Carl von Ossietzky Universität Oldenburg

Collector Field and Energy Demands

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Learning outcomes

- Understand the main parameters for characterizing energy demands and their influence on the collector field performance/design

- Understand the influence of different variables (e.g. orientation, tilt mass flow,...) on the collector field performance/outcome

- Understand the main differences of different flow regimes in the collector field

- Get to know basic control strategies for the solar loop in solar thermal systems

- Understand main hydraulic “tools” promoting correct system behaviour

Outline

- **Energy demands: characterization**

- **Performance of collector field:**
  - Incident Radiation
  - Collector temperature
  - Operation strategies: mass flow
  - Control strategies
  - Pressure losses
  - Stagnation behaviour

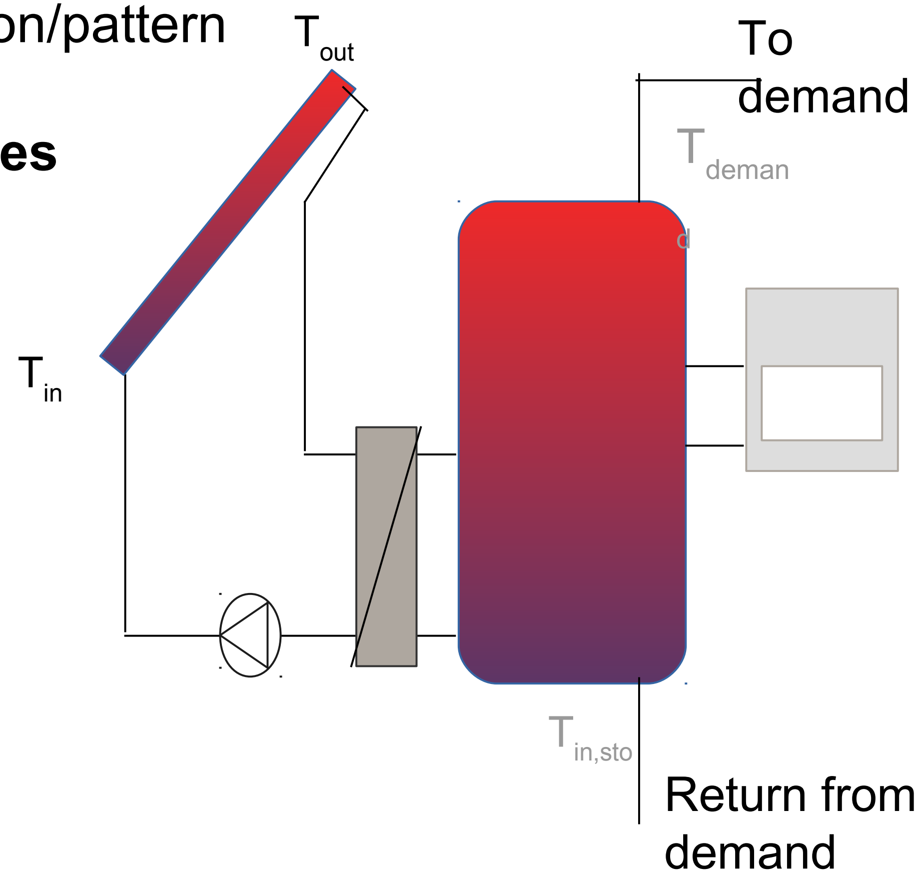
Characterizing energy demands

Example: DHW + SH demands

- Seasonal (and **daily!)** variation/pattern

- Supply (desired) **temperatures** **(T_{demand})**

- Return temperatures (from demand, $T_{in,sto}$)



Characterizing energy demands

Example: DHW + SH demands

Space heating (SH)	Domestic hot water (DHW)
Large seasonal variation	All year round constant, small seasonal variation
Continuous daily profile	Daily profile with short high-power peaks
Low temperature applications (30-50°C) depending on emission system	High delivery temperature (45-60°C)
High return temperatures (25-35°C)	Low return temperatures (4-20°C)

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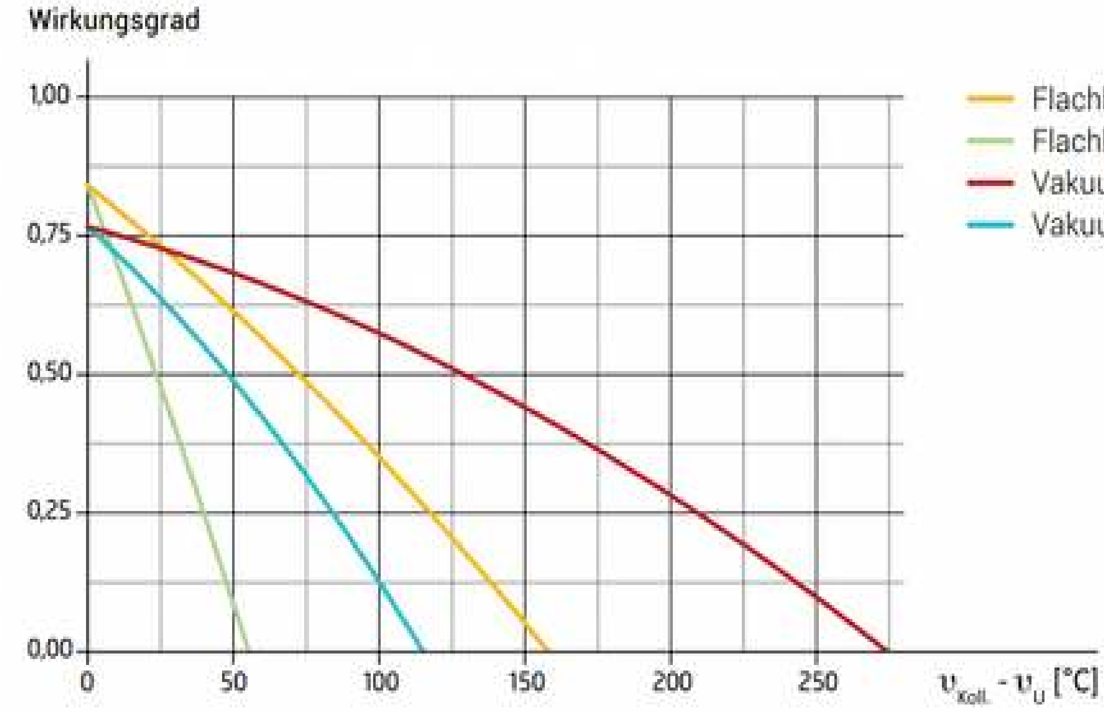
Collector loop

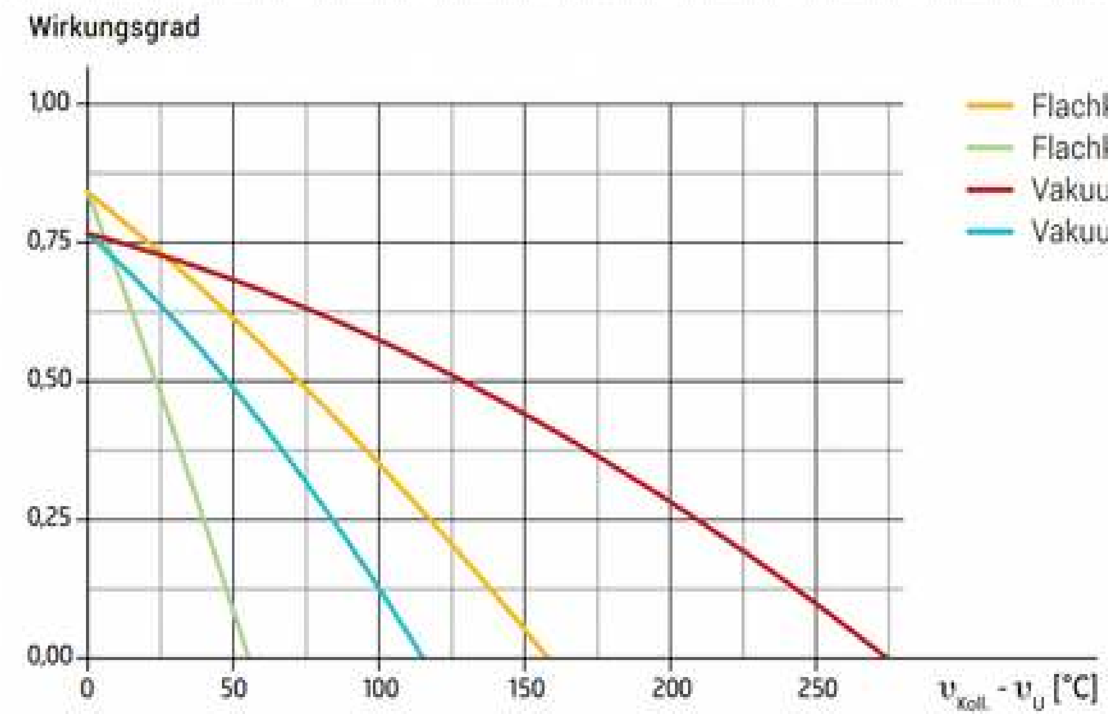
Performance



Source: Corradini et al., 2014

Collector loop

Performance



Source: Corradini et al., 2014

Main variables:

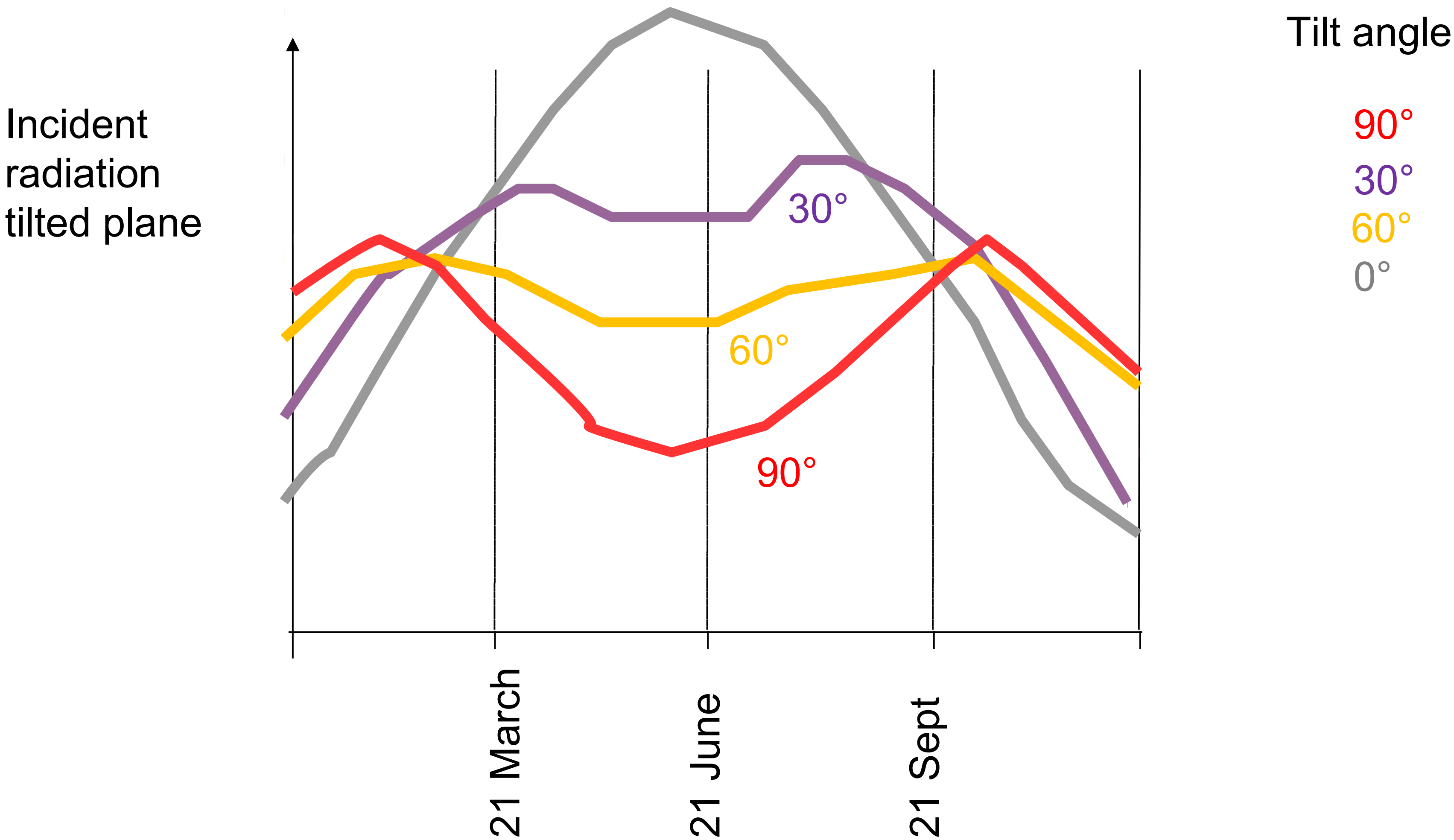
→ **Average temperature**

→ **Radiation**

→ Ambient temperature

Incident radiation

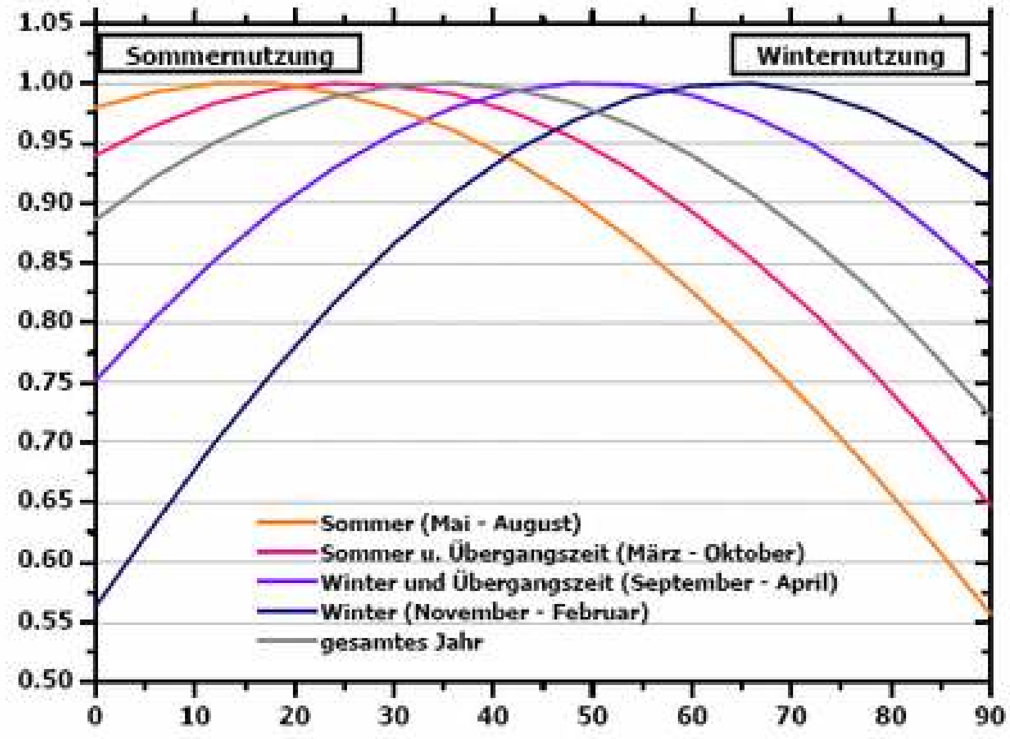
Tilt of the collector field



Incident radiation

Tilt of the collector field

Relative change in the incident radiation



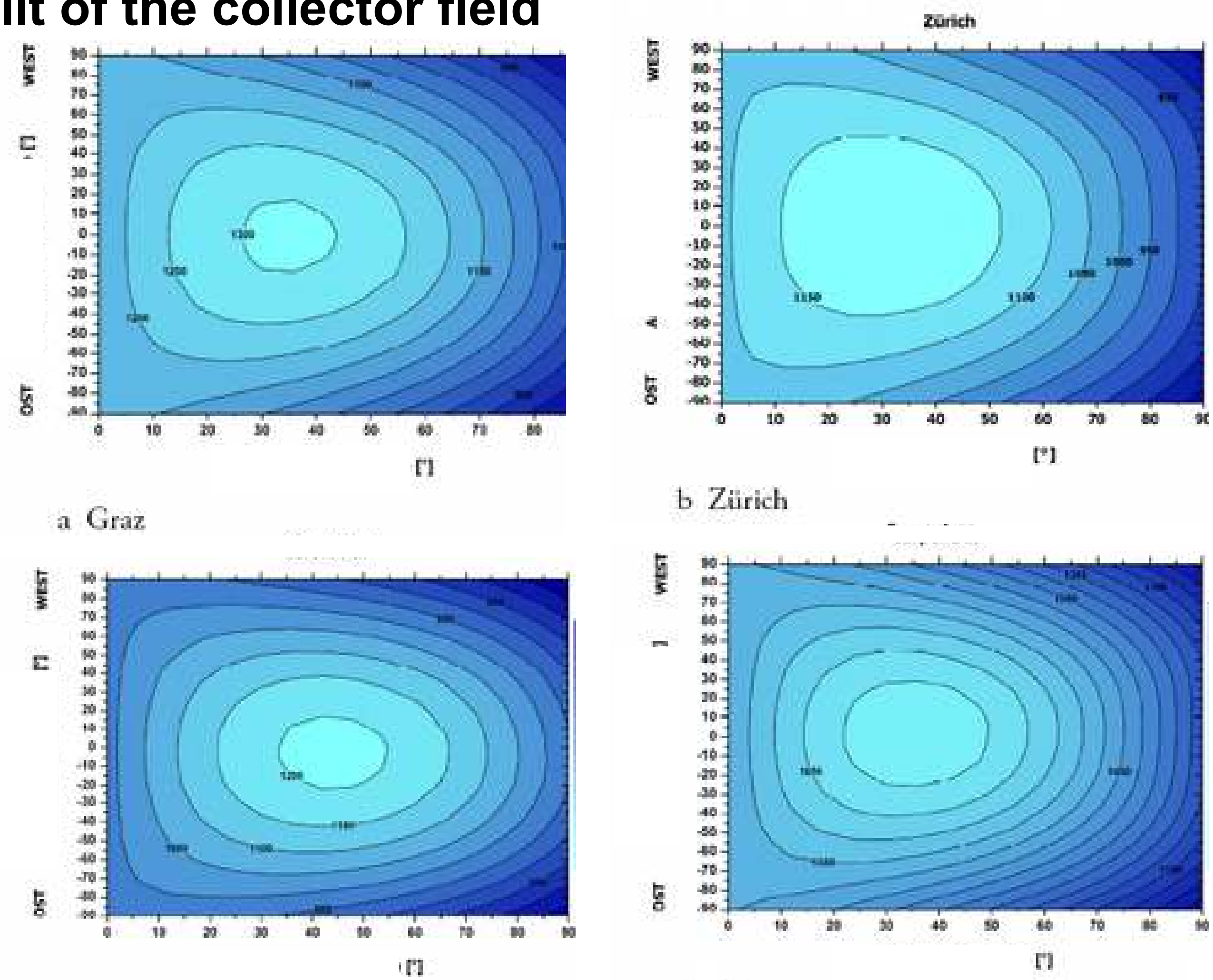
Tilt angle for south oriented area

Source: Heimrath, 2004

Incident radiation

Orientation and tilt of the collector field

Solar resource [kWhm^{-2}a^{-1}]



a Graz
b Zürich
c Stockholm
d Carpentras

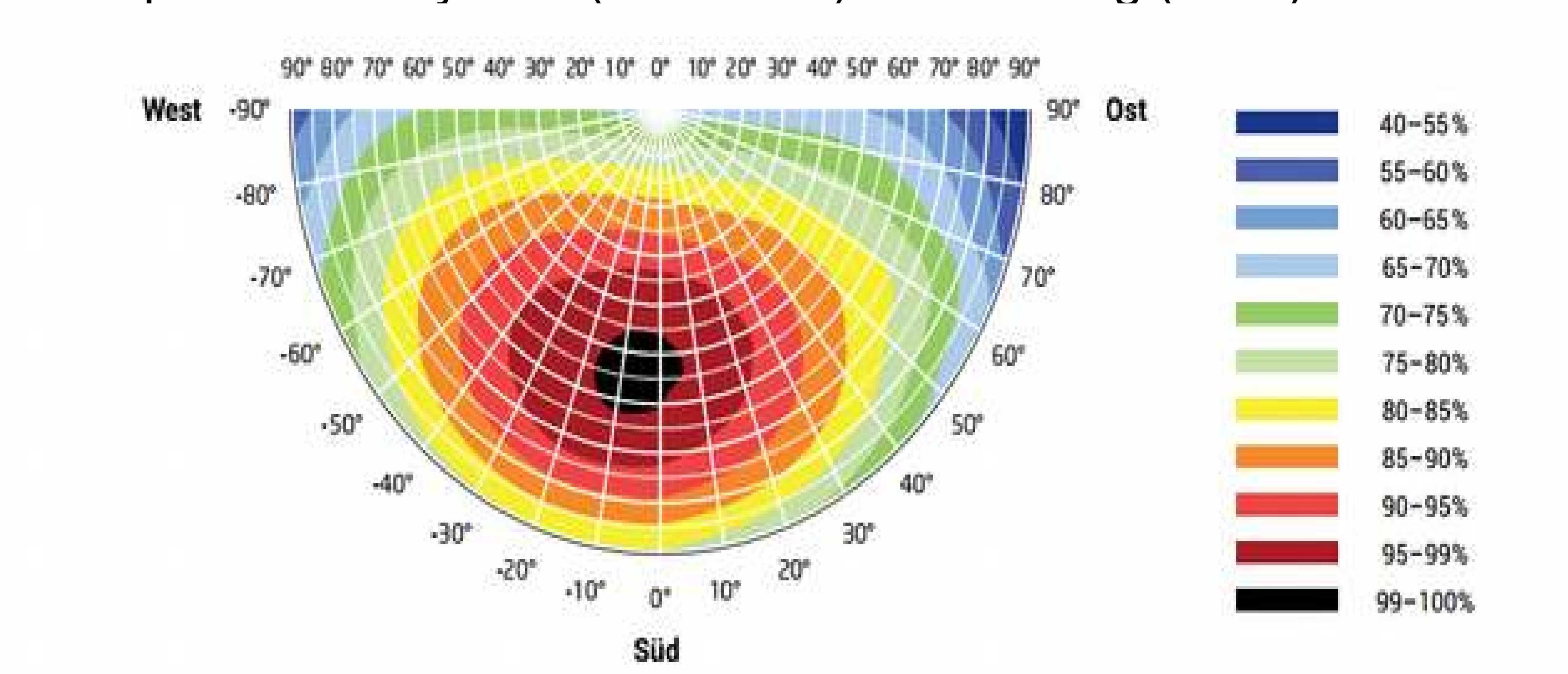
Source: Heimrath, 2004

Incident radiation

Orientation and tilt of the collector field

Maximizing collector energy yield: <u>**demand specific!!**</u>

Example: Combi-system (DHW+SH) in Würzburg (GER)



Source: Corradini et al., 2014

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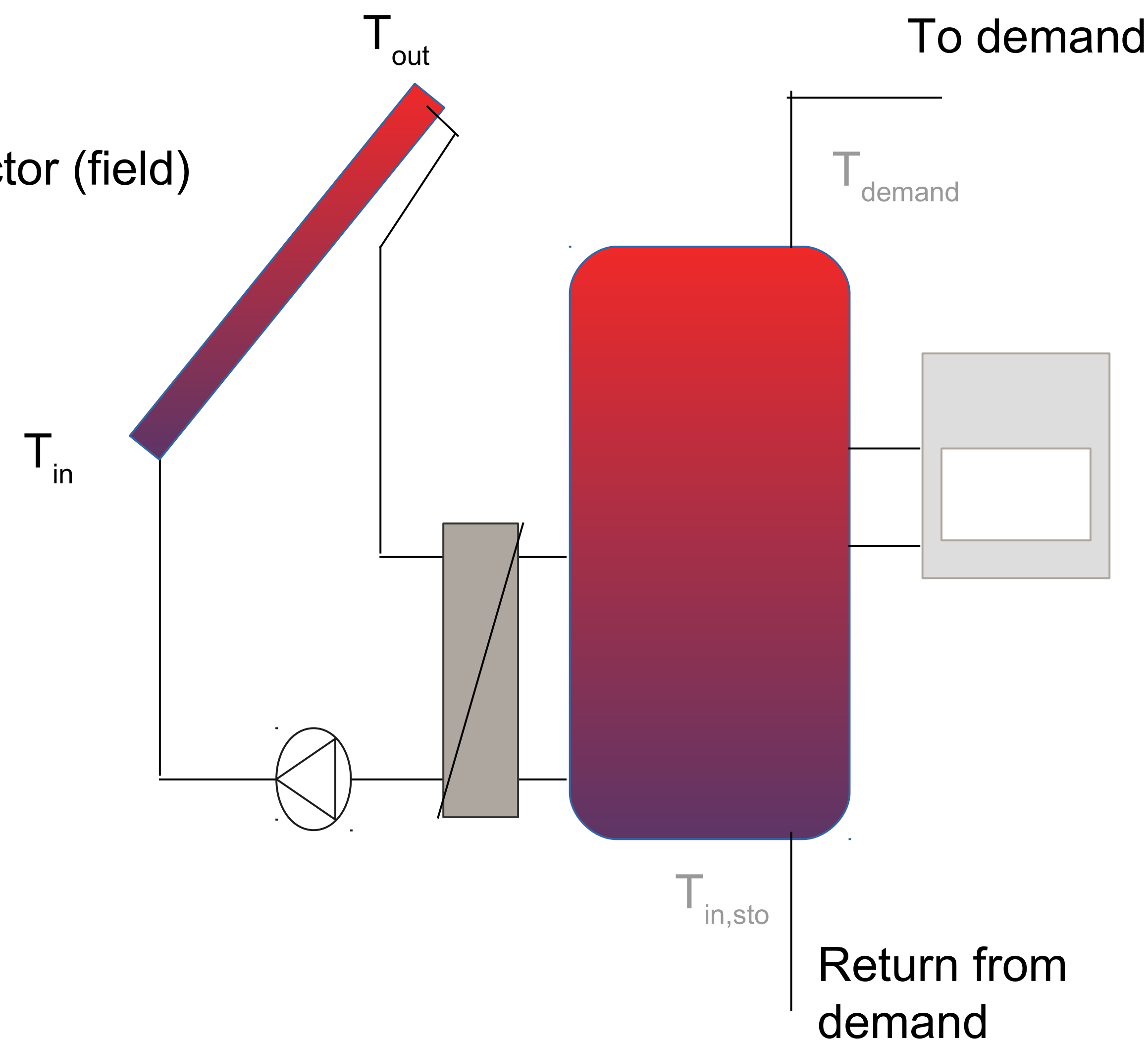
Operation strategies

Collector loop

Average temperature collector (field)
= f (inlet, outlet, mass flow)

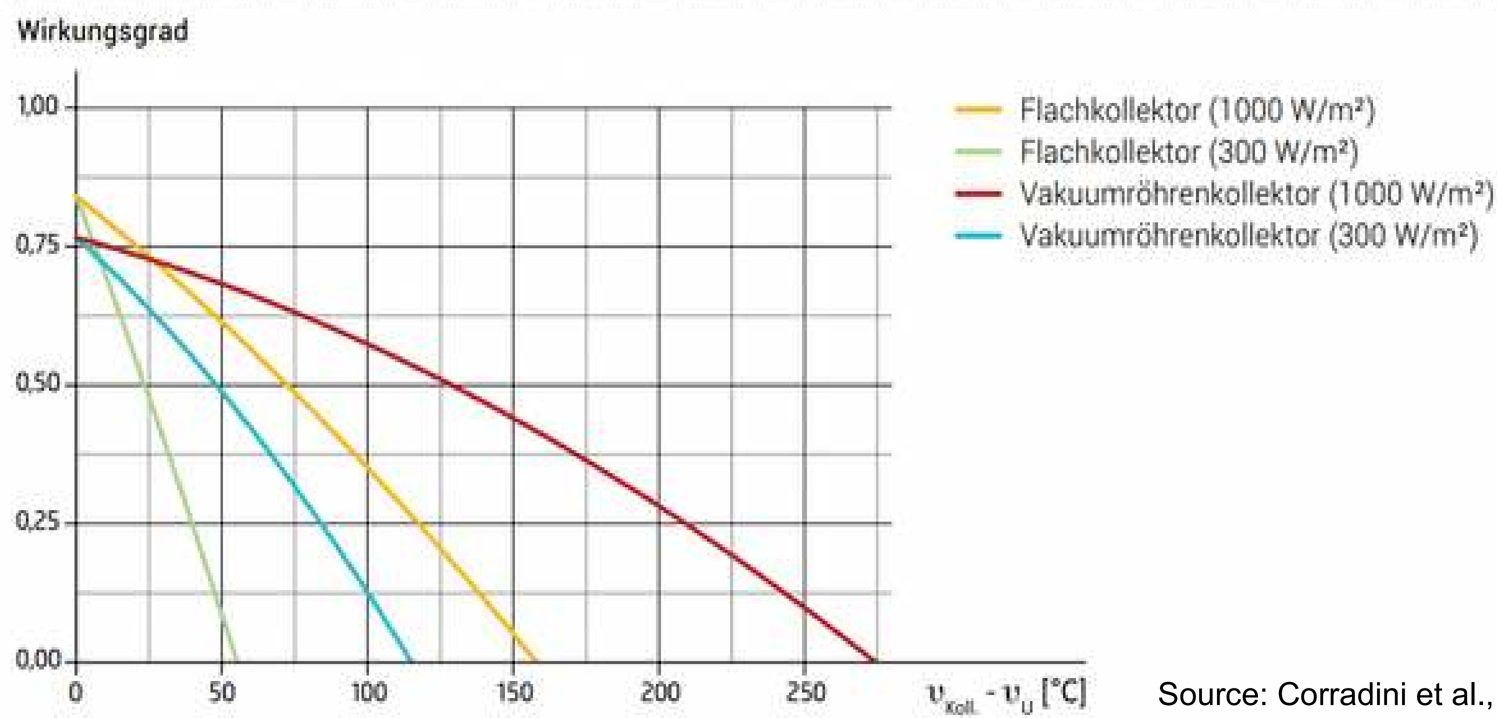


Operation strategies

Collector loop

High flow systems: 30 -70 $lh^{-1}m^{-2}$; ΔT_{coll} ≈ 8-15 K

Low flow systems: 8 -18 $lh^{-1}m^{-2}$, ΔT_{coll} ≈ 40-55 K



Source: Corradini et al., 2014

Operation strategies

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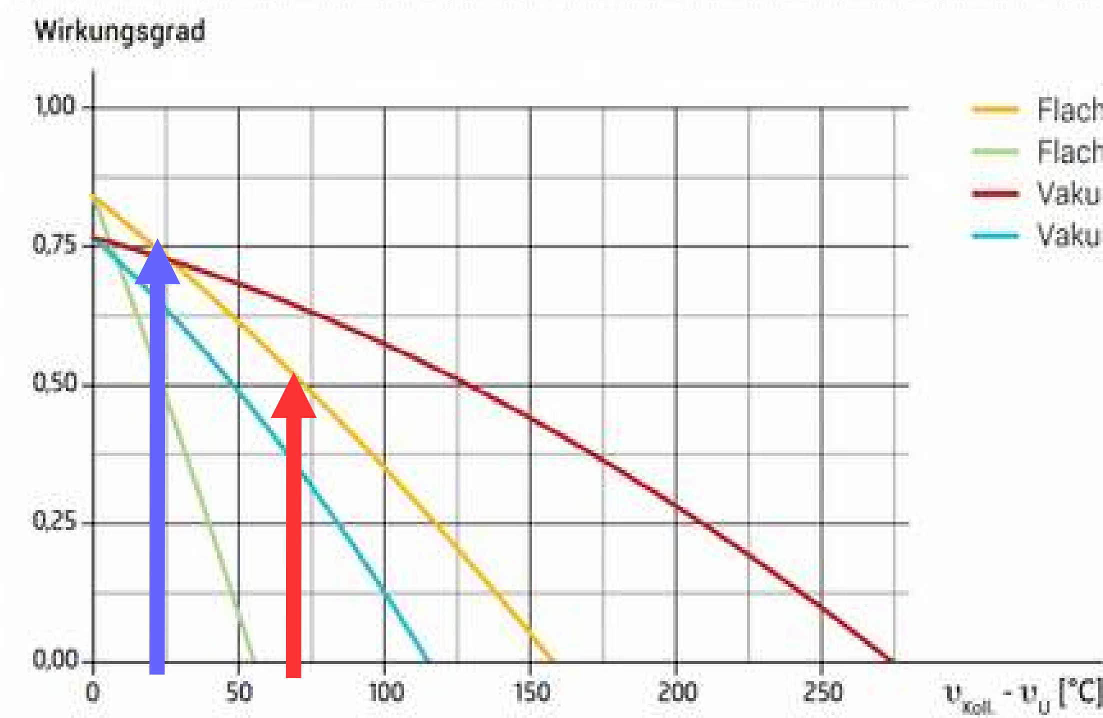

Source: Corradini et al., 2014

Operation strategies

Collector loop

High flow systems: 30 -70 $lh^{-1}m^{-2}$; ΔT_{coll} ≈ 8-15 K

Typically used for DHW production in small systems (single family houses)

High efficiency of collector field (low ΔT_{coll})

Slow warming up of storage (pre-heating)

Low flow systems: 8 -18 $lh^{-1}m^{-2}$, ΔT_{coll} ≈ 40-55 K

Worst collector efficiency (high ΔT_{coll})

End-use temperature given by solar loop (not pre-heating) -> less auxiliary energy required

Operation strategies

Collector loop

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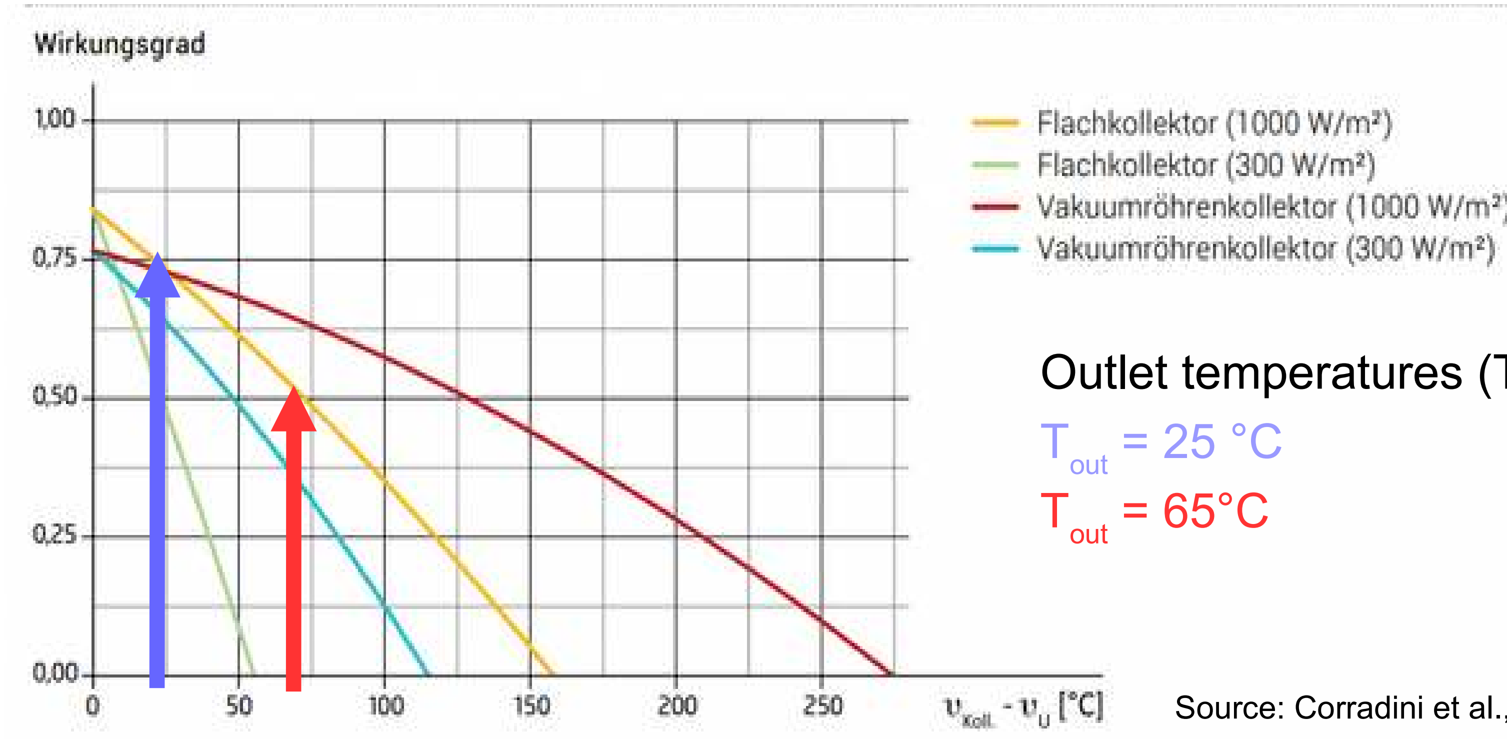

Outlet temperatures (T_{in} = 15°C):

T_{out} = 25 °C

T_{out} = 65°C

Source: Corradini et al., 2014

Operation strategies

Collector loop

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Matched flow systems: variable 8-70 $lh^{-1}m^{-2}$, ΔT_{coll} ≈ 8 - 55 K

constant $T_{out,coll}$ as a function of G, $T_{storage}$, Q_{demand}

High/Low flow operation

Operation strategies

Collector loop

Matched flow systems: variable 8-70 $lh^{-1}m^{-2}$, ΔT_{coll} ≈ 8 - 55 K

constant T_{outl} as a function of G, $T_{storage}$, Q_{demand}

High/Low flow operation

$\Delta T_{coll\text{-}sto} = T_{out} - T_{sto}$

Pump turned on:

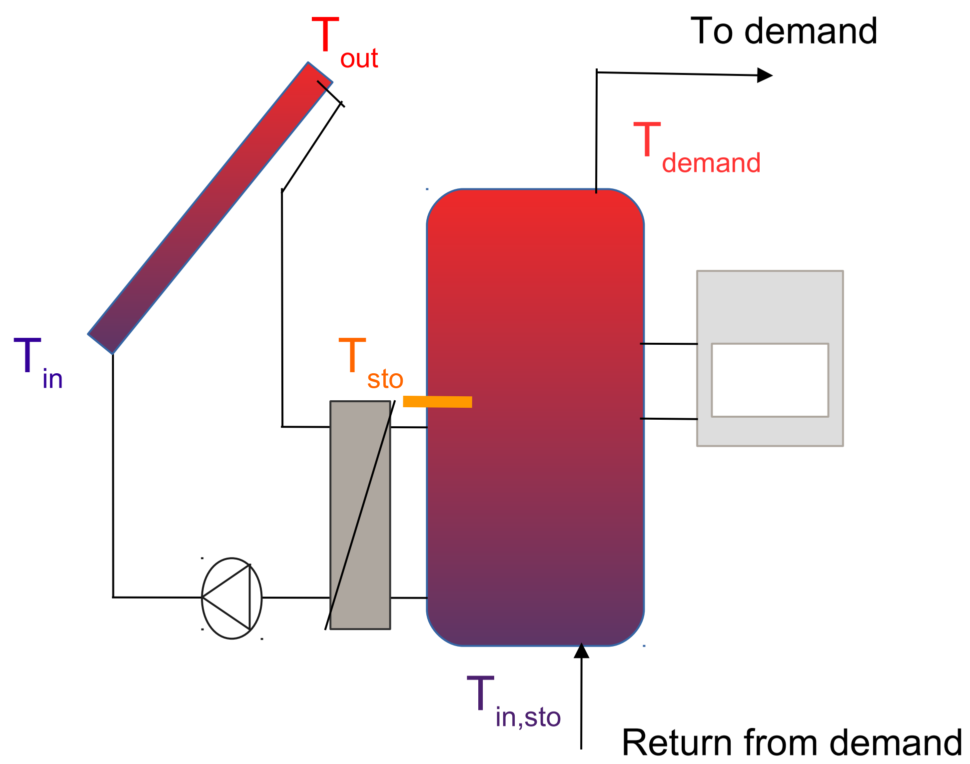
$\Delta T_{coll\text{-}sto} > \Delta T_{ON}$

$\mathbf{\Delta T_{ON} = 10\ K}$

Pump turned off:

$\Delta T_{coll\text{-}sto} < \Delta T_{OFF}$

$\mathbf{\Delta T_{OFF} = 3\ K}$



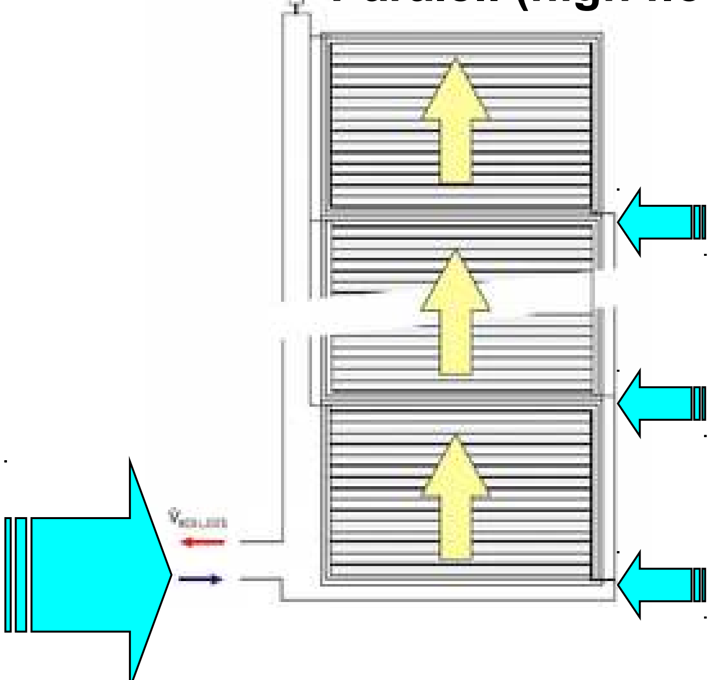
Operation strategies

DESIGN: depending on required ΔT_{demand}:

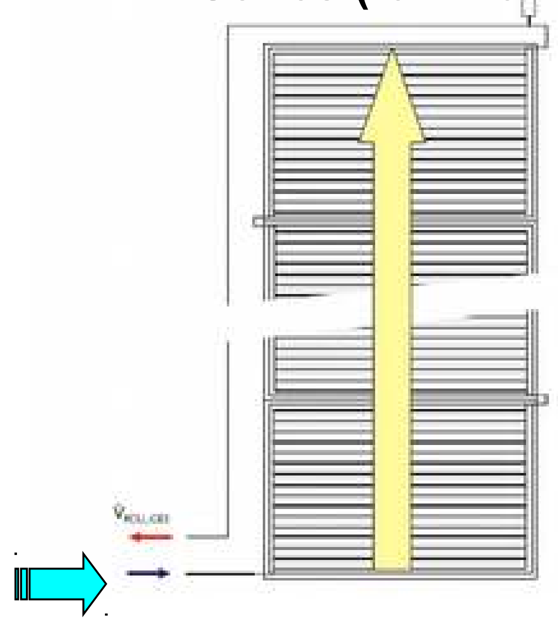
- DHW (+SH): low flow, ΔT_{demand} > 30K

- Only SH: high flow, ΔT_{demand} < 10K

Paralell (high flow)



Series (low flow)



Source: Heimrath, 2004

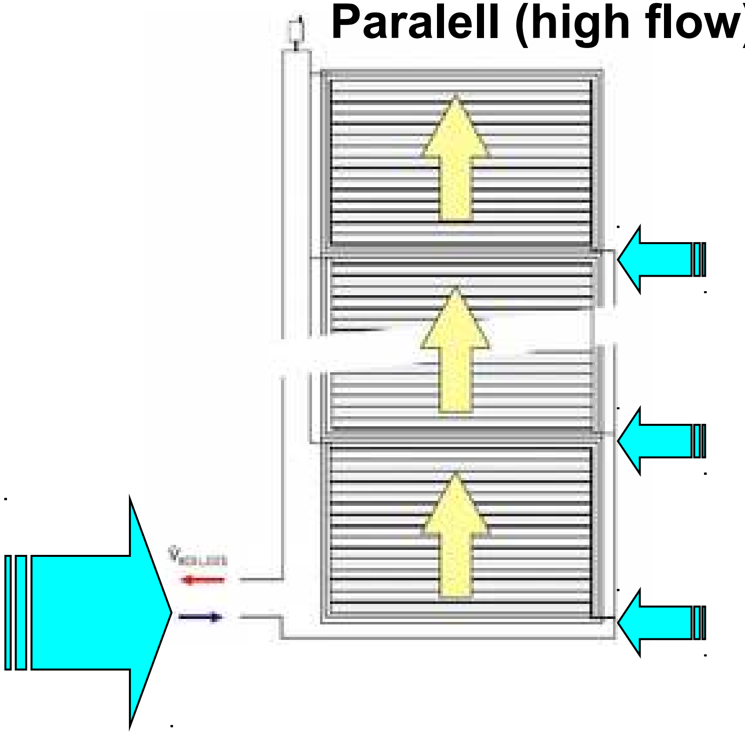
Operation strategies

Example: A_{coll} = 6 m^2 ; G =800 W/$m^{2;}$

- Series: m=10 l/h$m^{2;}$ η_{coll} =0.6

- Parallel: m=30 l/h$m^{2;}$ η_{coll} =0.75

Paralell (high flow)



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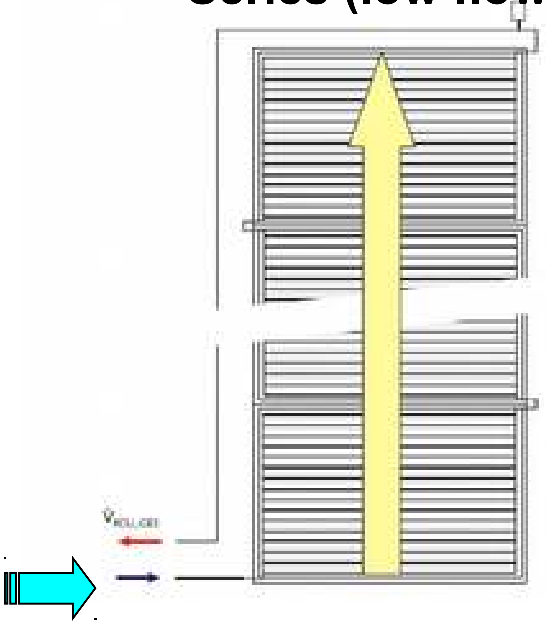
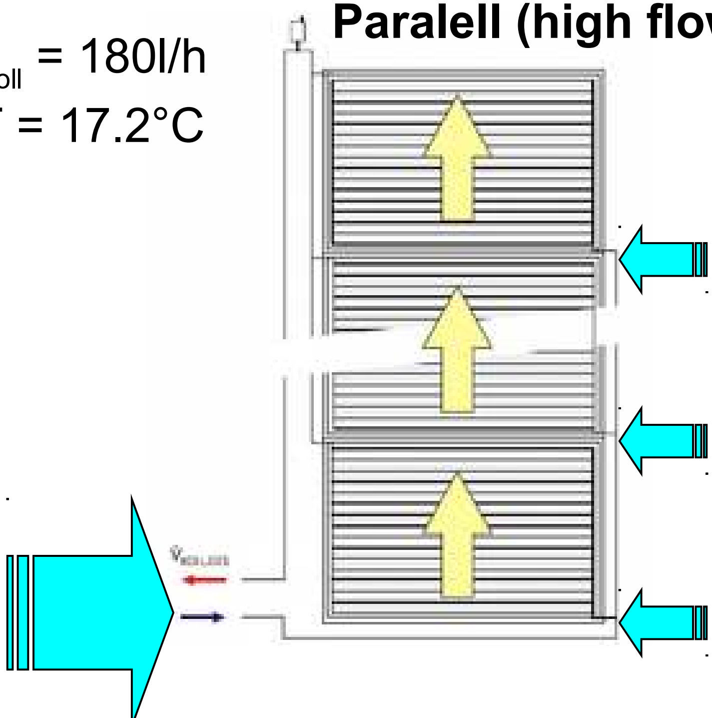


Operation strategies

Example: A_{coll} = 6 m^2 ; G =800 W/m^{2};
- Series: m=10 l/hm^2 ; η_{coll} =0.6
- Parallel: m=30 l/hm^2; η_{coll} =0.75

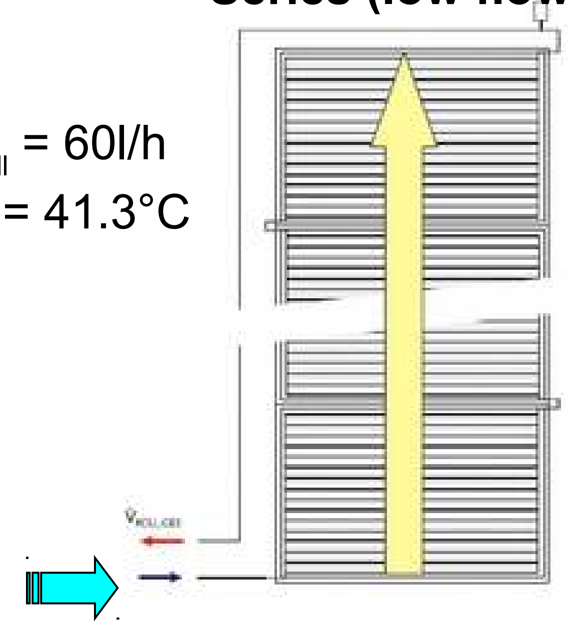
m_{coll} = 180l/h
ΔT = 17.2°C

Paralell (high flow)



Series (low flow)

m_{coll} = 60l/h
ΔT = 41.3°C



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Operation strategies

Pressure losses: hydraulic balance

$$\Delta p = R_{pipes}$$

$$R_{pipes} \quad \frac{\lambda \; \rho}{! \; A}$$

Collector area [m²]	Max pressure losses [mbar]
< 50	300
<200	600
500	800

R_{pipe}, hydraulic resistance [Pa/m]

λ, pipe friction factor (function of the flow type – turbulent, laminar)

V, volumetric flow rate [m^3/s]

D, pipe diameter [m]

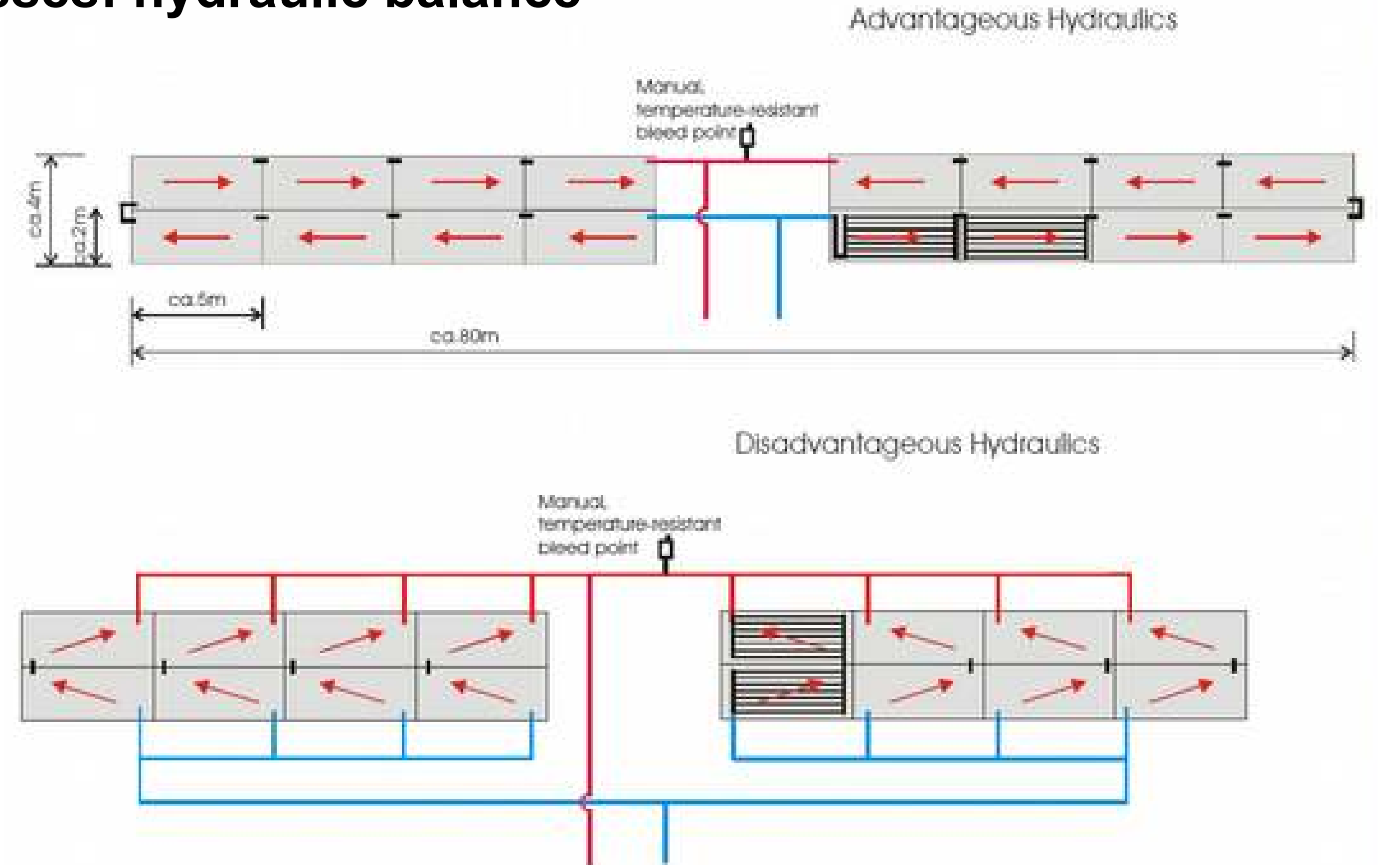
A, pipe cross section [m^2],

Operation strategies

Pressure losses: hydraulic balance

Series (low flow)

Parallel (high flow)



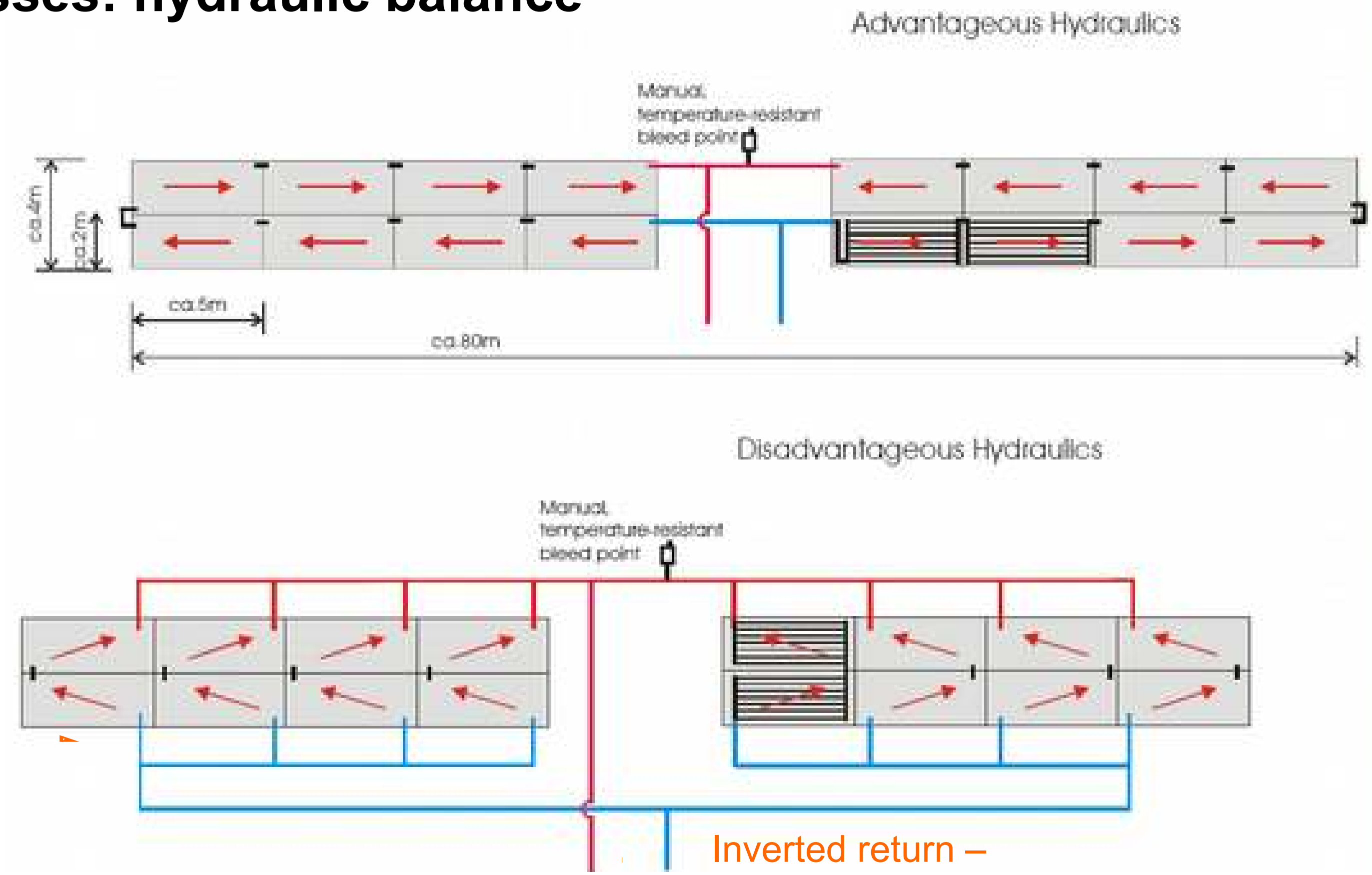
Source: AEE. 2004

Operation strategies

Pressure losses: hydraulic balance

Series (low flow)

Parallel (high flow)



Inverted return – compensate Δp in all parallel connections!

Source: AEE. 2004

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Stagnation behaviour
Critical system temperatures

- Maximum fluid temperature allowable for circulation pump:110°C

- Max. hot water temperature (storage): 95°C

- Max. temperature for propylene glycol/water mixture (degradation): 105-140°C

Stagnation behaviour

Low flow systems

Advantages

- Increased solar fractions (energy savings), 10-25%

- Reduced lime deposits in storage
- Cost reduction:
    - Smaller pipes
    - Smaller pumps
    - Reduced solar collector fluid volume

Disadvantages

- Too high temperatures
- Thermosyphoning during summer nights in collector field

Stagnation behaviour

Low flow systems

Possible Solutions to avoid overheating

- Increase collector flow in hot (summer) periods

- Collector flow at nighttime (cooling down) in hot periods

- Drain back systems

- Stop pump in hot periods -> Evaporation of solar collector fluid and expanded volume kept in expansion vessel (Stagnation).

Stagnation behaviour

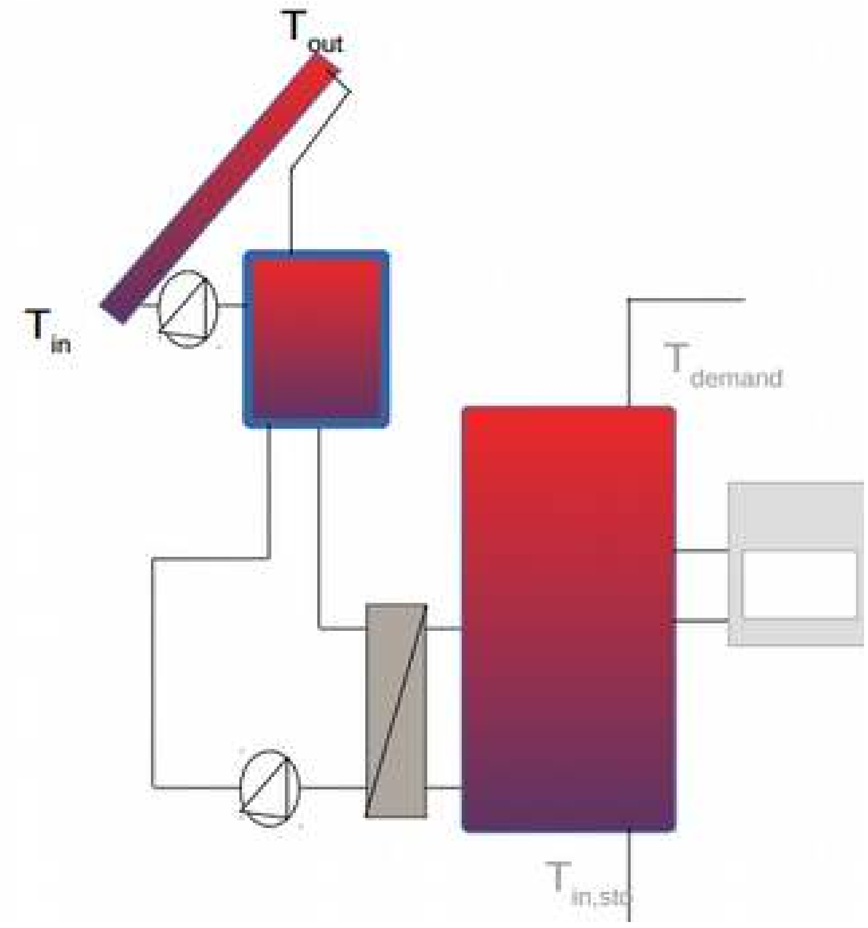
Drain back systems

- No pressurized circuit: no safety valves, expansion vessel....

- Water as heat transfer medium

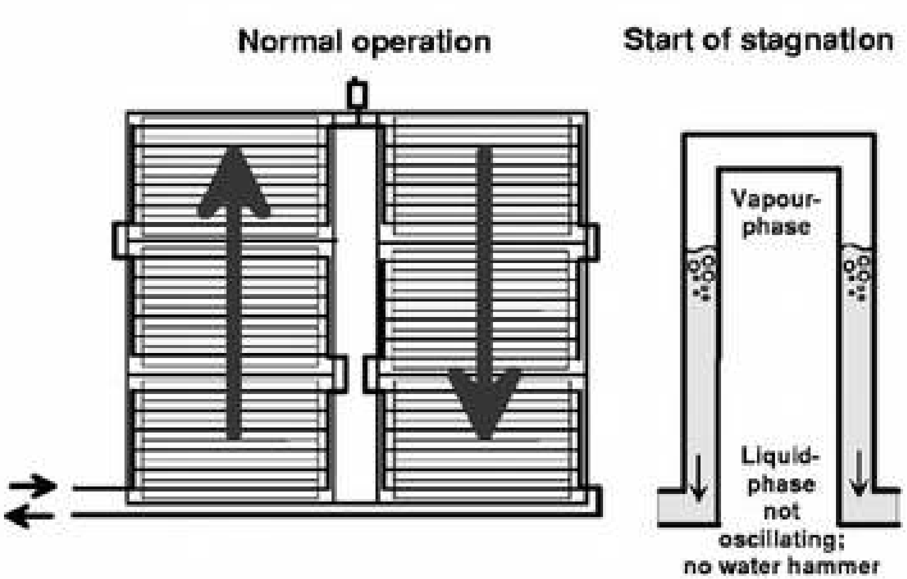
- Additional volume for drain back is needed

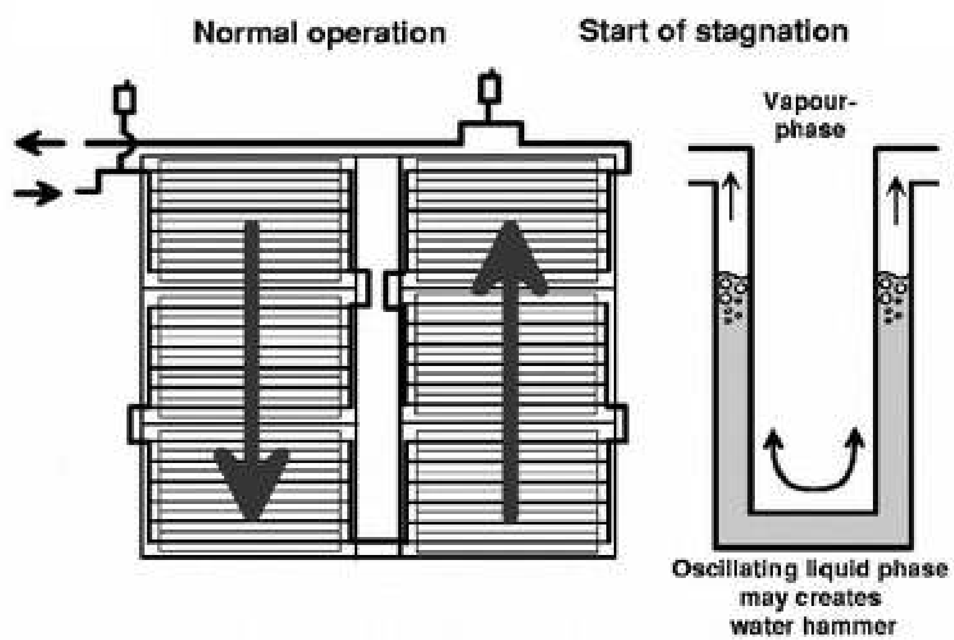
- Additional control system



Stagnation behaviour

At least one manifold at the bottom to allow liquid (not yet vaporized)
be evacuated!
→ Otherwise more liquid needs to be evaporated (500 times volume more)!





Source: AEE, 2004

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References

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