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Technical description, sizing and calculation methods of large scale combined solar systems

Gundula Tschernigg

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- Plant hydraulics of combined solar systems in large applications
  - 2 pipe system
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- Connection of large solar fields

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State of the art

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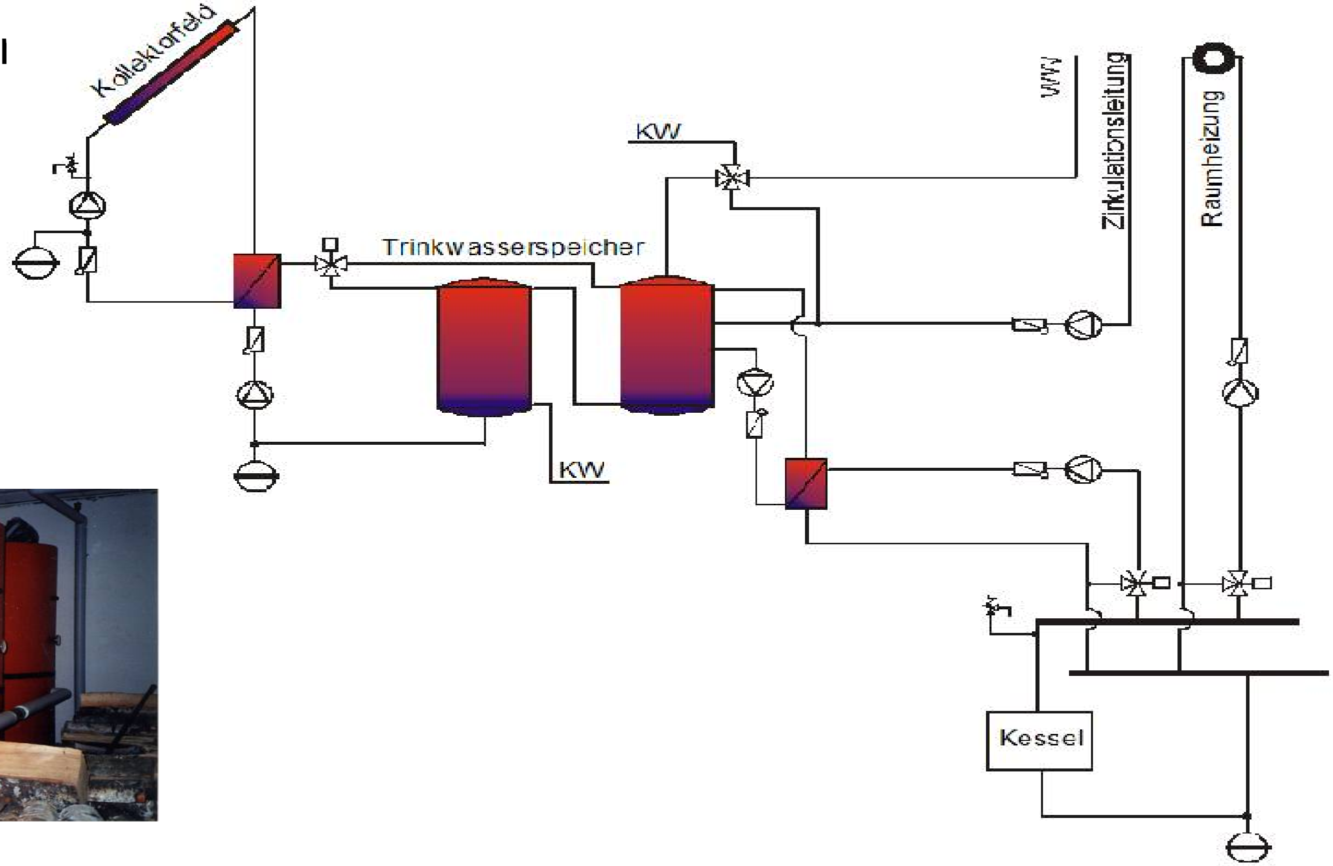
Development of combined solar systems

- Combined solar systems of the 1st generation in Austria

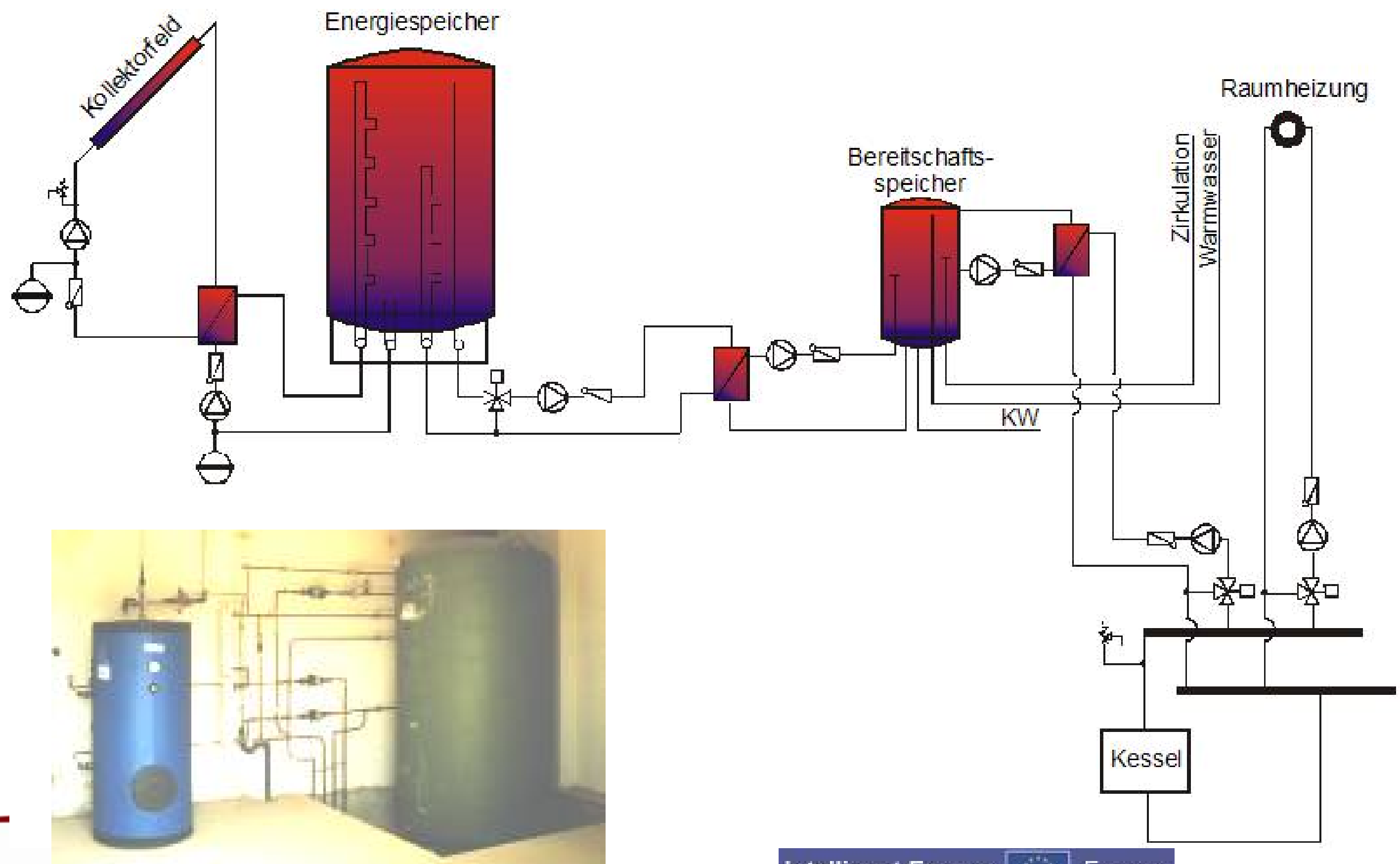
  (Started at the beginning of the 90's until the end of the 90's, at a small number of dwellii



Development of combined solar systems

- Combined solar systems of the 2nd generation in Austria

  (Started in the middle of the 90's until today)



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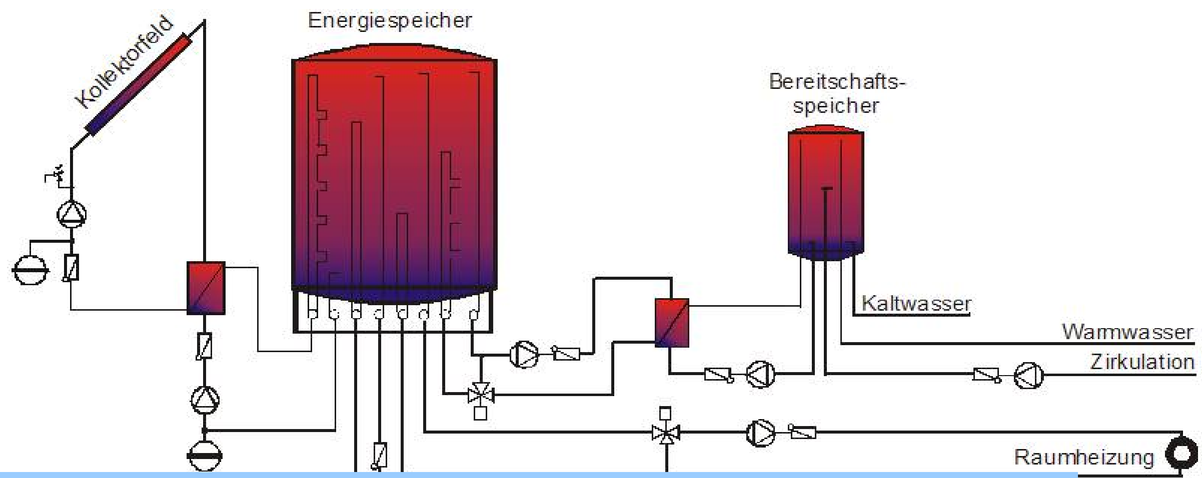
Numerous results of measurement showed….

- Solar supported distribution nets of the 1st and 2nd generation are not always working as efficiently as they should (losses!)
- Return temperatures are usually very high

Heat producer up to 20%

Heat storage up to 30% of the total heat demand

Heat distribution up to 40%



⇒ low annual system performance (often 30 to 40%)

⇒ low specific solar gains and covering degrees

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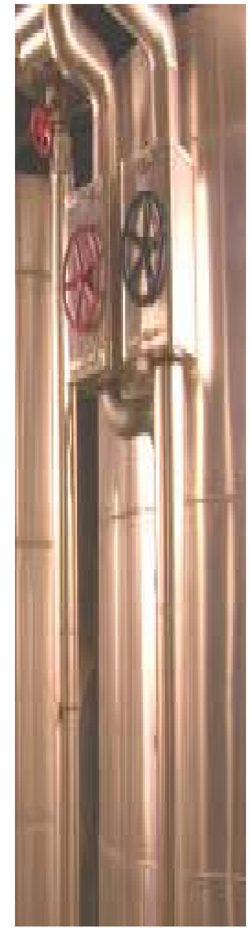
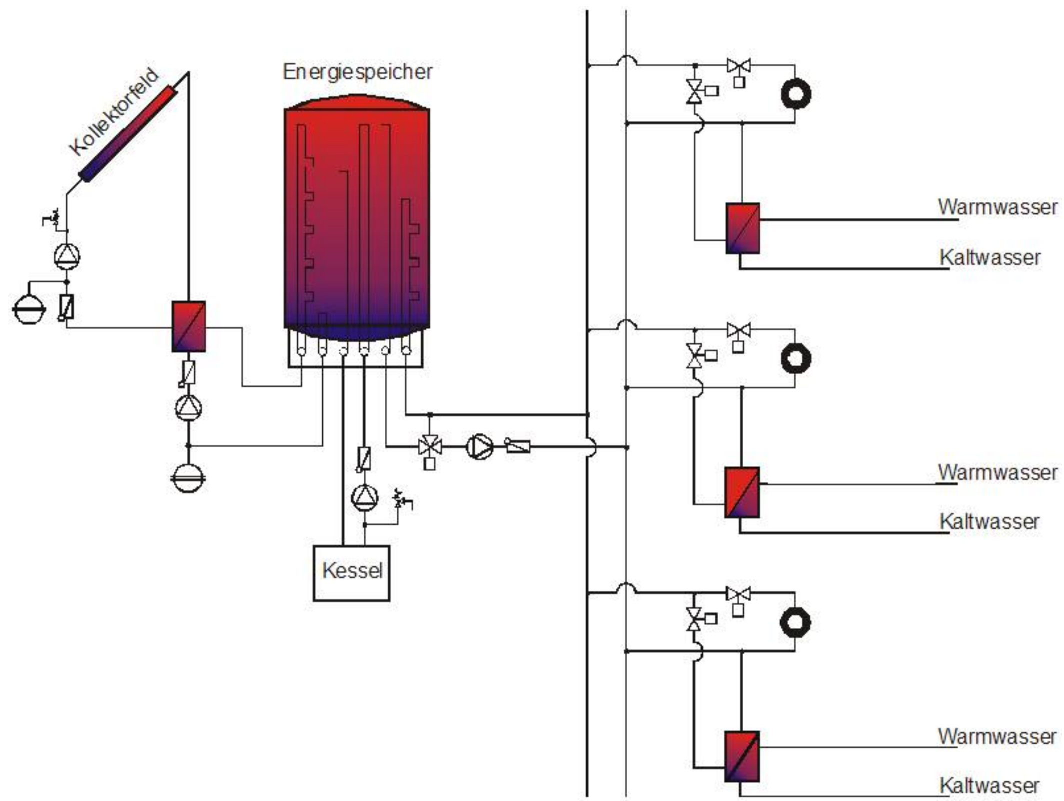
Requirements of solar supported heat distribution nets of the 3rd generation

- Holistic systems
- Adapted basic conditions for the use of solar systems
- Conceptional reduction of calorific losses
- Highest comfort for occupants
- Hygienically harmless drinking water heating up
- Economically meaningfully
- Modern control of operating
- Apart from the employment in new buildings an employment in existing buildings must be possible

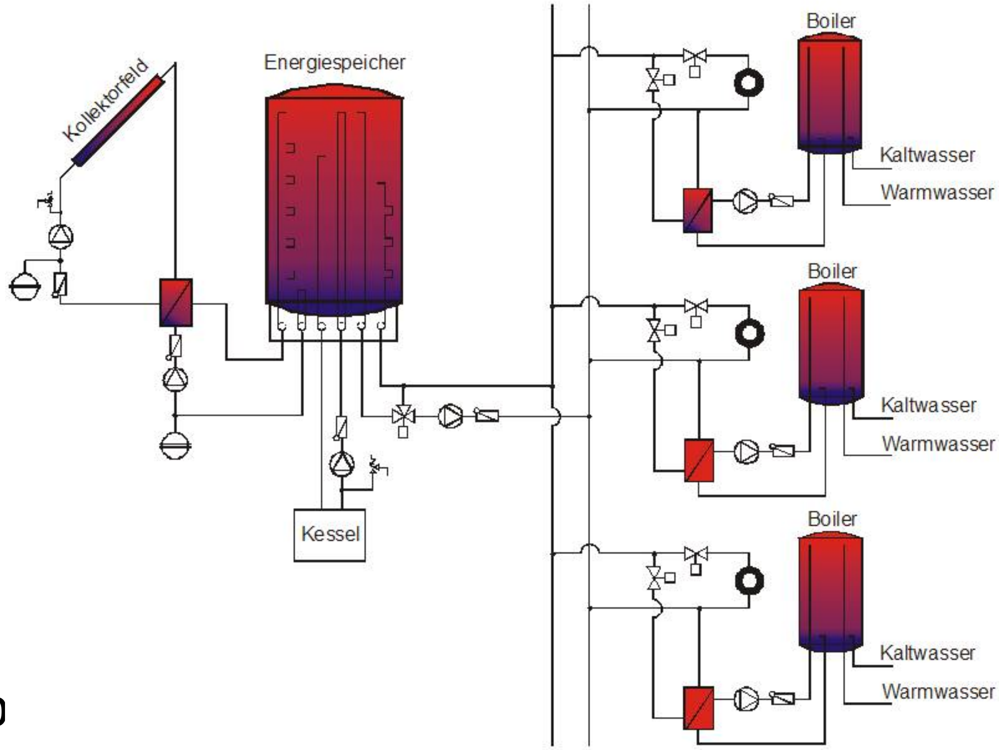


2-pipe systems can absolutely fullfill these requirements!

Plant hydraulics of combined solar systems in large applications

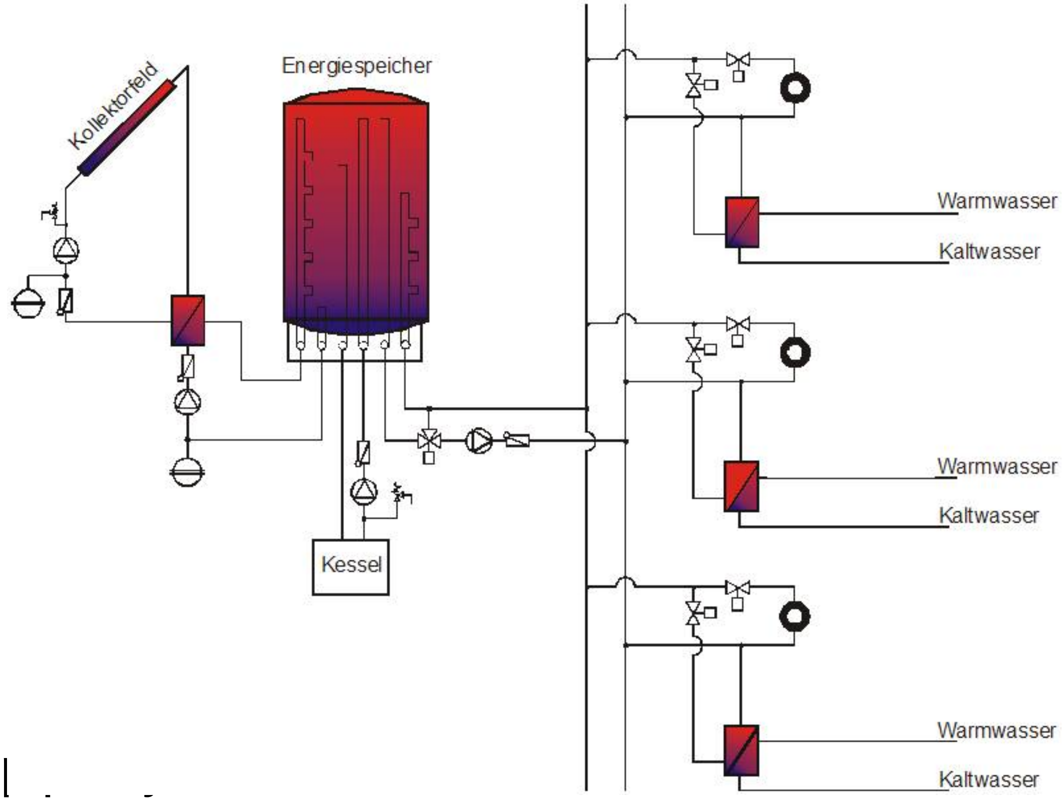


Solar supported heat systems of the 3rd generation in Austria



- Heat distribution from a 2-pip
- Hot water heating with a decentralised storage
- Meaningful employment with small energy densities

Solar supported heat systems of the 3rd generation in Austria



- Heat distribution from a 2-
- Hot water heating in a decentralised flow principle
- Meaningful employment with small and high energy densities

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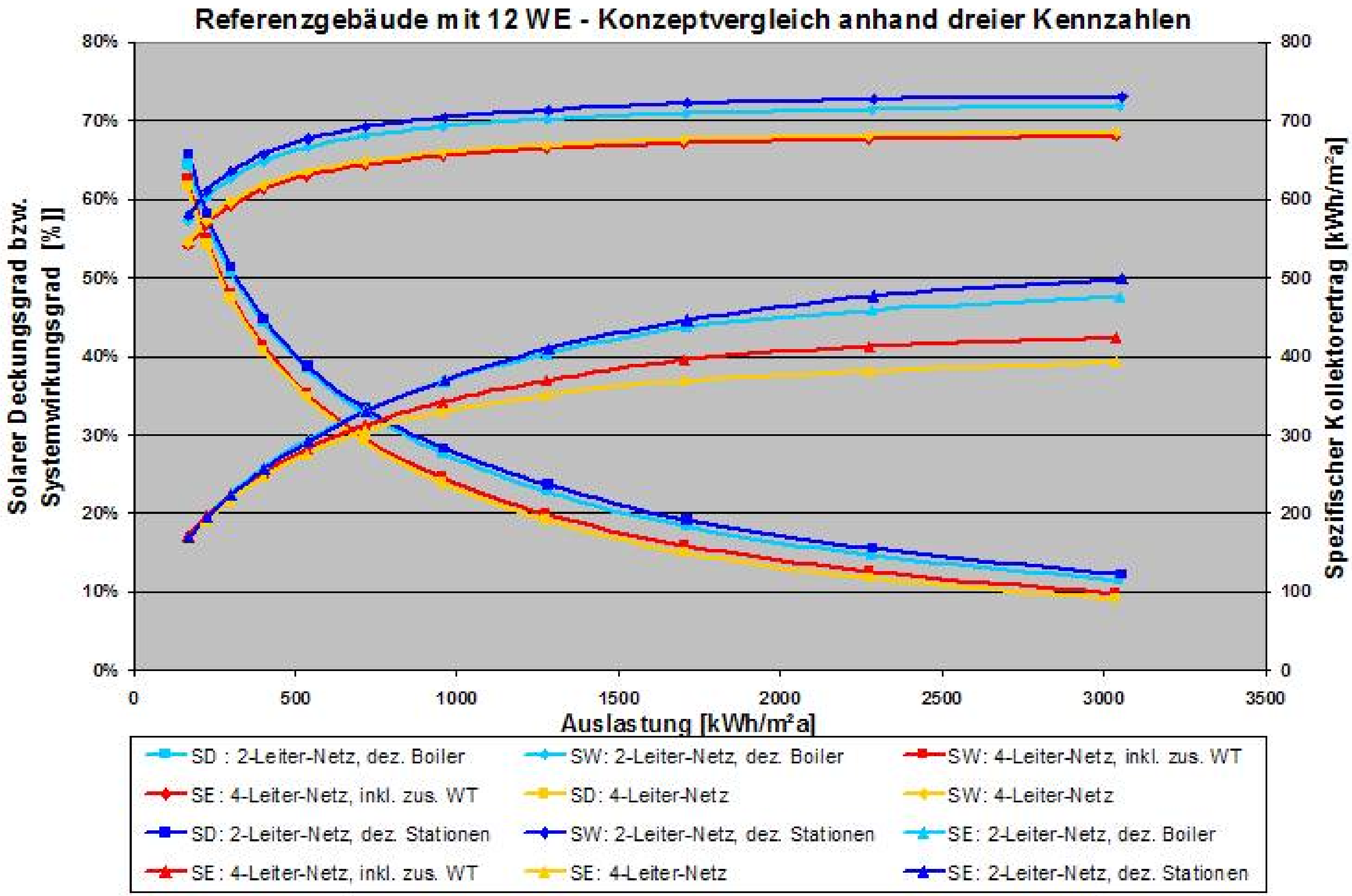
Advantages of 2-pipe systems



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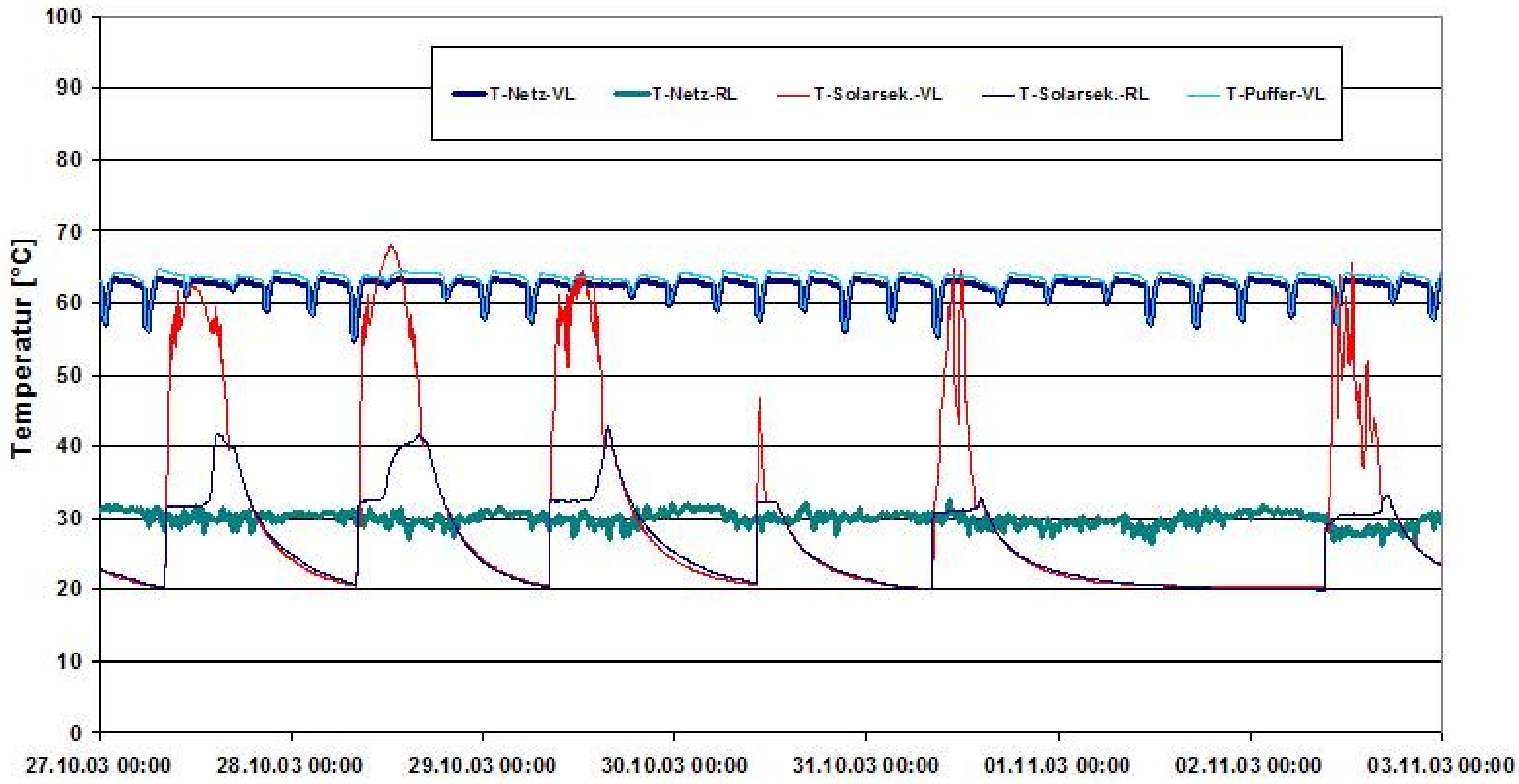
Advantages of 2-pipe systems

- Return is nearly constant at 30°C and offers best conditions for the use of solar thermal systems



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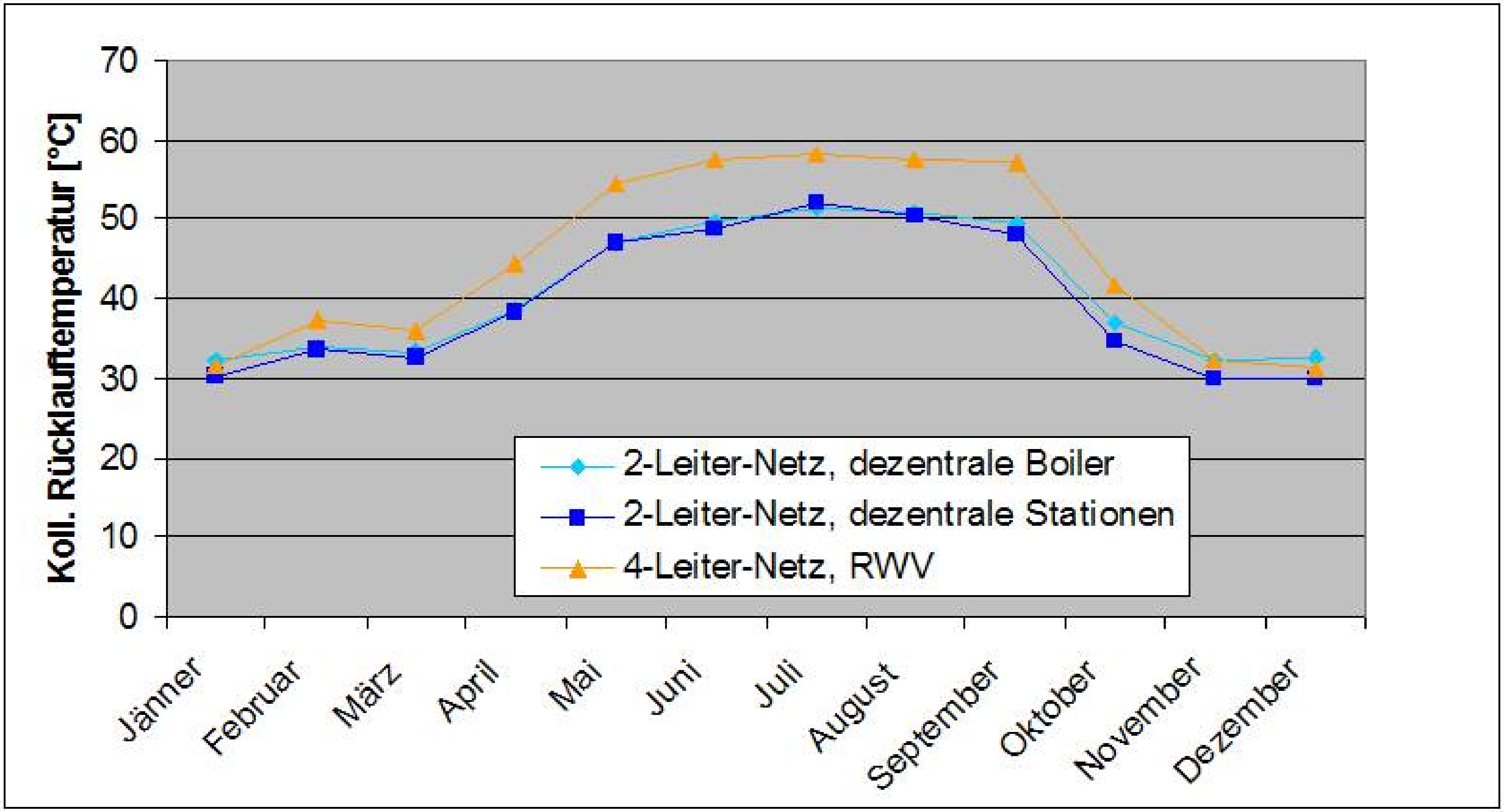
Advantages of 2-pipe systems

- Comparison of annual return temperatures of three different systems, 12 units, 20% solar covering degree



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Advantages of 2-pipe systems

- Distribution losses are set to a minimum
- Because of the system a automatically heat support can be achieved
- Extensive tests show cheaper heat prices compared to 4-pipe systems
- A gain in comfort and absolutely harmless water hygiene
- Reduction of the error frequency in industrial manufactured substations and no auxiliary energy is needed

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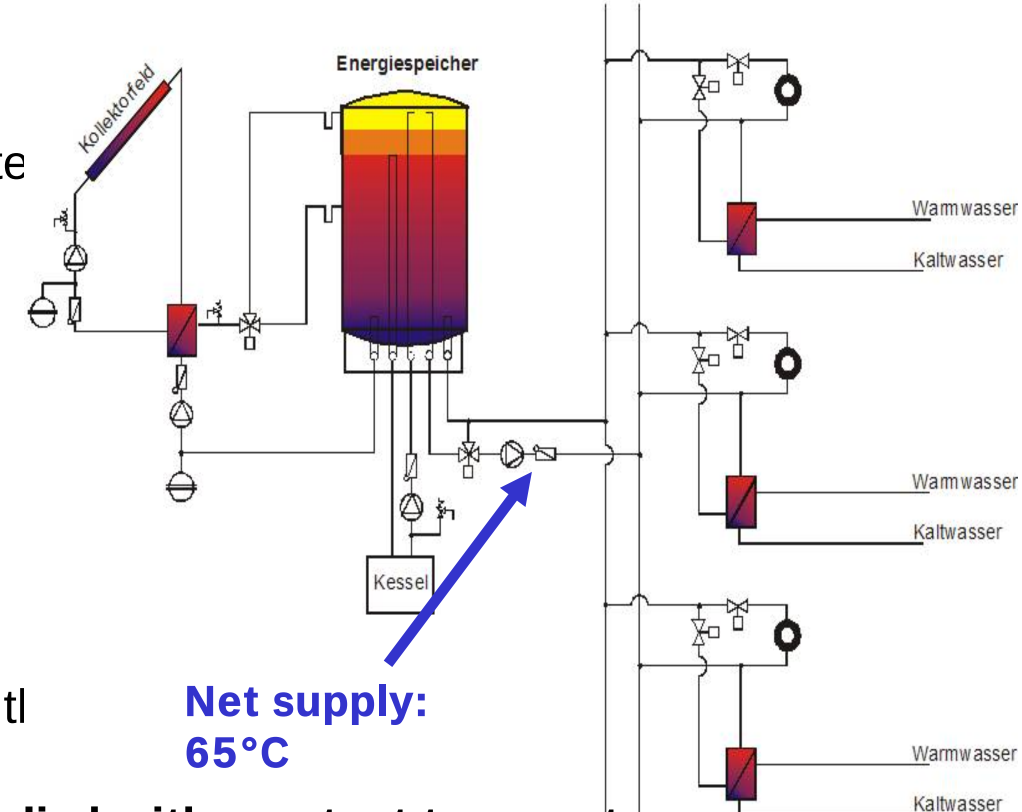
Solar supported energy distribution nets: 2-pipe systems with decentralised district heating substations

- Solar system
  - If an energy storage is integrate
    - > Operational mode: Low (Matched) Flow
- Conventional boiler:
  - Feeds into the energy storage
- Heat distribution:
  - With a pair of pipes (2 pipes)
- Hot water preparation:
  - Decentralised flow principle in tl flat



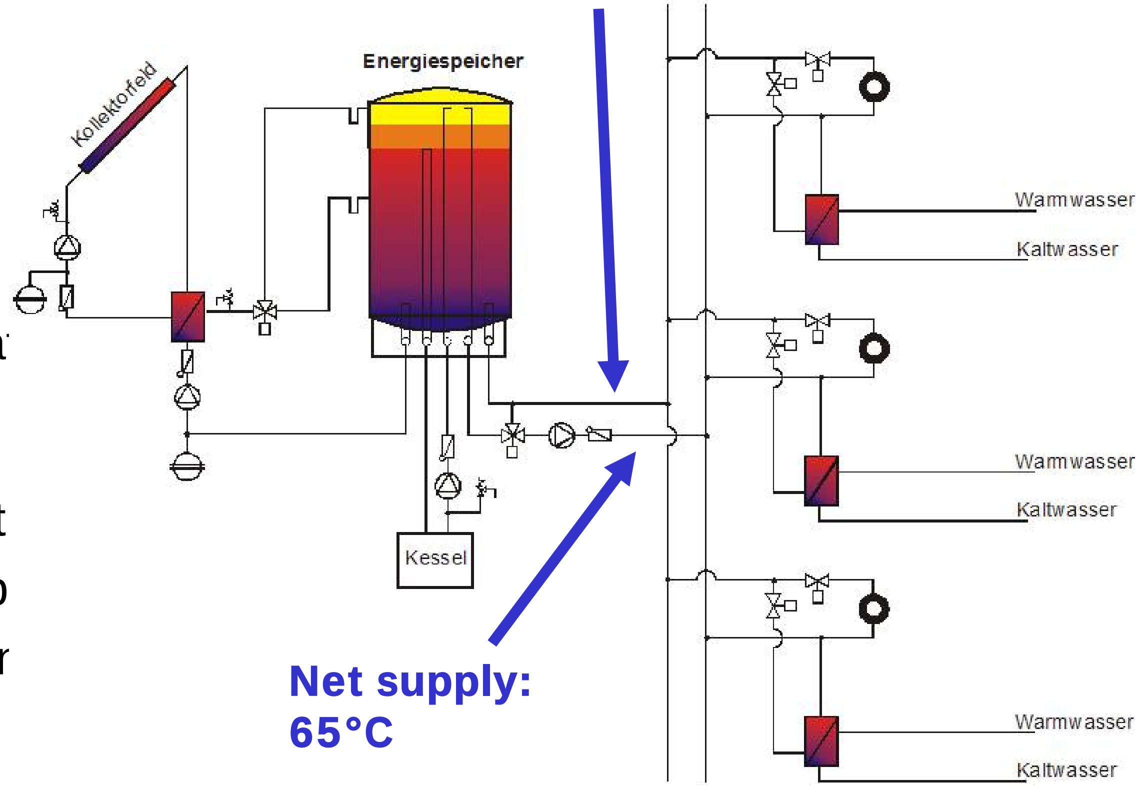
<u>Important</u>: The distribution net is supplied with constant temperatures (approximately 65 °C) during summer and winter

<u>Important</u>: the upper part of the storage needs to be kept on a minimum temperature (65°C) →security of supply

<u>Important</u>: Heater dimensioning 65/40

Solar supported energy distribution nets: 2-pipe systems with decentralised district heating substations

- Important components:
  - Mixing valve
  - Pump
  - District heating substa
- Application:
  - New building, resident buildings in compact b method, reconstructior



Advantage: The hole year low return temperatures of approximately 30°C → few distribution net losses

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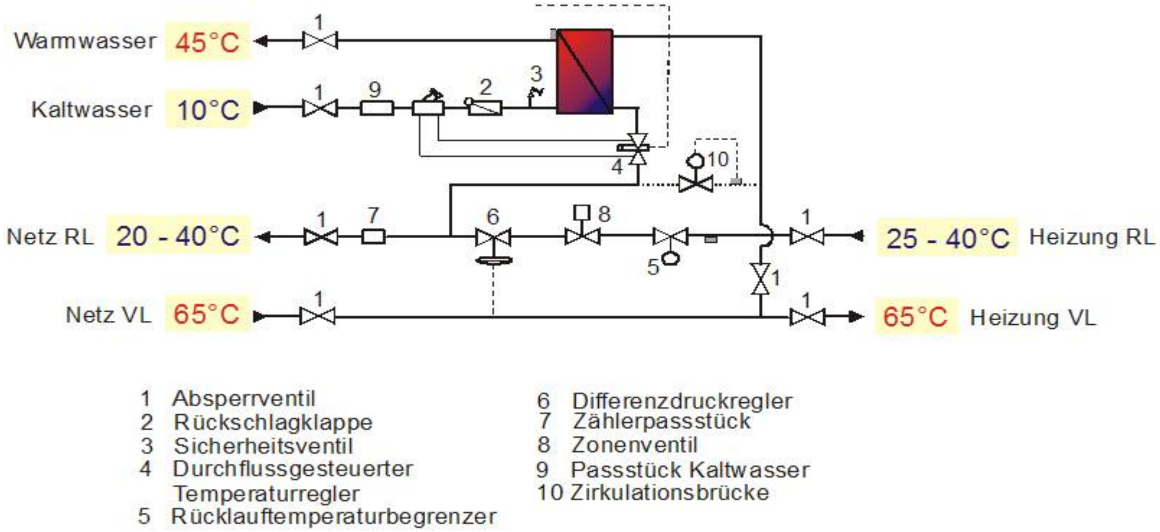
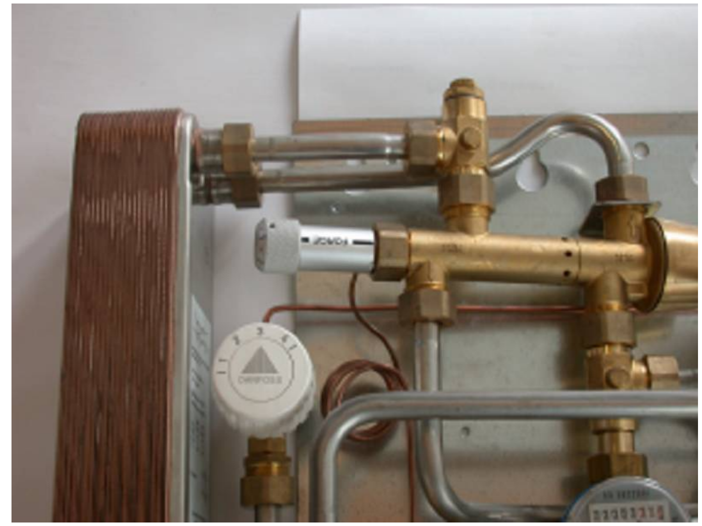
Substations

- Advantages of substations:
  - Industrial manufacturing
  - Highest quality criteria
  - No external energy requirement
  - Low investment costs
  - Individual design (finery, in the wall, different geometry)

All components for decentralized hot water heating and space heating are contained

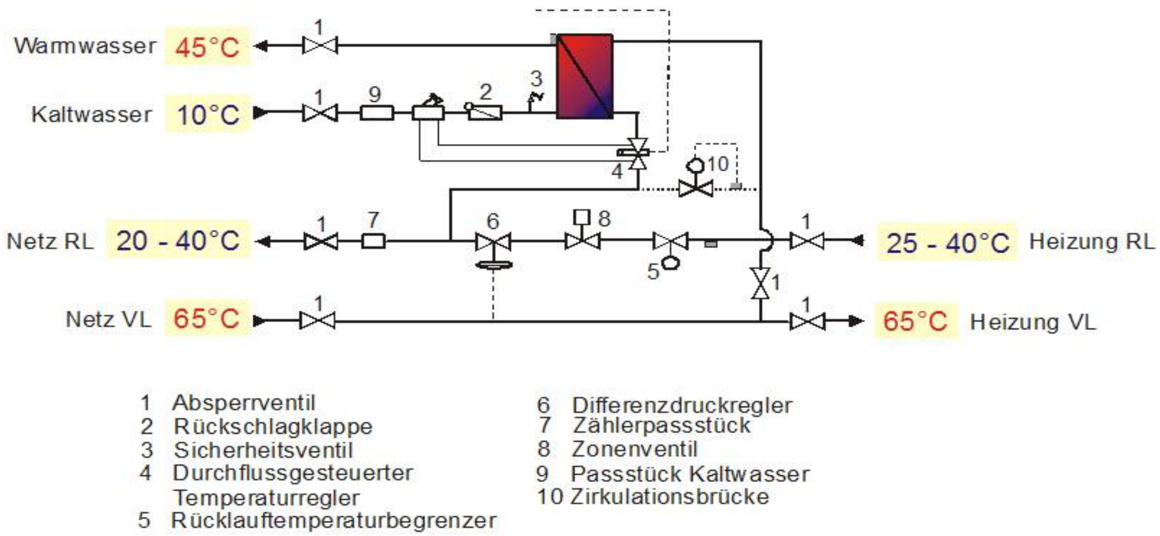
Functions of substations





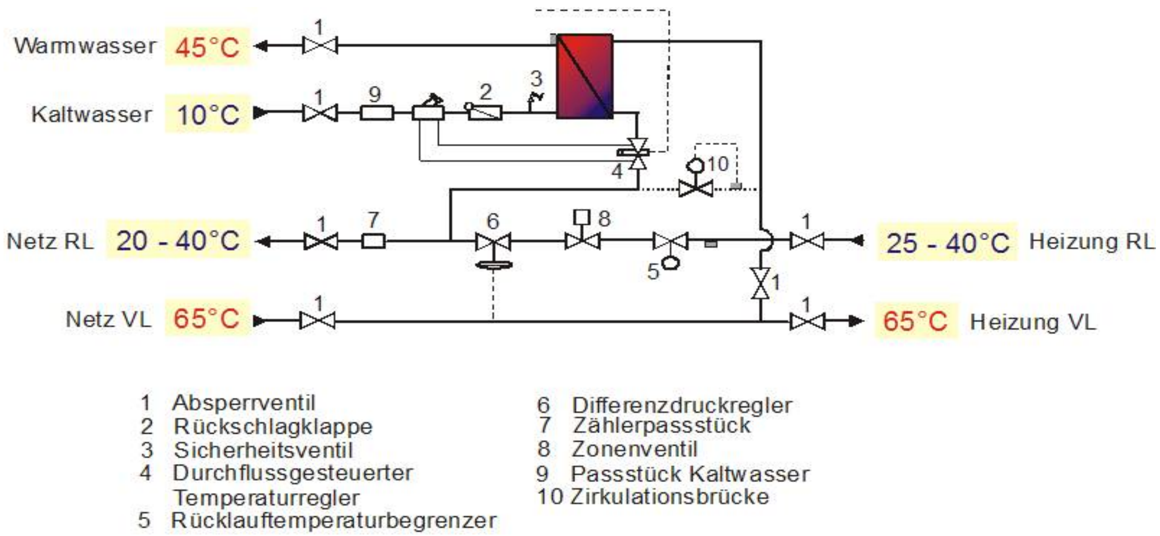
- Important components for hot water preparation:
  - Plate heat exchanger: hot water is produced when its needed
    - Small risk of legionella
    - Highest hygiene
  - Proportional controller: regulates the hot water temperature and adapts the flow rate to the hot water consumption
    - No calcification because of the temperature limit
  - Circulation bridge: constant return temperature and comfort

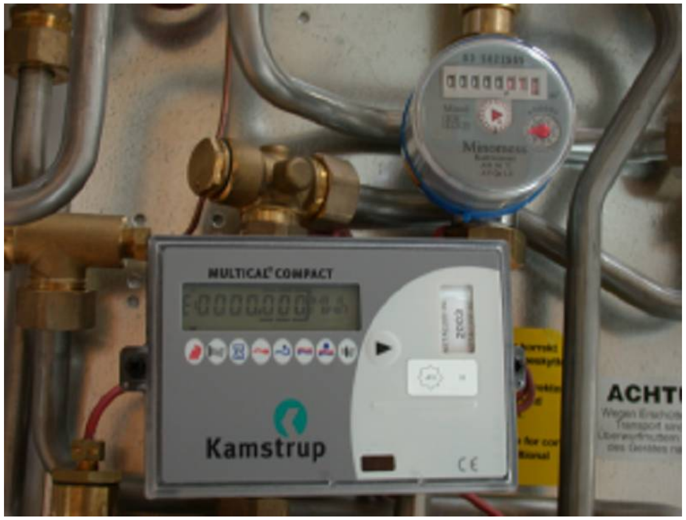
Functions of substations



- Important components for heat preparation:
  - Differential pressure regulating valve: hot water is produced when its needed
    - > Provide a constant mass flow in individual units of the dwellings
    - > Inappropriate adjusting can be prevented by fixed pre-setting
  - Return controller: are used in the return and fixed on 40°C
  - Thermostatic valve: control the temperature in the units

Measuring devices of substations





- Important components for measuring the demand:
  - Water meter
    - measures the total amount of hot water used in a unit
  - Heat meter
    - measures the total amount of hot water and heat used in a unit
  - Can be read out manually or via a bus-sytem

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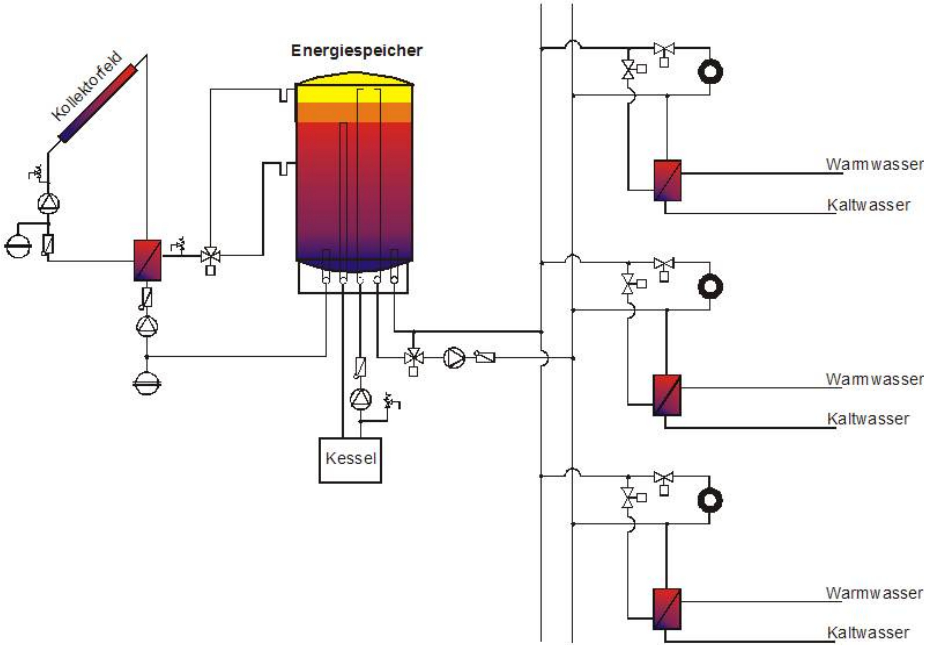
Distribution net

- Characteristics of 2-pipe systems with substations
  - Strongly varying flow due to the decentralized hot water preparation
  - Constant flow temperatures over an entire operational year



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Distribution net

- Volume flow
  - Between summer and winter varying volume, usage of two pumps:
    - > Pump for summer
    - > Pump for winter
    - > Reduction of the needed electricity
  - Ascending pipe needs to be regulated correctly, usage of a differential pressure regulating valve
  - Mixing valve: temperatures up to 95 °C during summer mean highest requirements on the mixing valve

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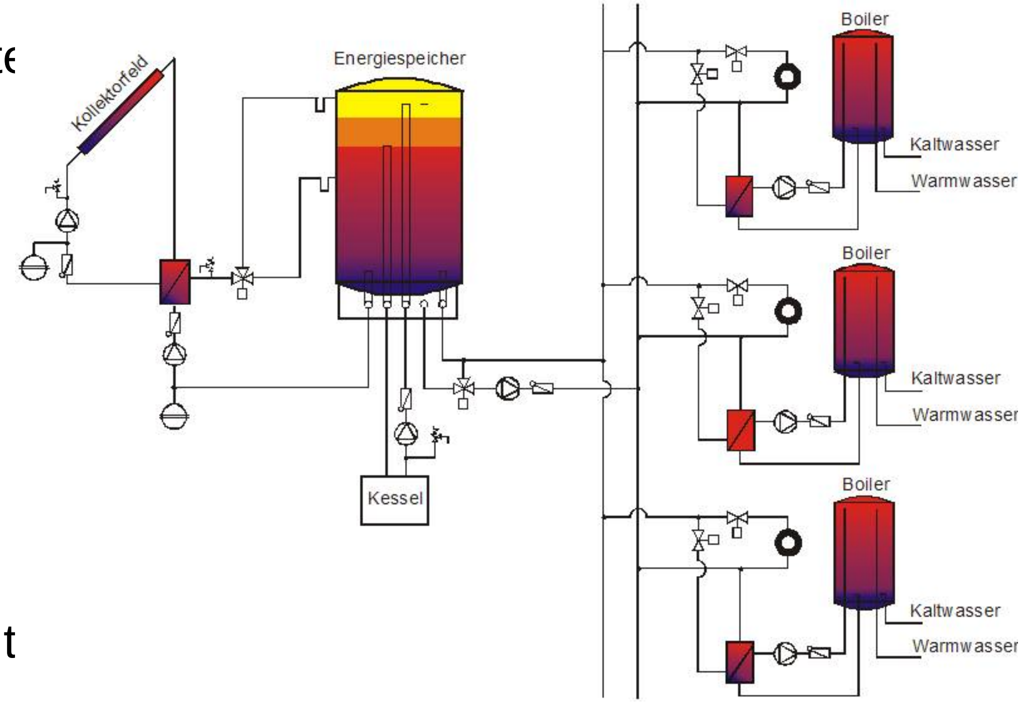
Solar supported energy nets: 2-pipe systems with decentralised hot water storage

- Solar system
  - If an energy storage is integrate
    - Operational mode: Low (Matched) Flow
- Conventional boiler:
  - Feeds into the energy storage
- Heat distribution:
  - With a pair of pipes (2 pipes)
- Hot water preparation:
  - Decentralised flow principle in t



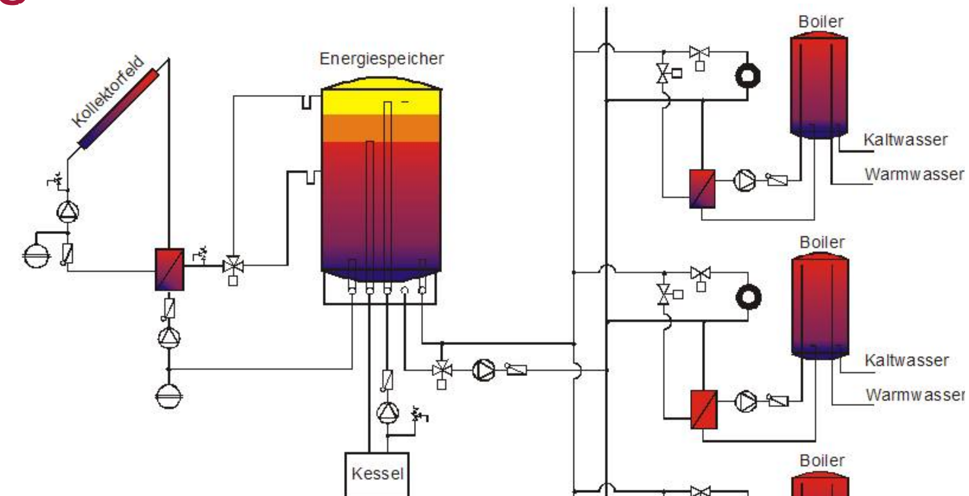
Important: The distribution net is used 22h to 23h for the heat supply and just 1h to load the boiler

Important: the upper part of the storage needs to be kept on a minimum temperature (65°C) →security of supply

Important: Heater dimensioning 65/40

Solar supported energy nets: 2-pipe systems with decentralised hot water storage

- Important components:
  - Mixing valve
  - Pump
  - Decentralized load substations
- Application:
  - New building, residential buildings ir compact building method, reconstru (already existing devices can sometimes be further used)



Advantage: Low return temperatures from the beginning of the boiler load

Advantage: Distribution losses are reduced during summer (pipes are heated up just once/day)

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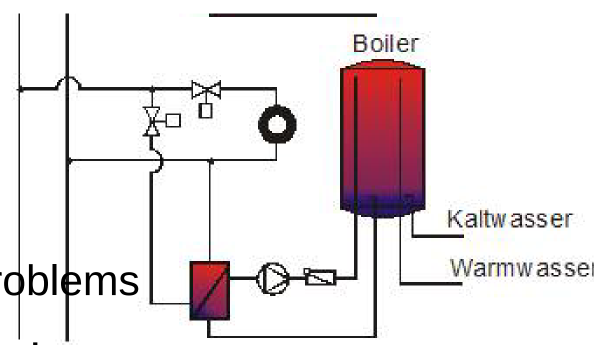
Hot water preparation / Space heat supply

- Hot water storage:
  - Dimensioning on a daily use of 150-200 litres
  - Placement: storage, toilet, bath, possibly cellars
    - > Importantly: short ways to the taps
- Loading of the hot water storage:
  - external heat exchangers
    - > Deep return temperatures can be obtained
    - > Importantly: hydraulic uncoupling
- Loading:
  - Low loads, irradiation-strong time periods (at noon), load duration (1h), enough volume of hot water in the storage
- Space heat supply:
  - Dimensioning of radiators on a max. 65/40°C
  - Usage of low temperature systems possible without any problems
- During the season without heating the system is just used to heat up hot water



Summary

2 pipe systems with substations

Application:
- new buildings
- reconstruction
- dwellings and terraced houses

Advantages:
- low investment costs
- hygienical hot water preparation
- compact
- low required space
- low distribution losses
- amount of hot water is unlimited
- comfort

Disadvantages:
- pump is used the whole year
- operating current

2 pipe systems with decentralized hot water storage

Application:
- new buildings
- residential buildings in compact building method
- reconstruction

Advantages:
- heats up the distribution net just once a day (low distribution losses)
- hygienical hot water preparation
- Possible usage of already existing devices

Disadvantages:
- higher investment cost because of the decentraized hot water storage
- more space is needed

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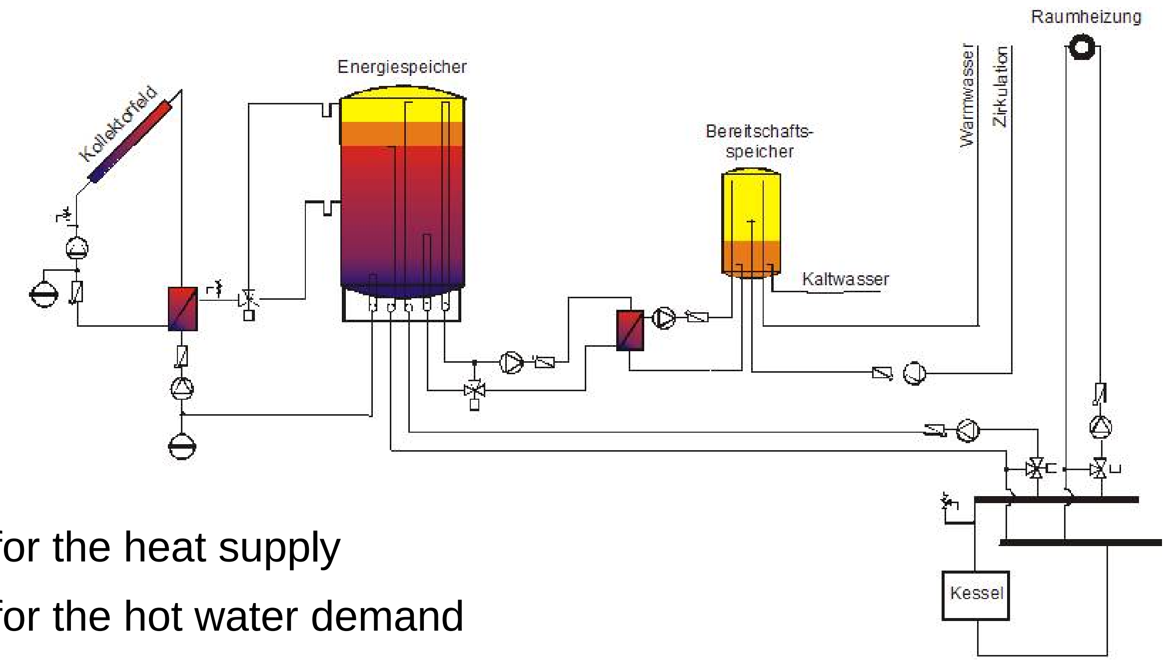
Solar supported 4-pipe systems

- Application
  - Reconstruction of buildings with already existing central hot water distribution

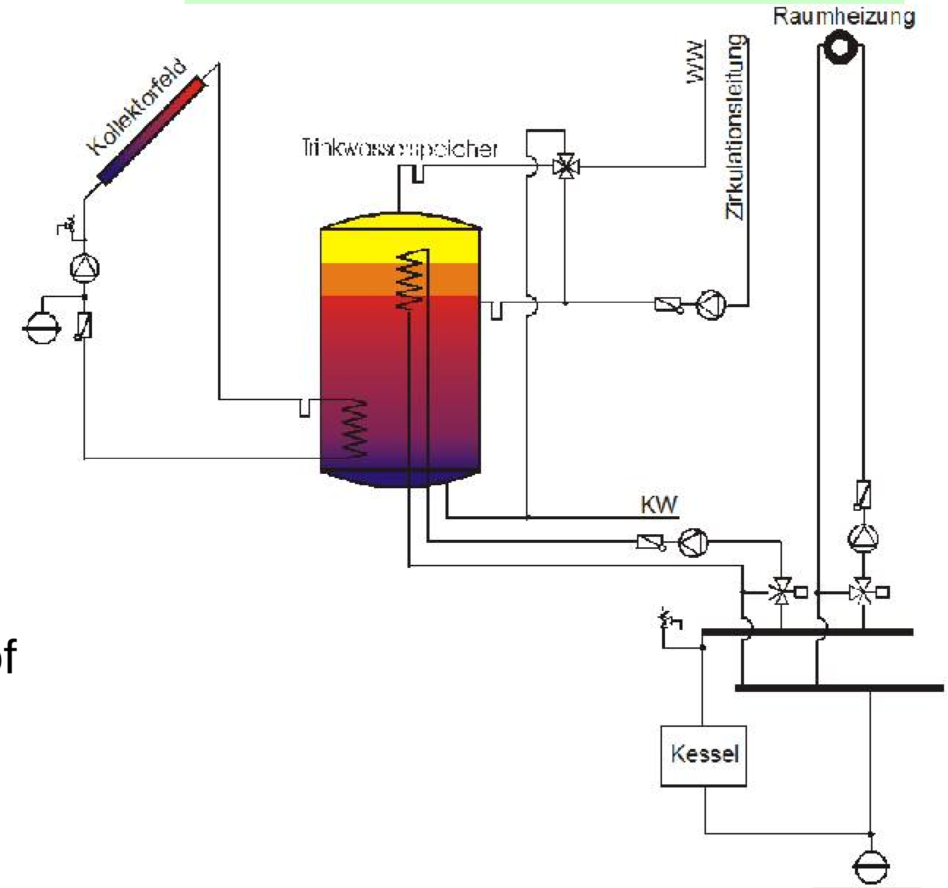


- Functions:
  - One pair of pipes for the heat supply
  - One pair of pipes for the hot water demand
- Separation in:
  - Systems with one storage (max. 10 units)
  - Systems with two storages (larger dwellings)

4-pipe system with hot water storage

- Application: for a maximum of 10 flats
- Hot water storage
  - Cost-intensive by interior coating or high-grade steel
  - high requirements on water hygiene
- Integration of the solar system
  - Internal heat exchanger
  - Plate heat exchanger
- Temperature delimitation of the storage on 60°C: Calcifying danger of the external heat exchanger

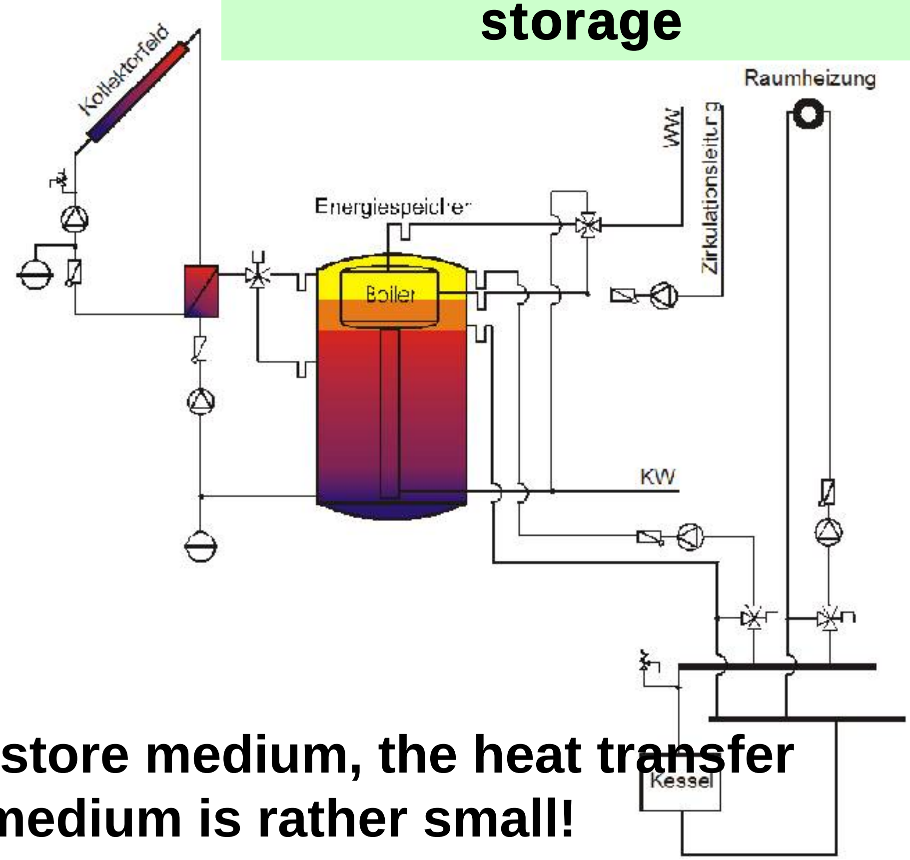
Systeme with hot water storage



4-pipe system with one steel storage

- Steel storage
  - Is used as energy storage
- Integration of the solar system
  - Internal heat exchanger
  - Plate heat exchanger
- Hot water preparation
  - Internal water storage
  - Internal tube heat exchanger

Systeme with steel storage

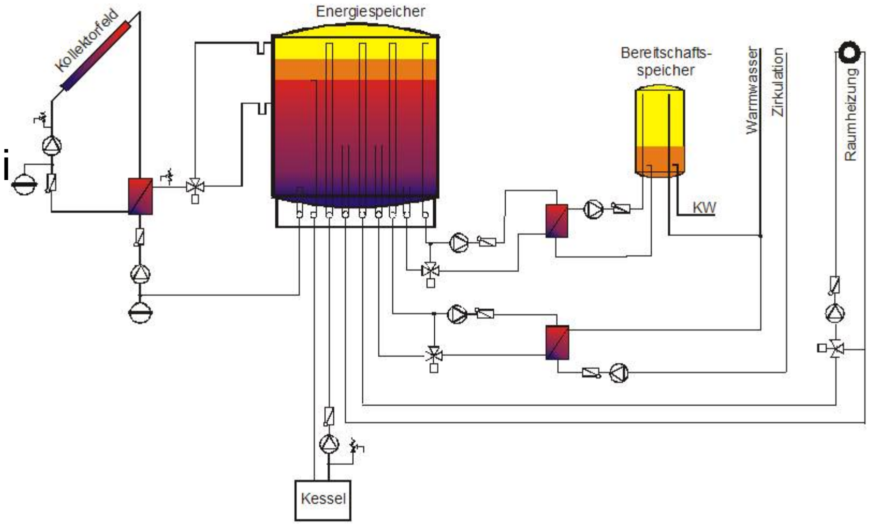


Because of the standing energy store medium, the heat transfer between hot water and storage medium is rather small!

Supply security is ensured by the provision of a large amount of hot water and large boiler or tube heat exchanger area

4-pipe system with two-storage systems

- Application
  - For large hot water consumption > 10 uni



- Layout
  - Central energy storage (steel), Central hot water storage to cover peak loads
  - Conventional heat generator feeds exclusive in the energy storage
  - Energy storage supplies the space heating

Increased solar results up to 10% compared to solar systems for the hot water preparation -> should be included in heat heating system!

Sometimes old storages can be used!

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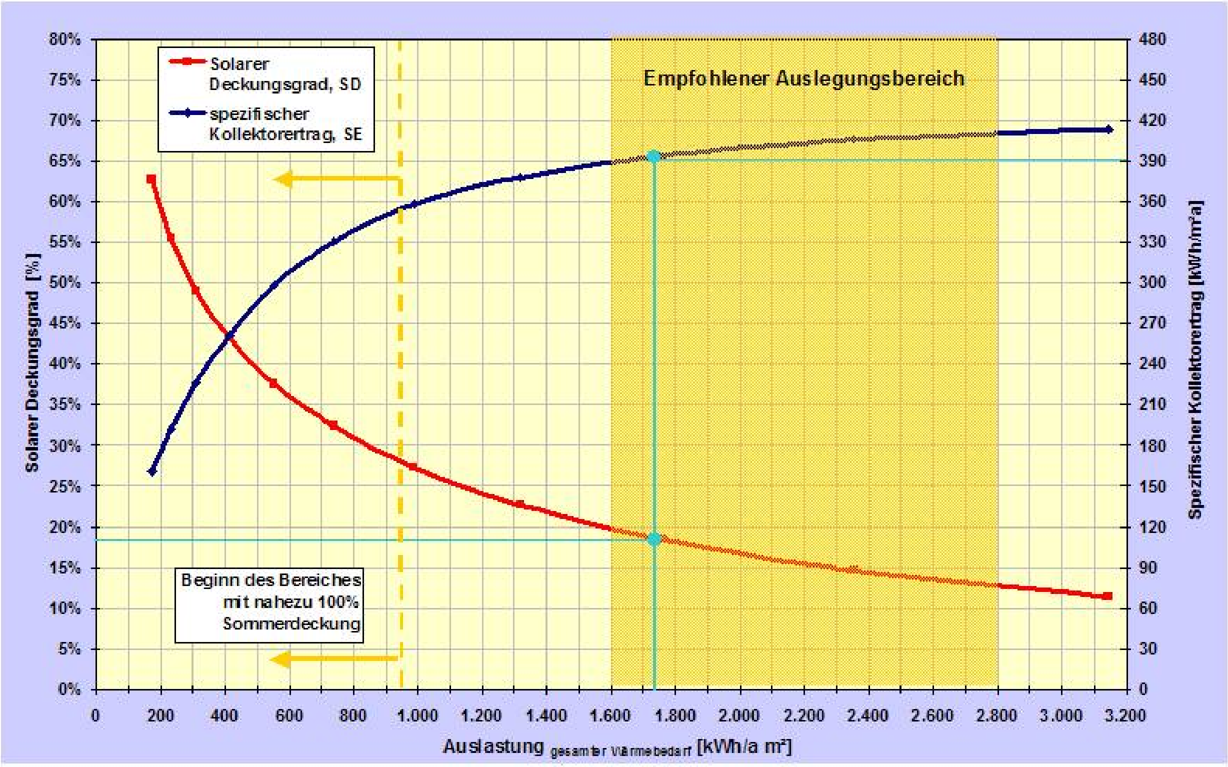
Dimensioning of combined systems in dwellings



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Dimensioning of combined systems in dwellings

- Dimensioning of the characteristics:
  - collector surface [m ²]
  - Storage volume [litre]
- Are considered:
  - Energetic and economical aspects
  - Dimensioning with easy understandable nomographs

- Distinction between:
  - Dimensioning nomographs for combined systems / hot water systems
- Possible results:
  - Gross collector surface [m ²]
  - Solar storage volume [litre]
  - Solar covering degree at the total energy need [%]
- Conditions for the dimensioning; knowledge of:
  - Annual hot water and heat demand
  - Introduce an auxiliary characteristic number: loa

$$load = \frac{total\ demand\ of\ heat\ and\ hot\ water}{net\ collecot\ or\ area} = \frac{kWh/year}{m^2}$$

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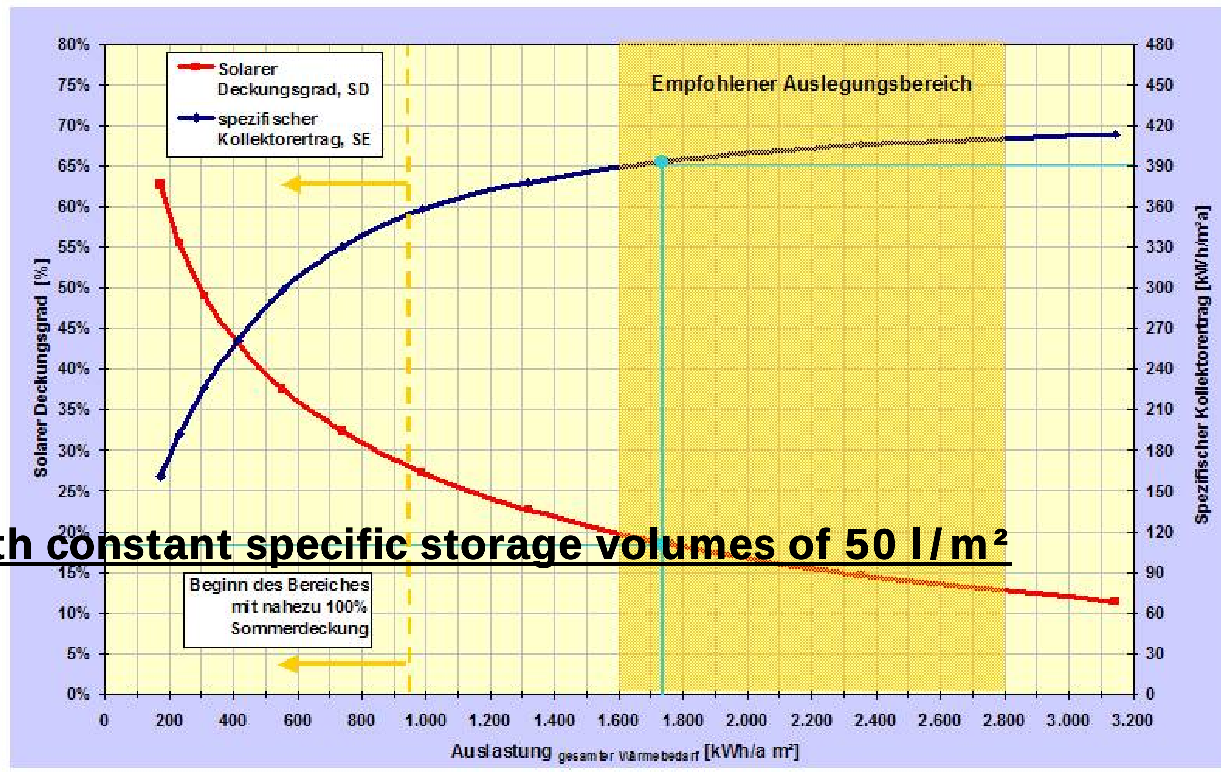
Distinction of the dimensioning strategy

- Most important factors on investment and solar fraction – storage and collector area
- 1. Dimensioning in the cost/use optimum
  - Recommended collector area with a solar fraction of 12% appr. 0,9m²/person - 20% appr. 1,4m²/person
- 2. Dimensioning on almost 100% summer covering
  - Recommended collector area with a solar fraction of 28% appr. 2m²/person
- Fixed surface



The nomograph works with constant specific storage volumes of 50 l / m² gross collector area!

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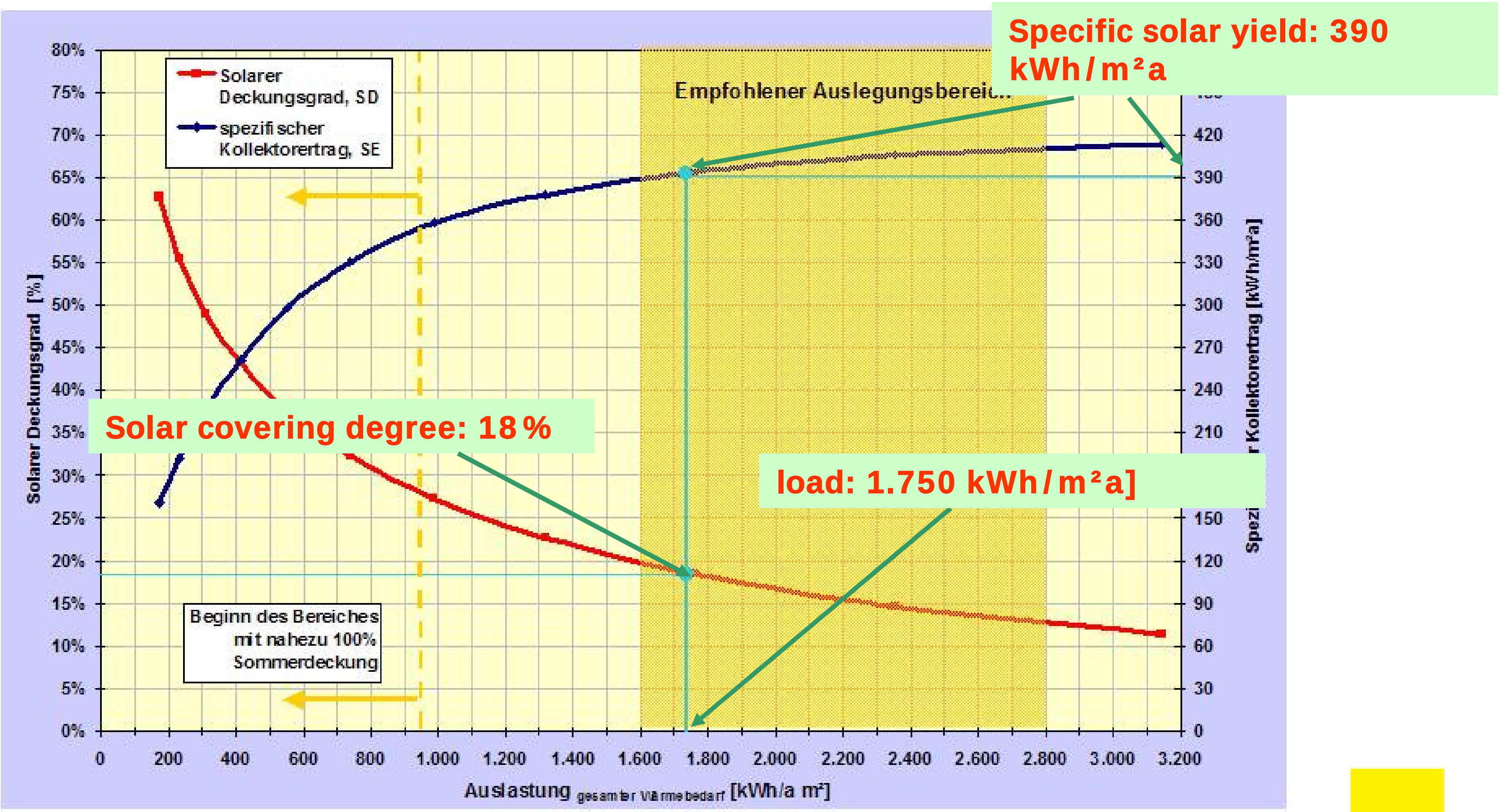
Dimensioning example

Residential building with 21 accommodation units
Heat demand: appr. 120.000 kWh/a
Hot water demand: appr. 32.000 kWh/a
Complete demand: 152.000 kWh/a
Desired solar covering degree for the energy demand: appr. 18 %

Wanted data:

Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]



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Complete demand: 152.000 kWh/a
Desired solar covering degree for the energy demand: appr. 18 %

Wanted data:
Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]

- **1.step: determination of the load -> 1.750 kWh/m²a**
- **2.step: determination of the collector area**

$$collector\,area = \frac{total\,demand\,of\,heat\,and\,hot\,water\,[kWh/a]}{load\,[kWh/m^2.a]} = area\,[m^2]$$

$$collector\ area = \frac{152.000\,kWh/a}{1.750\,kWh/a} = 87\,m^2$$

- **3. Step: storage volume: 87m²x50l/m² = 4.350l**
- **4. Step: annual solar yield**

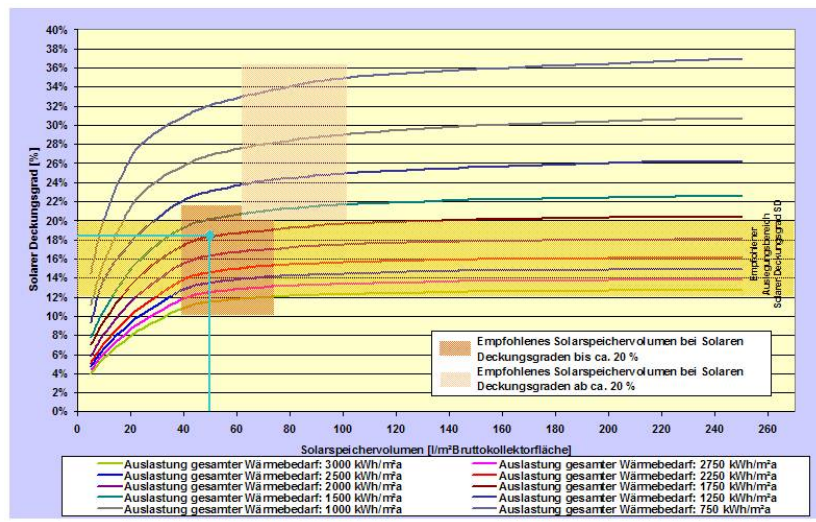
$$solar\ yield = specific\ solar\ yield\ [kWh/m^2.a] * gross\ collector\ area\ [m^2] = solar\ yield\ [kWh/a]$$

$$solar\ yield = 390\ [\mathrm{kWh/m^2a}]\ \mathrm{x}\ 87\ [\mathrm{m^2}] = 33.930\ \mathrm{kWh/a}$$

The previous dimensioning nomograph works with constant specific solar storage volumes [50 Liter/m ² brutto collector area]

Valid with dimensioning in cost / use optimum (solar covering degrees between 12 % and 20 %)

If you want to dimension solar systems with higher solar covering degrees, you need use the following dimensioning nomograph!



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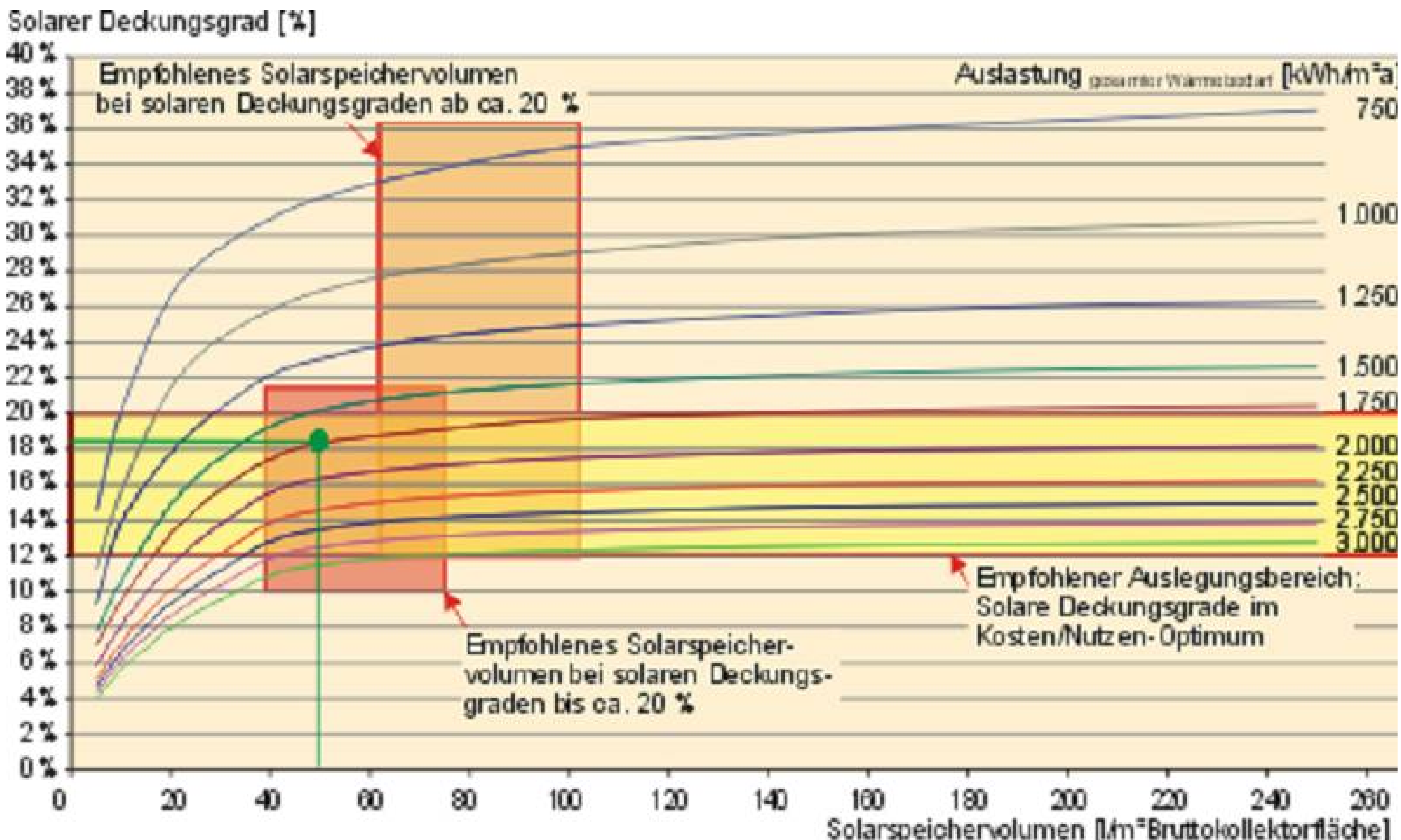
Specific dimensioning nomograph - suitably even for higher solar covering degrees



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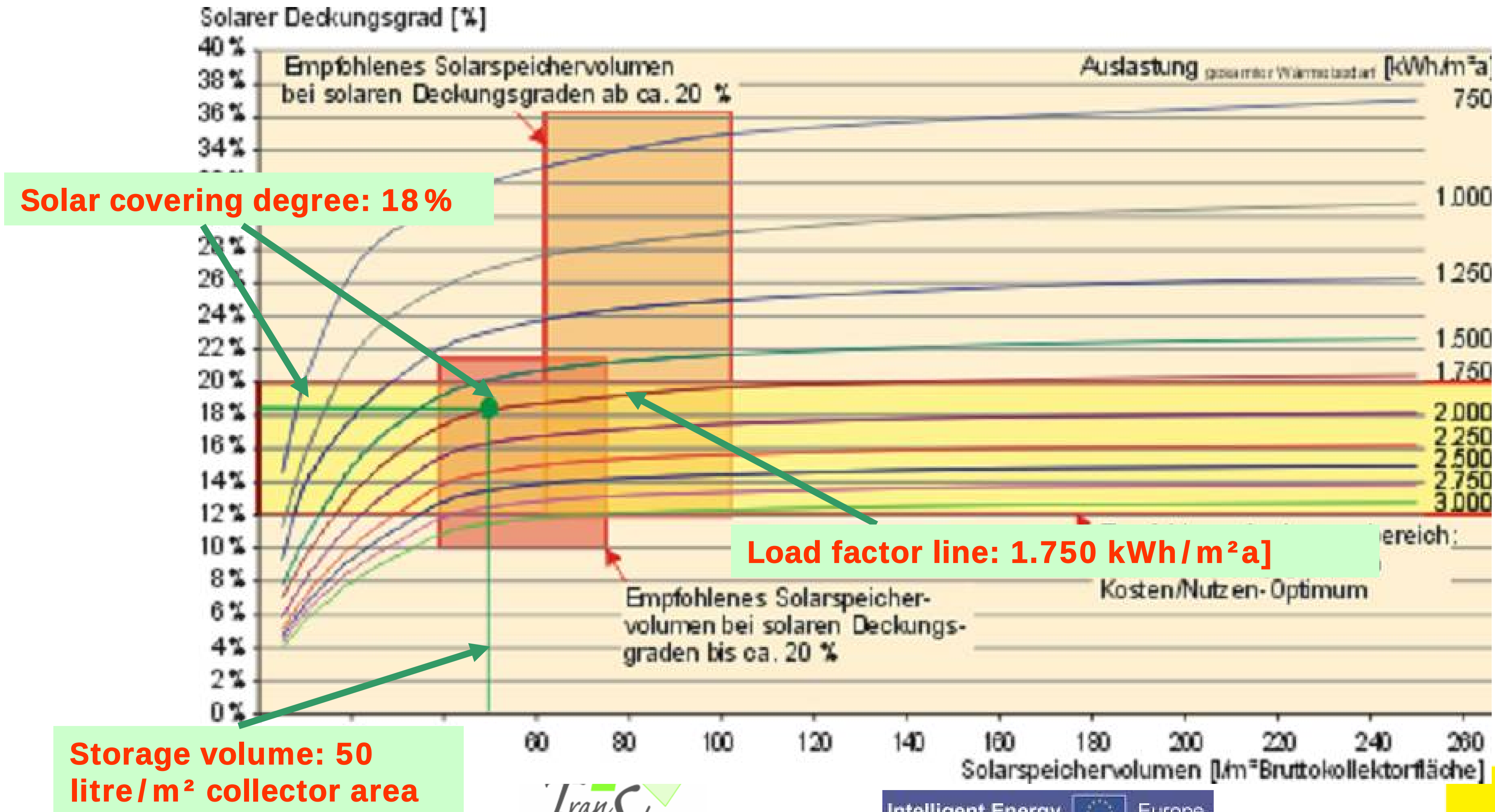
Wanted data:
Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]



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Complete demand: 152.000 kWh/a
Desired solar covering degree for the energy demand: appr. 18 %

Wanted data:
Gross collector surface [m²]
Storage volume [litre]
Annual solar yield [kWh/a]

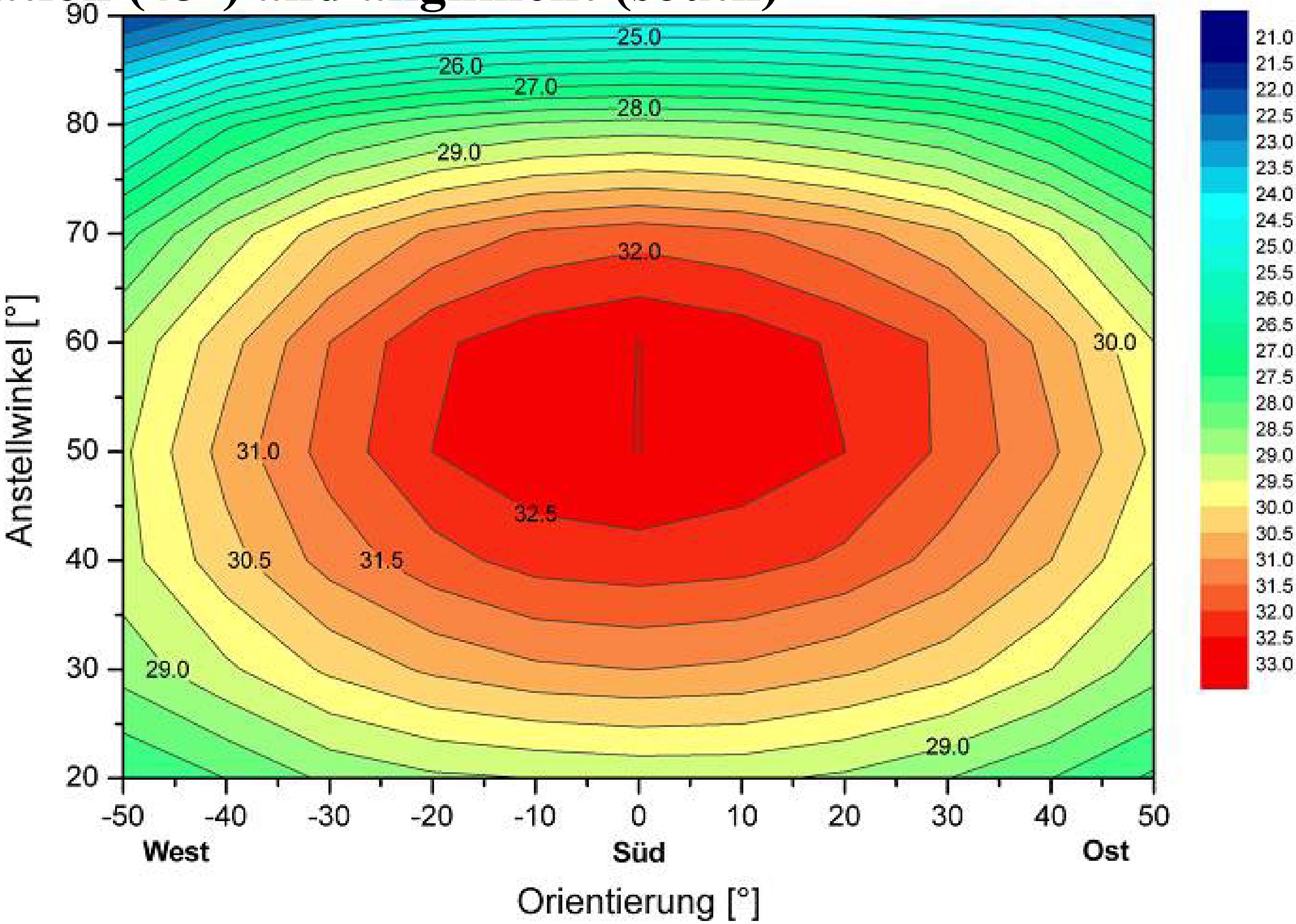
- **1.step: determination of the load factor line-> 1.750 kWh/m²a**
- **2.step: determination of the collector area**

$$collector\,area = \frac{total\,demand\,of\,heat\,and\,hot\,water\,[kWh/a]}{load\,[kWh/m^2.\,a]} = area\,[m^2]$$

$$collector\ area = \frac{152.000\,kWh/a}{1.750\,kWh/a} = 87\,m^2$$

- **3. Step: storage volume: 87m²x50l/m² = 4.350l**

This is a nomograph to correct the previous dimensioning nomographs which is based on a fixed defined collector inclination (45°) and alignment (south)



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Ranges of recommended angles of inclination and alignment of collector surfaces in dependence of the solar covering degree

Desired dimensioning	Solar covering degree	Recommended collector angle of inclination	Recommended collector alignment
Dimensioning in cost/use optimum	appr. 12%	25 to 40°	preferable South, tolerable deviation eastward 45° and the
	appr. 20%	30 to 45°	preferable South, tolerable deviation eastward 45° and the west 45°
Dimensioning with 100% summer covering	appr. 28%	40 to 55°	preferable South, tolerable deviation eastward 45° and the west 45°

Connection of large collector fields

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Requirements on collector connections

- Heat transfer between absorbers and heat distribution media as good as possible
- Pressure losses by the collector flow as small as possible
- Standard dimensions from the manufacturers should be used
- To reduce the calorific losses, the material and assembly costs a small cross section of pipes is needed

Serial connection is desired

Flow principle: „Low flow“

Advantages of large-scale installations compared to single collectors

- Large-scale installation

- Single collector

- Reduction in installation time by crane
- Reduction in connection number
- Daily performance of over 300m² collector surface (100m² inclusive elevation)
- Quality increase by process and locally reduced connection expenditure

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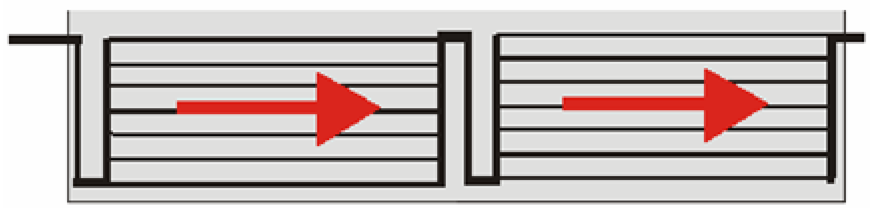
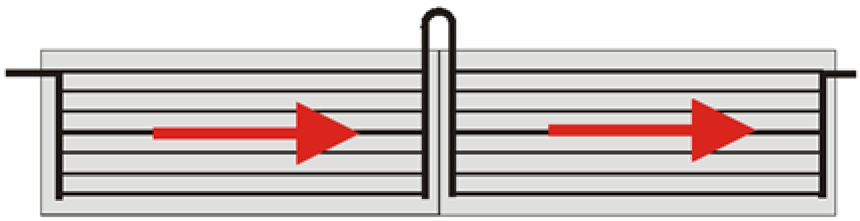
Expansion Compensation

Copper with 200 K ΔT: expansion: 3,5 mm/m

- Expansion loops in the collector



- External expansion loop with flexible pipe



- Collector manufacturer must indicate the maximum number of single collectors in series and/or the use of expansion loops

General Aspects

- Connect as much as possible collectors in series
- Turbulent flow in the collector should be achieved -> optimal efficiency
- Use of insulation valves in parallel collector fields -> separate purging of the collector fields
- In unequal parallel collector fields
  - Alignment of the different mass flows
  - Use of circuit control valves
  - Highest temperature-resistance
  - Positioning of valves so far as possible from the collector (mostly in the return)

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Thank you for your attention!

Contact:

DI (FH) Gundula Tschernigg
arsenal research

Giefinggasse 2, 1210 Wien, Austria
ph: +43 (0) 50550-6374, f: +43 (0) 50550-6613
mobile: +43 (0) 664/ 825 11 75
gundula.tschernigg@arsenal.ac.at
www.arsenal.ac.at/eet