Sustainable water heating solutions through solar systems

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Learning Objectives

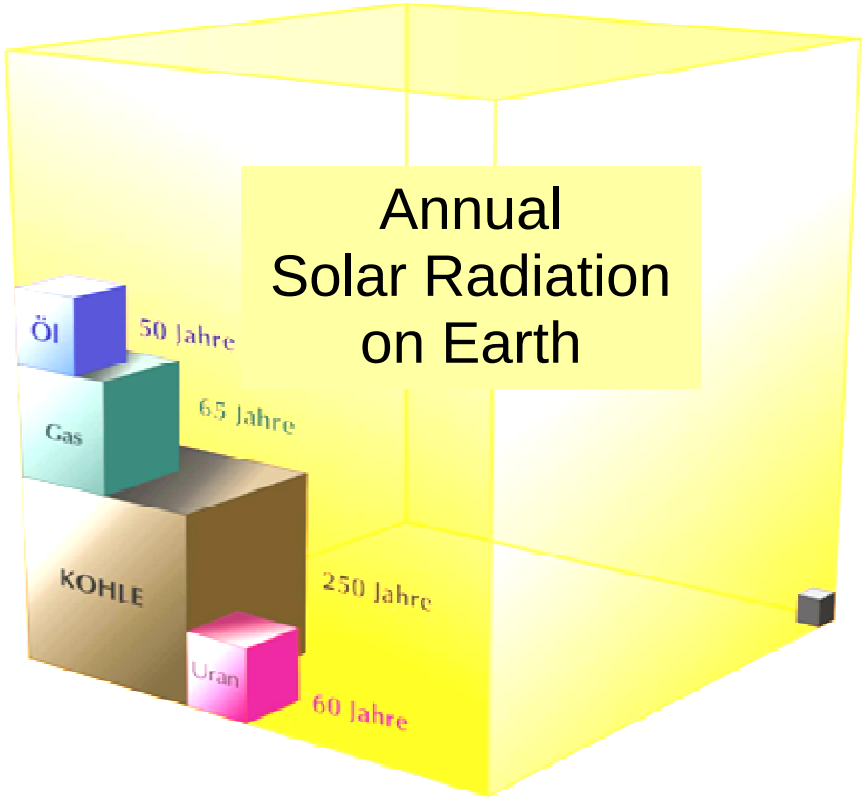
At the end of this program, participants will be able to:

1. *Solar energy – potential, characteristics*
2. *Components of a forced circulation solar thermal system*
3. *Solar collectors – types, installation*
4. *Design of solar thermal systems for buildings*

Solar energy – The power source of the Earth

Greatest potential – smallest utilisation

Estimated fossil fuel sources

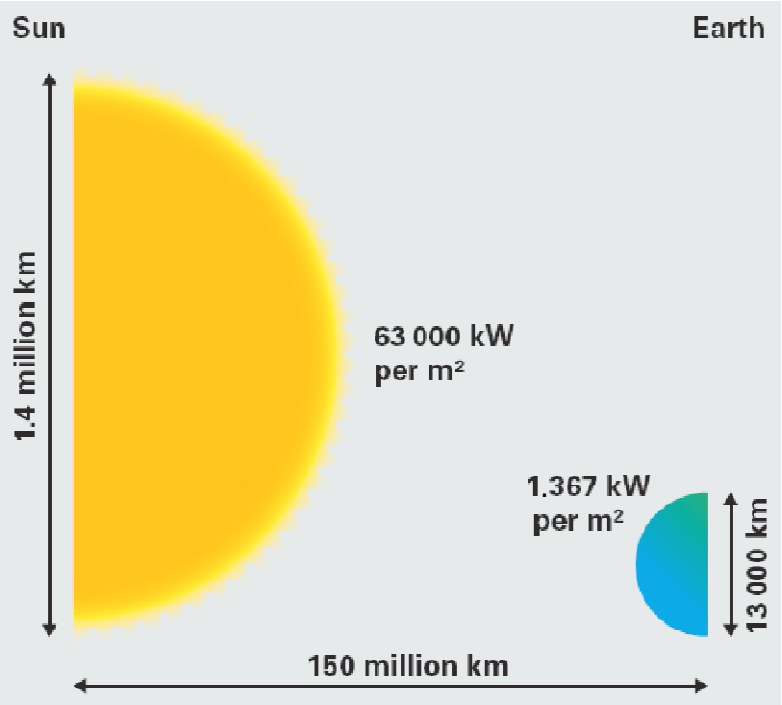


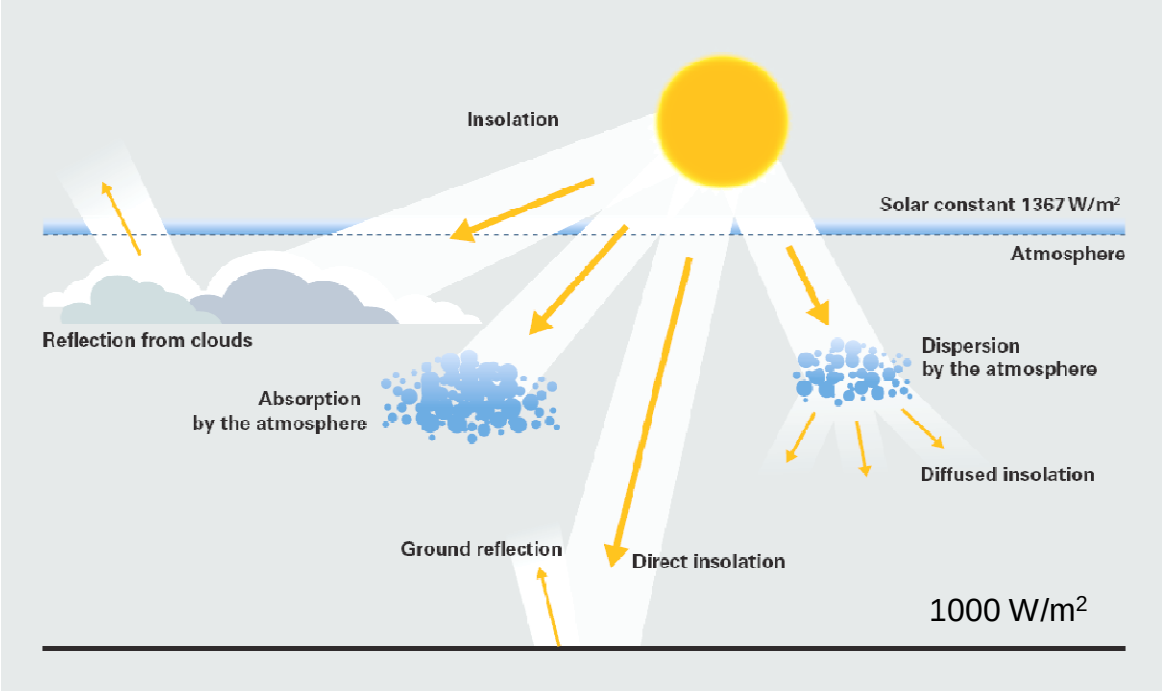
Annual energy consumption on Earth

In less than **four hours** the sun radiates the **annual energy demand** of the world's population to the earth.

Solar energy – The power source of the Earth

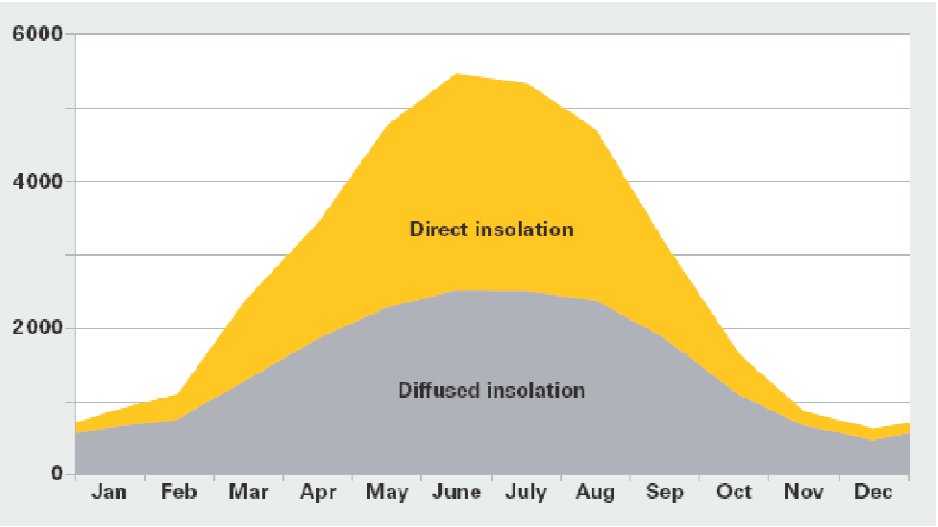
Solar radiation on Earth

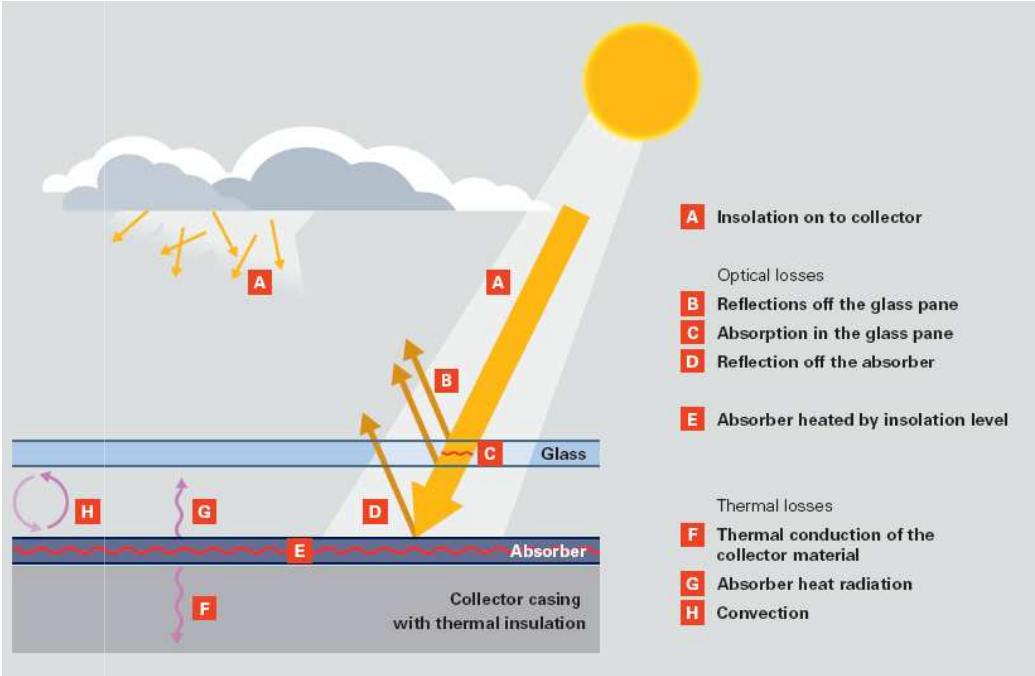




The atmosphere reduces the radiation level of the sun. A part of its radiation is absorbed and reflected. A further part reaches the Earth's surface as diffused and direct radiation.

Solar energy – The power source of the Earth
Solar radiation on Earth



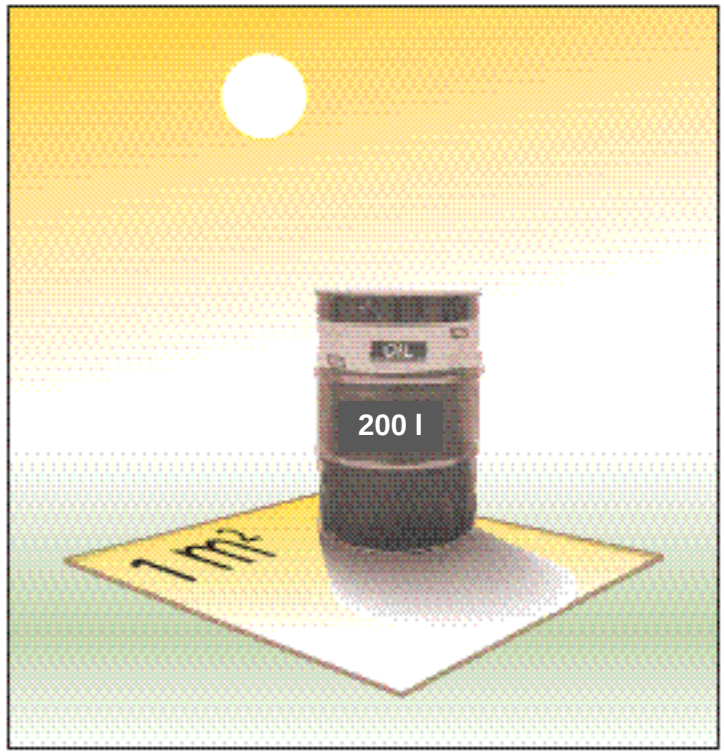


The difference between direct and diffused radiation is, for solar applications, particularly relevant for concentrated systems (parabolic or elongated hollow reflectors) as these systems utilise only direct radiation
In Germany, the proportion of diffused radiation as a percentage of global radiation is, as an annual average, approx. 50 percent – less in summer, more in winter.
In Jordan the value is quite similar, around 45%.

Solar energy – The power source of the Earth

Annual energy amount (global radiation)

Country	City	Annual energy amount kWh / m² x year
Saudi Arabia	Riyadh	2187
Jordan	Amman	2150
Syria	Damascus	2096
UAE	Abu Dhabi	2032
Iran	Tehran	1856
Lebanon	Beirut	1734
Italy	Milano	1222
Germany	Frankfurt	1048
France	Paris	1024
UK	London	956



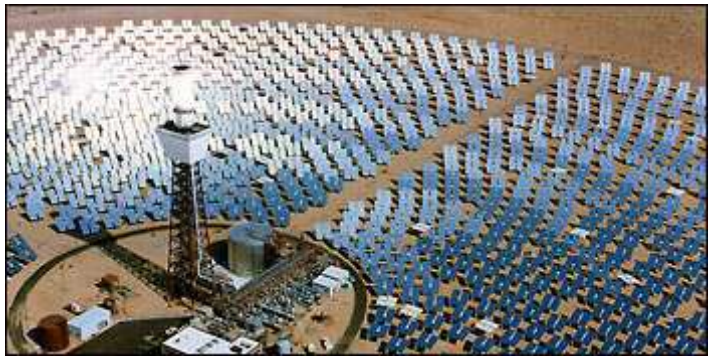
On average across the year, there is around 2187 kWh per m² of insolation, which corresponds to an energy content of approx. 200 litres of heating oil or 200 m³ of natural gas.

Solar energy – The power source of the Earth

What can we do with solar energy?

Generating heat (solar thermal)
and electricity (photovoltaic)

Solar lighting



Concentrated solar power

Biomass

Solar energy – The power source of the Earth

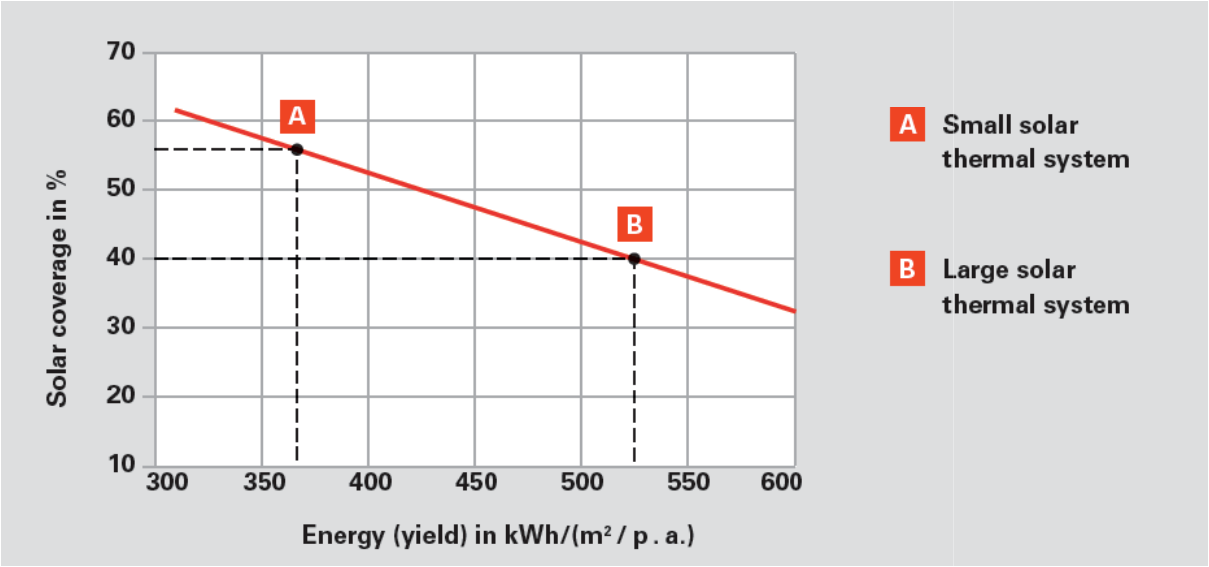
What can we do with the solar thermal systems?

- Domestic hot water >80%
- Pool heating
- Heating support in cold climates
- Process heat
- Solar desalination
- Solar cooling with absorption chillers

Solar thermal systems are ideally suited for DHW heating and central heating backup. Thanks to the freely available solar energy, your investment will pay for itself within a few years through high savings on fossil fuel.

Solar energy – The power source of the Earth
Solar coverage for DHW heating

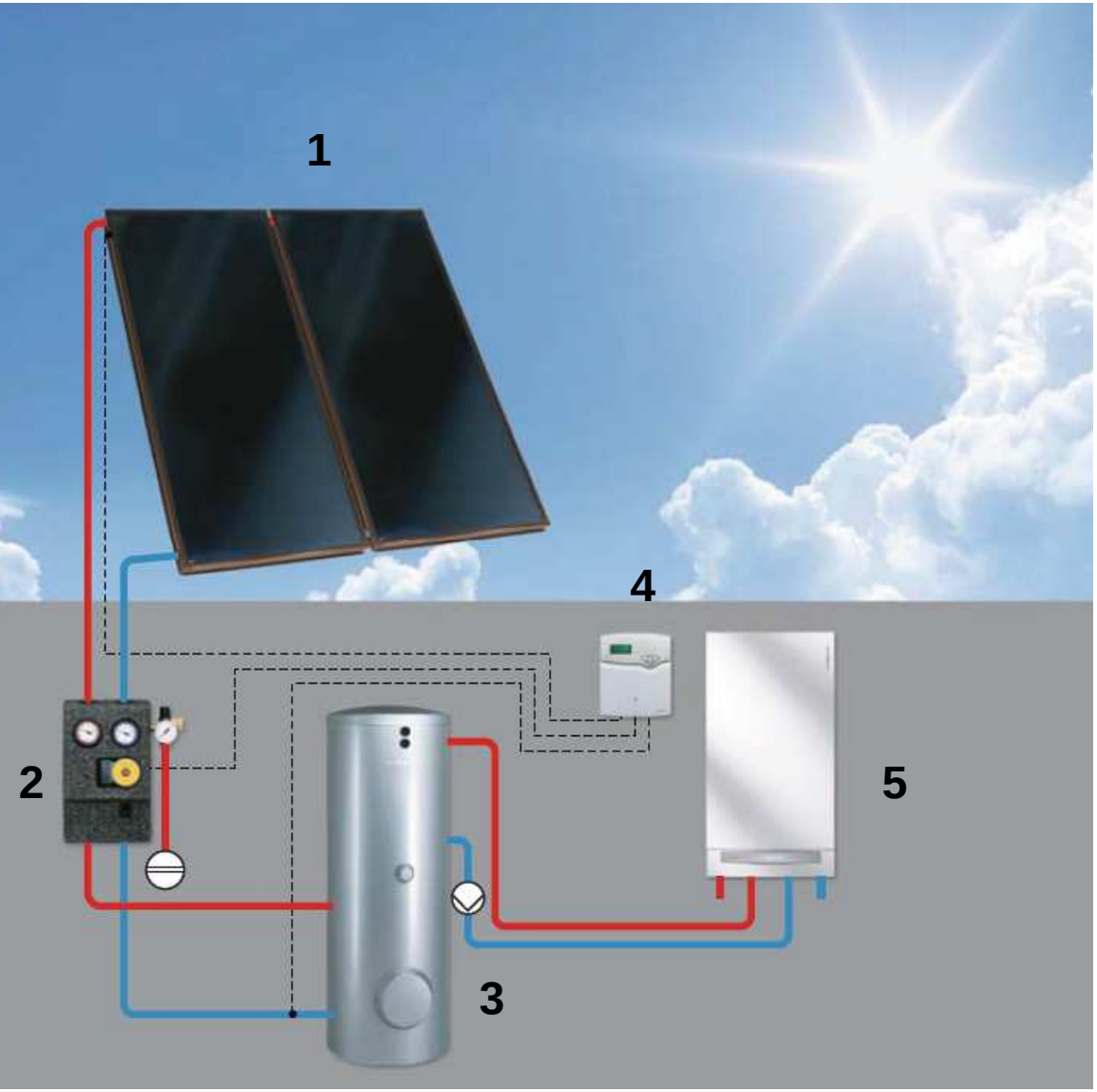
- Fundamental parameters of a solar thermal systems:
  - Energy Yield
  - Solar coverage
- One general rule applies. The higher the solar coverage, the lower the specific yield per square meter collector area – this is due to the unavoidable excesses in summer and the low collector efficiency.



A good compromise between solar coverage and solar yield must be found for every solar thermal system.

A good compromise between yield and solar coverage is generally also a good compromise between investment outlay for the solar thermal system and savings in conventional energy.

Solar thermal system
System components



1 – Solar collectors

2 – Pumping station

3 – Dual mode or multi mode DHW cylinder

4 – Control unit

5 – Back-up system – oil/gas boiler, electrical or heat pump

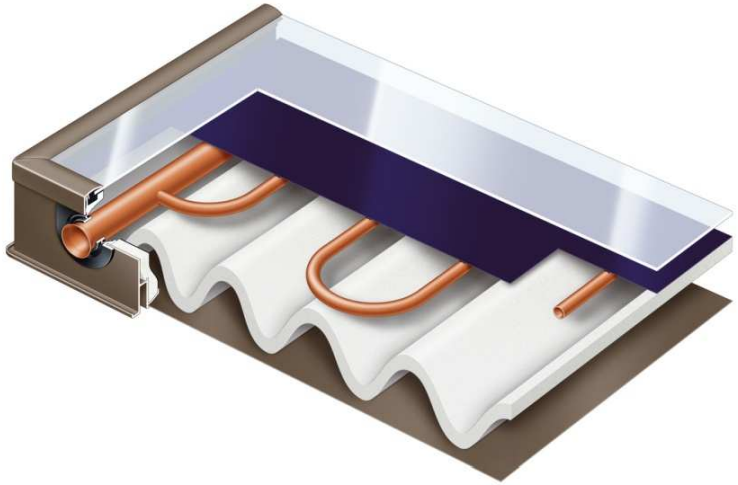
Solar energy – The power source of the Earth
Solar collectors

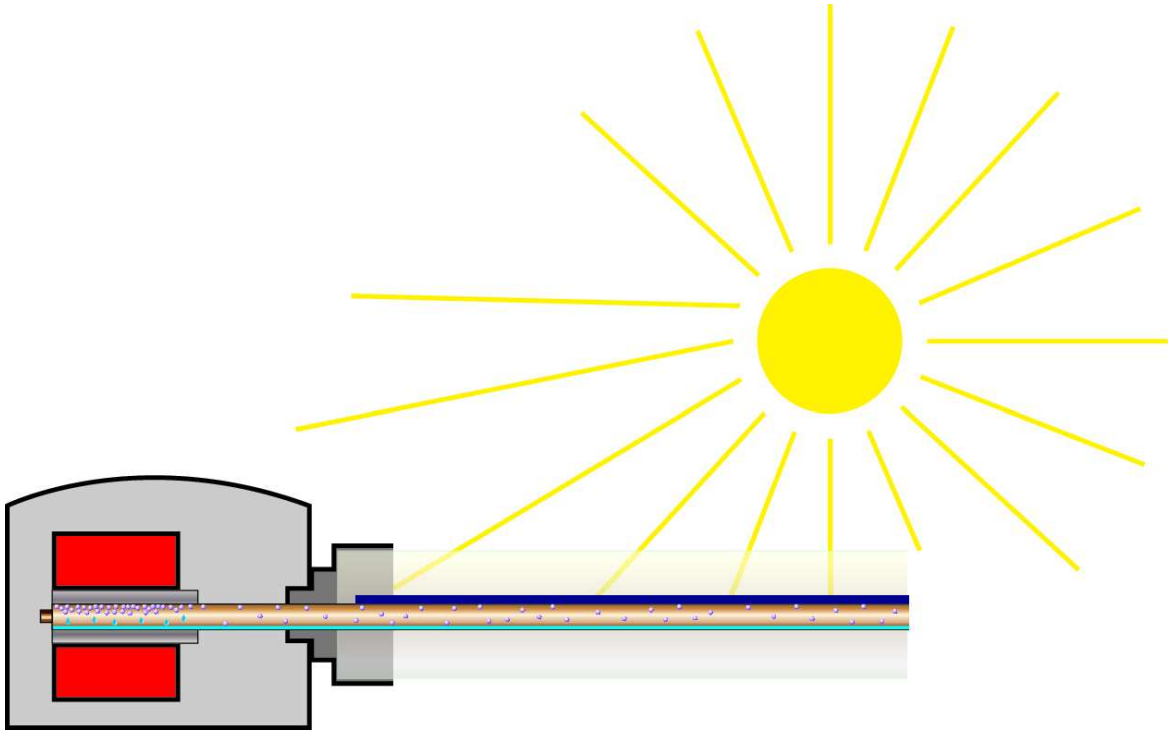
Flat plate collectors

Evacuated tube collectors
Heat pipe technology

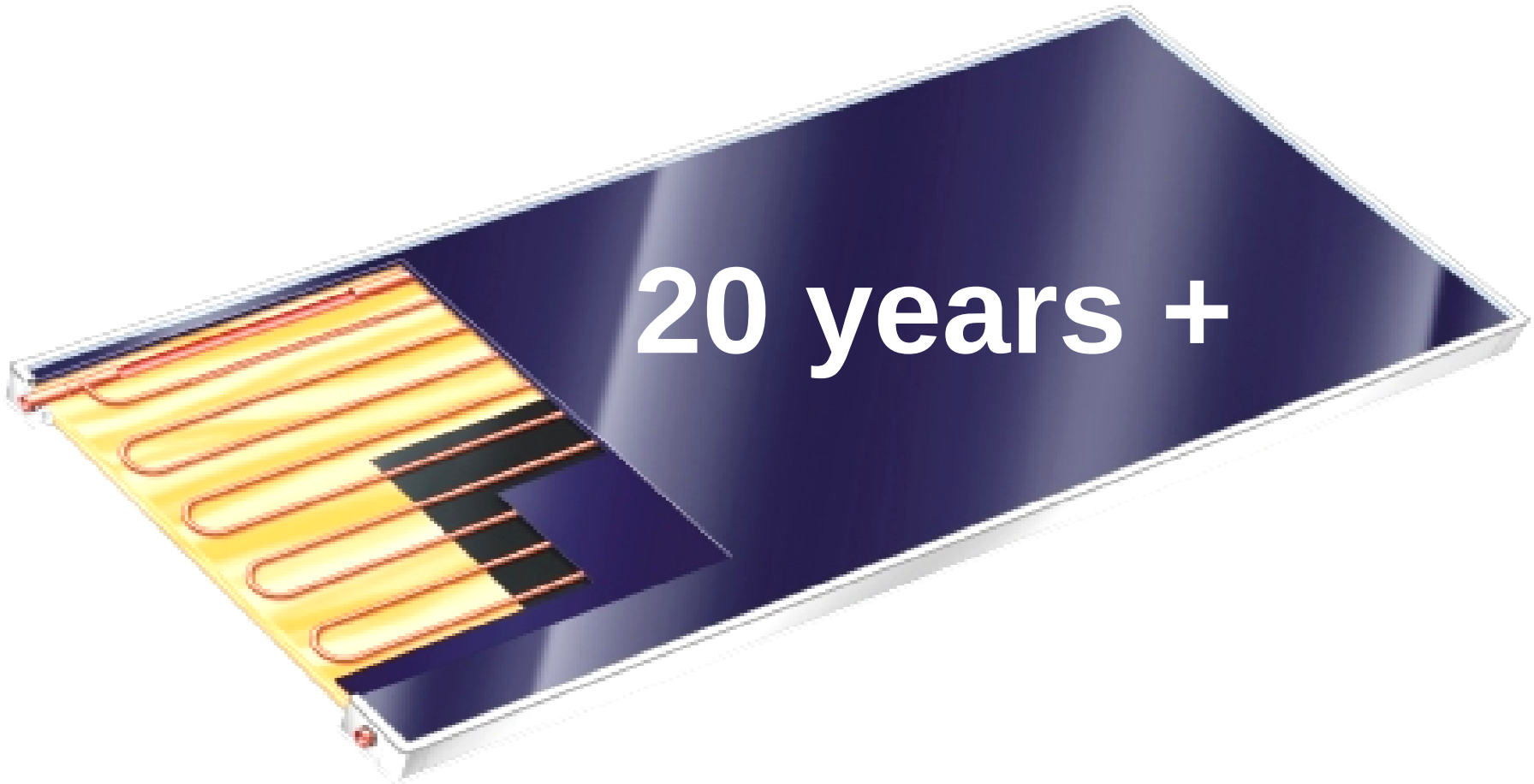
Solar energy – The power source of the Earth

Solar collectors





Solar collectors
Life expectation

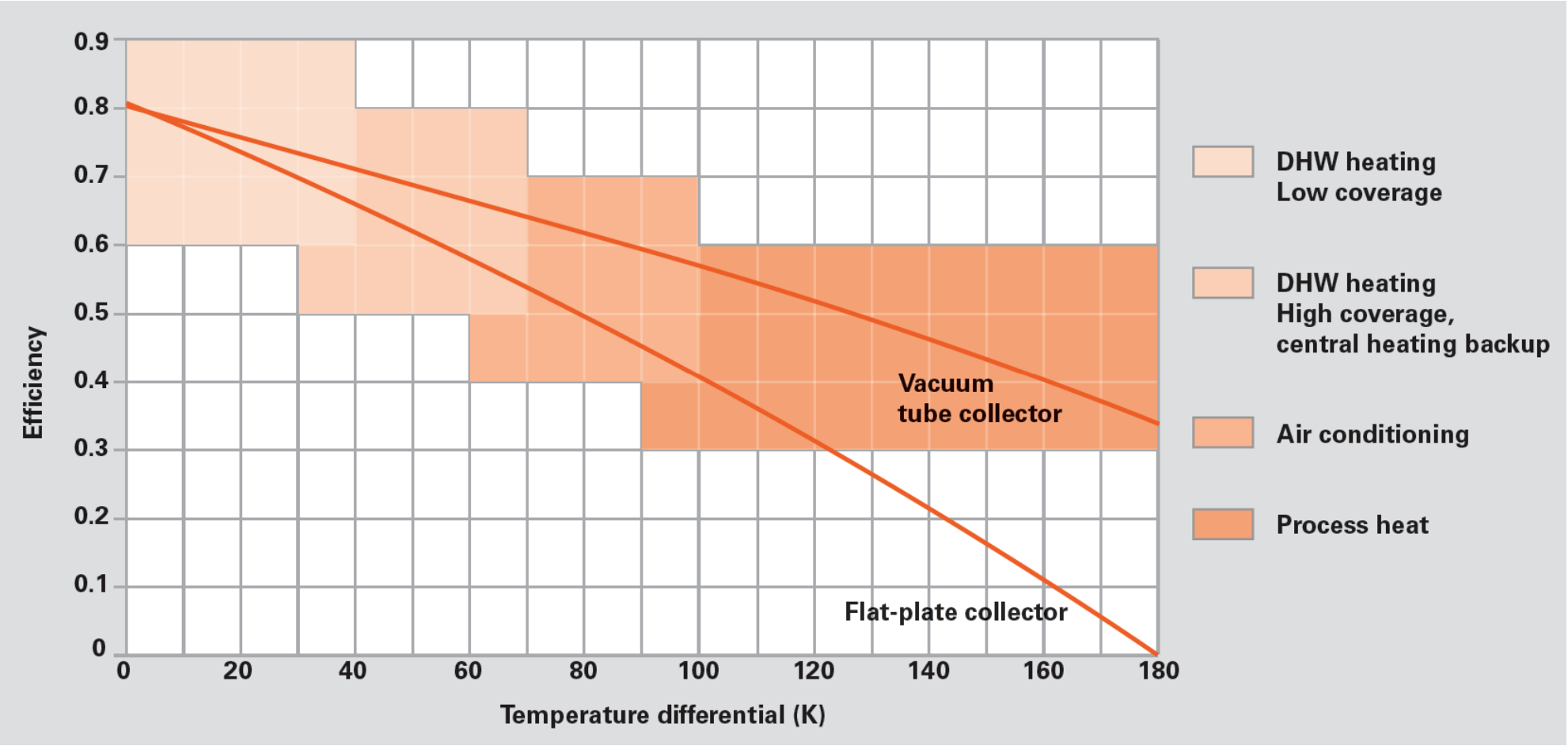


Solar collectors
Life expectation

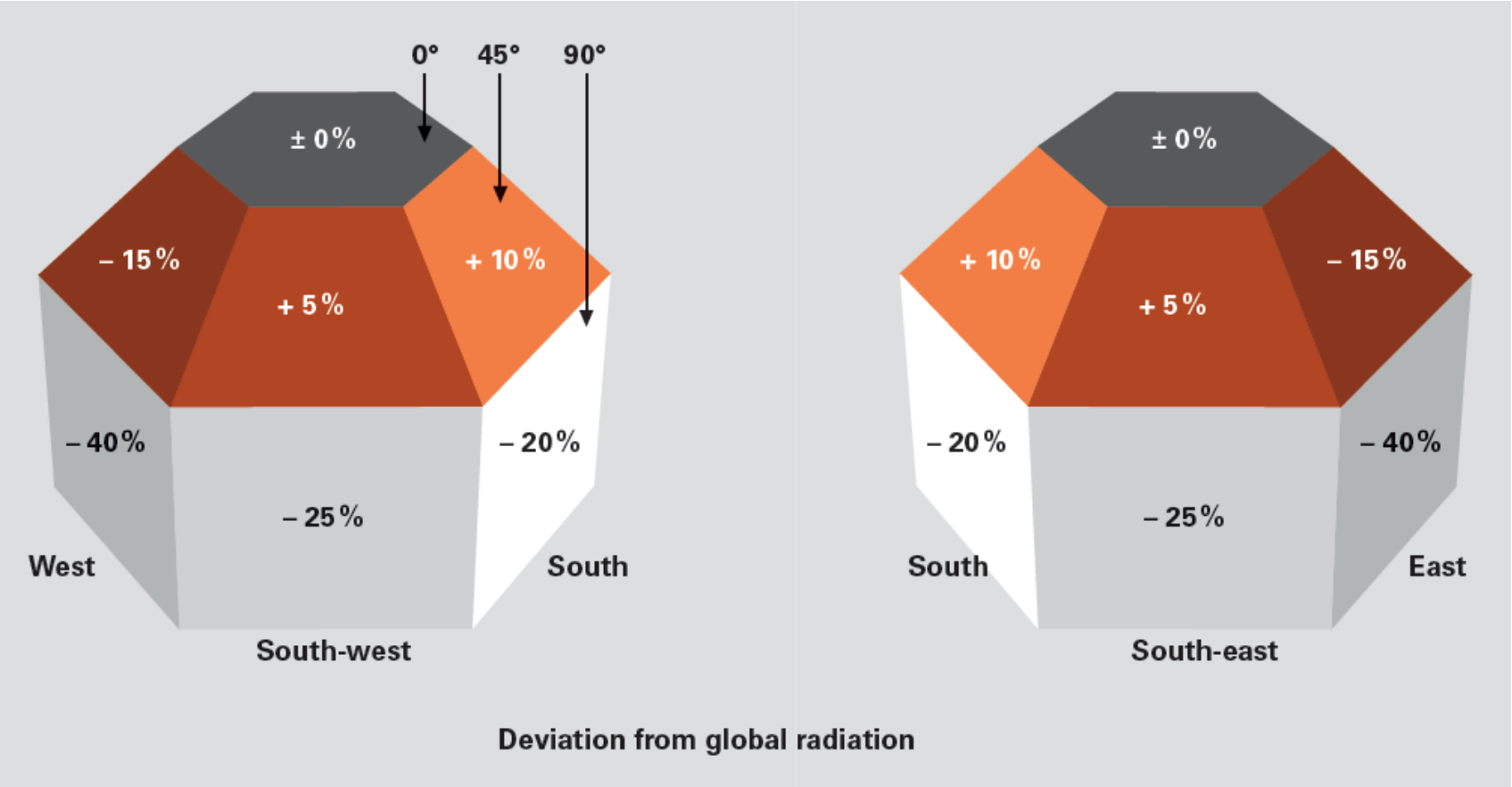
30 years

35 years

Solar collectors
Efficiency curves

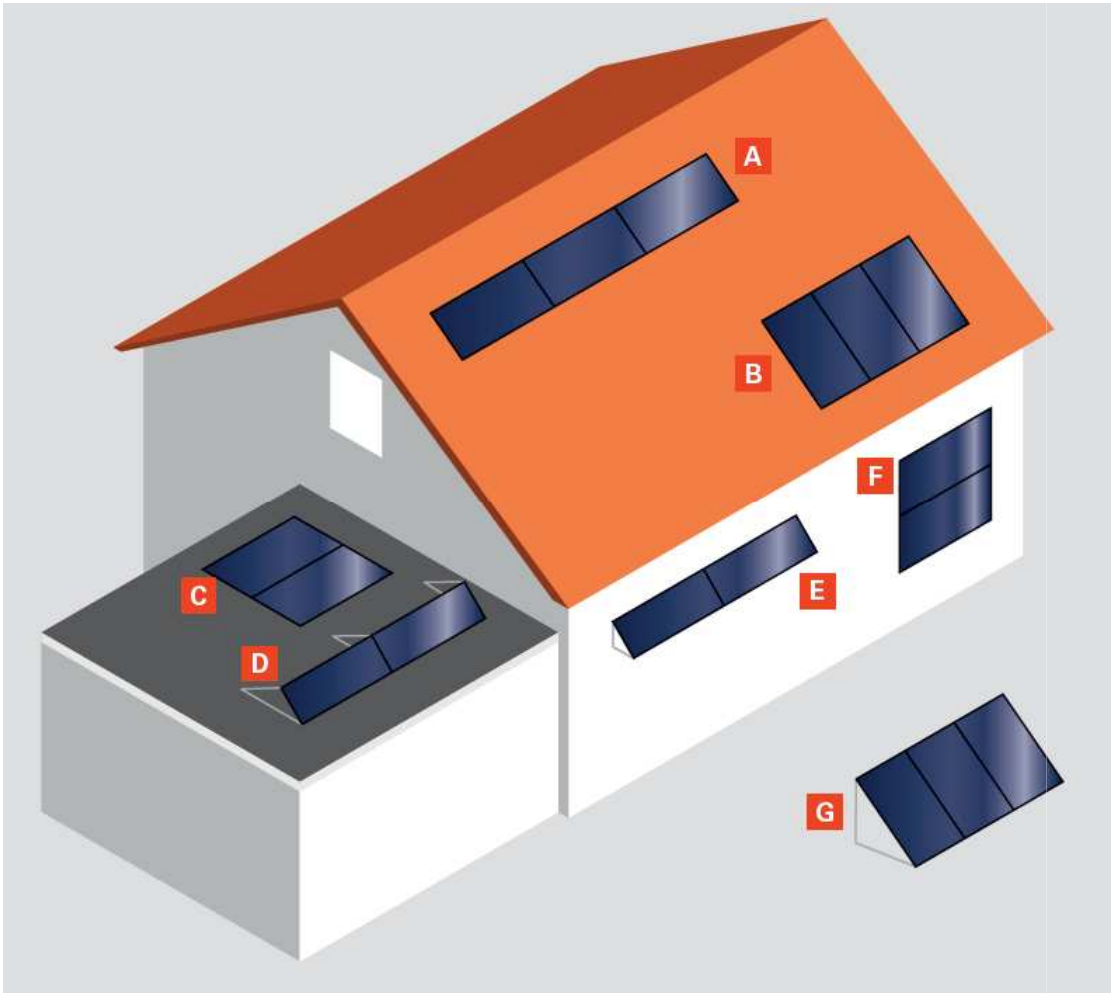


Solar collectors
Collector orientation



Subject to the angle and orientation of a surface, the level of insolation – relative to a horizontal area – reduces or increases.
A range can be defined between south-east and south-west and at angles between 25 and 70°, where the yields achieved by a solar thermal system are ideal. Greater deviations, for example, for systems on a wall, can be compensated by a larger collector area.

Solar collectors
Installation options



A , B – Pitched roof

C, D – Flat roof

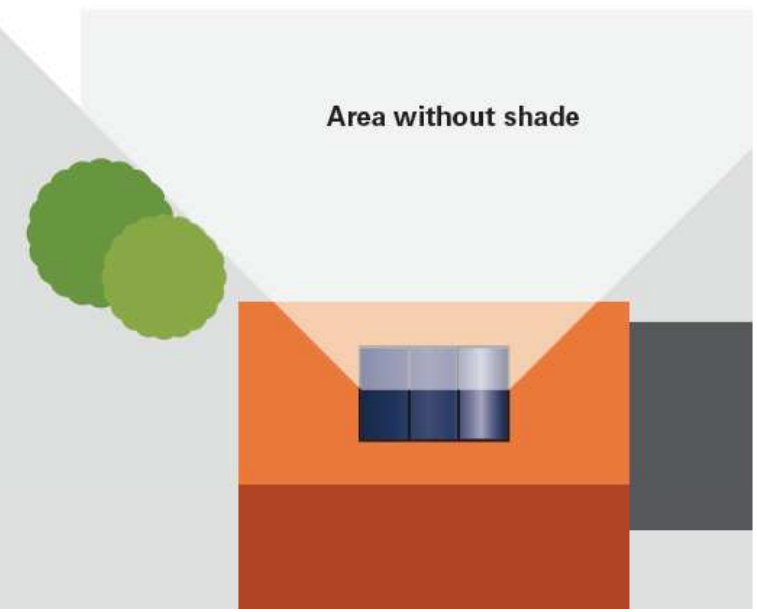
E, F – Wall, balcony rail, balustrade

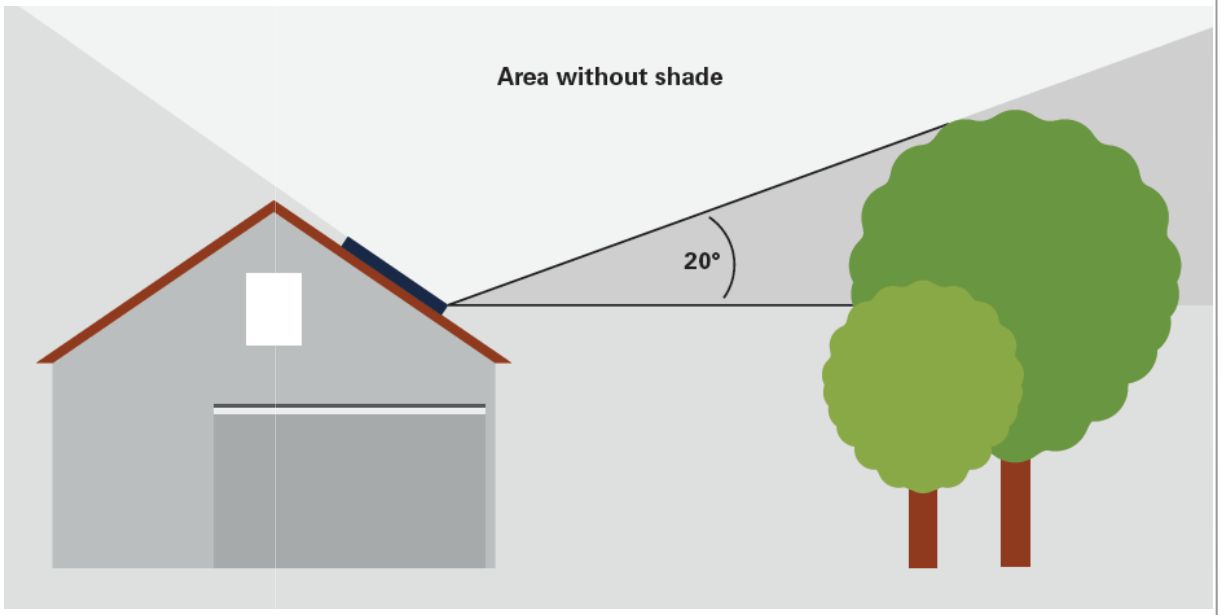
G – Freestanding installation

Flat plate collectors cannot be installed horizontally.

Heat pipe collectors can be installed almost horizontally (inclination of only 3^{o})

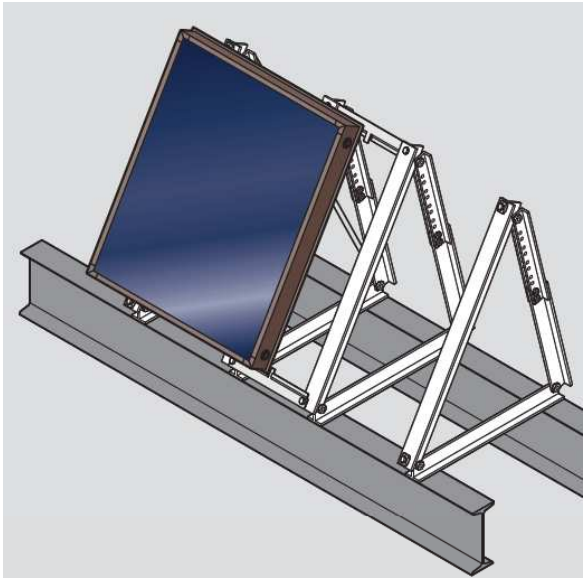
Solar collectors
Collector shading

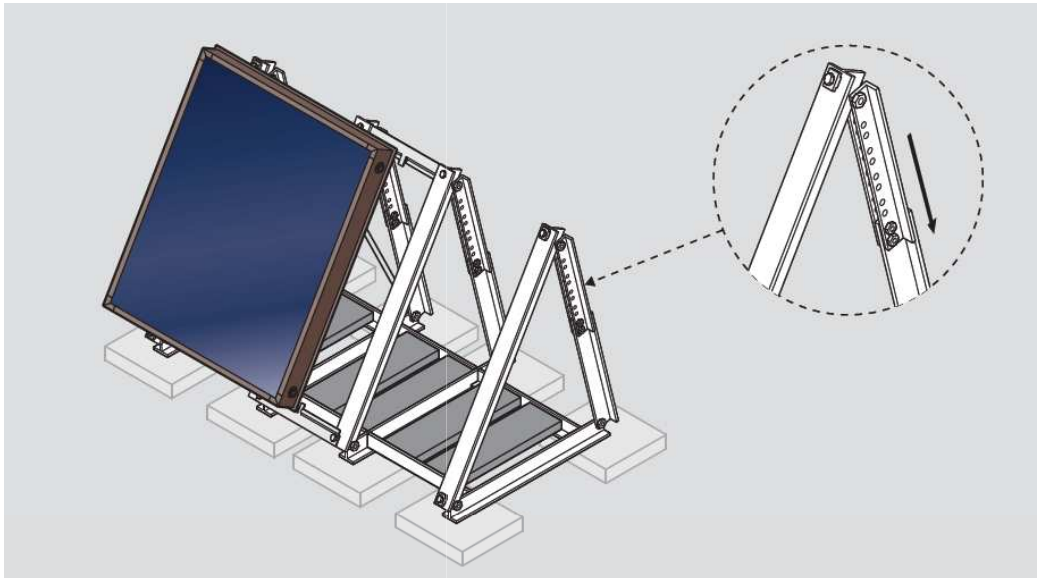


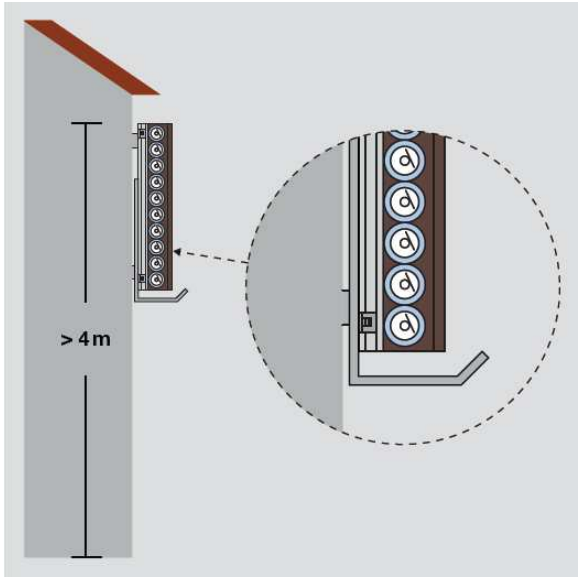


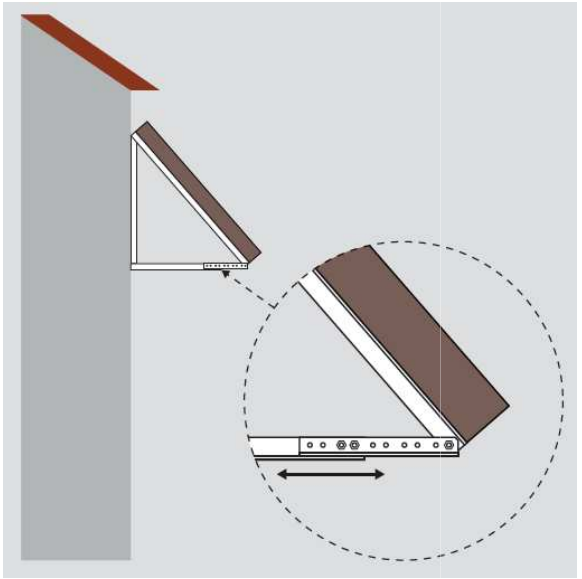
The question of shading must also be given serious consideration. Looking at the installation from a collector facing south, the area between south-east and south-west must be free of shade at an angle towards the horizon not exceeding 20˚ . It should be remembered that the system is to operate for longer than for 20 years, and that during this period trees would grow substantially

Solar collectors
Collector fixing



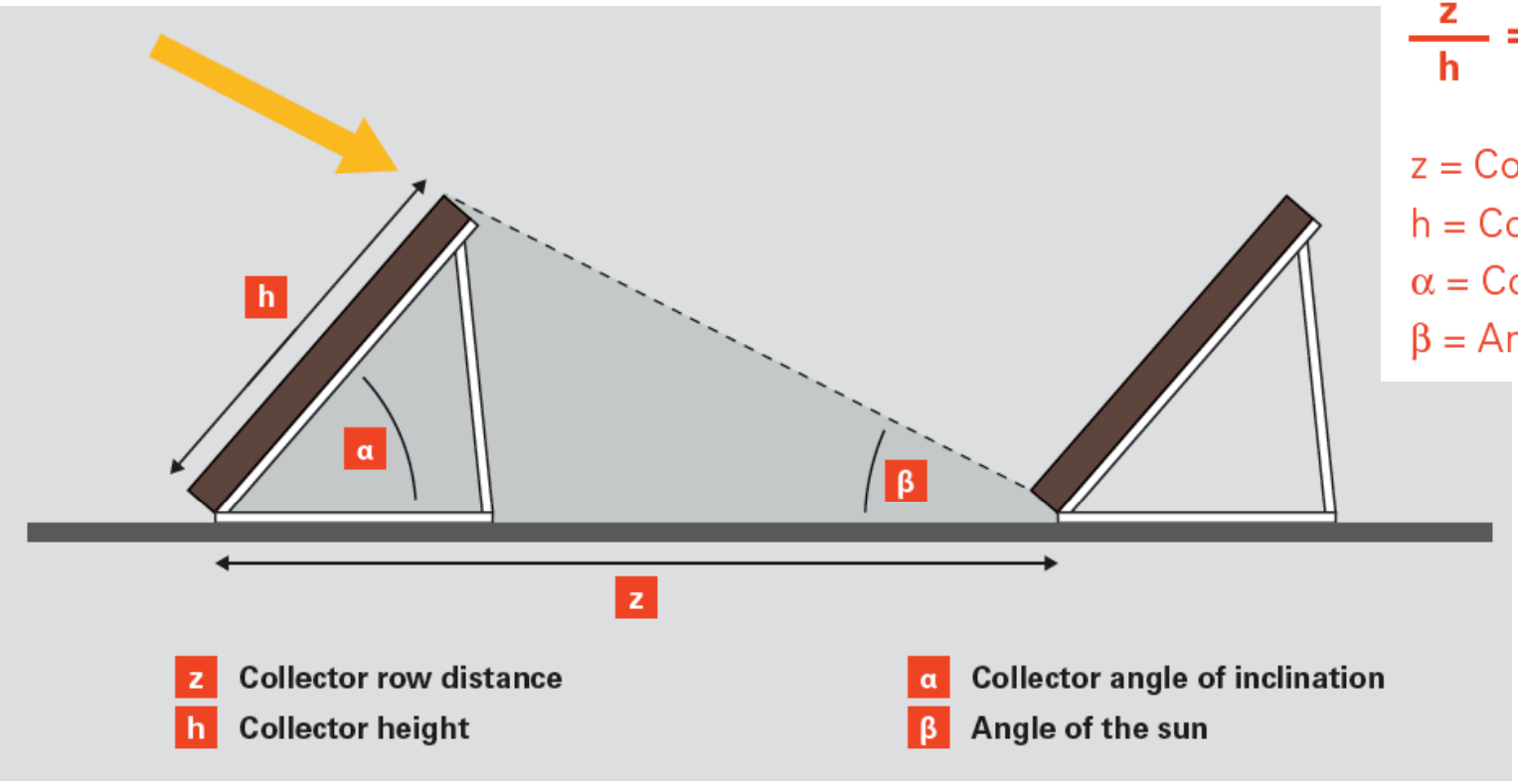






A collector system can be installed on any solid substructure or be freestanding. For freestanding installations, the collector system is secured against slippage and lift-off by weights (ballast).

Solar collectors
Clearance between collector rows

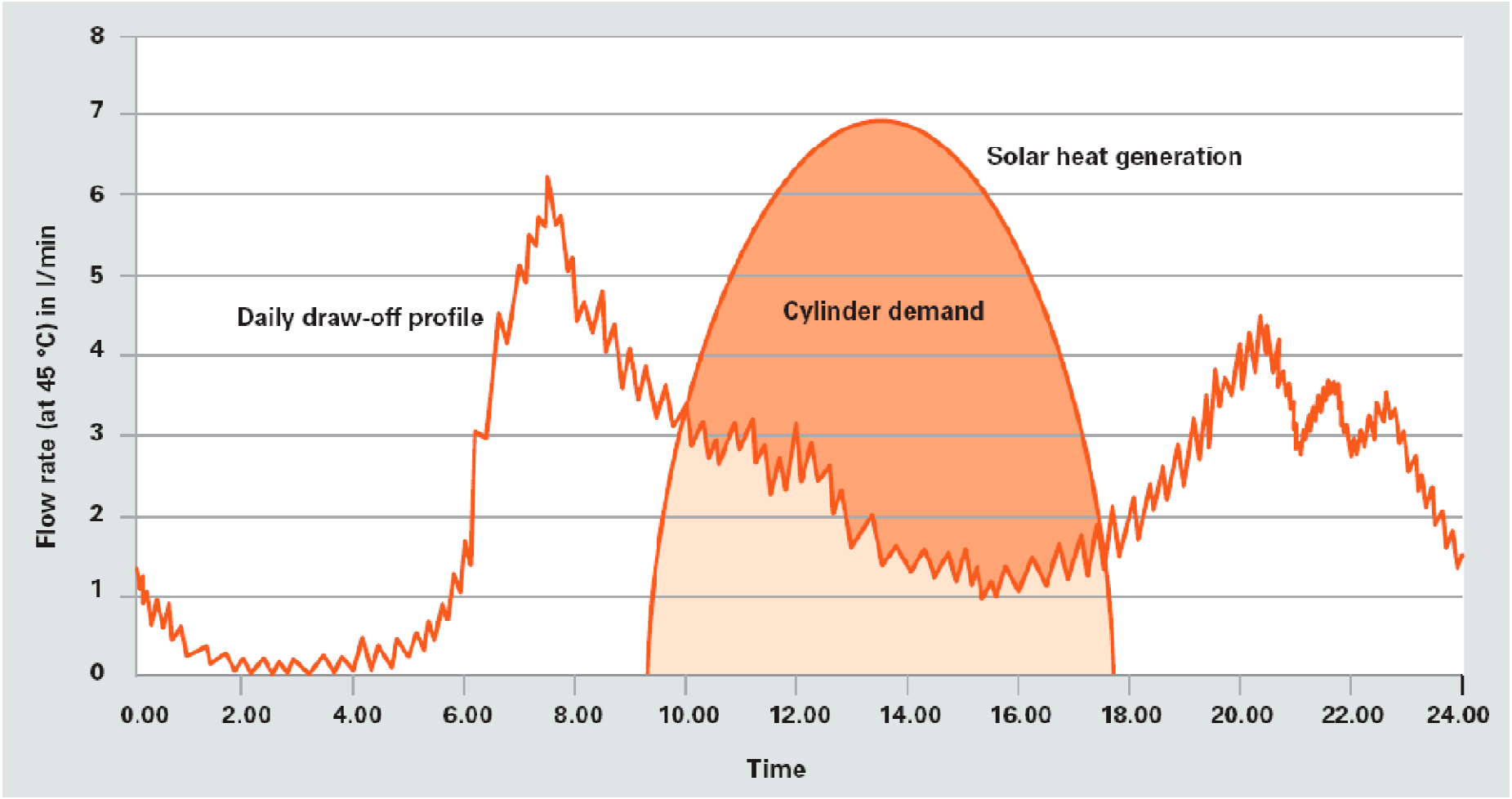


$$\frac{z}{h} = \frac{\sin(180° - (\alpha+\beta))}{\sin\beta}$$

z = Collector row clearance
h = Collector height
α = Collector angle of inclination
β = Angle of the sun

When installing several rows of collectors in series behind each other, suitable clearance to prevent shading must be maintained.

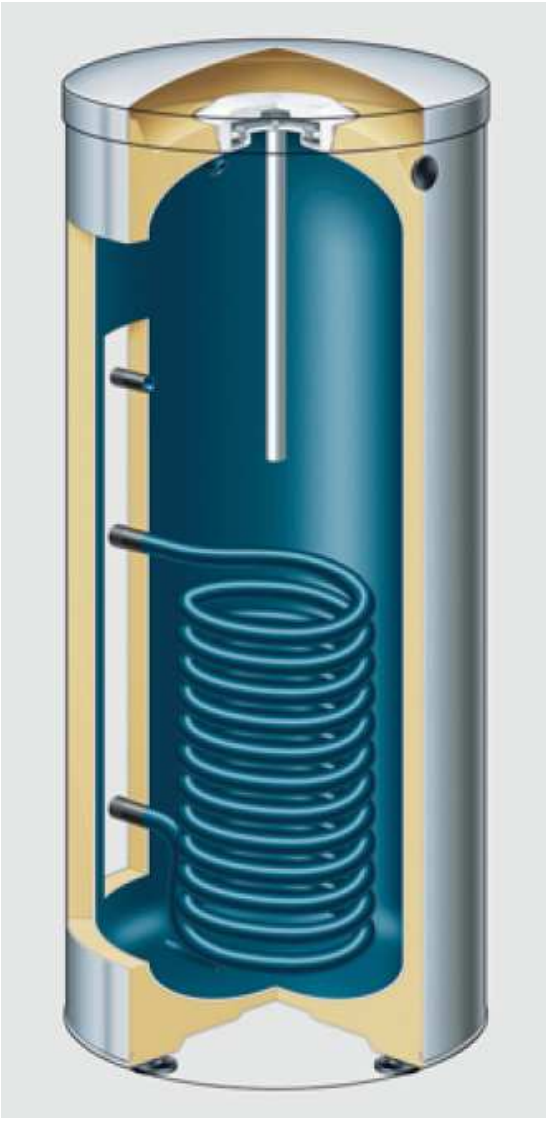
DHW cylinders
Why to store energy?



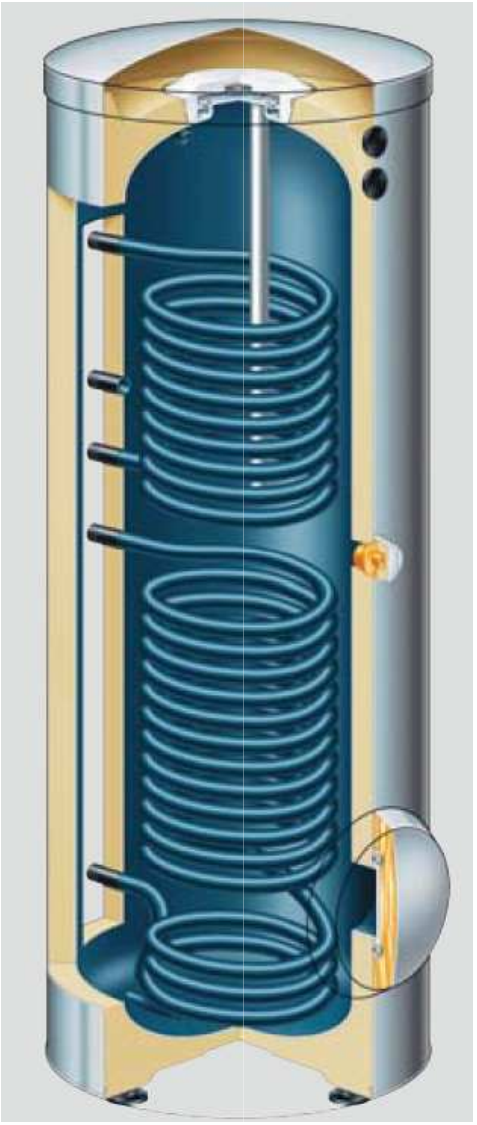
The period of heat generation and the period of heat consumption are rarely the same.

DHW cylinders / buffer tanks

Types



Mono mode DHW cylinder

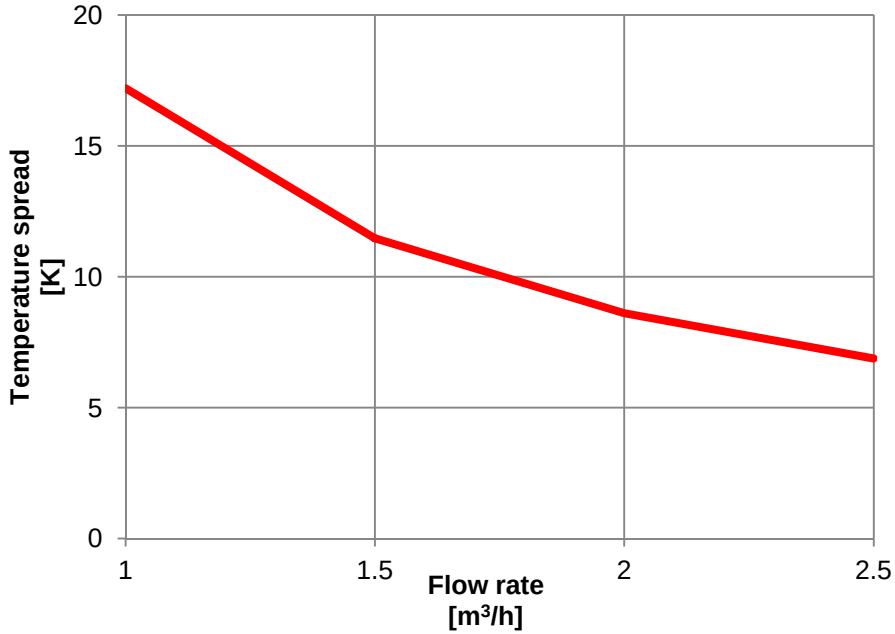


Dual mode DHW cylinder

Heating water buffer cylinder

Primary circuit
Determining the flow rate

- For flat collectors and heat pipe evacuated tube collectors, the minimum specific flow rate should be 25 l/(h x m^2) at 100% pump rate.



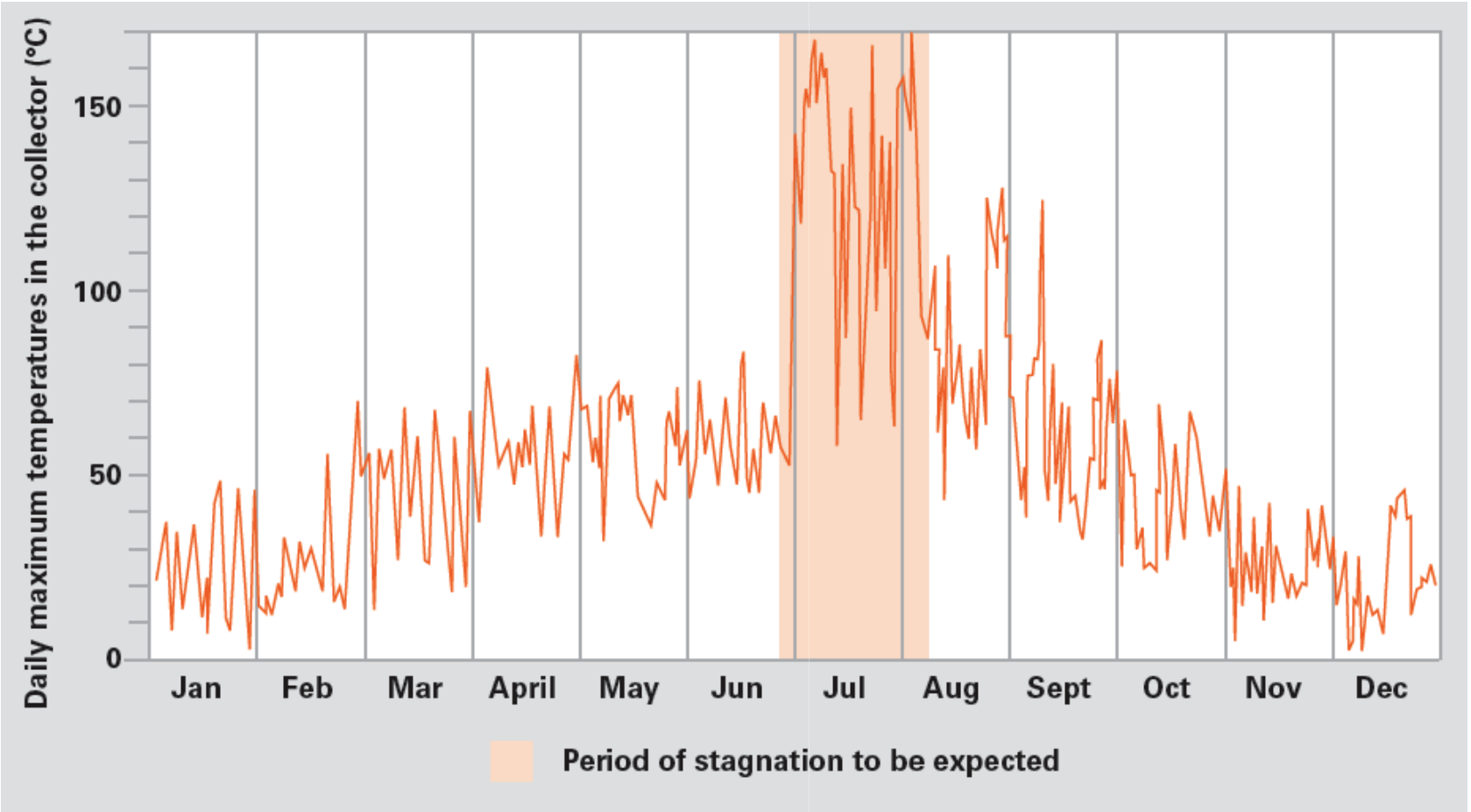
- Low flow rate -> high temperature spread
- High flow rate -> low temperature spread

Low flow rate -> high average collector temperature -> low collector efficiency

BUT

Low flow rate -> smaller pump (less energy consumption) -> smaller pipes.

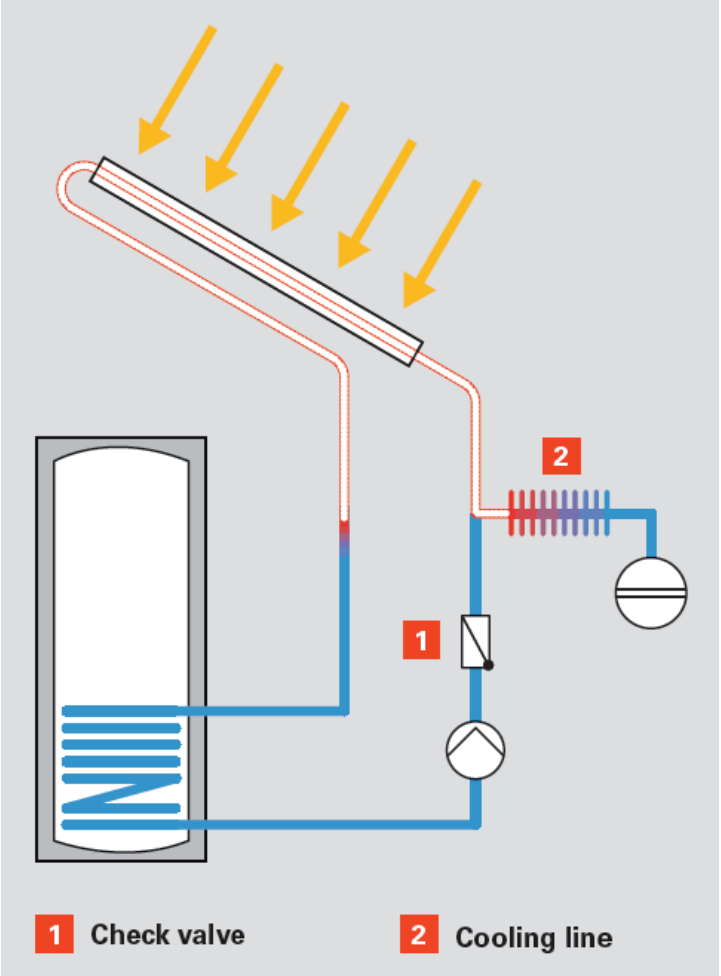
Primary circuit
Stagnation



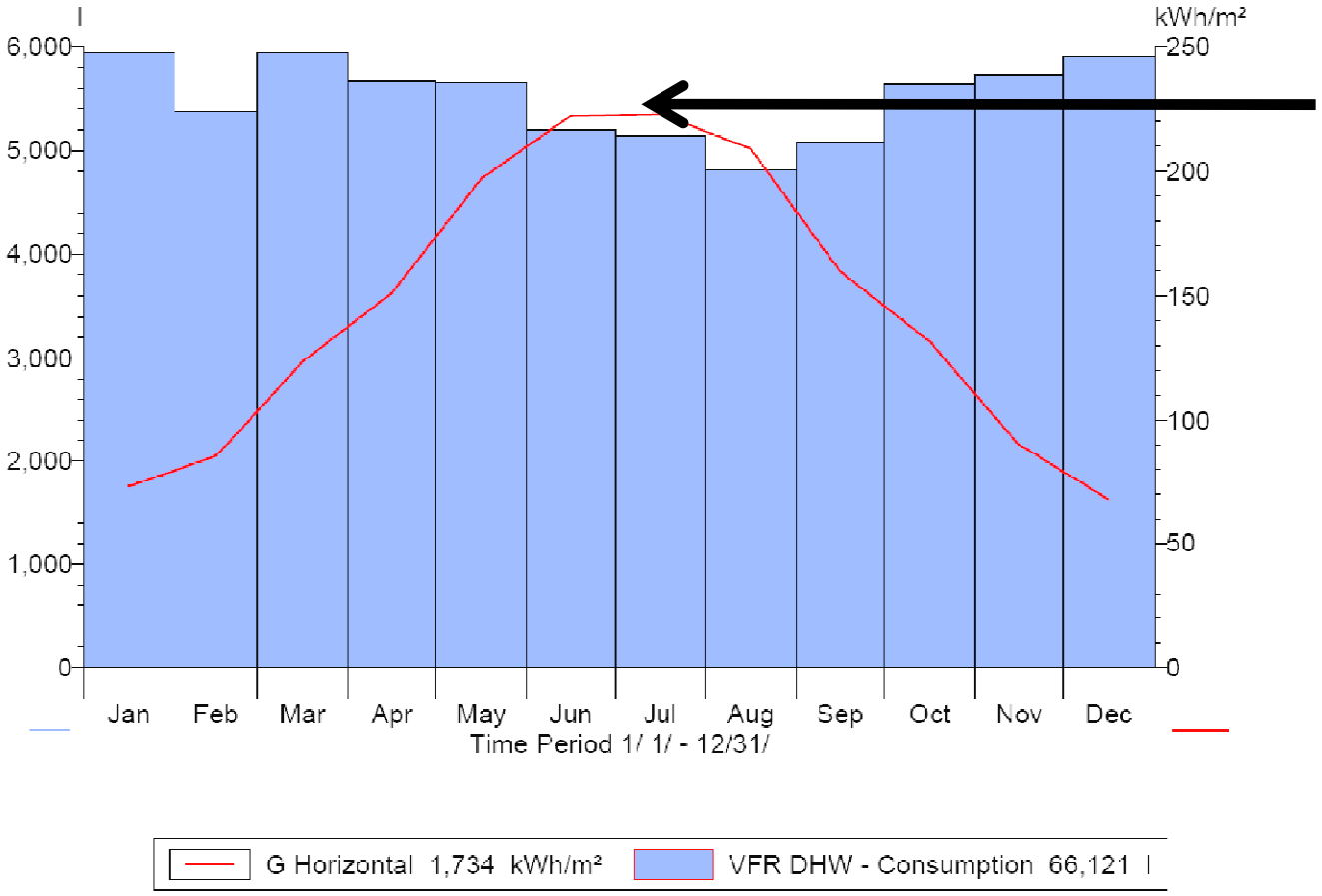
The simulation shows the time when the stagnation is to be expected

Primary circuit
Stagnation

- Safety aspects to be considered in the design:
  - The system must not be damaged by stagnation
  - The system must not represent any risk during stagnation
  - Following stagnation, the system must return to operation automatically.
  - Collectors and connecting lines must be designed for the temperatures expected during stagnation



Solar thermal system
Sizing a system for DHW heating

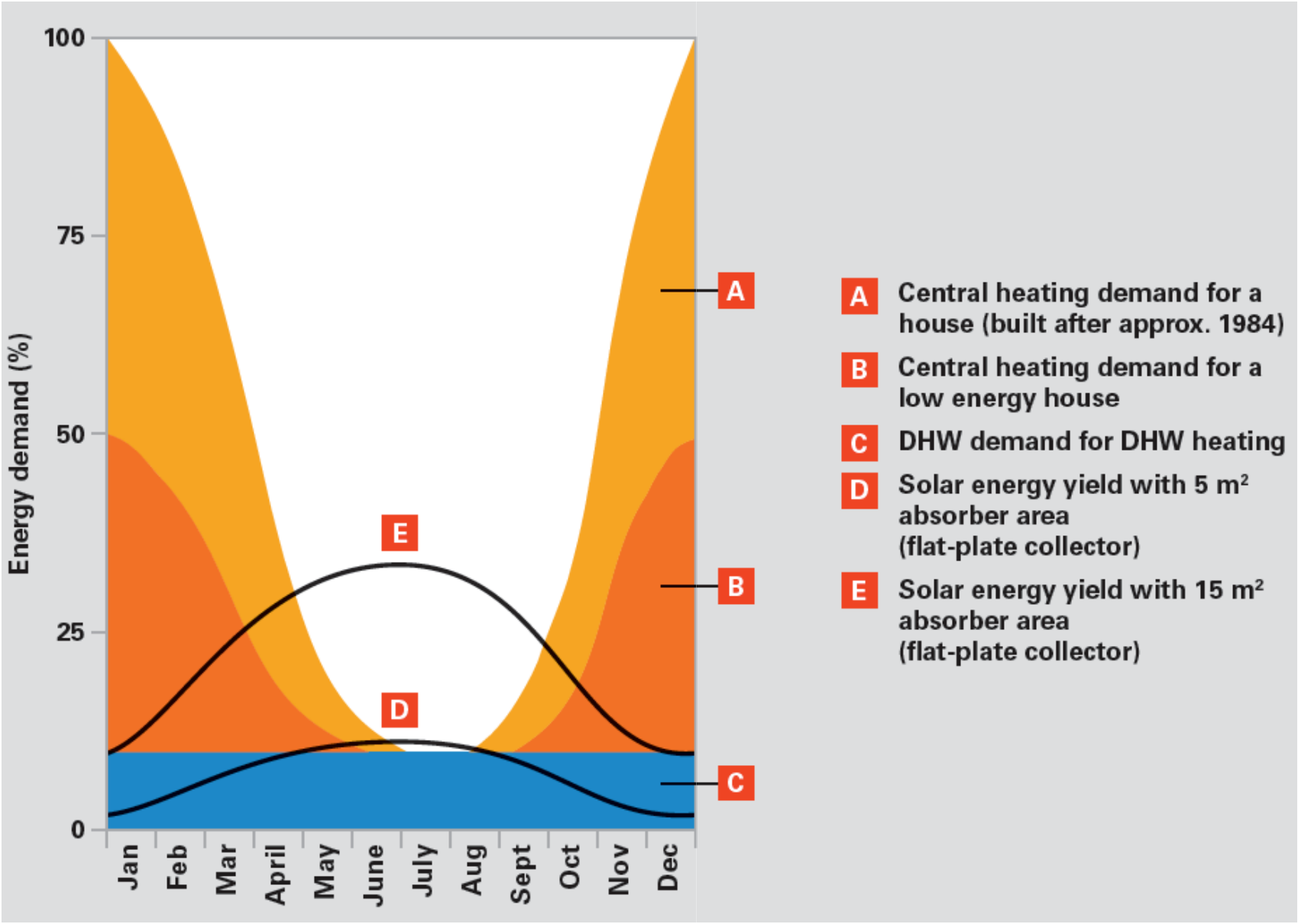


The solar system has to be selected for the maximum energy level

The solar system cannot cover 100% the DHW demand!!!

Solar thermal system

Sizing a system for DHW and space heating



Solar thermal system

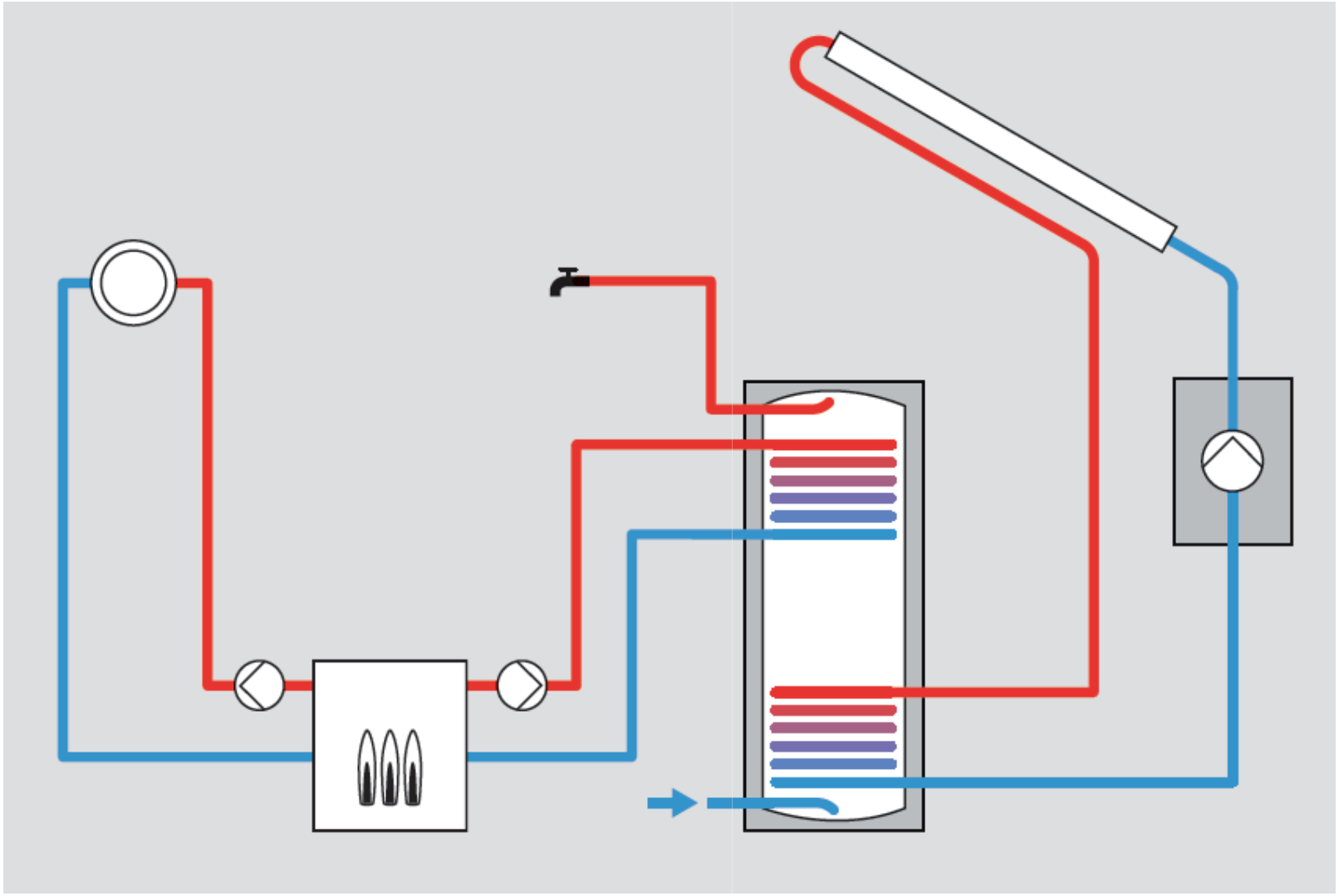
Thumb rules

DHW demand: **50 l/pers/day at 60^{o}C**

Collector area: **1 m2 at 100 l of DHW at 60^{o}C**

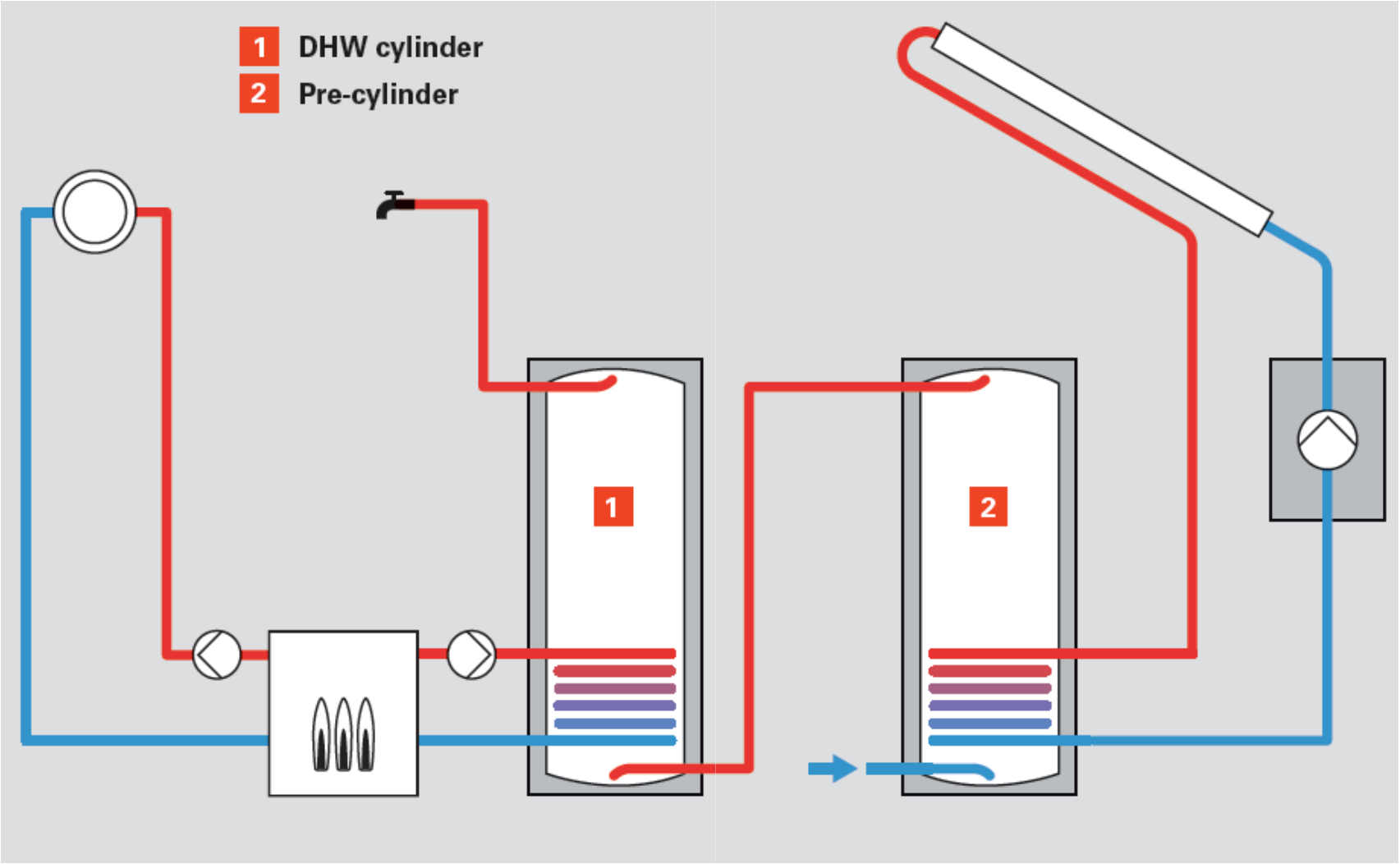
Buffer tank: **50 l/m^{2} of absorber area**

Solar thermal system
System examples



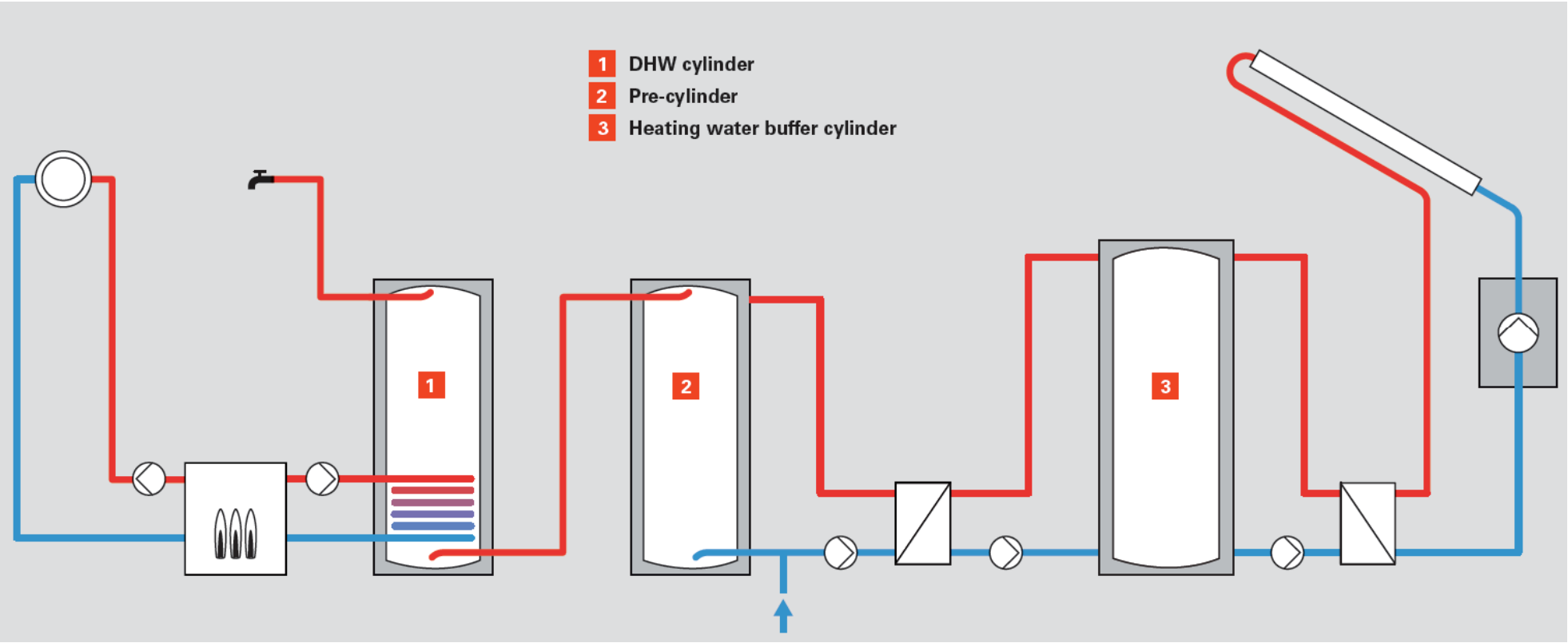
System with dual mode cylinder

Solar thermal system
System examples



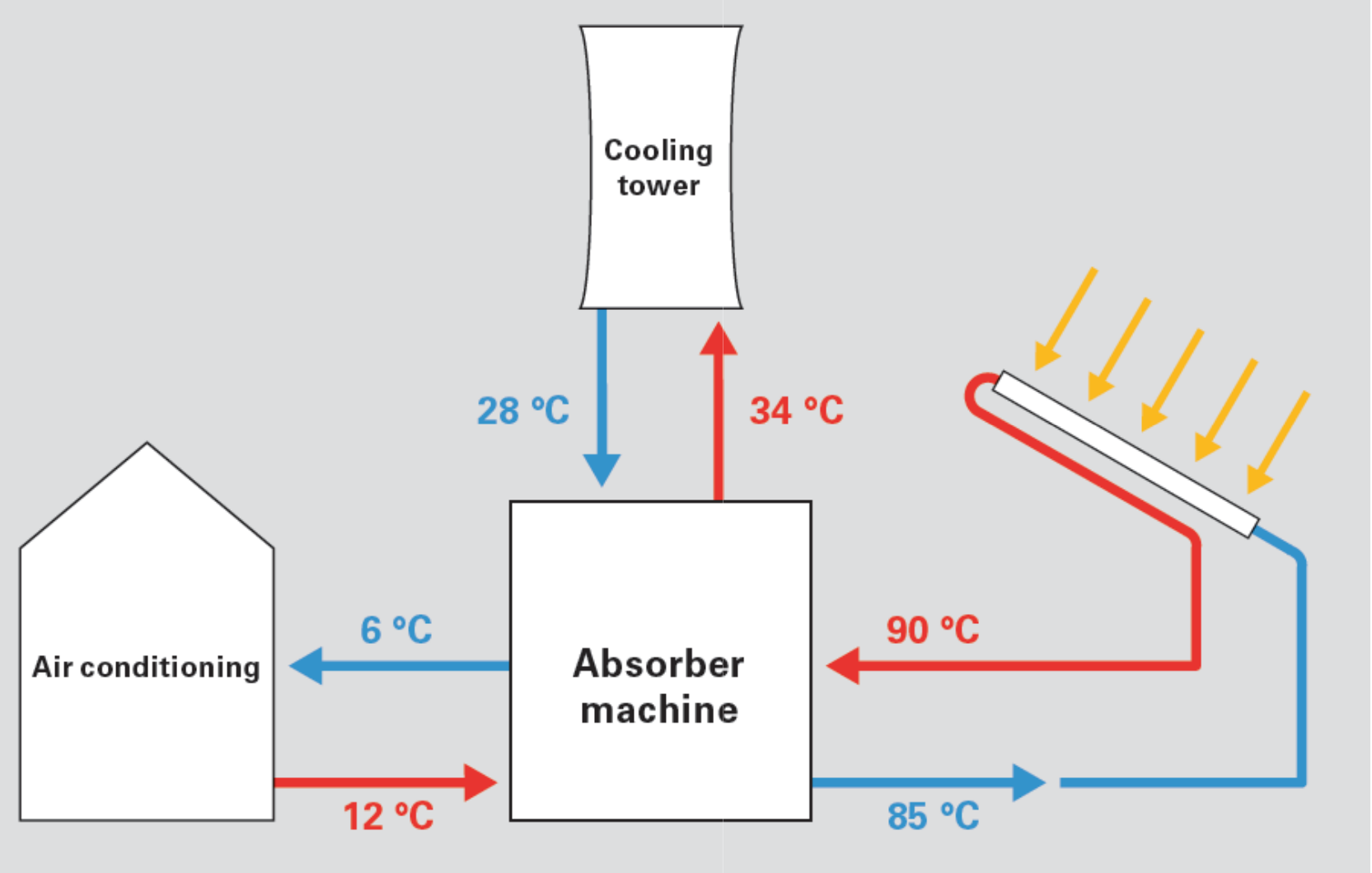
System with pre cylinder

Solar thermal system
System examples



System with heating water buffer cylinder

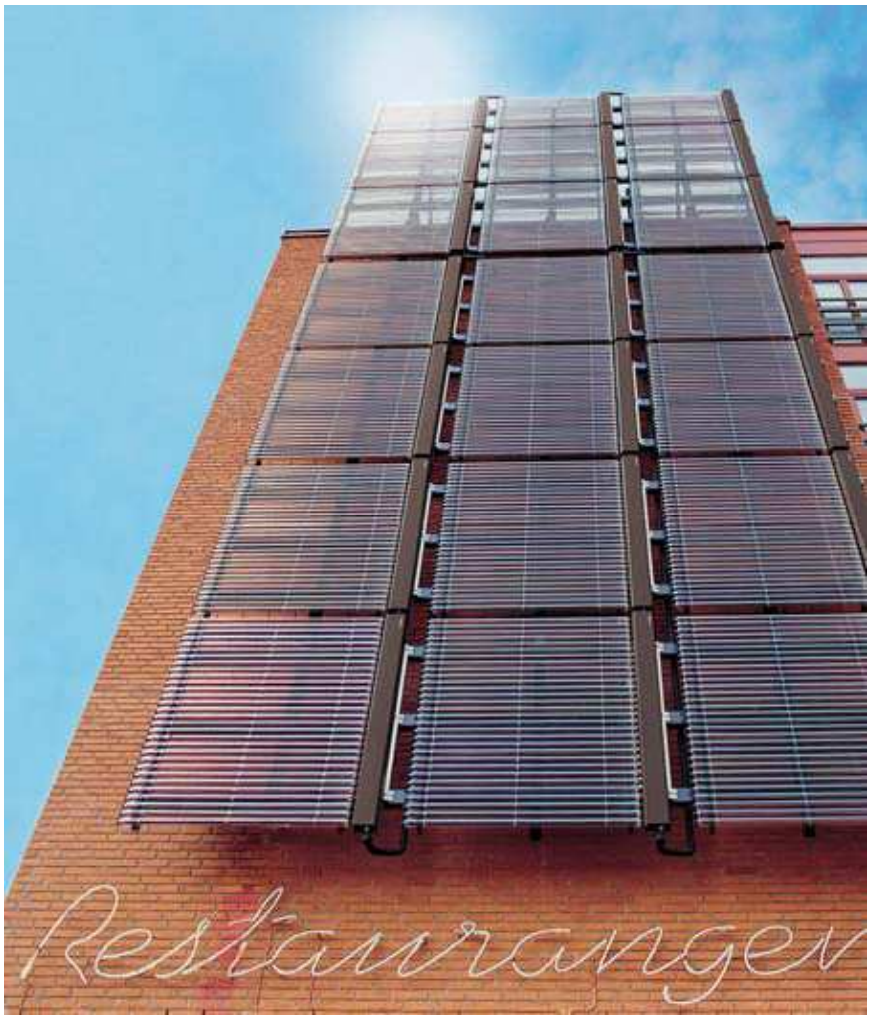
Solar thermal system
System examples



Solar cooling

Solar thermal system
Installation examples

Collectors as a design element of the Heliotropes in Freiburg, Germany.



Wall installation

Solar thermal system
Installation examples

Roof integration

Flat roof installation (horizontally)

Solar thermal system
Installation examples

Collectors providing shade

Pitch roof installation

Solar thermal system
Installation examples

Flat roof installation with ballast

Pitch roof installation

References – United Arab Emirates
Palm Jumeirah solar energy system

Location	Dubai – Palm Jumeirah, UAE
Array area	14 x 192 m^2 (2.688 m^2)
Collector type	Vitosol 200-F
Year of installation	2007
Application type	Domestic Hot water
Type of facility	Residential building