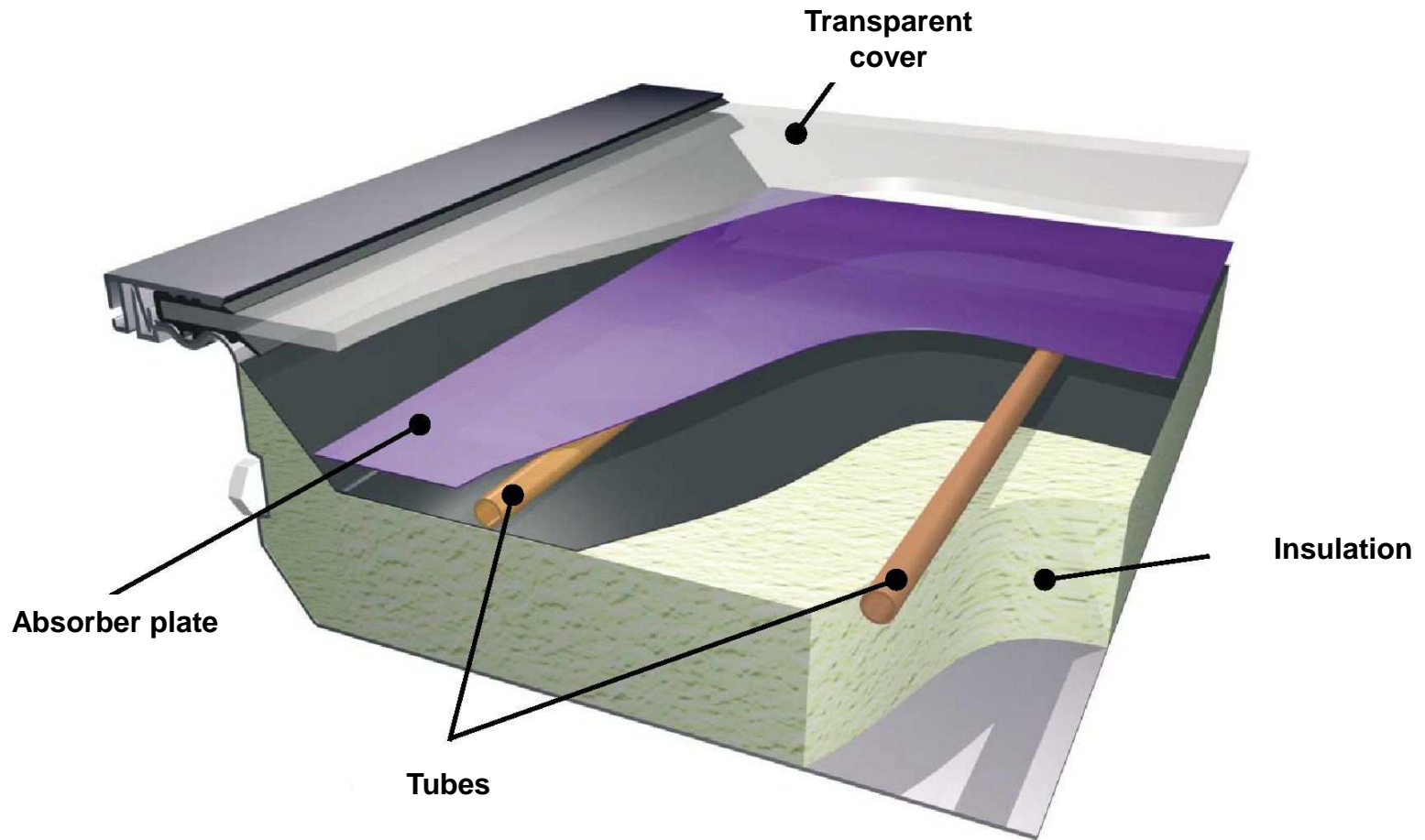


# FLAT-PLATE COLLECTOR



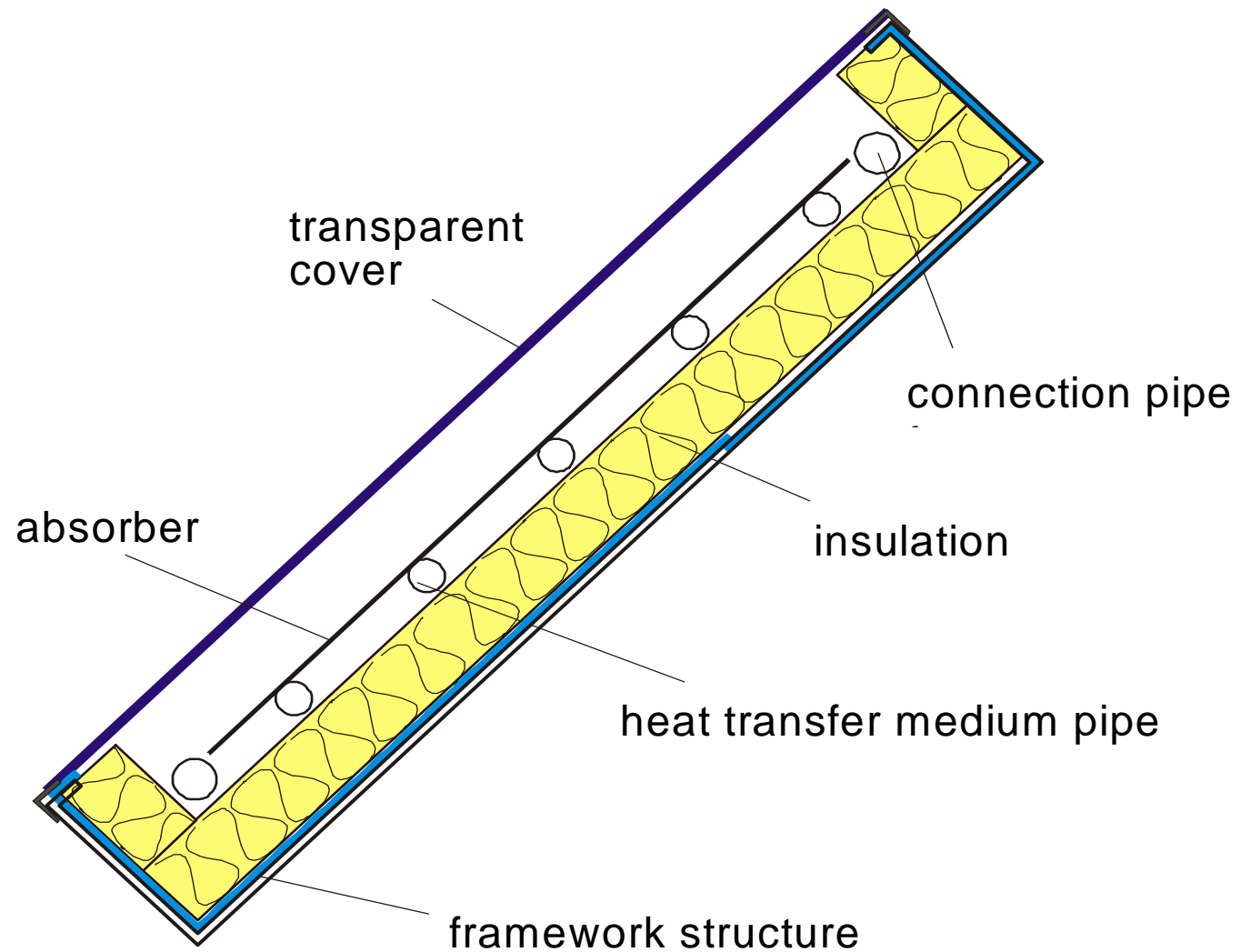
Source: IEA SHC Task 33

# FLAT-PLATE COLLECTOR



Source: Consolar

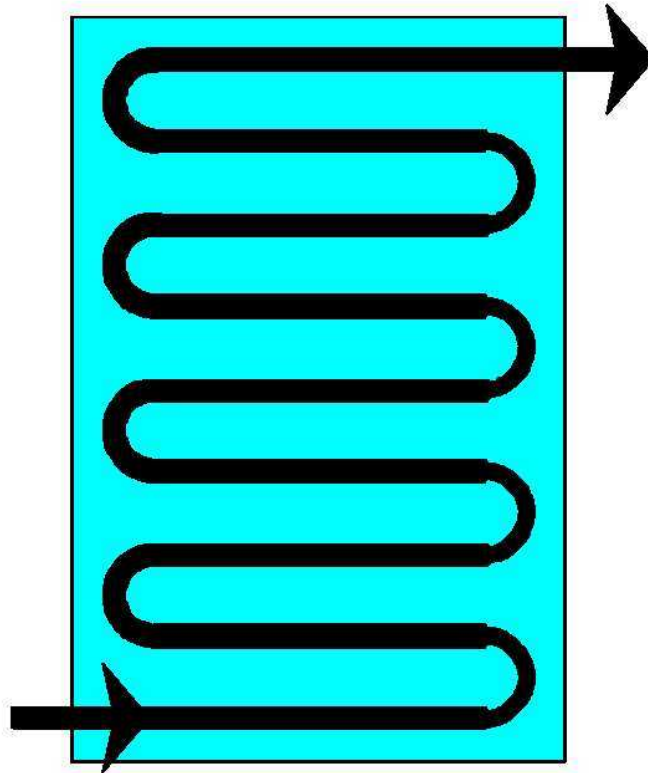
# FLAT-PLATE COLLECTOR



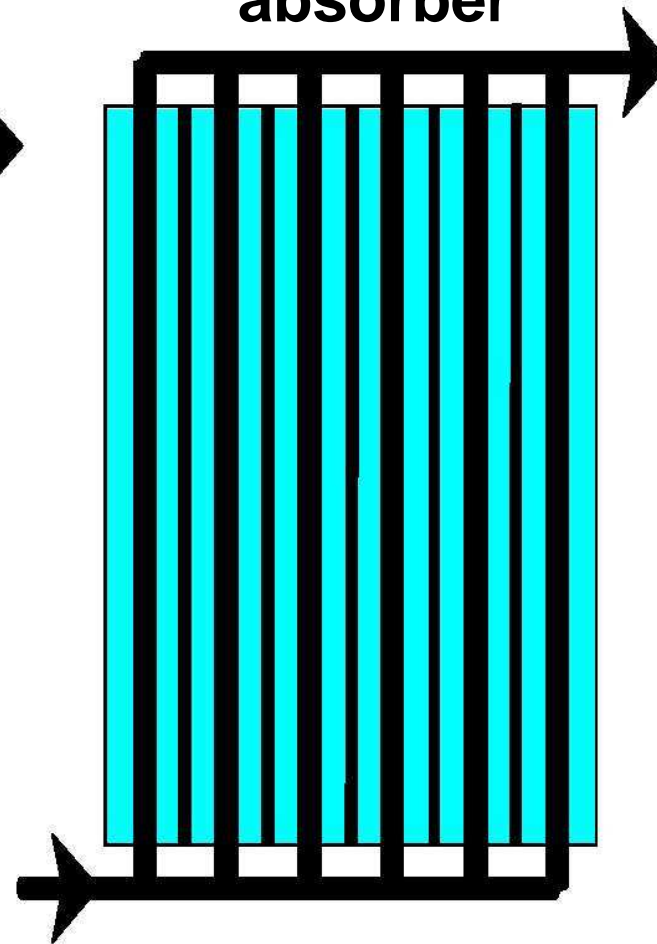


## ABSORBER - TYPES

**Meander  
absorber**



**Harp  
absorber**



# Manufacturing of a Solar Collector



# Manufacturing of a Solar Collector



Source:GREENoneTEC / ESTIF

# Manufacturing of a Solar Collector



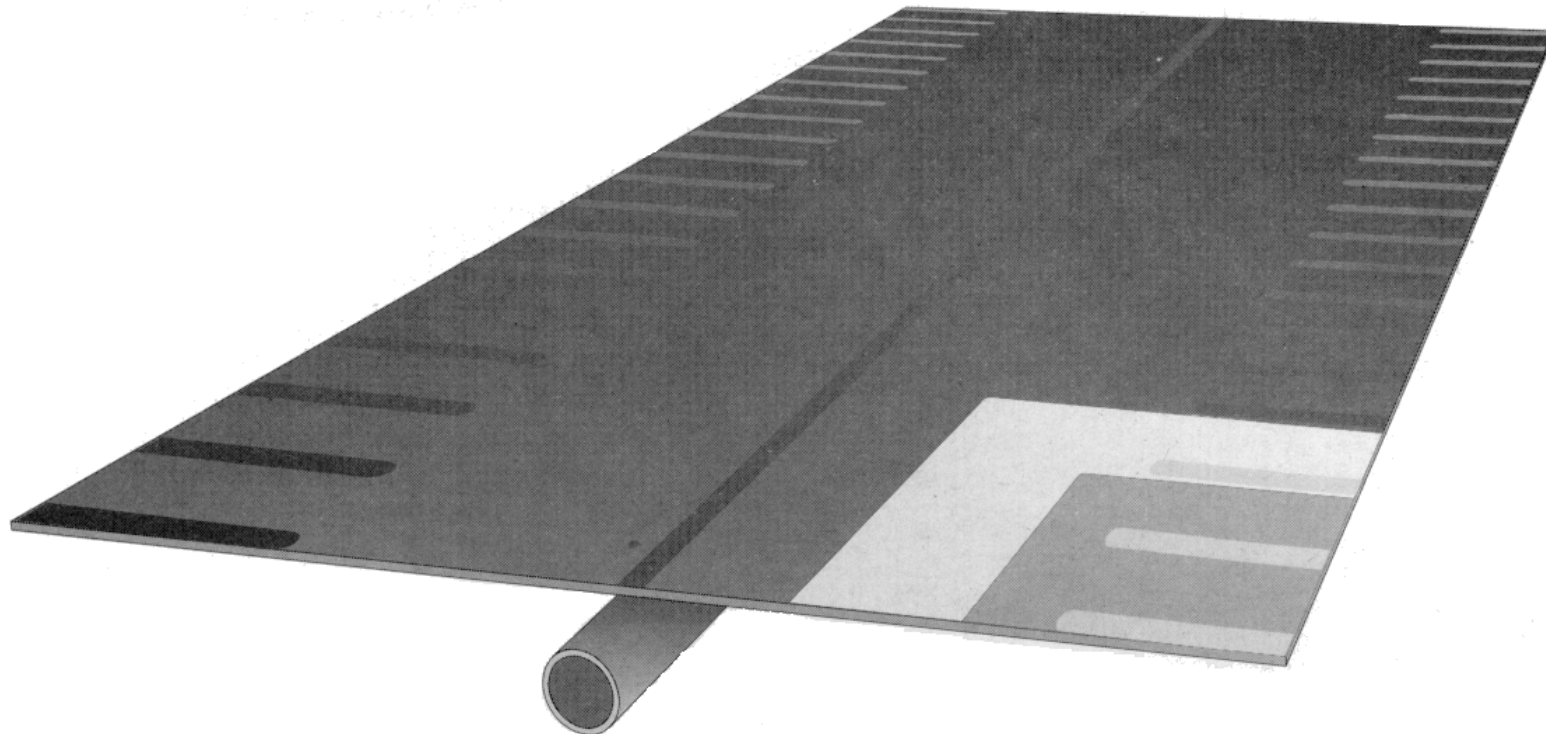
Source:GREENoneTEC / ESTIF

# Strip absorber

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# Strip Absorber

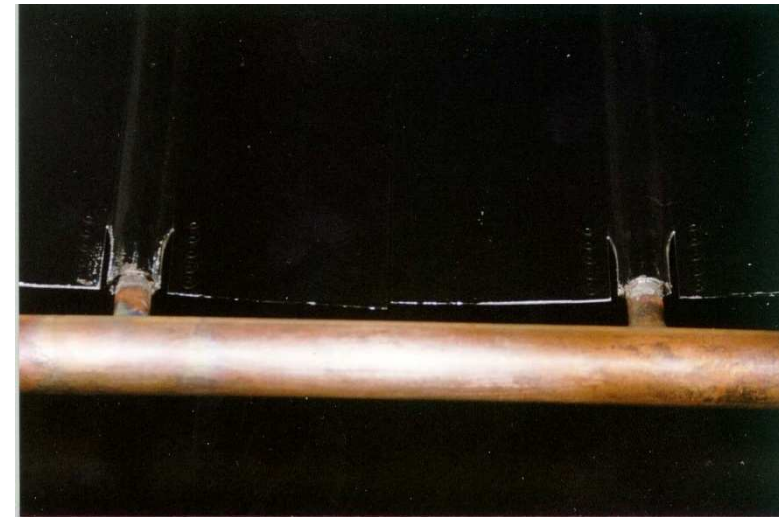
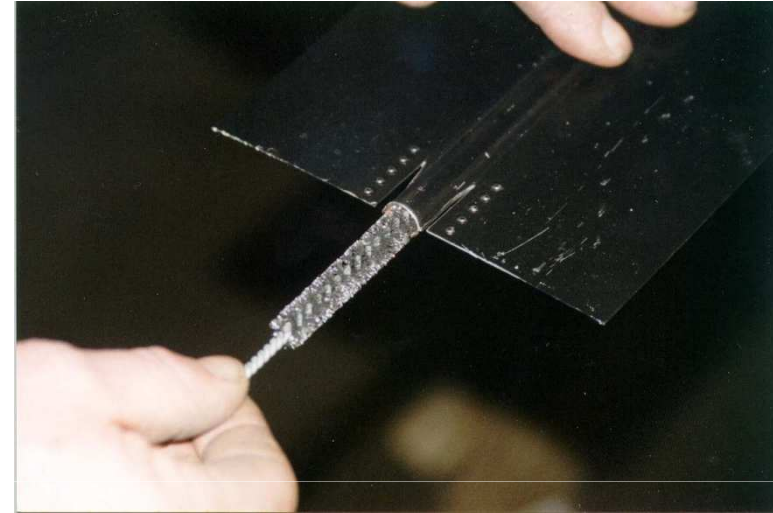
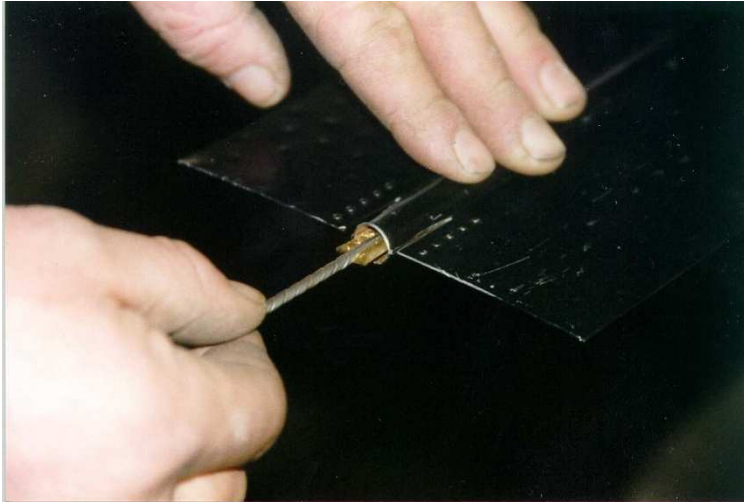
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# Strip Absorber



# Local Production in Uganda

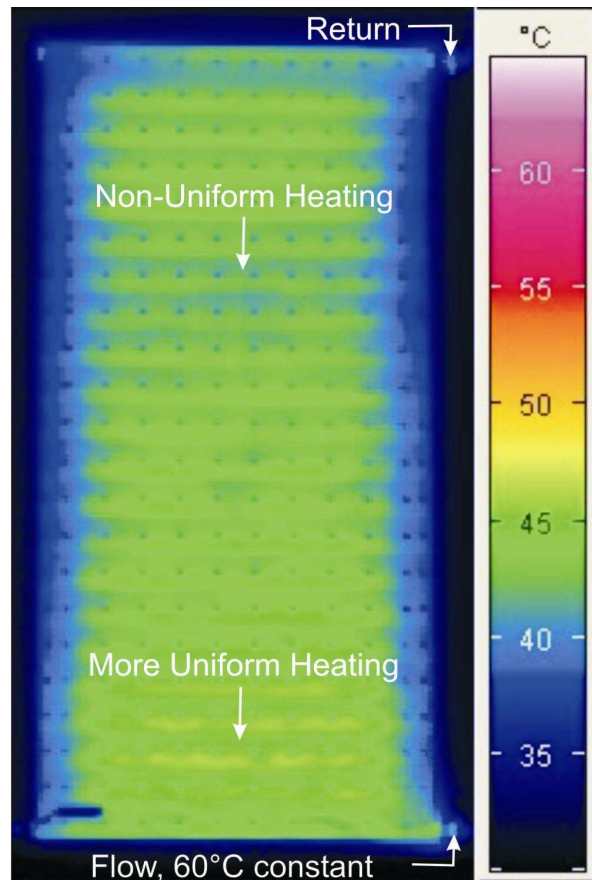
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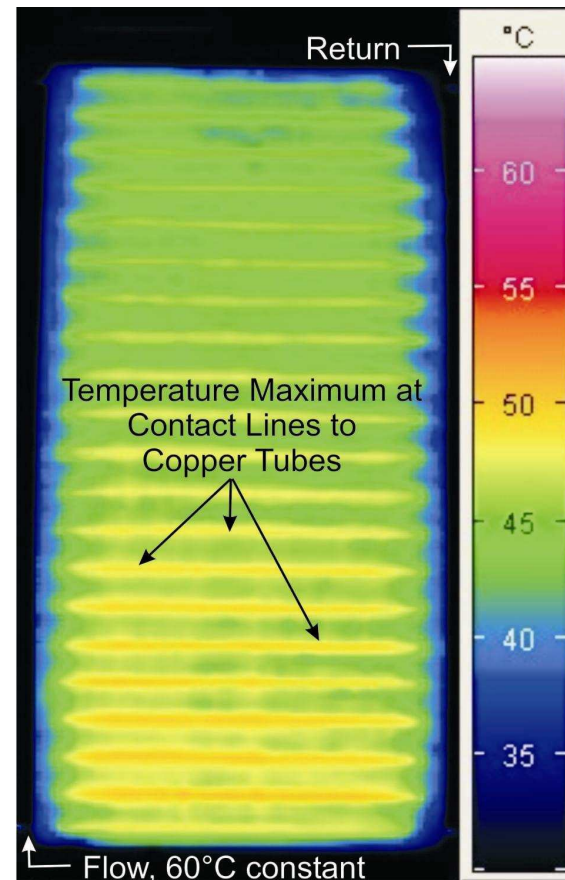




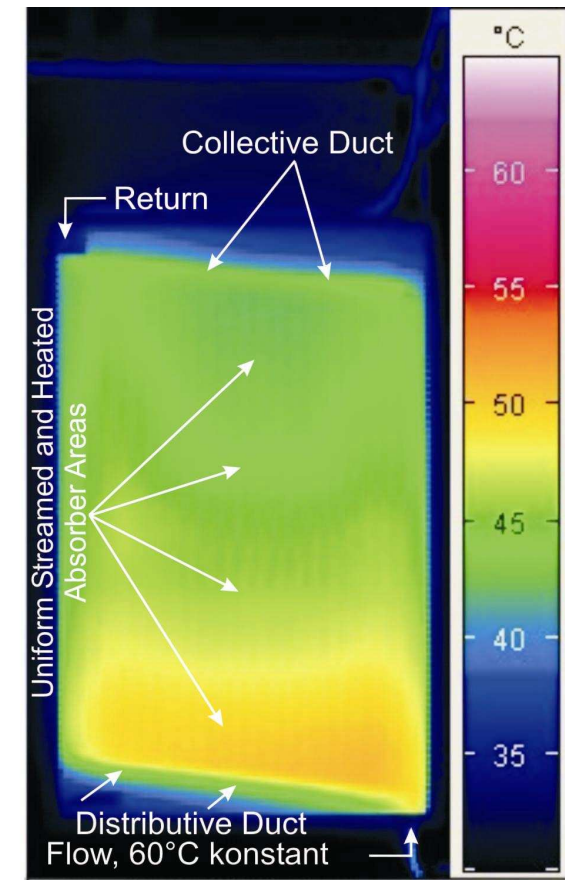
# Thermographic Photographs of Various Absorber Types



Clamped Sheet-Pipe Absorber



Ultrasonic Welded Sheet-Pipe Absorber

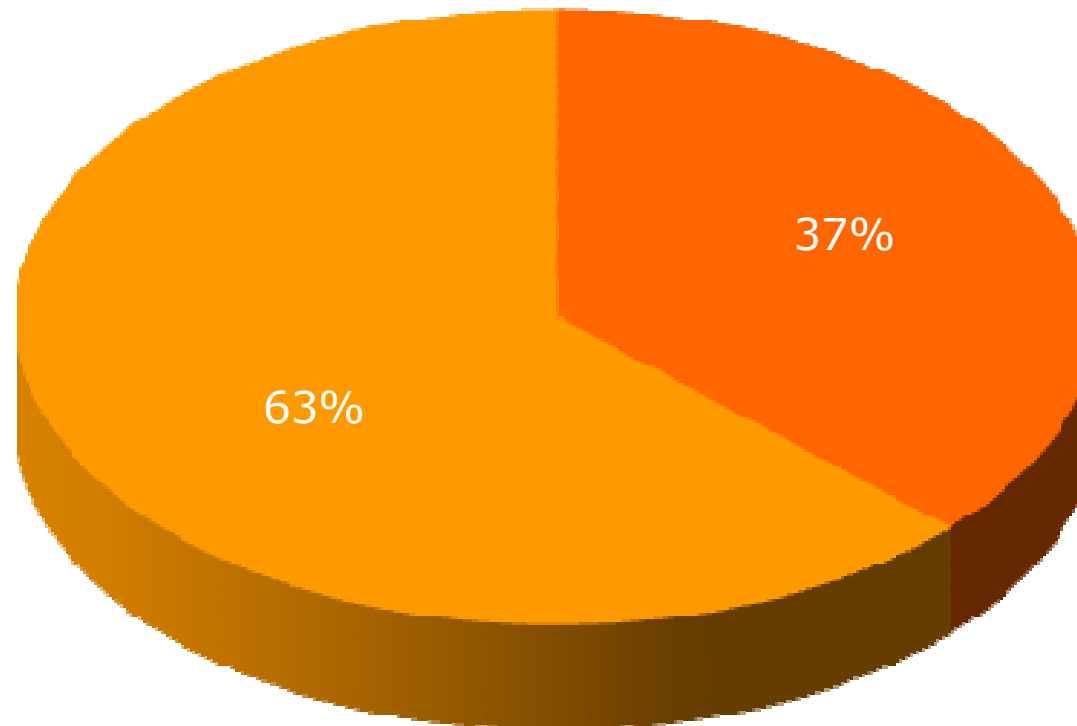


Roll-Bond Absorber

Source: Treikauskas, Ingolstadt University

# Absorber Material

## Aluminum or Copper?



- Aluminum
- Copper

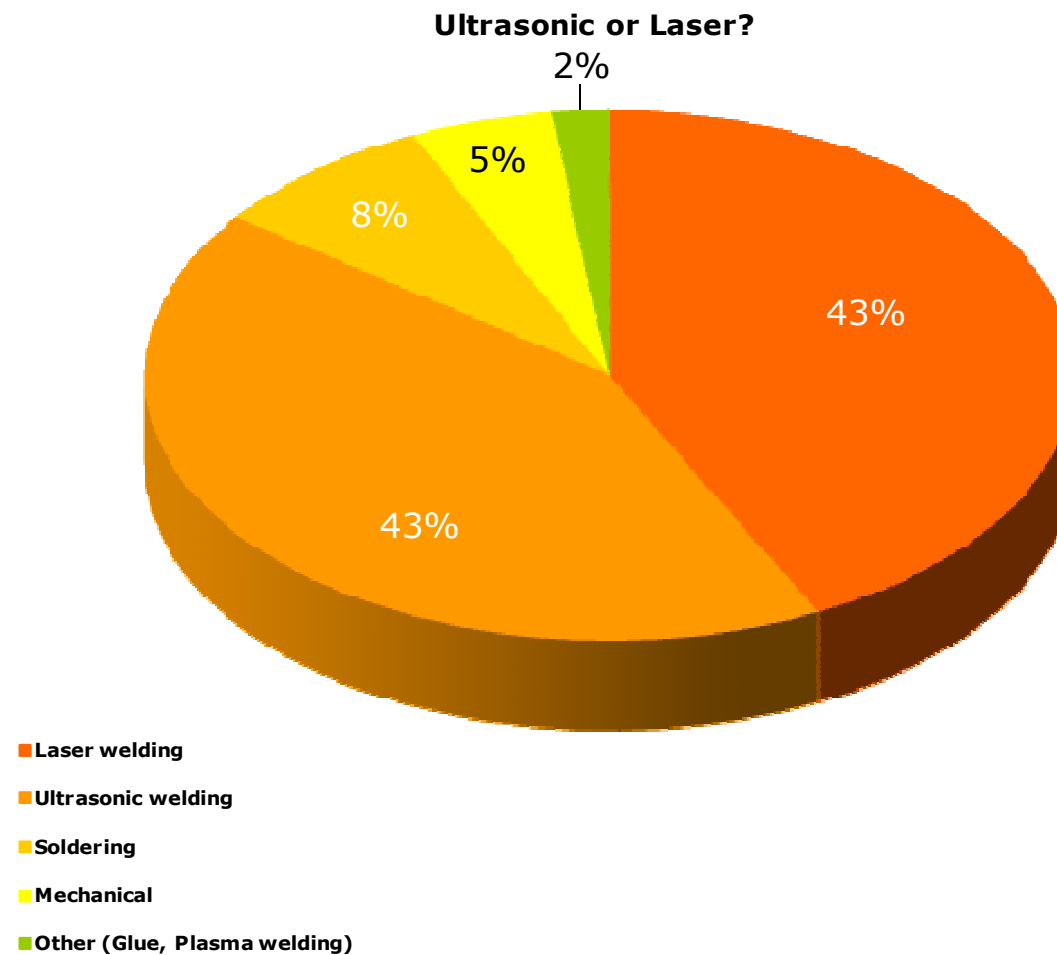
Source: Sonne, Wind und Wärme, 2009

# Ultrasonic or Laser Welding?

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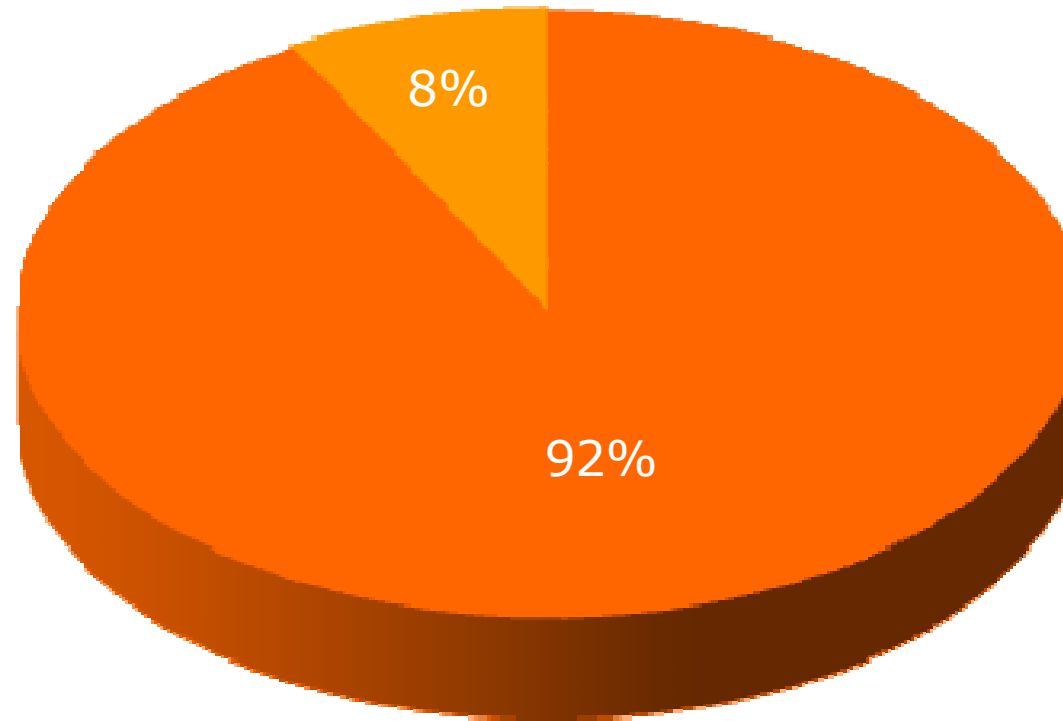
Development Cooperation



Source: Sonne, Wind und Wärme, 2009

# Full Size or Strip Absorber

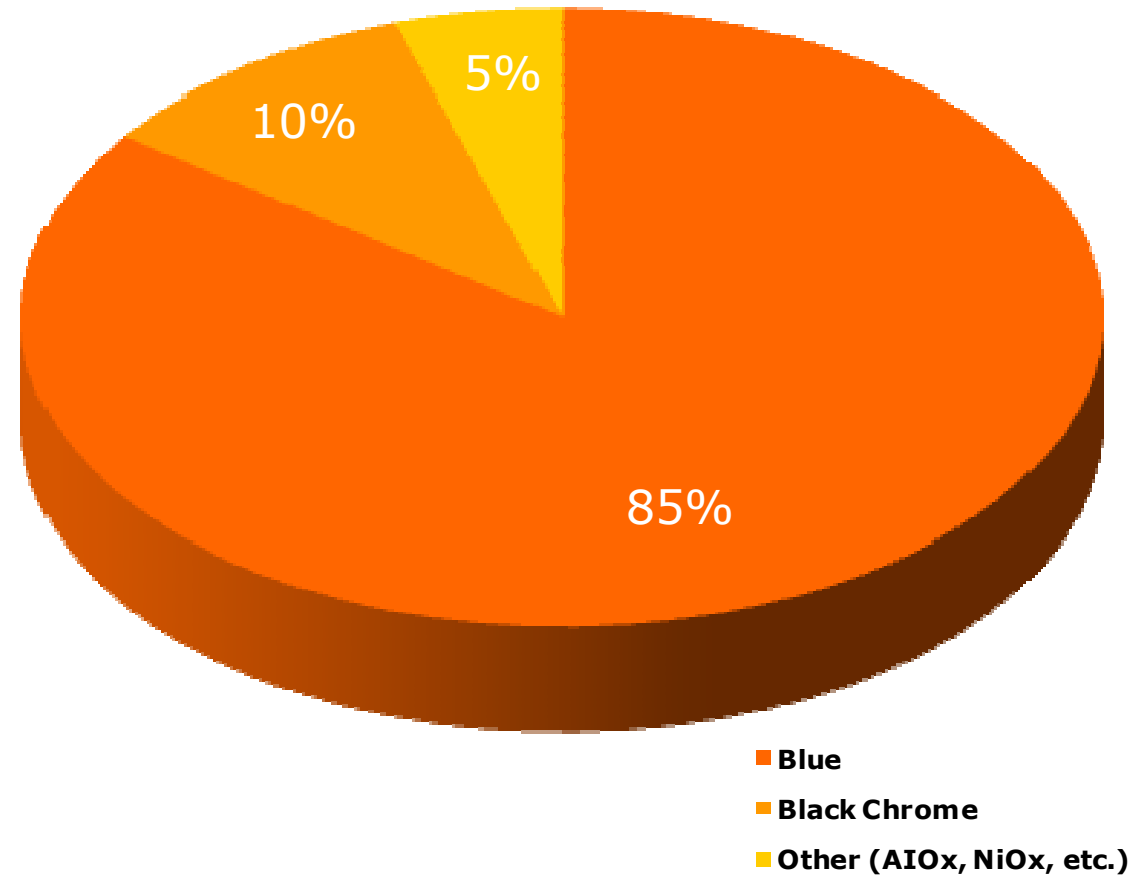
Full Size or Strip Absorber



- Full Size
- Absorber Strip

Source: Sonne, Wind und Wärme, 2009

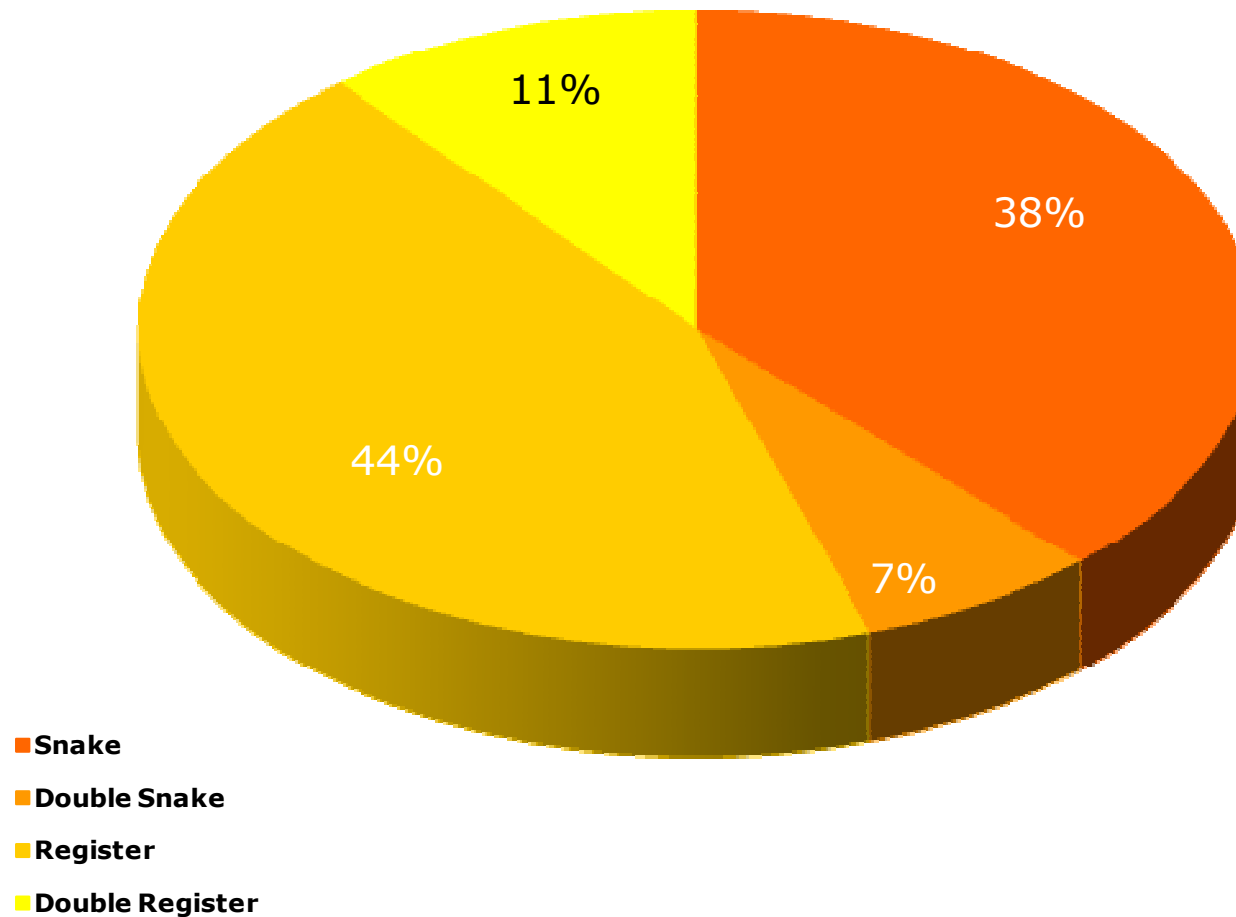
## Blue or black?



Source: Sonne, Wind und Wärme, 2009

# Snake Type or Register Absorber?

Snake Type or Register?



Source: Sonne, Wind und Wärme, 2009

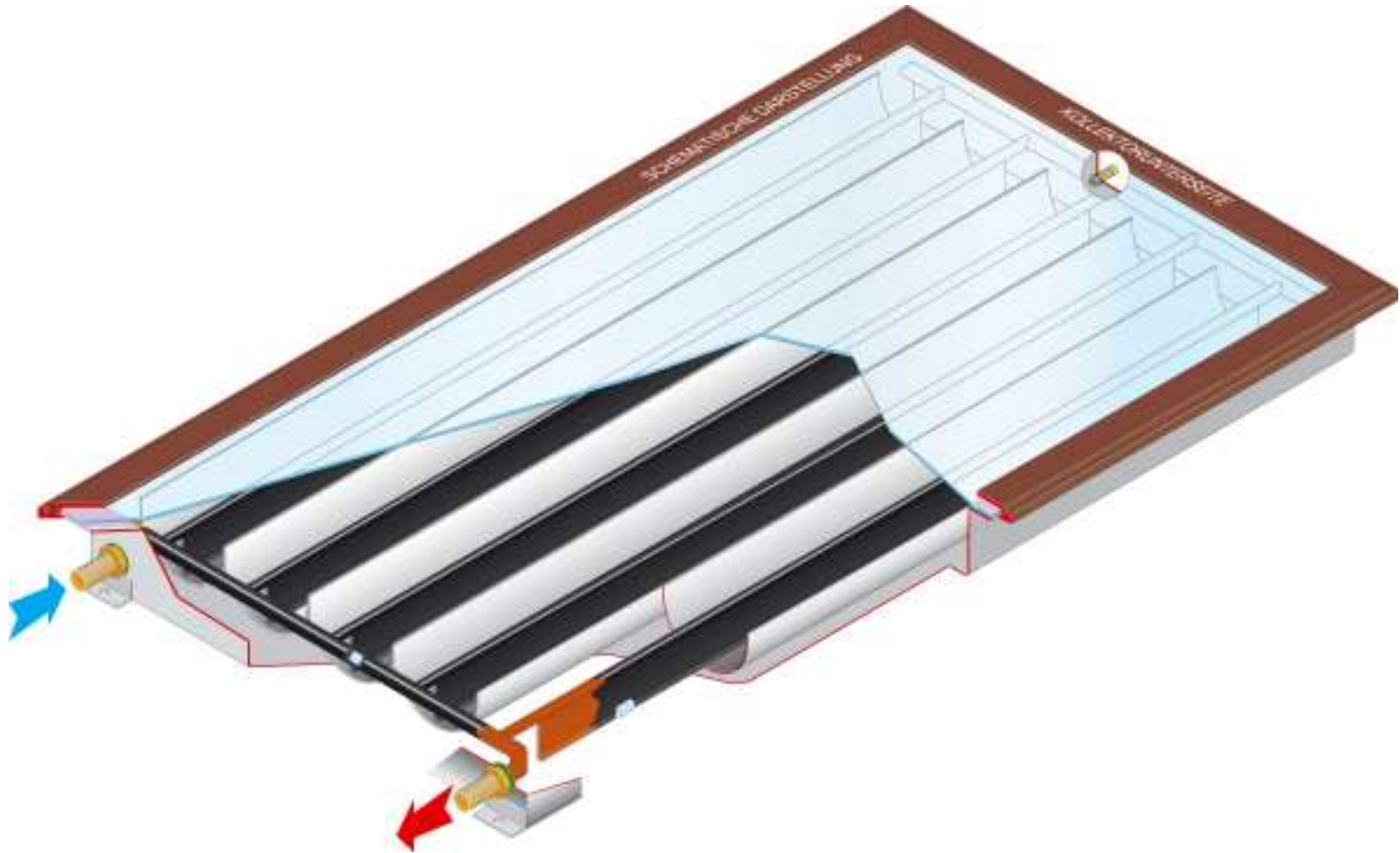


# CPC - COLLECTOR

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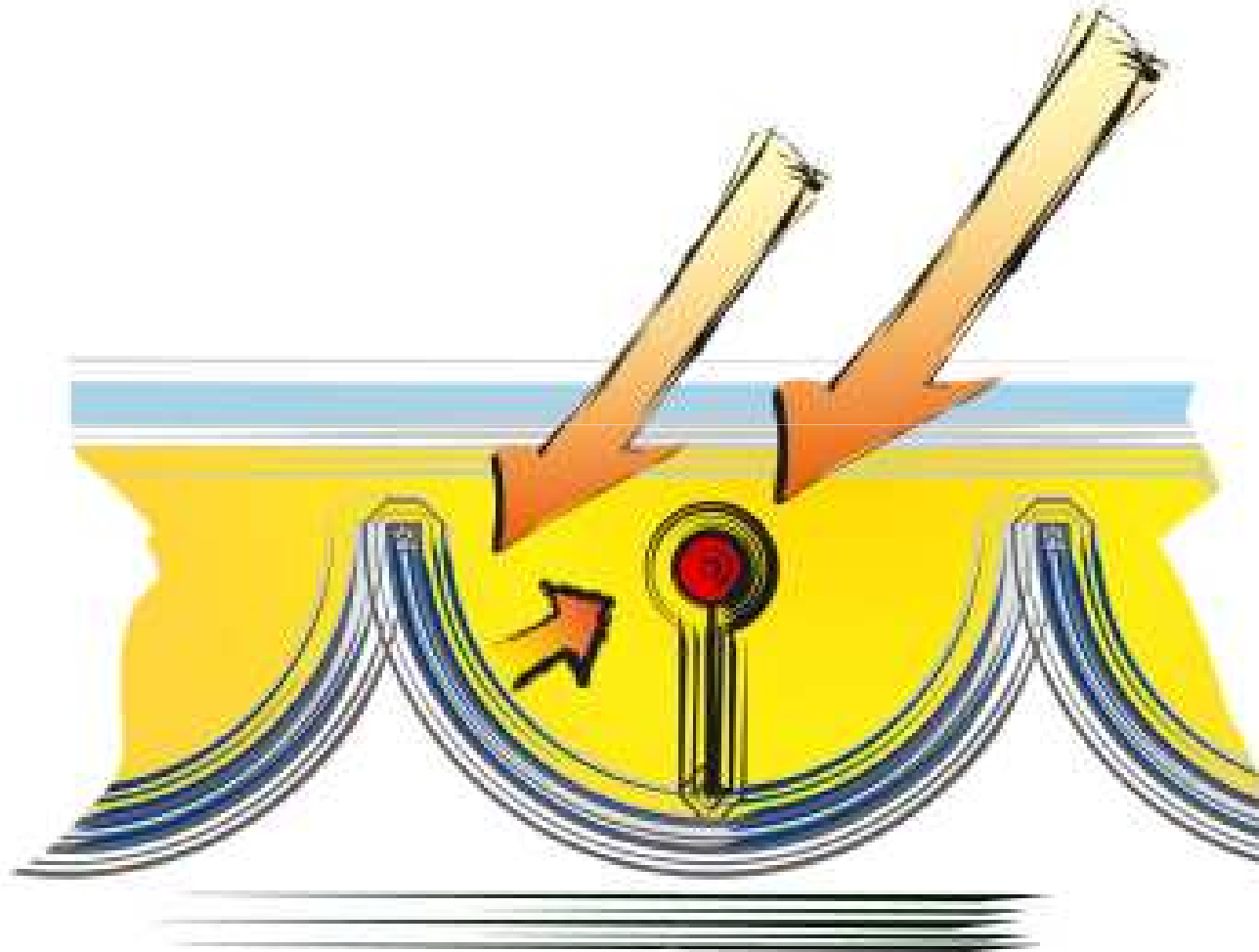


# CPC - COLLECTOR

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# Evacuated Tube Collectors

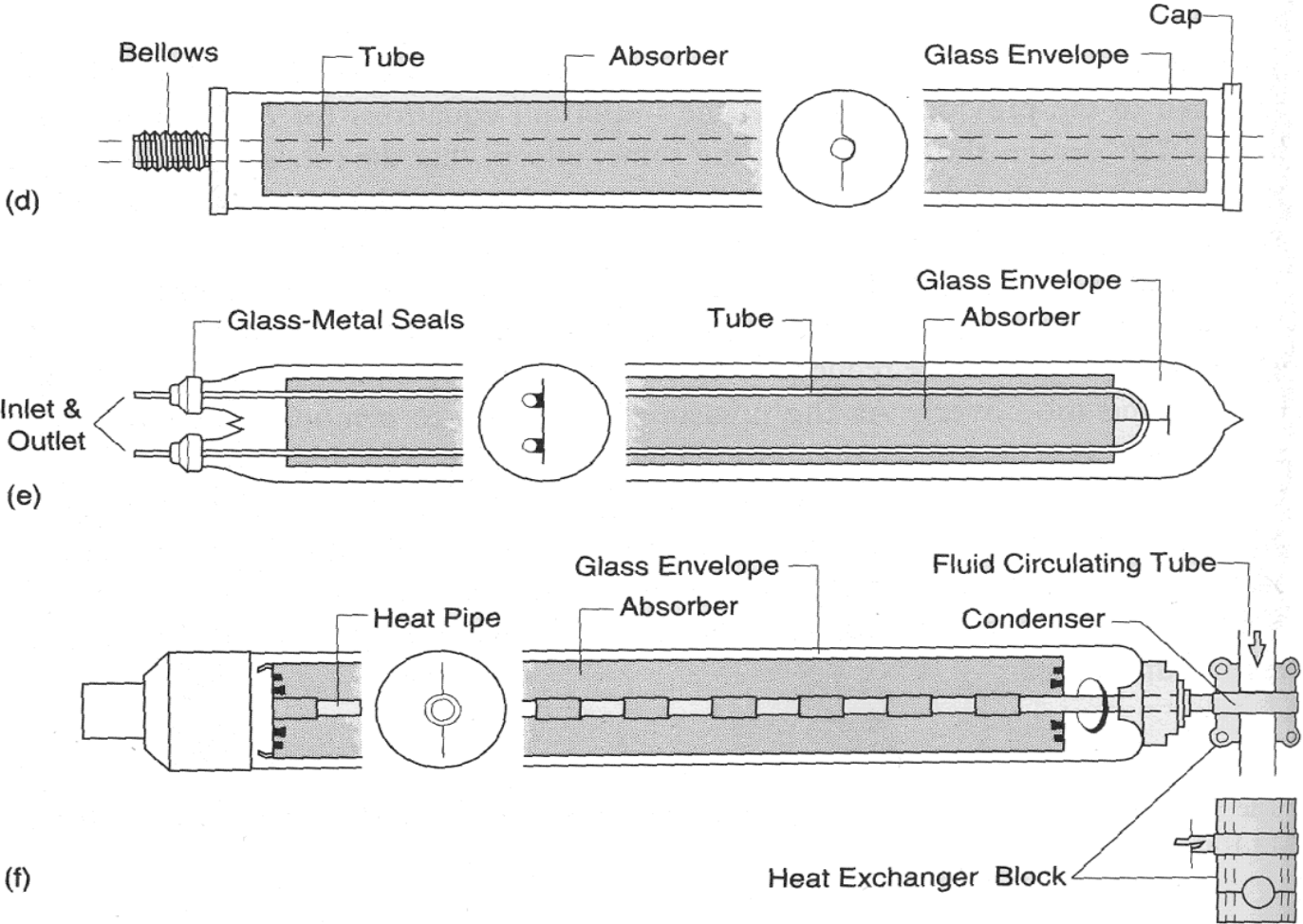
financed by

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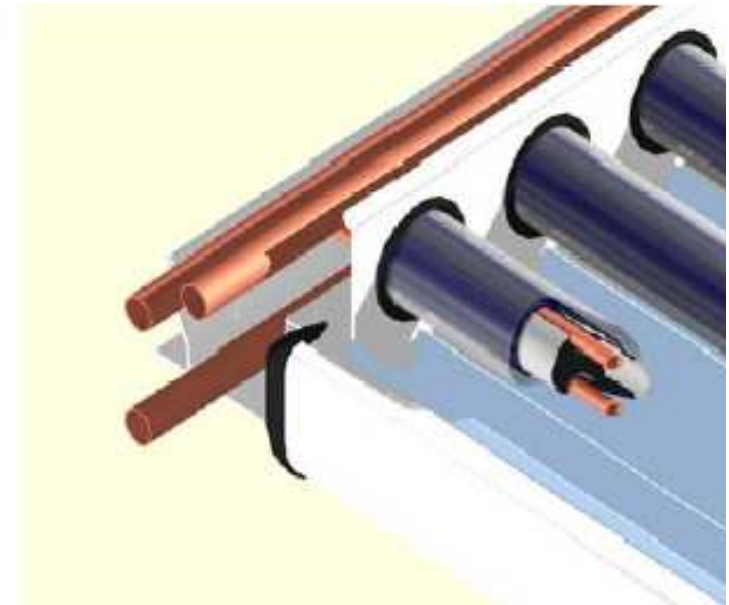
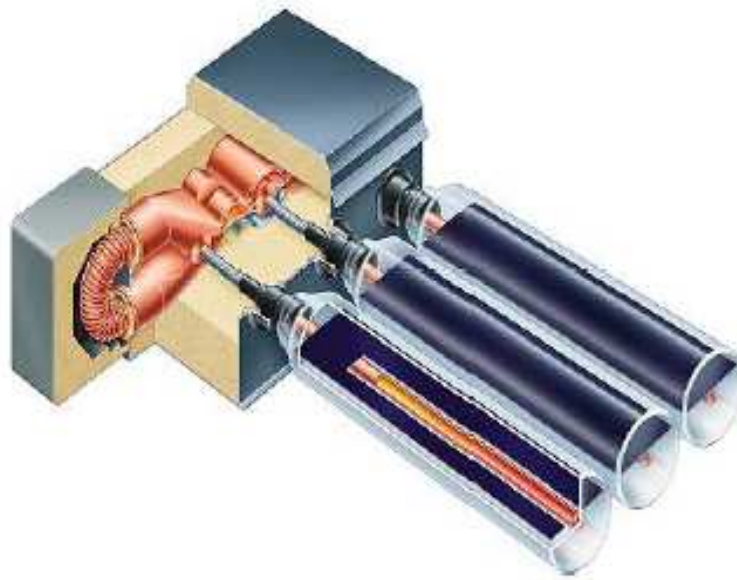
Development Cooperation



# Evacuated Tube Collectors

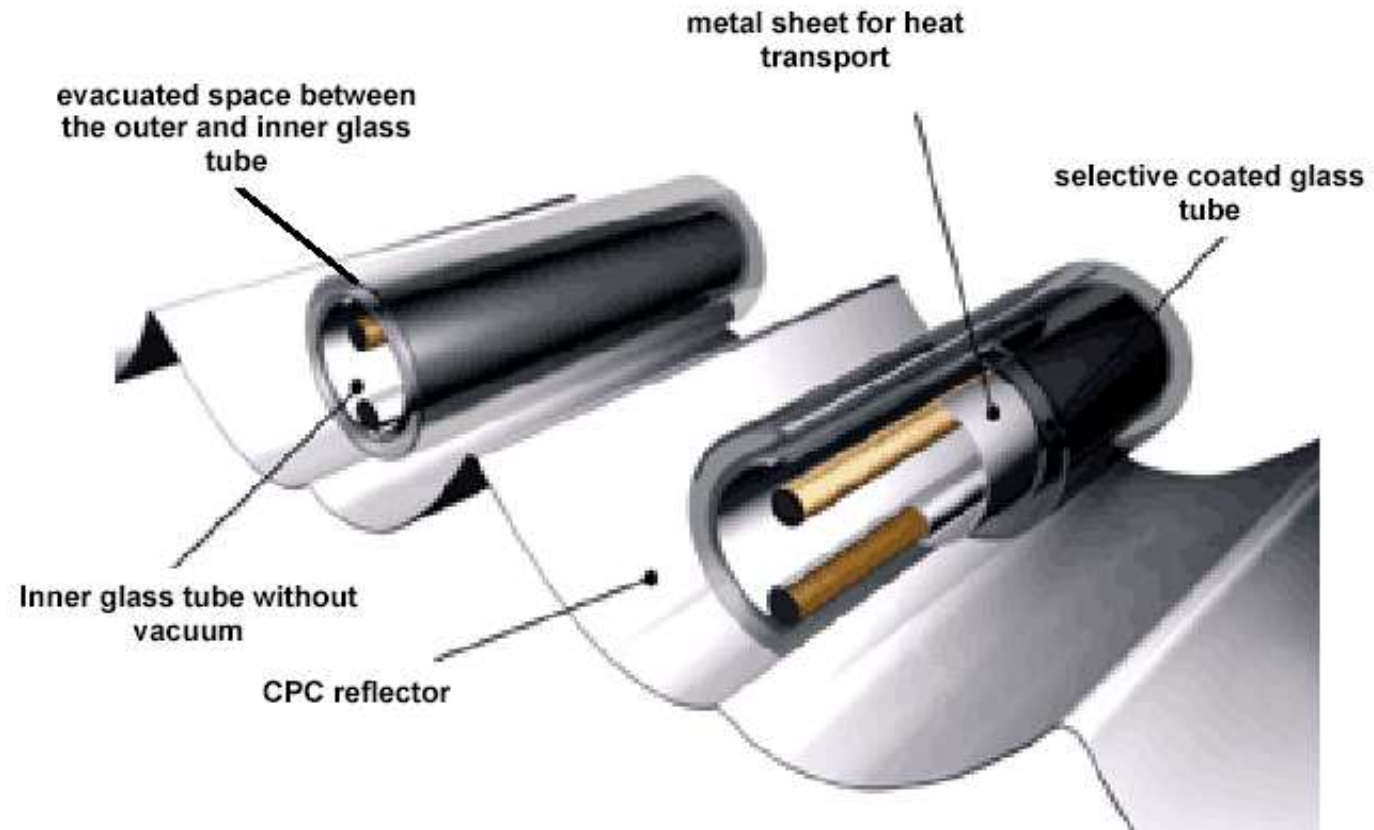


# Evacuated Tube Collectors



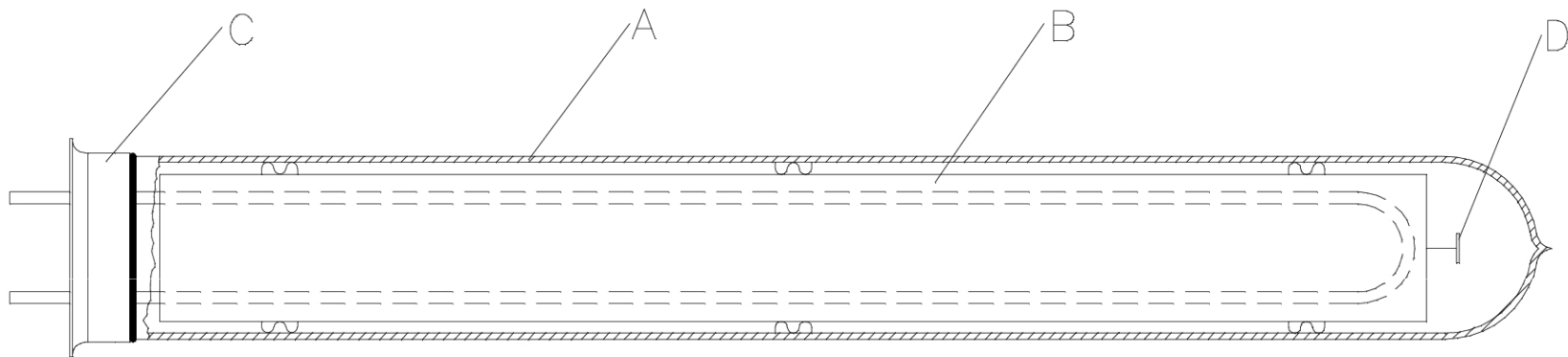
Heatpipe, Vitosol 300 (left) / Direct coupled Sydney Collector (right)

# Direct flow U-tube with cylindrical absorber



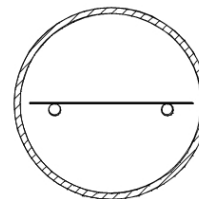
Detail Sydney collector

# Direct flow U-tube with flat absorber



A: Tube (Borosilicate glass)

B: Absorber (selectively coated)

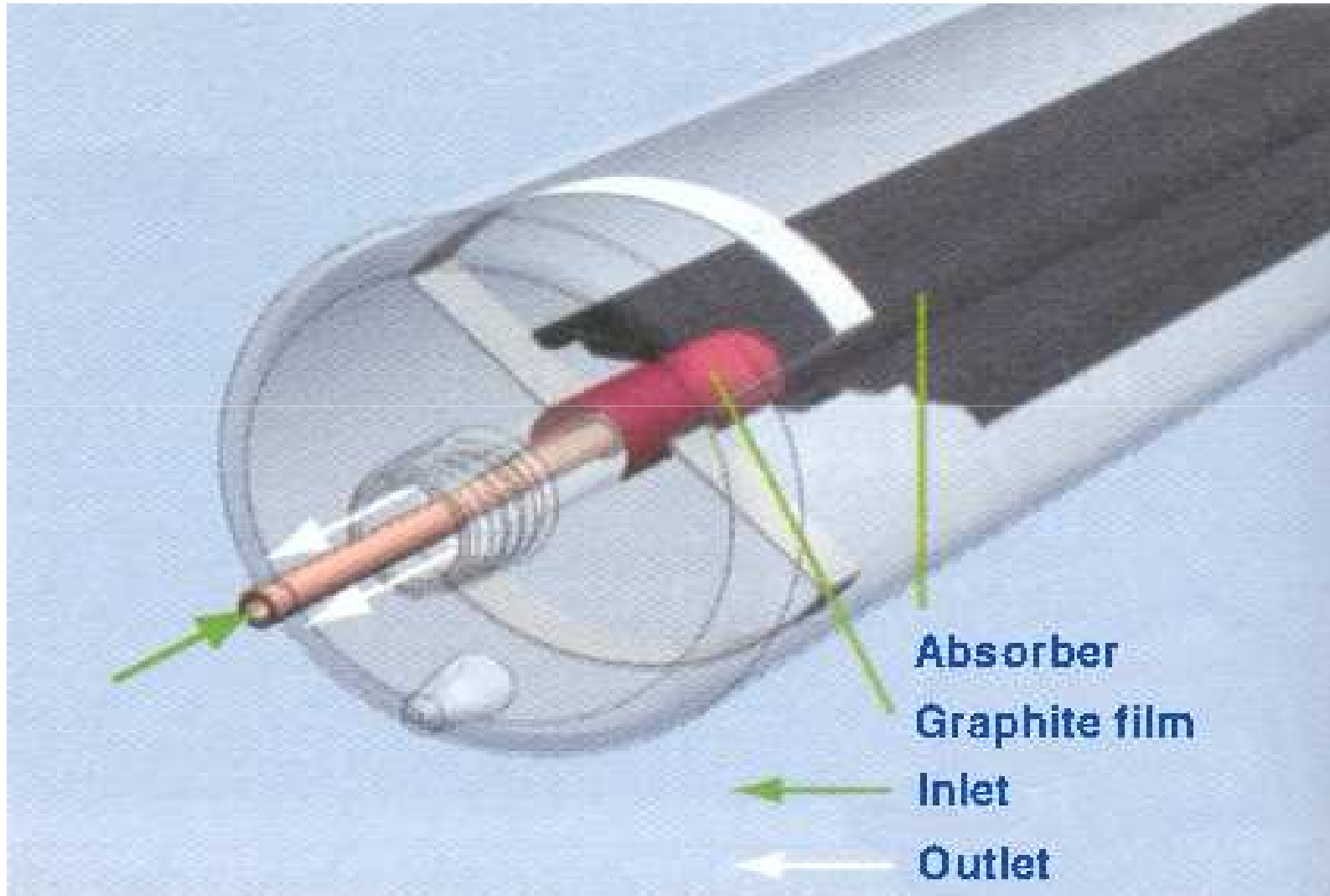


C: Metal end cap

D: Getter

Source: Frei, U.: Kollektoren in solarthermischen Systemen, SPF Solartechnik Prüfung Forschung, TriSolar98

# Lenz Tube



Source: SWW 08/20006 S.46

# Evacuated Tube Collectors

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Detail Sydney collector

# Evacuated Tube Collectors

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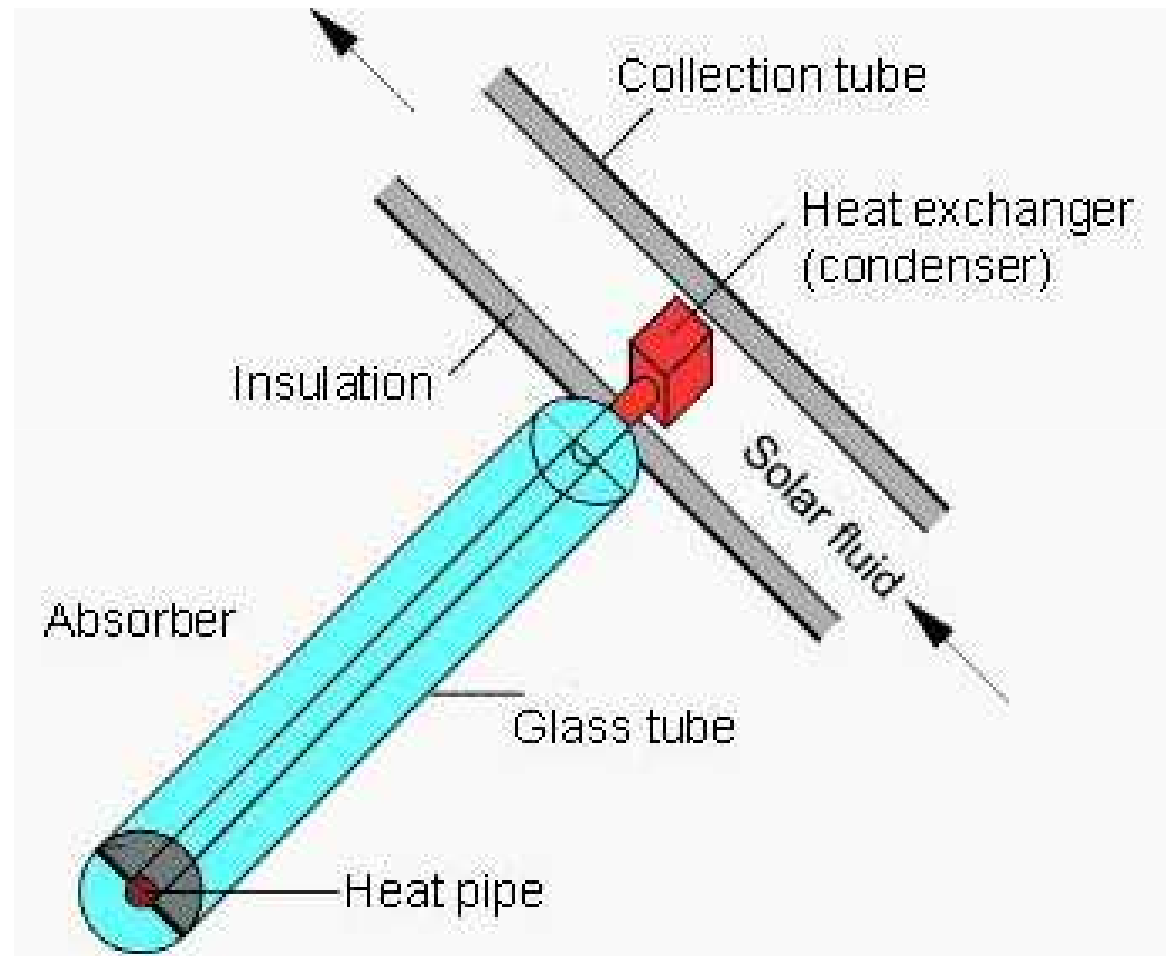
# Evacuated Tube Collectors – Heat Pipe



# Evacuated Tube Collectors – Heat Pipe



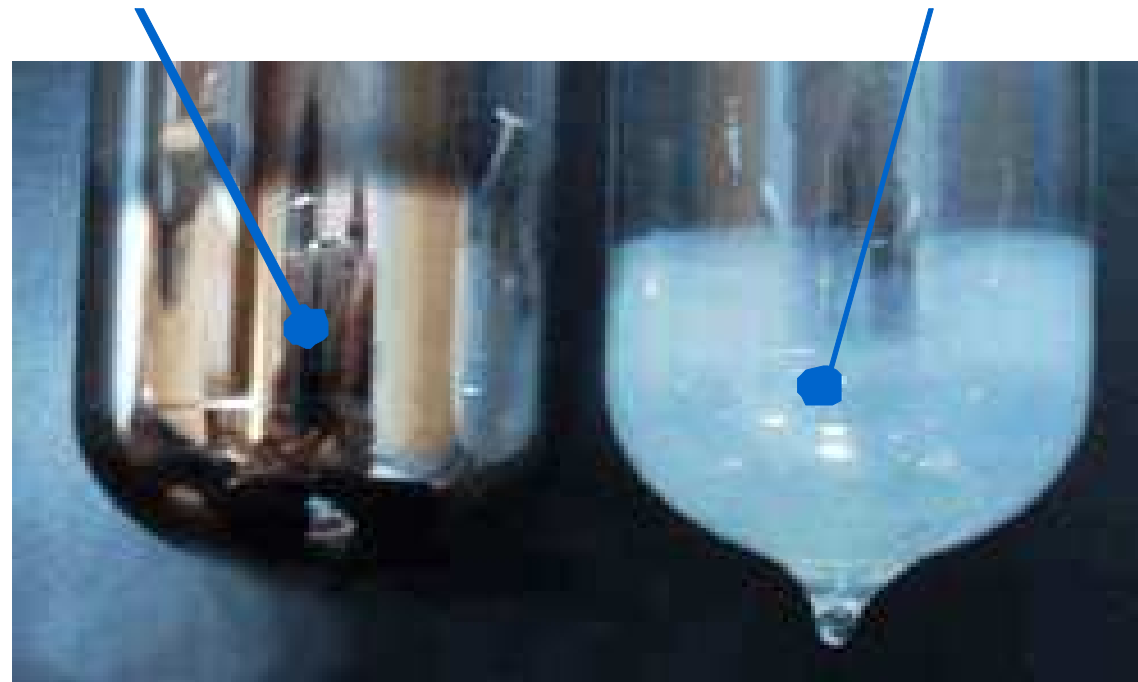
# Heat Pipe Principle – Wet Connection



# Error-indication

Vacuum present

Vacuum faulty



<http://www.solardirect.com/>

# Evacuated Tube Collectors

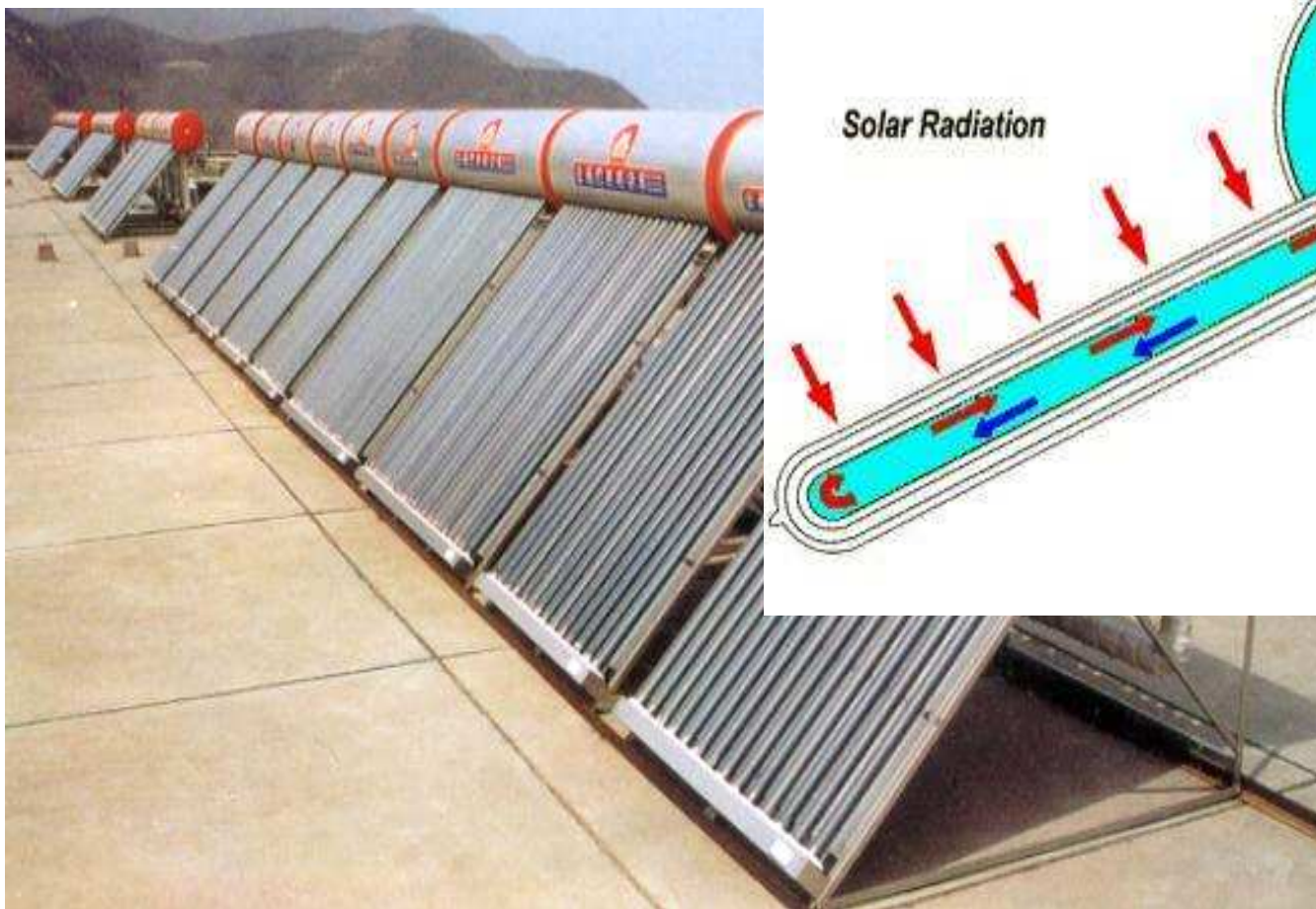
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# THERMOSYPHON SYSTEM - China



# Evacuated Tube Collectors

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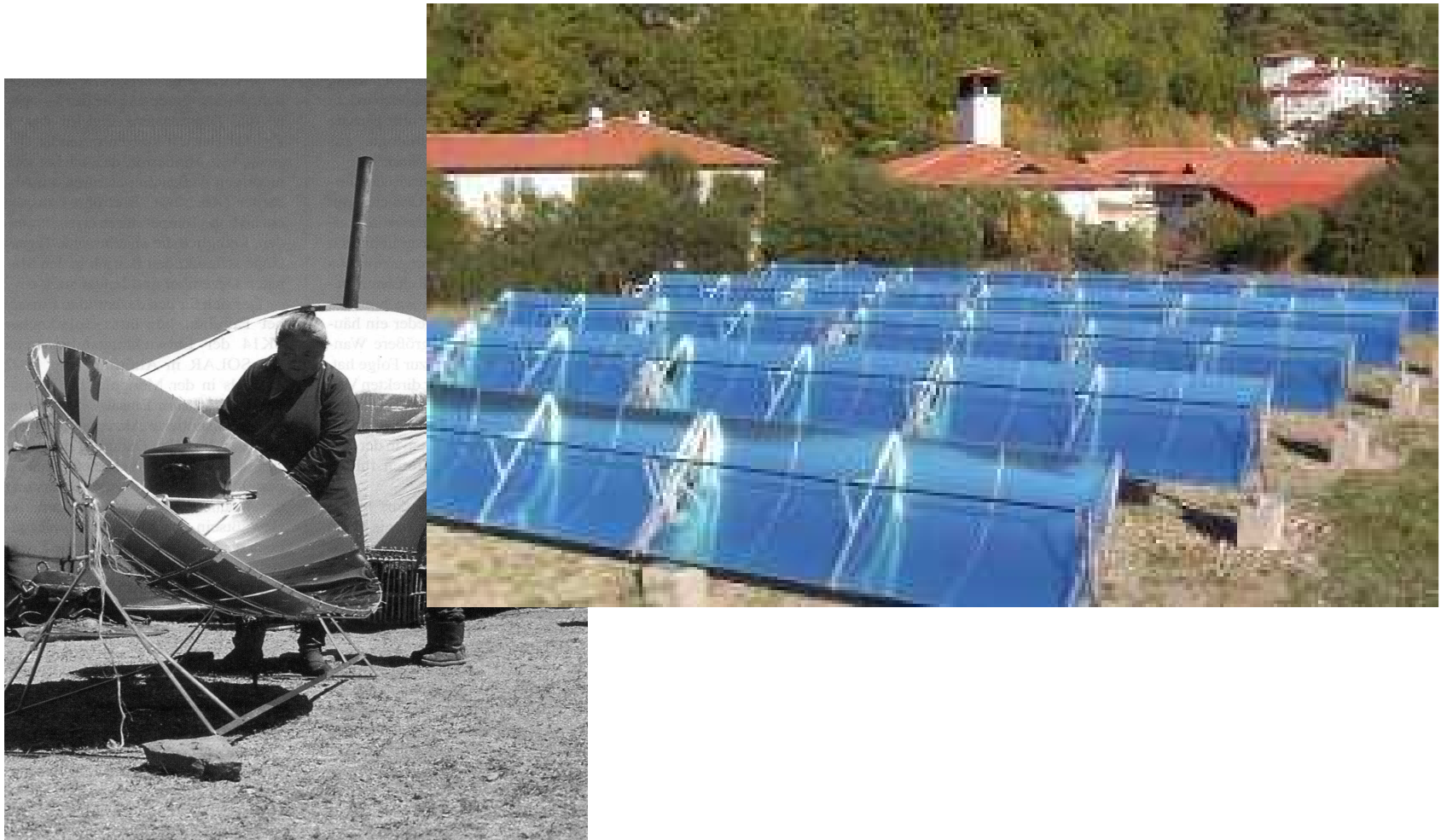
Source: Consolar

# Concentrating Collectors

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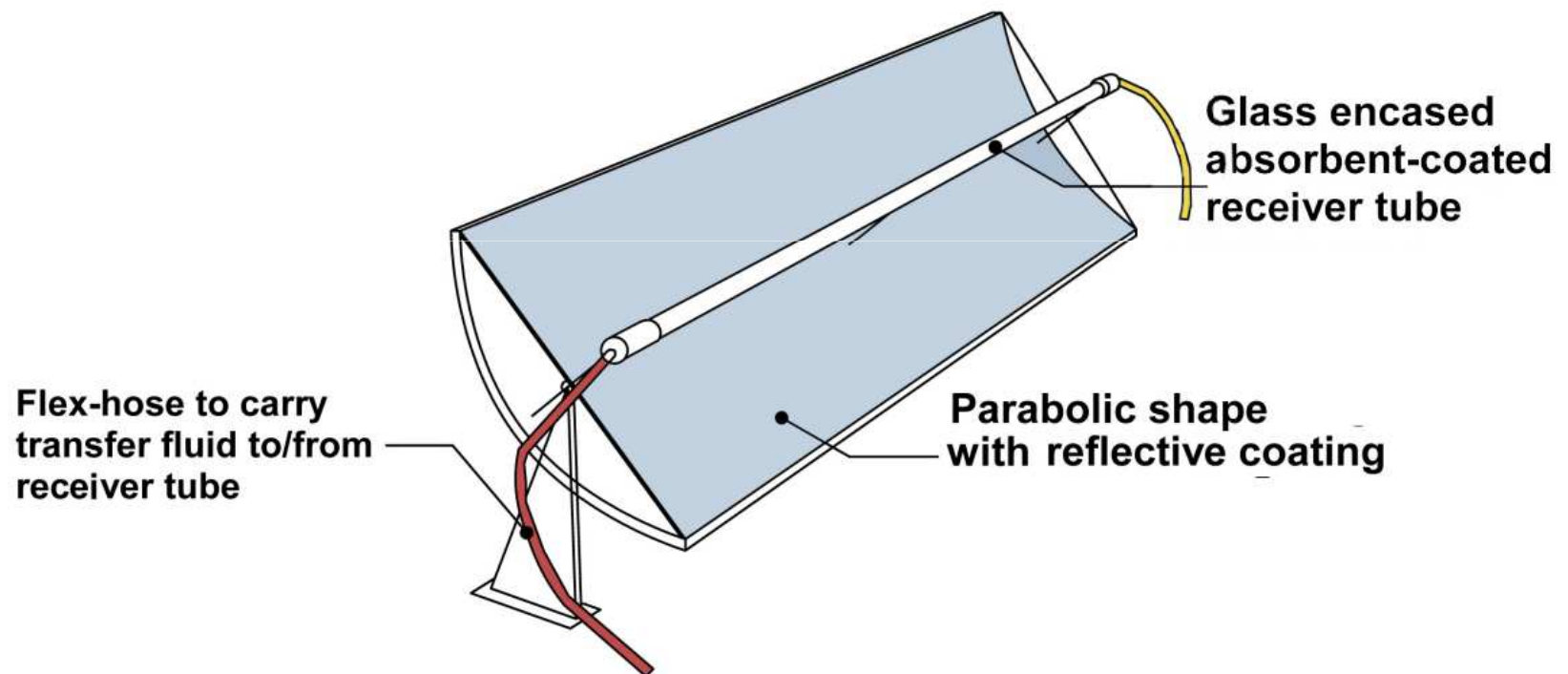


# Parabolic Trough Collector

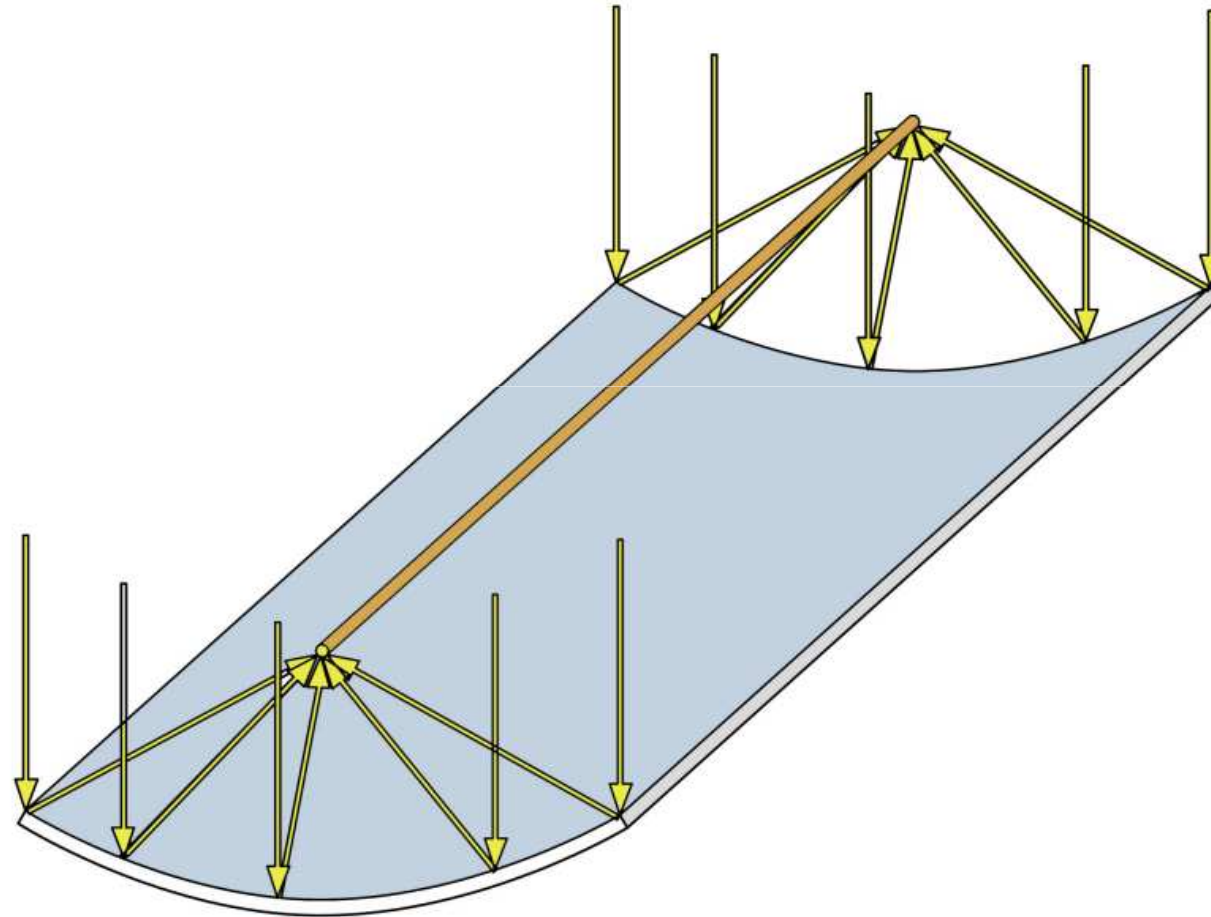
financed by

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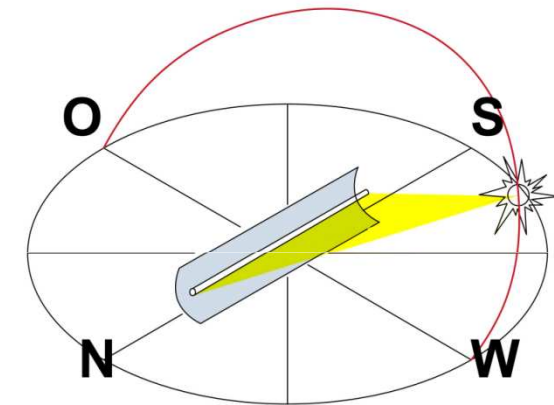
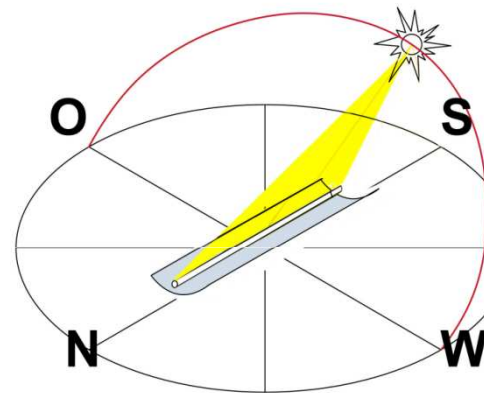
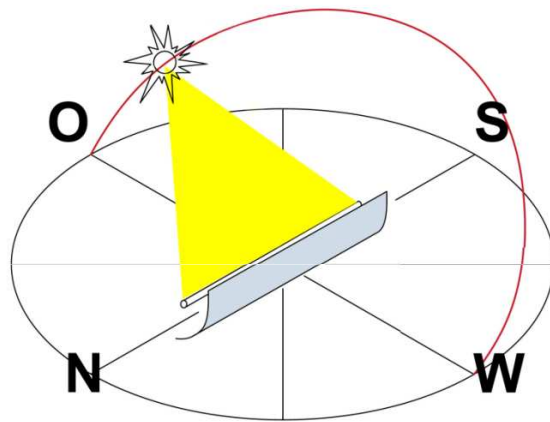
Development Cooperation



# Working Principle - PTC



# Tracking of the sun



Collector axis oriented north-south

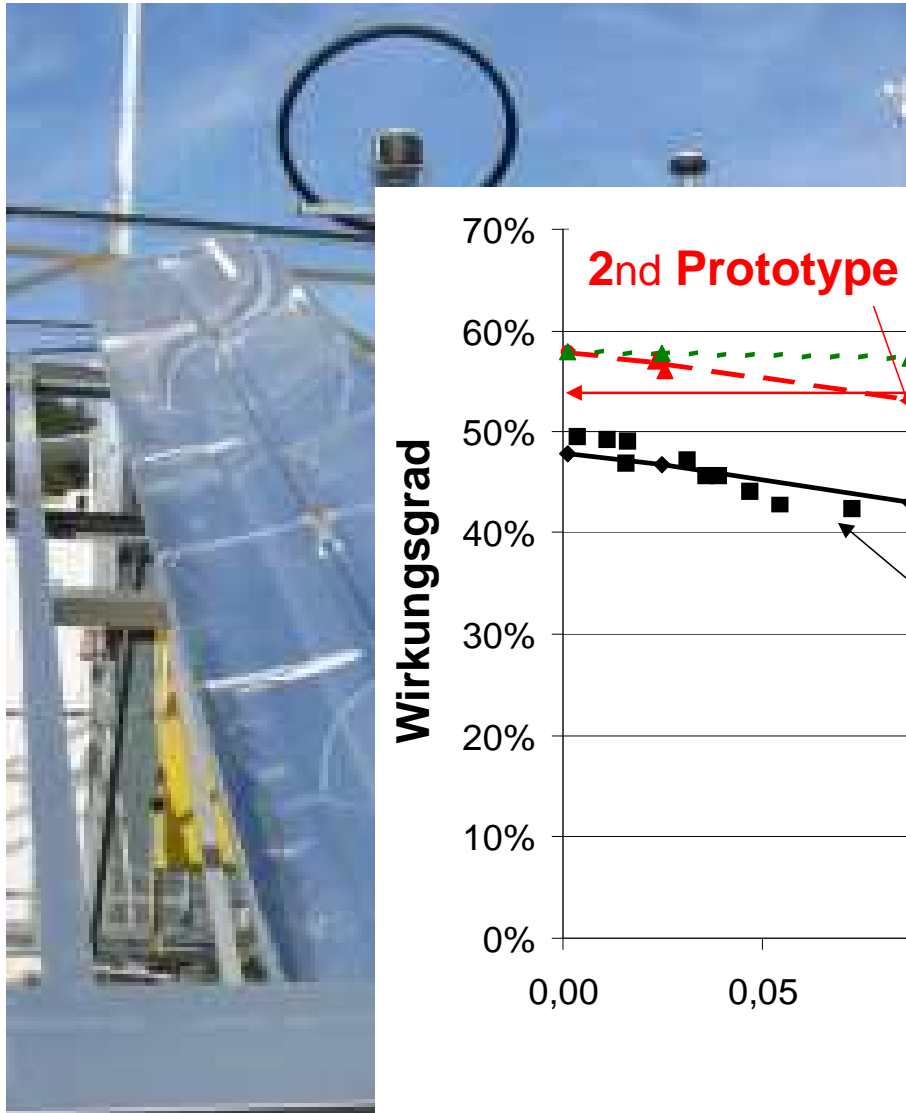
# Built Examples

financed by

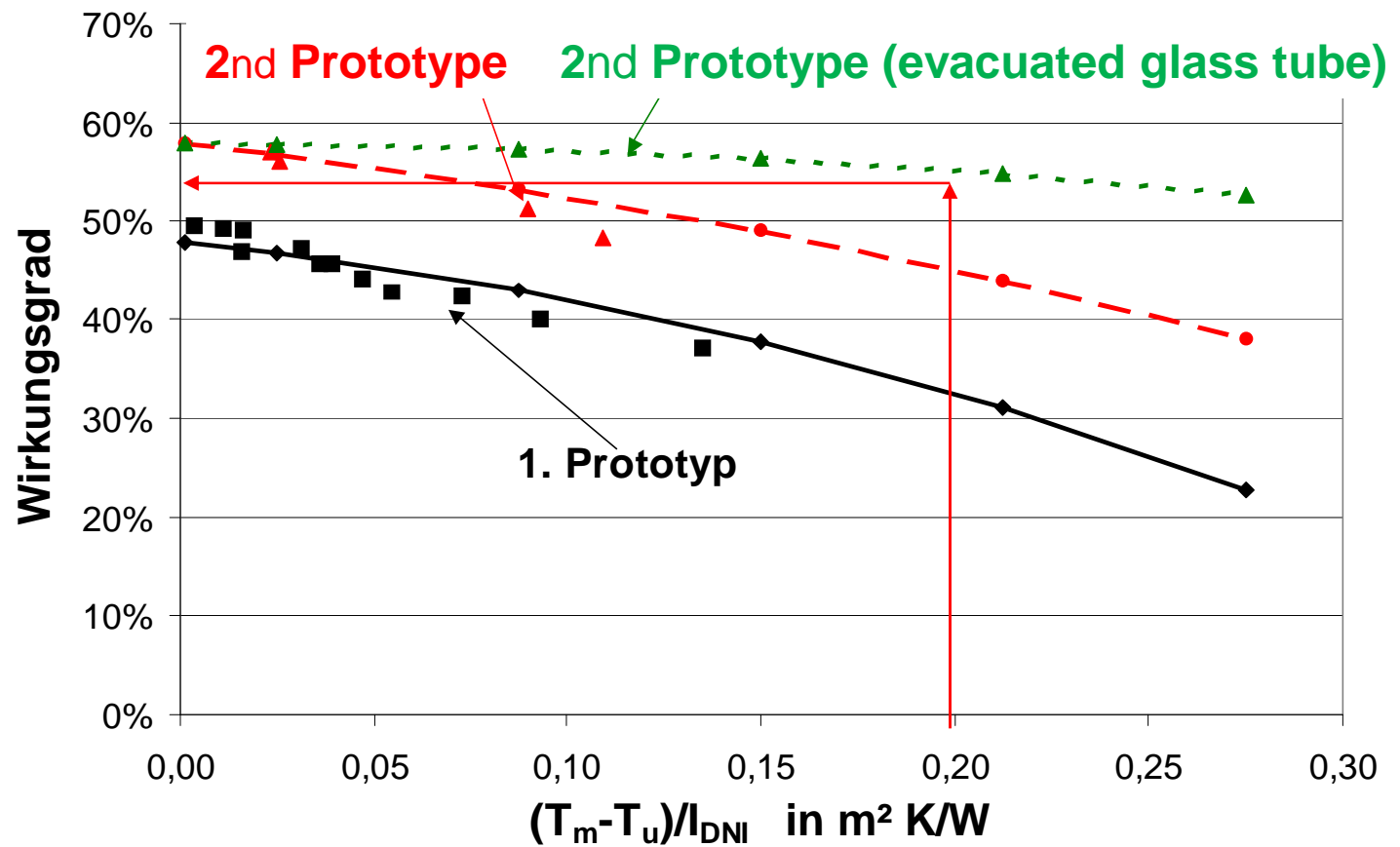
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# Process Heat Collectors



AEE INTEC and Button Energy



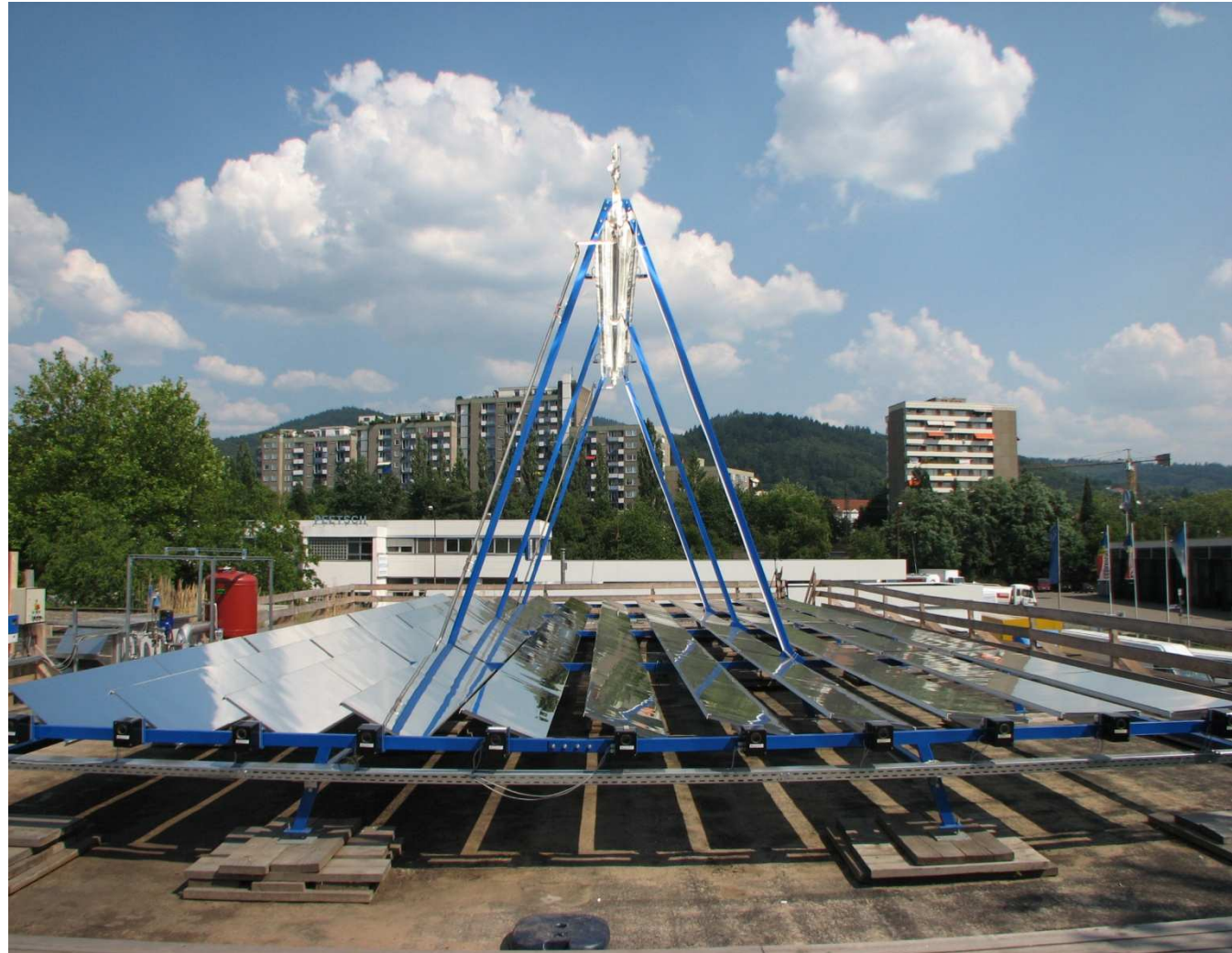


# Fresnel Process Heat Collector

**PSE AG**  
**Germany**

Aperture area: 88 m<sup>2</sup>

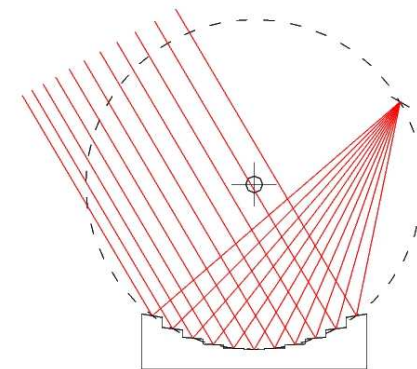
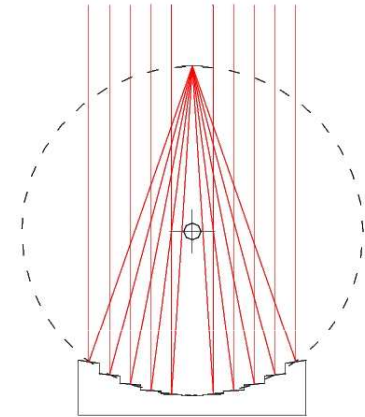
Working temperature:  
max. 200°C



# CONCENTRATING COLLECTORS - CCSTaR



Universitat de les Illes Balears

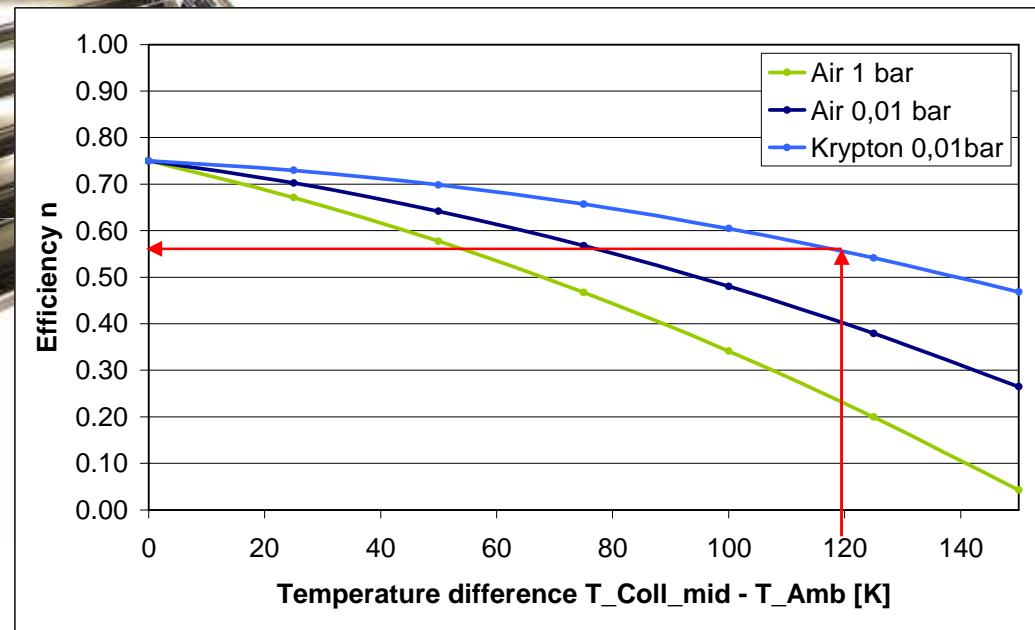


# Process Heat Collectors

## CPC Collector



Concentration: 1,8x



**LoCo EvaCo** (Low concentrating evacuated flat collector), ZAE Bayern





# COLLECTOR MATERIALS

financed by  
Austrian  
Development Cooperation



# ABSORBER MATERIALS THERMAL CONDUCTIVITY

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

# 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*

# ABSORBER COATING

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Development Cooperation



Source: Alanod-Sunselect / ESTIF

# TRANSPARENT COVER MATERIALS

cover	thickness [mm]	weight [kg/m <sup>2</sup> ]	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

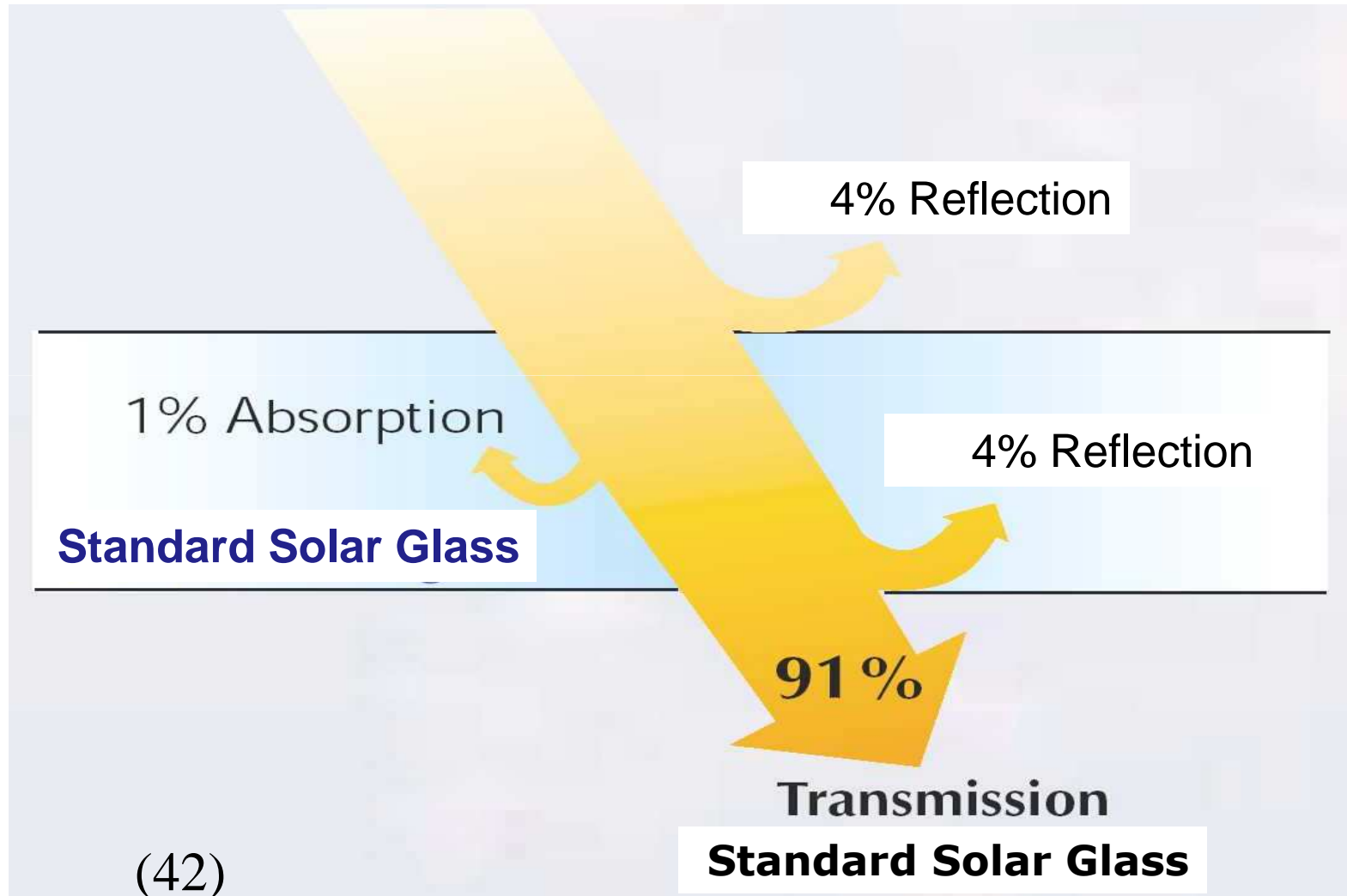


\*) danger of breaking determined by high collector temperatures

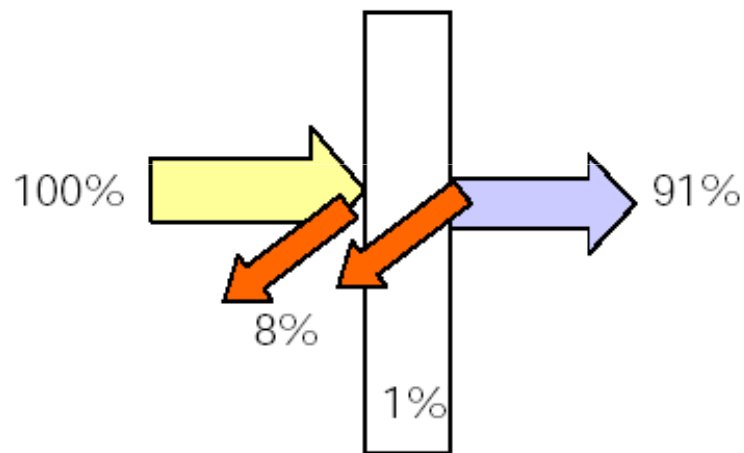
# Collector test



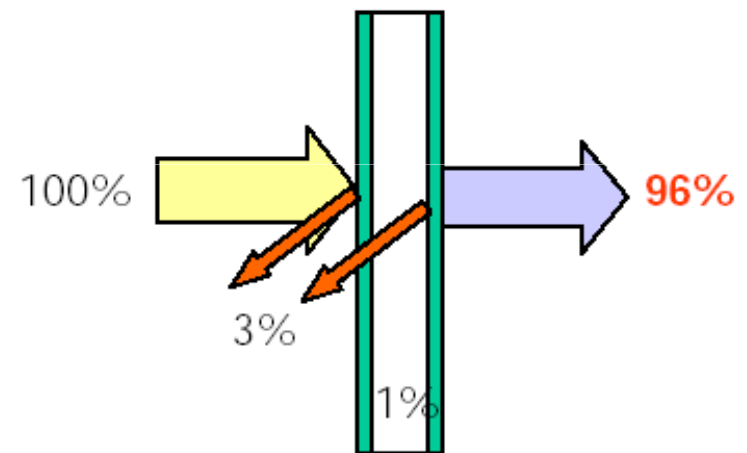
# TRANSPARENT COVER MATERIALS



# TRANSPARENT COVER MATERIALS



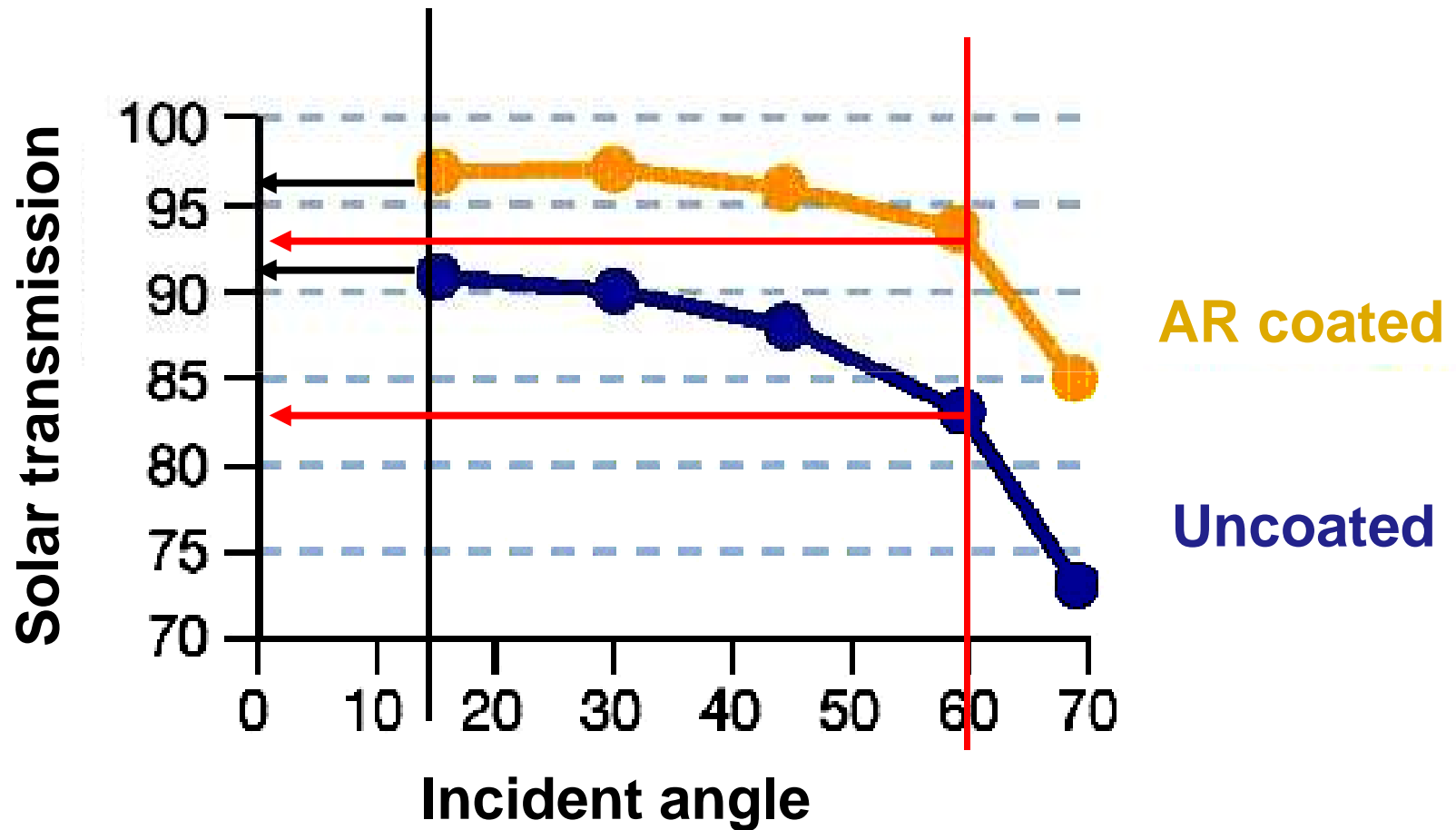
**Solar glass**



**Solar glass with antireflective coating**

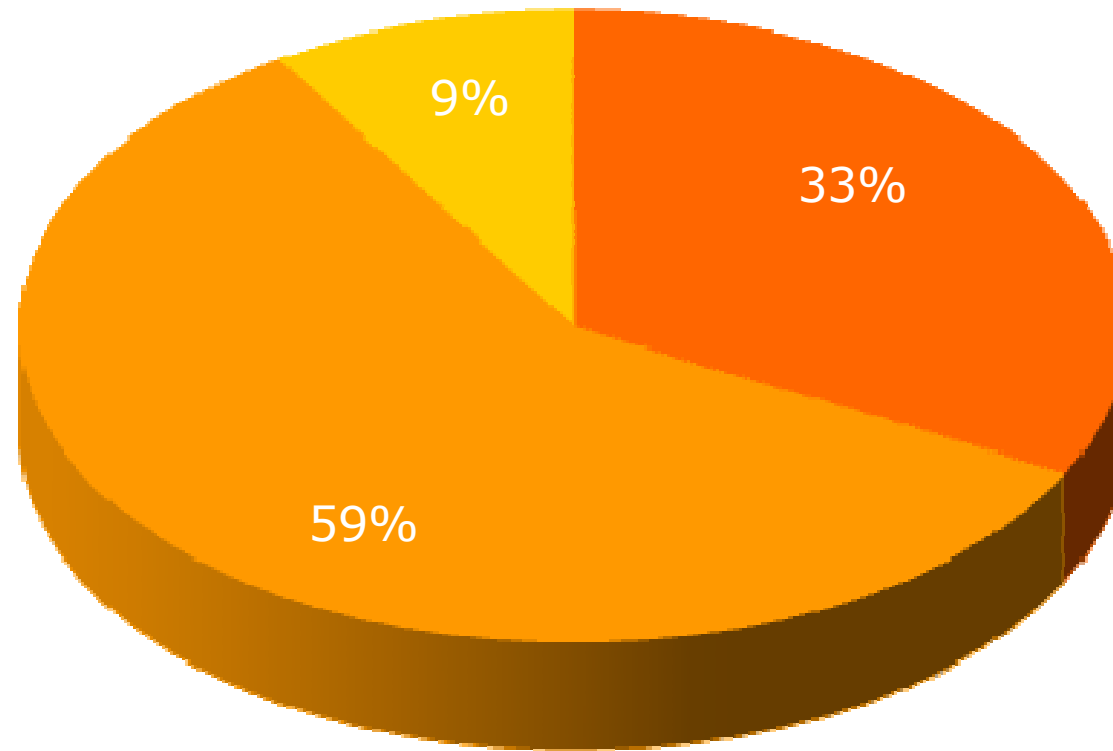


# TRANSPARENT COVER MATERIALS



(42)

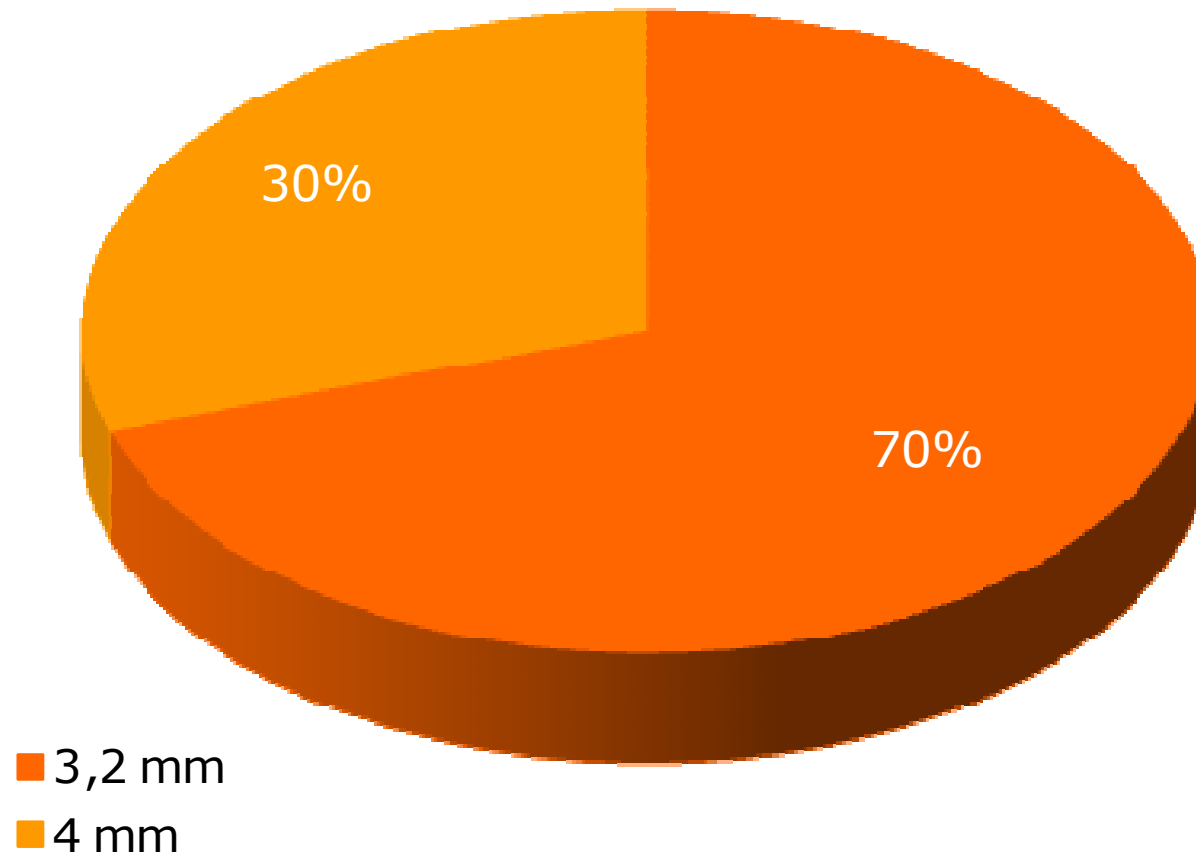
# Market Share of Clear and Structured Glass



- clear glass
- structured glass
- AR-glass

Source: Sonne, Wind und Wärme, 2009

# Glass Thickness



Source: Sonne, Wind und Wärme, 2009

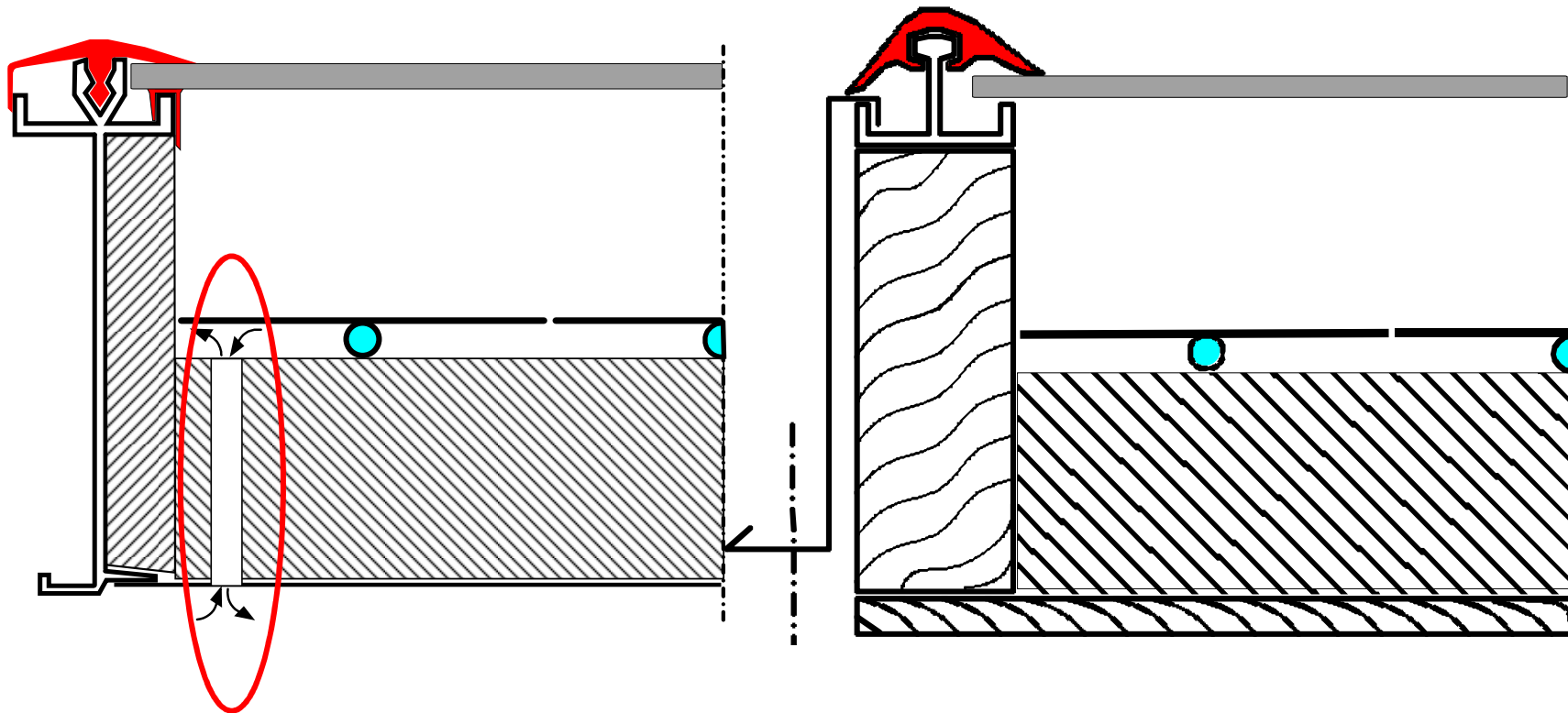
# INSULATING MATERIALS

<b>insulating material</b>	<b>max. allowable temperature</b> [°]	<b>density</b> [kg/m <sup>3</sup> ]	<b>conductivity</b> [W/mK] at 20°C
Mineral wool	> 200	60 - 200	0.040
Glass wool	> 200	30 - 100	0.040
Glass wool	> 200	130 - 150	0.048
Polyurethane foam	< 130	30 - 80	0.030
Polystyrol foam	< 80	30 - 50	0.034

# Absorber Manufacturing Processes

	<i>Production Process</i>	<i>Deficiencies</i>
<b>substance-to-substance connections</b>	Spot Welding	- not possible with all metals, susceptible to corrosion, ...
	Soft-Soldering	- low processing temperature (stagnation!!!), - emission of flux residues, ...
	Ultrasonic Welding	- no continuous substance-to-substance connection, ...
	Laser Welding	- very high processing temperature, - micro-cracks in welding spots
	Plasma Welding	- very high processing temperature, ...
<b>non substance-to-substance connections</b>	Splicing	- low processing temperature (stagnation!!!), - low heat conductivity of adhesive, ...
	Clamping (various designs)	- low heat conductivity of clamping (non uniform contact pressure, ..), ..

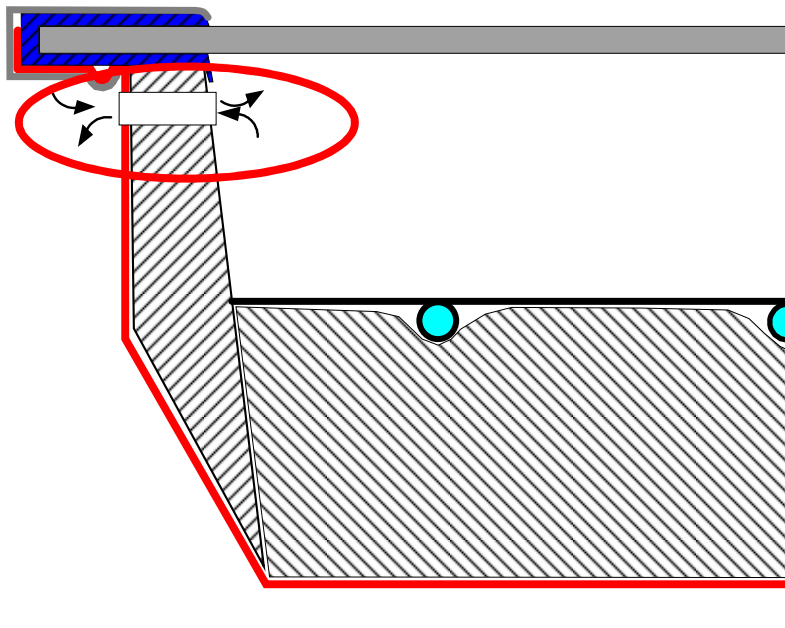
# FLAT-PLATE COLLECTOR – Simple Design



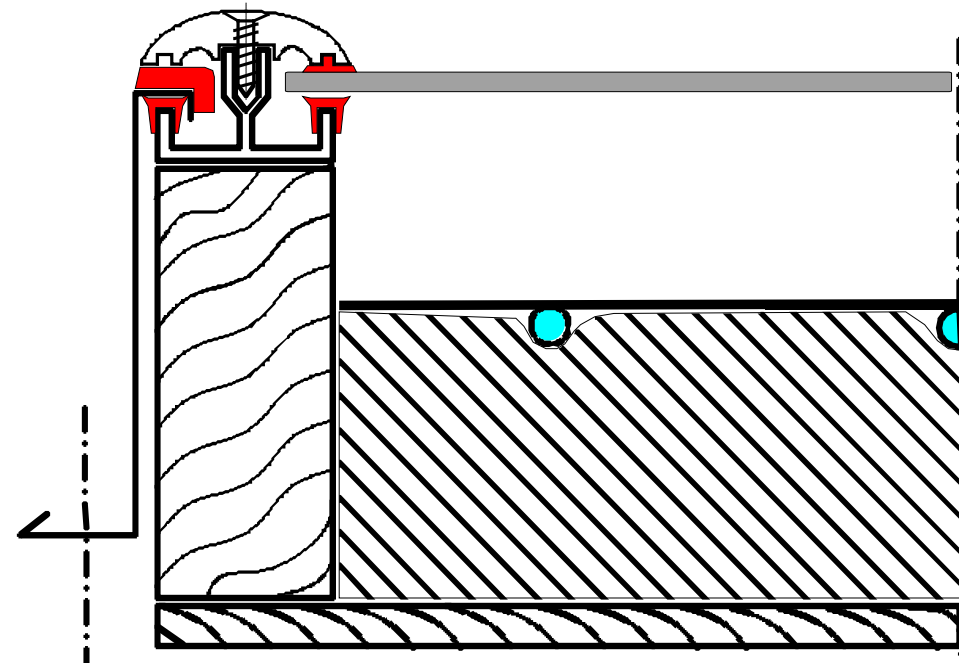
Modul Collector

Roof Integrated Collector

# FLAT-PLATE COLLECTOR – Advanced Design

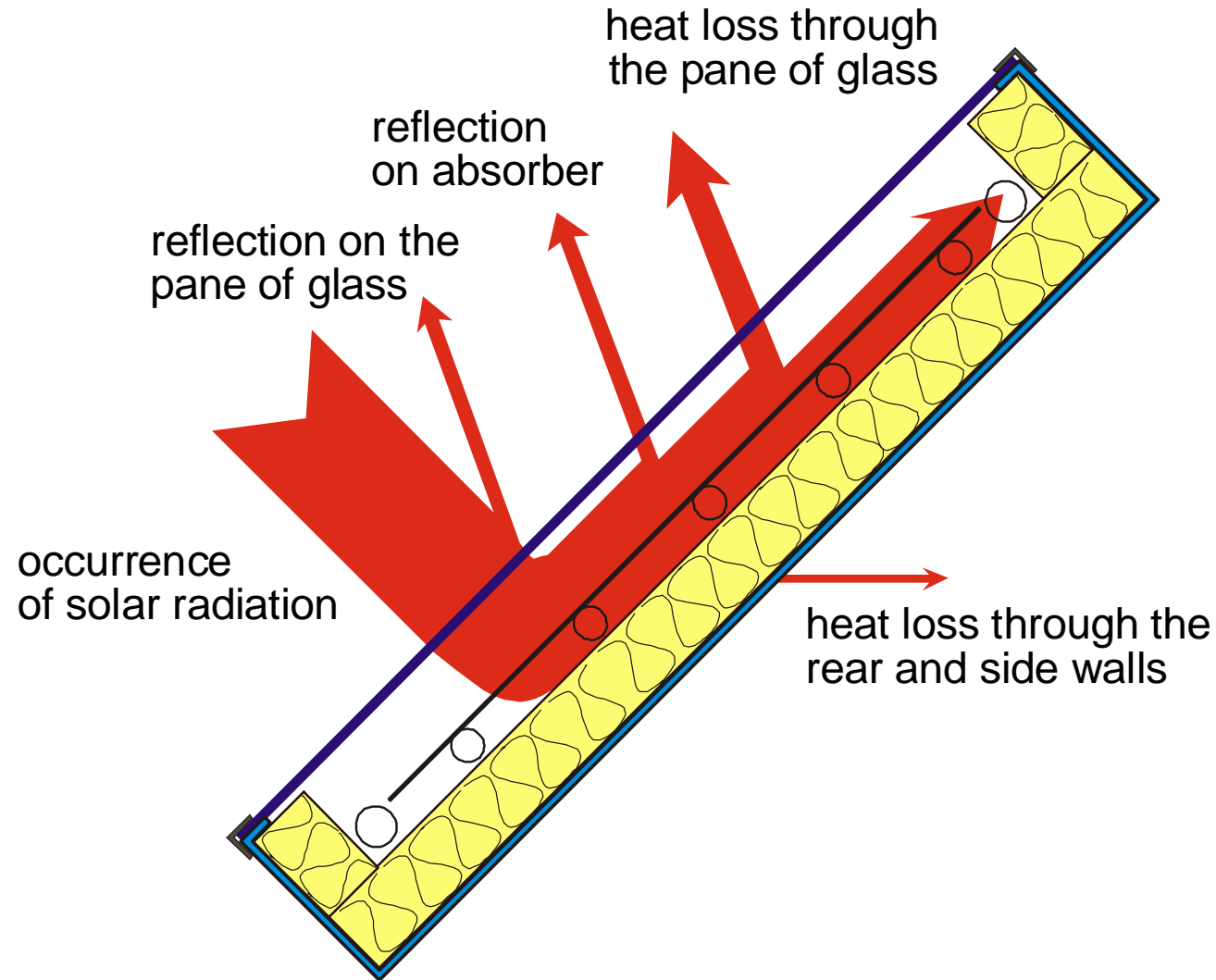


Module Collector



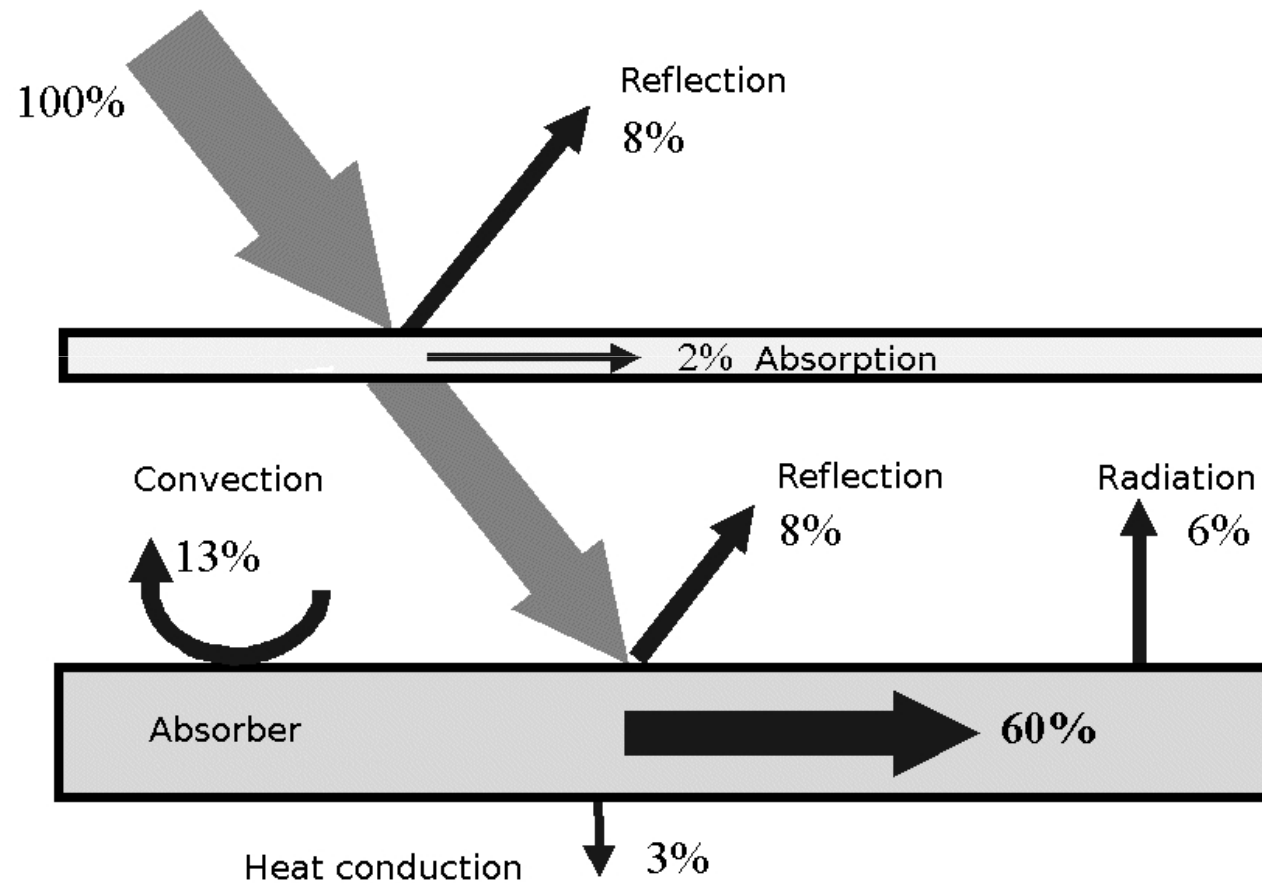
Roof Integrated Collector

# Physical Processes inside a Flat-Plate Collector





# Losses of a basic Flat-plate Collector



Source: Source: Wagner & Co.

# Characteristic Values of Flat-plate and Evacuated Tube Collectors

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

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

**$FR$**  is the collector's heat removal factor

**$T$**  is the transmittance of the cover

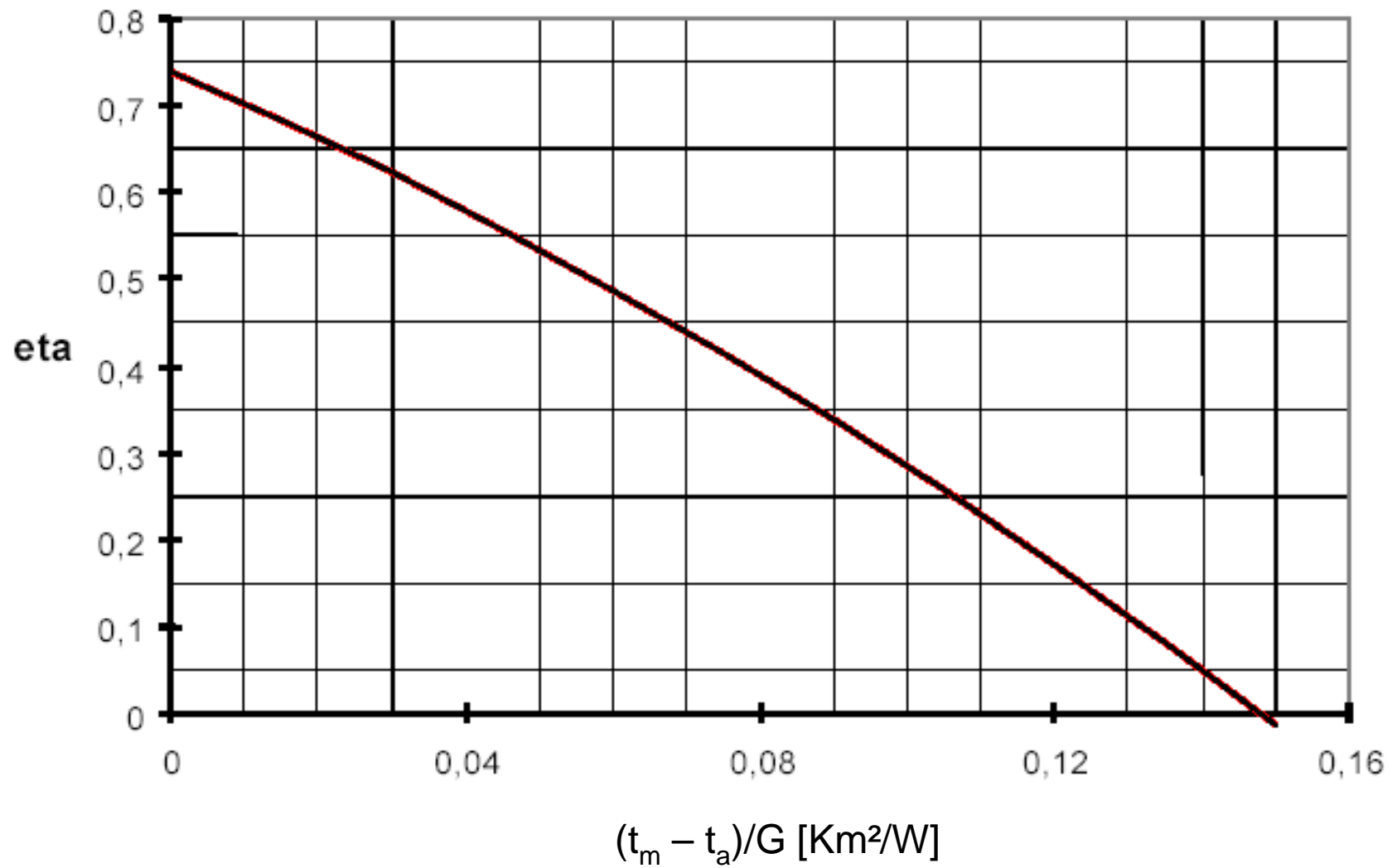
**$\alpha$**  is the shortwave absorptivity of the absorber

**$G$**  is the global incident solar radiation on the collector

**$UL$**  is the overall heat loss coefficient of the collector

**$T$**  is the temperature differential between the heat transfer fluid entering the collector and the ambient temperature outside the collector.

# Collector Efficiency Curve



# Collector Efficiency

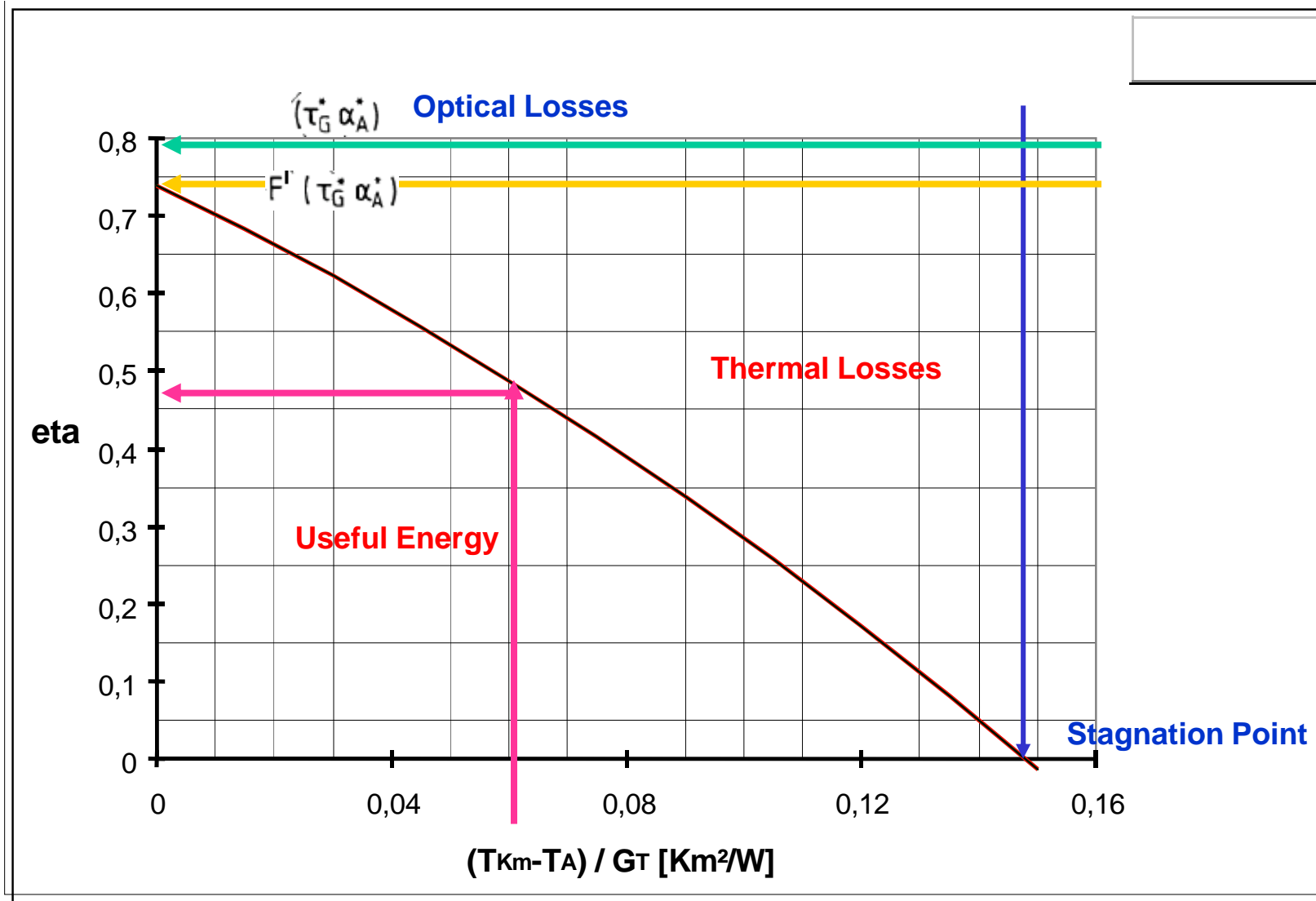
$$\eta = \frac{\text{useful energy}}{\text{solar energy}}$$

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

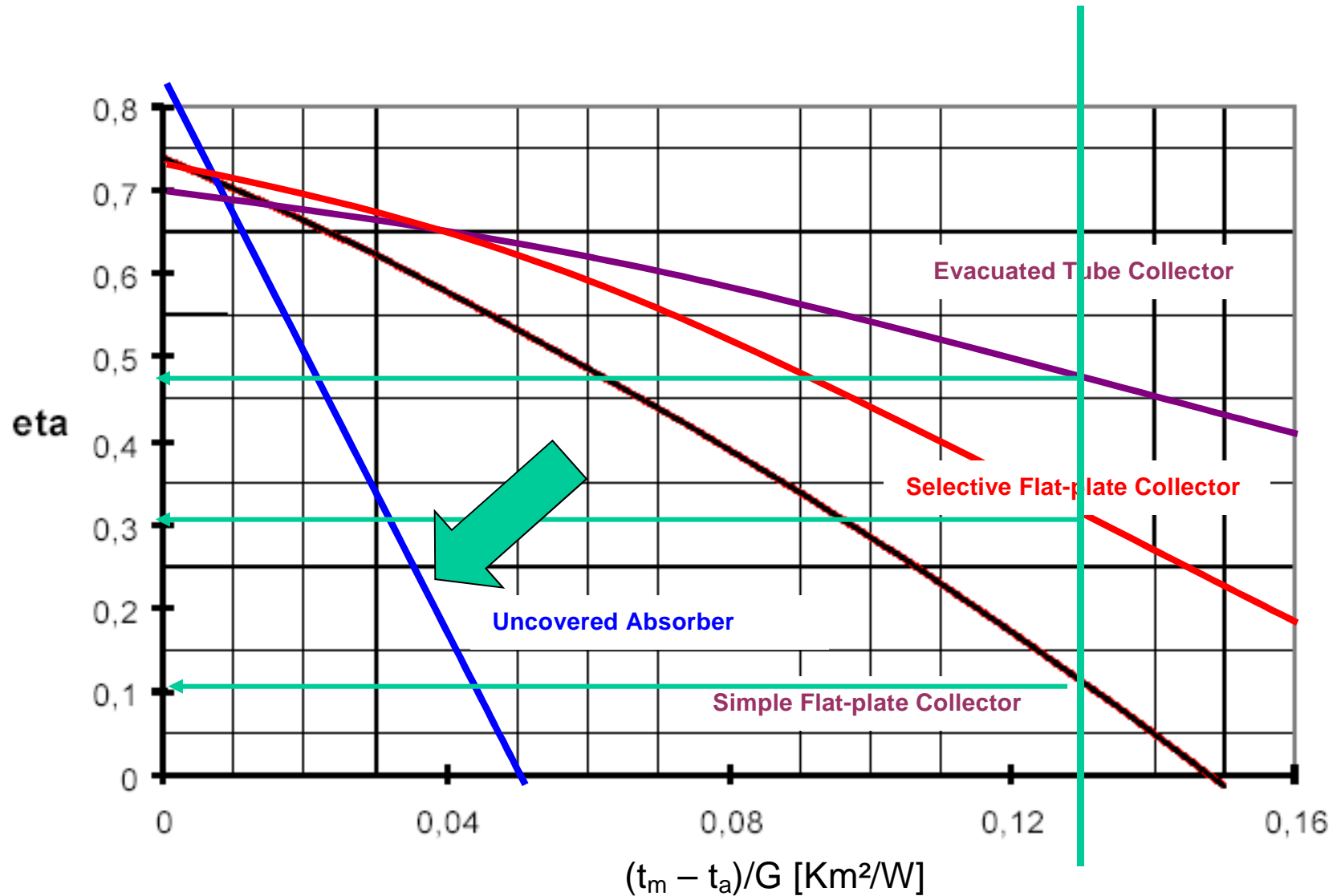
# Collector Efficiency

$\eta_0$	maximum efficiency (= efficiency at $t_m = t_a$ )	
$a_1$	linear heat loss coefficient	$\frac{W}{m^2 \cdot K}$
<b>s. T-Sol Collector data</b>		
$a_2$	quadratic heat loss coefficient	$\frac{W}{m^2 \cdot K^2}$
$t_m$	average temperature of the heat transfer fluid	$^{\circ}C$
$t_a$	ambient temperature	$^{\circ}C$
$G$	incident radiant energy (global radiation)	$\frac{W}{m^2}$

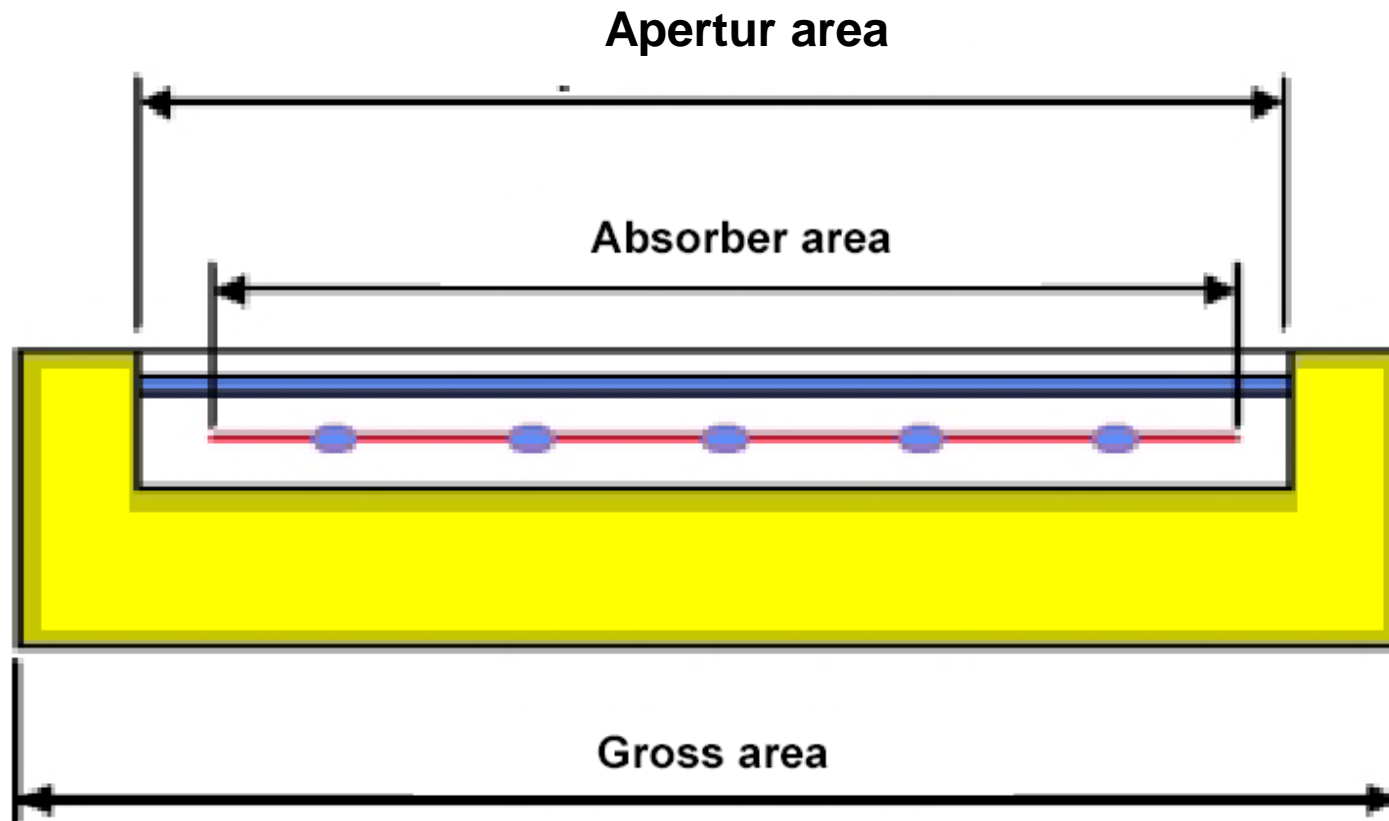
# Collector efficiency curve



# Efficiency of different collector types (calc)

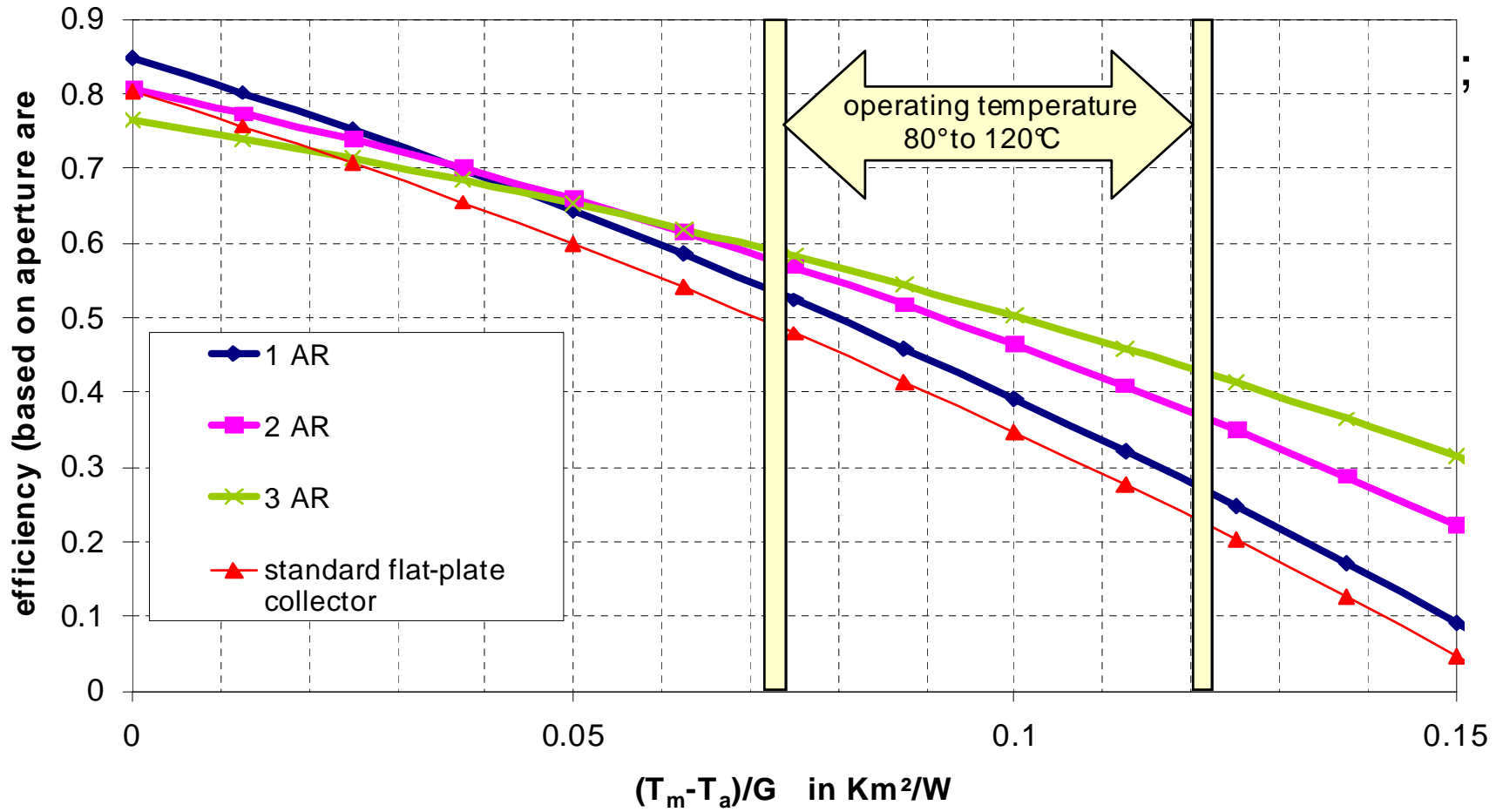


# Area Definitions



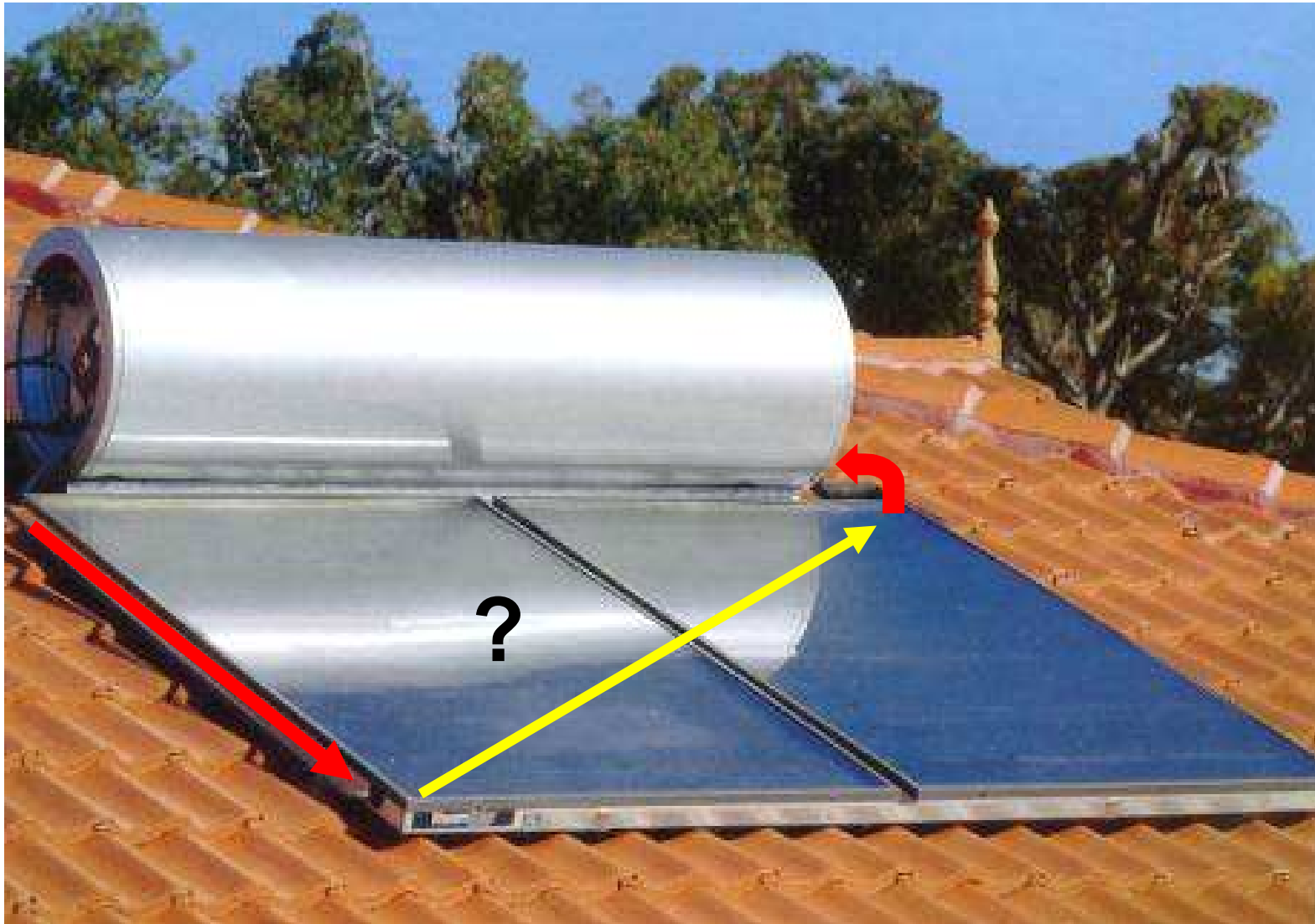


# Possible Improvements of FPC

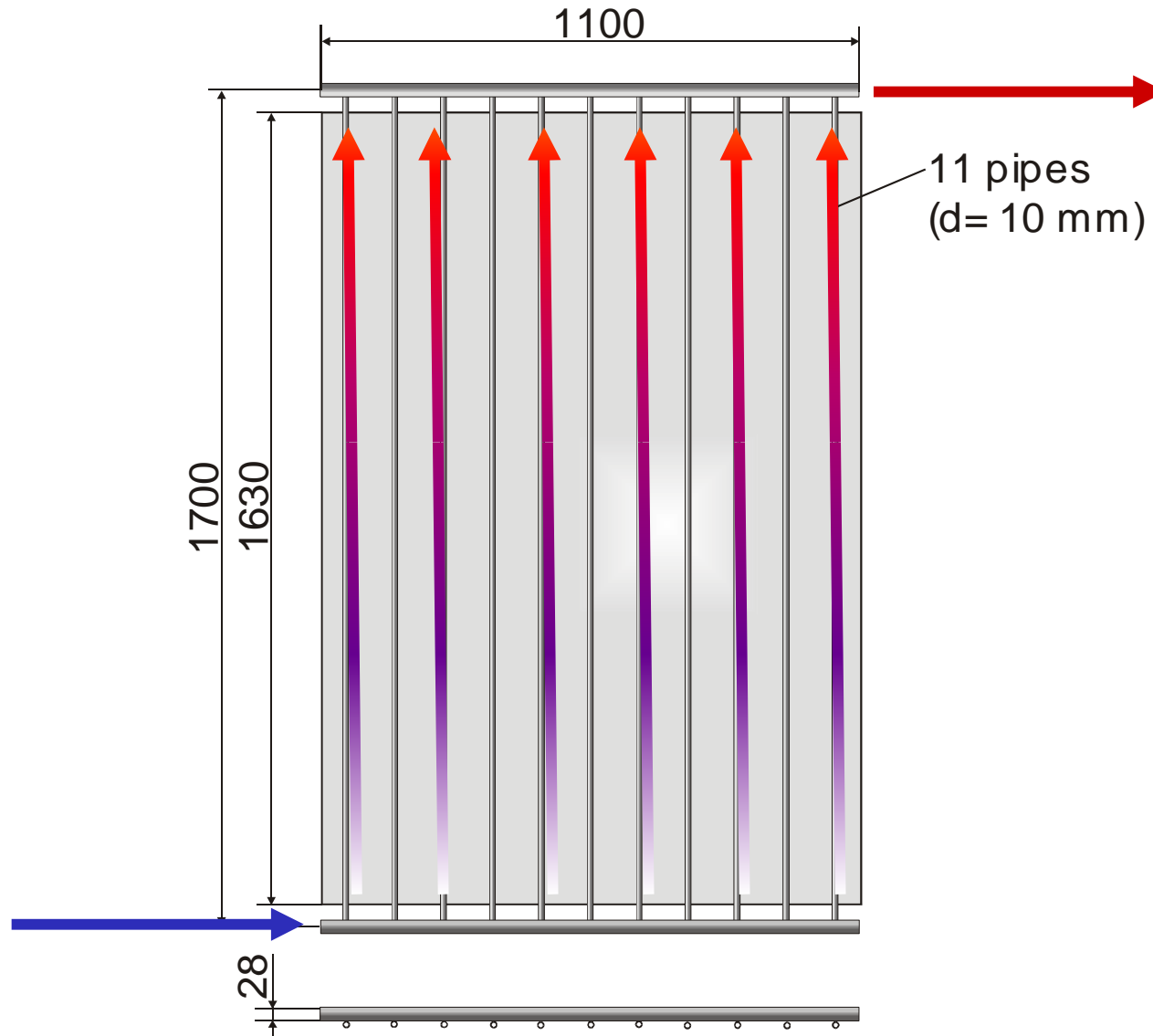


Source: IEA SHC Task 33

# Flat plate collectors



# Register-Type Absorber

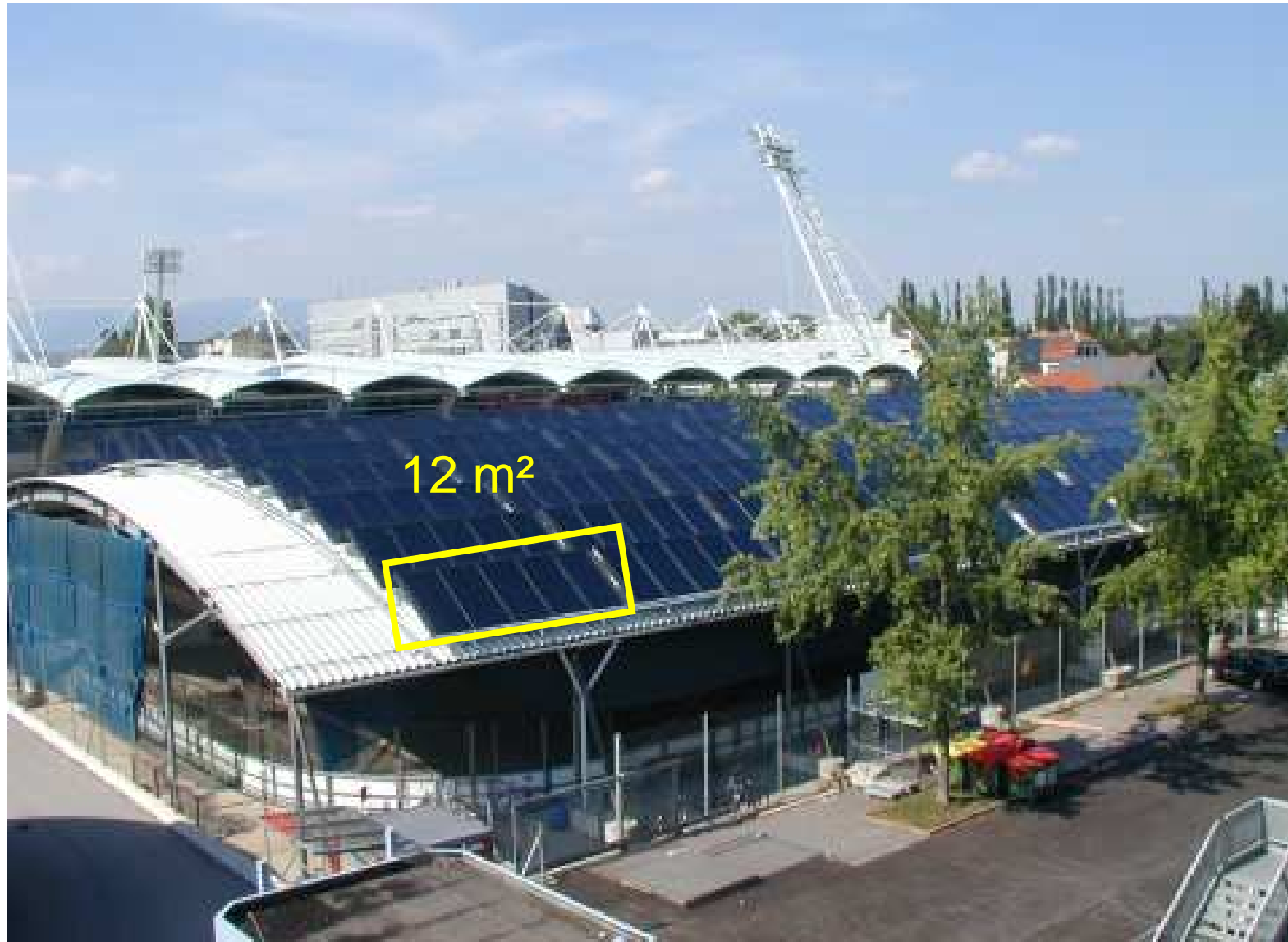


# Flat plate collectors

financed by

Austrian

Development Cooperation



# Hydraulic connection of collectors

