# Technical description, sizing and calculations methods of large solar systems


Stefan Stumpf

arsenal research

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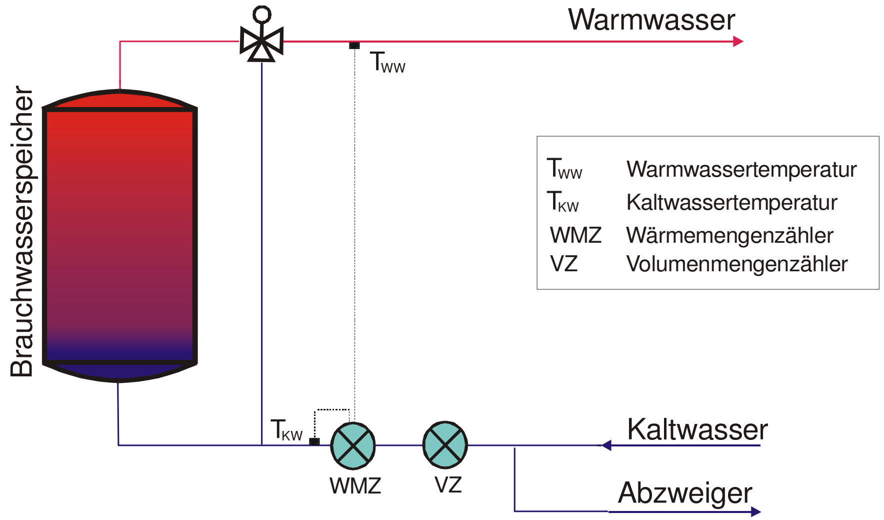
- Determination of hot water needs
- Plant hydraulics and dimensioning of solar systems in dwellings
- Connection of large collector areas
- Functional and yield control

# Determination of hot water needs
## Metrological collection

- Exactly and safe method of determination

- Measuring devices:
  - volumetric meter (constant T)
  - heat meter (also with varying T)




- At least during some weeks
- Daily values sufficiently
- Consider the position!

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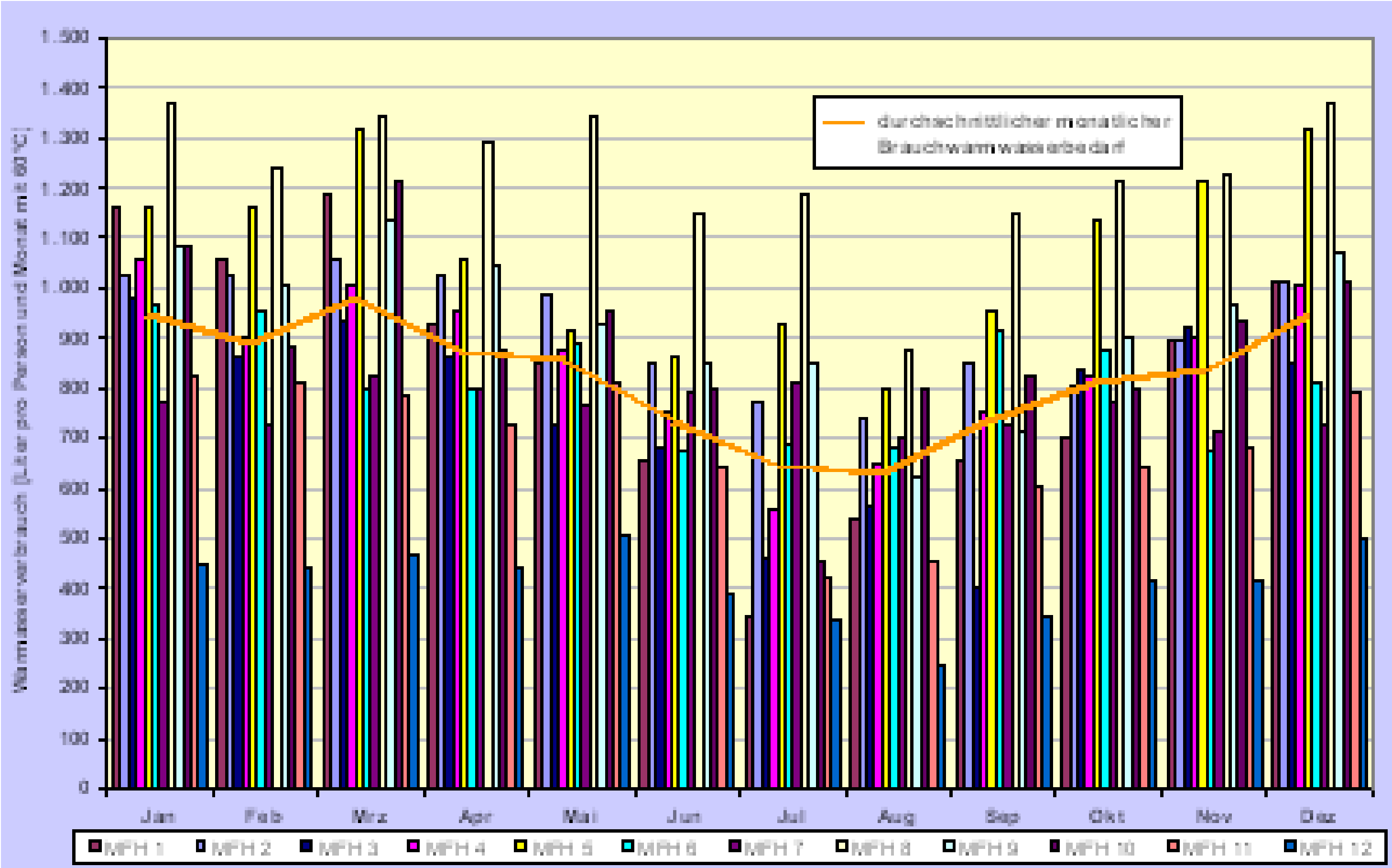


- Average hot water consumption (monthly/year) for 12 different dwellings – average water demand per person/month 60°C

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# Standard values of hot water consumption

- Daily hot water consumption dependent on the number of persons, age, living standard, etc..

| | Hot water consumption per day and person with a temperature of 60°C |
|---|---|
| simple Claims | 10 - 20 l |
| high Claims | 20 - 40 l |
| highest Claims | 40 - 80 l |

- Category social housing

| | Hot water consumption [litre] | Temperature level [°C] |
|---|---|---|
| Consumption per day and person | **30** | **60** |

# Calculation of hot water demand

$$Q_{WW} = \frac{V \cdot c_p \cdot \Delta T}{3600}$$

| | |
|---|---|
| $Q_{WW}$ | amount of hot water energy in kWh |
| $V$ | hot water demand in litre |
| $c_p$ | specific heat capacity of water (4,2 KJ/litre K) |
| $\Delta T$ | temperature difference between hot water and cold water in Kelvin |
| $T_{BW}$ | temperature of hot water in °C |
| $T_{KW}$ | temperature of cold water in °C |

$$X_{Pers} = \frac{W_{NF}}{33}$$ ( in Austria)

| | |
|---|---|
| $X_{Pers}$ | total amount of people |
| WNF | total useable living area in m² |
| $33 = W_{NFspez}$ | average specific useable living area per person in m² |

$$X_{Pers} = n_w \cdot 2{,}5$$ ( in Austria)

| | |
|---|---|
| nW | total number of flats |
| $2{,}5 = X_{Wspez}$ | average occupancy rate per flat |

$$Q_{BW} = \frac{V \cdot x \cdot c_p \cdot \Delta T}{3600}$$

| | |
|---|---|
| $Q_{BW}$ | daily amount of hot water energy in kWh |
| $V$ | specific hot water demand per person and day |
| $X$ | number of persons |

# Plant hydraulics and dimensioning of solar systems in residential buildings

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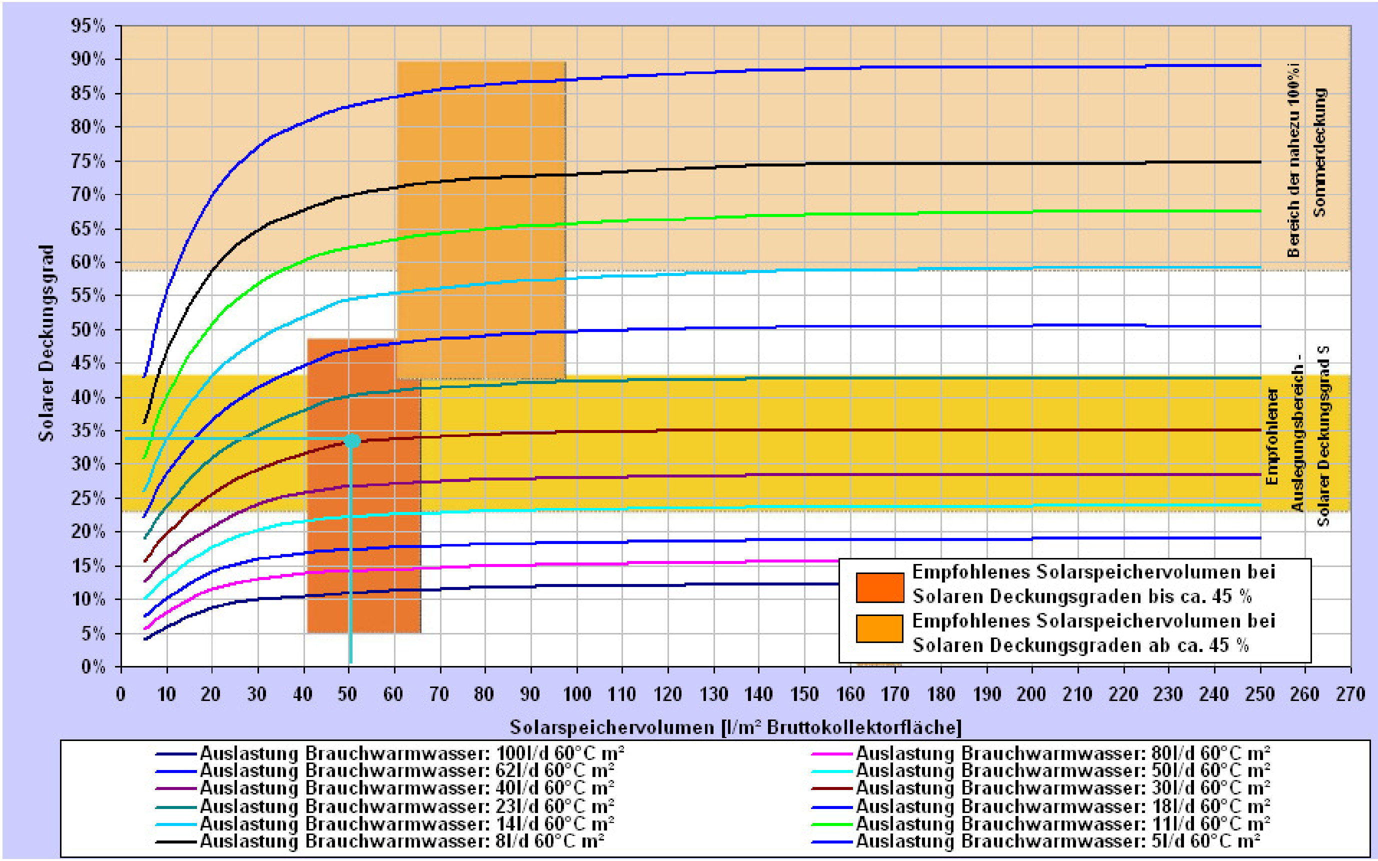
# Ways to dimension a solar system

- Most important factors on investment and solar fraction –storage and collector area
- 1. Dimensioning in the cost/use optimum
  - solar fraction 25% appr. 40 l/m² - 45% appr. 65 l/m² storage volume per square meter collector area
- 2. Dimensioning on almost 100% summer covering
  - solar fraction 60% appr. 65 l/m²- 95% appr. 100 l/m² storage volume per square meter collector area
- Conditions for the dimensioning; knowledge of:
  - average daily warm water consumption
  - Introduce an auxiliary characteristic number: load

$$load = \frac{daily\ hot\ water\ consumption}{net\ colle\,\mathrm{cot}\,or\ area} = \frac{litre\ with\ 60\,°C}{m^2}$$

# Dependence of solar covering degree and storage volume

- Nomograph for the determination of the gross collector surface and the solar storage volume in connection with the solar covering degree

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Residential building with 21 accommodation units

Hot water demand: appr. 1.575 Litre with 60°C/day

Desired solar covering degree for the water demand: appr. 34 %

# Dimensioning example

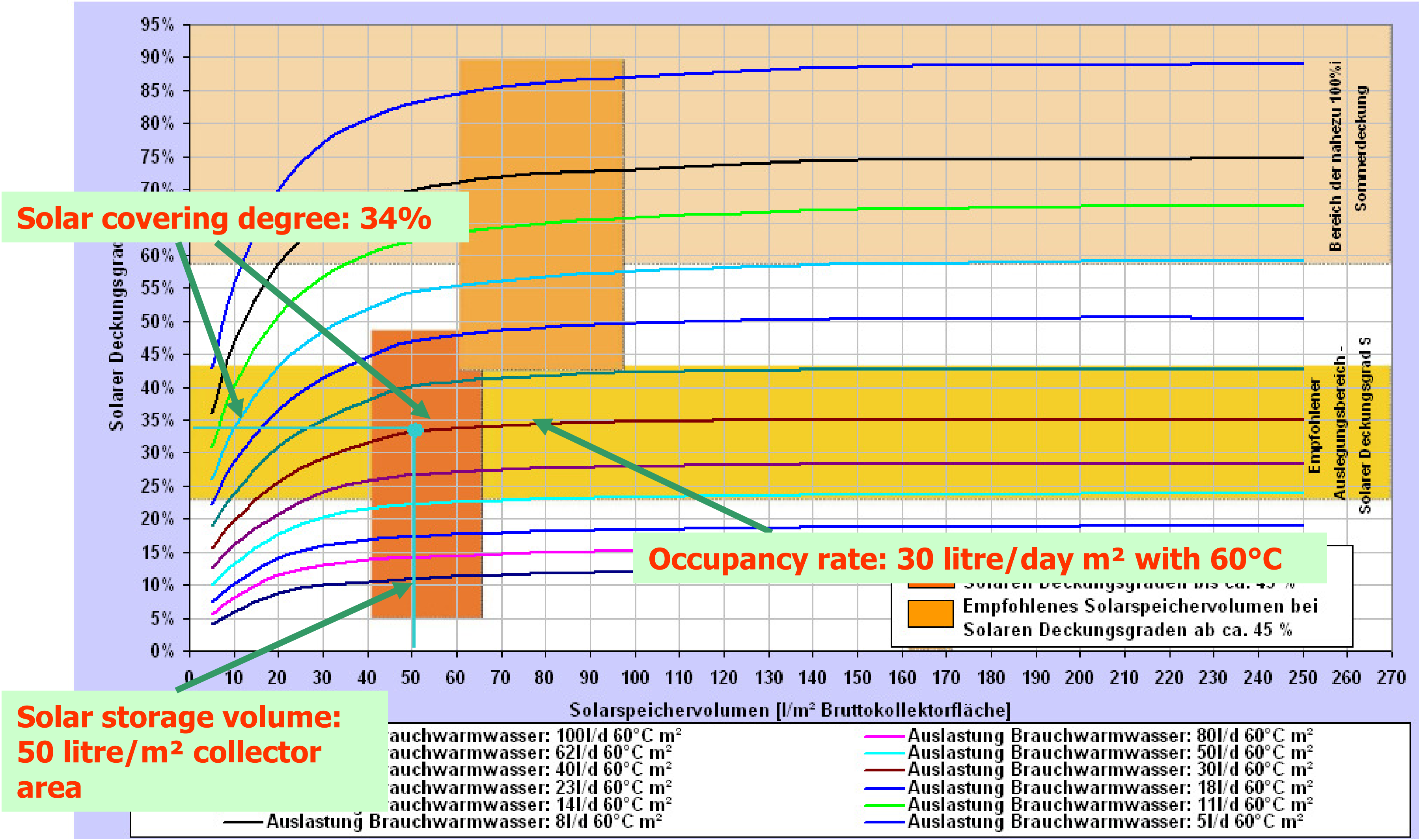
- **1.step: choice of the specific storage volume**
  - **34% -> 50 l/m²**
- **2. Step: determination of the load**

# Dimensioning example

**Residential building with 21 accommodation units**
**Hot water demand: appr. 1.575 Litre with 60°C/day**
**Desired solar covering degree for the water demand: appr. 34 %**

## Wanted data:

**Gross collector surface [m²]**
**Storage volume [litre]**



Residential building with 21 accommodation units

Hot water demand: appr. 1.575 Litre with 60°C/day

Desired solar covering degree for the water demand: appr. 34 %

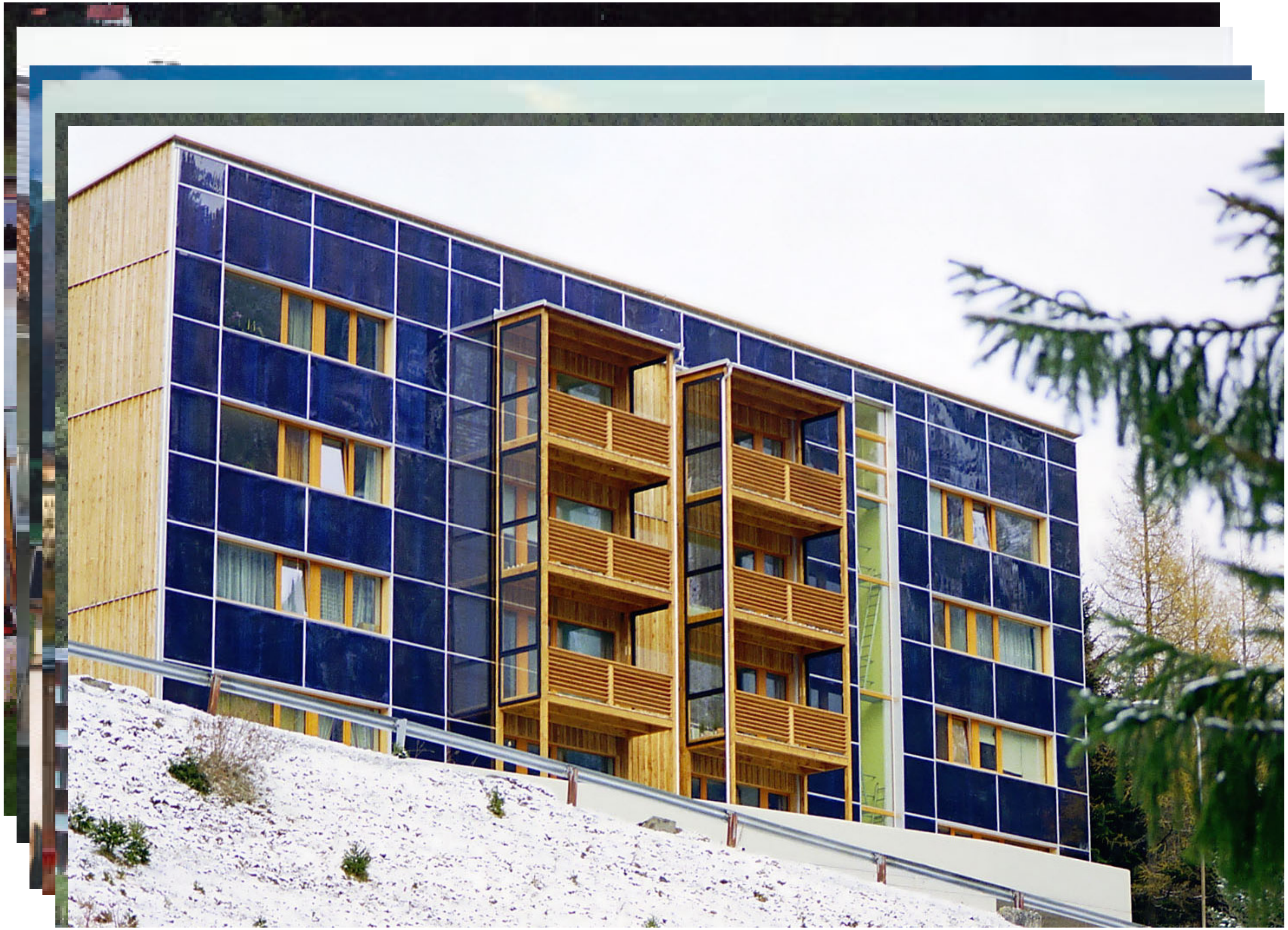
# Dimensioning example

- 1.step: choice of the specific storage volume
  - 34% -> 50 $l/m^2$
- 2. step: determination of the load -> 30 litre with 60°C
- 3.step: determination of the collector area

$$collector\ area = \frac{daily\ hot\ water\ consumption\ with\ 60°C / day}{30\ litre\ with\ 60°C / m^2 \bullet day} = area$$

$$collector\ area = \frac{1.575\ litre\ with\ 60°C / day}{30\ litre\ with\ 60°C / m^2 \bullet day} = 53\ m^2$$

- Storage volume: $53m^2 x 50l/m^2 = 2.650l$



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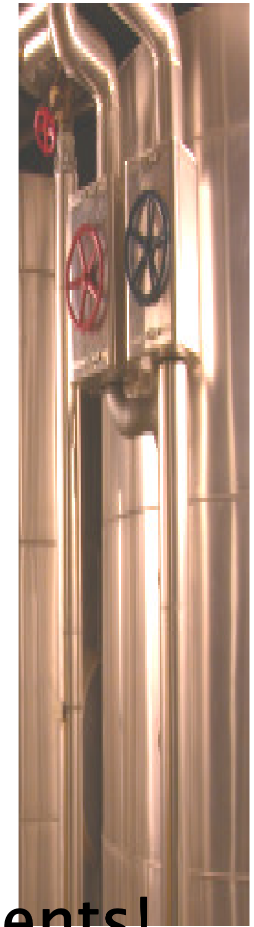
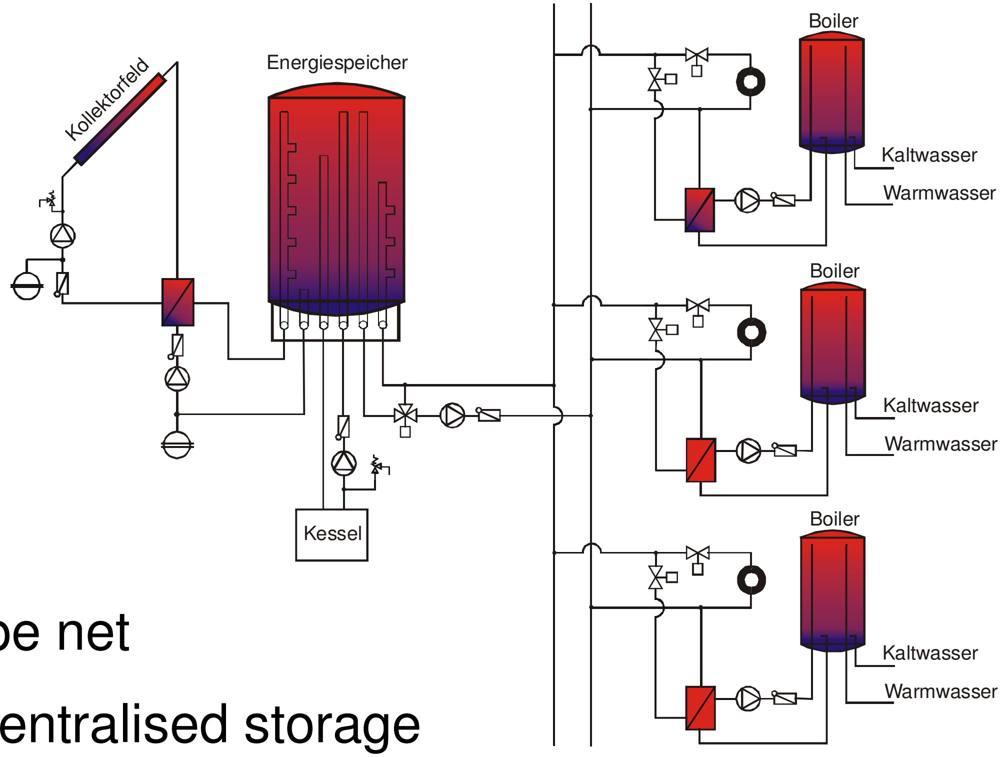
# Requirements of solar supported heat nets of the 3rd generation



- 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 nets can absolutely fullfill these requirements!**

# Solar supported heat nets of the 3rd generation




- Heat distribution from a 2-pipe net
- Hot water heating with a decentralised storage
- Meaningful employment with small energy densities (dwellings, etc.)

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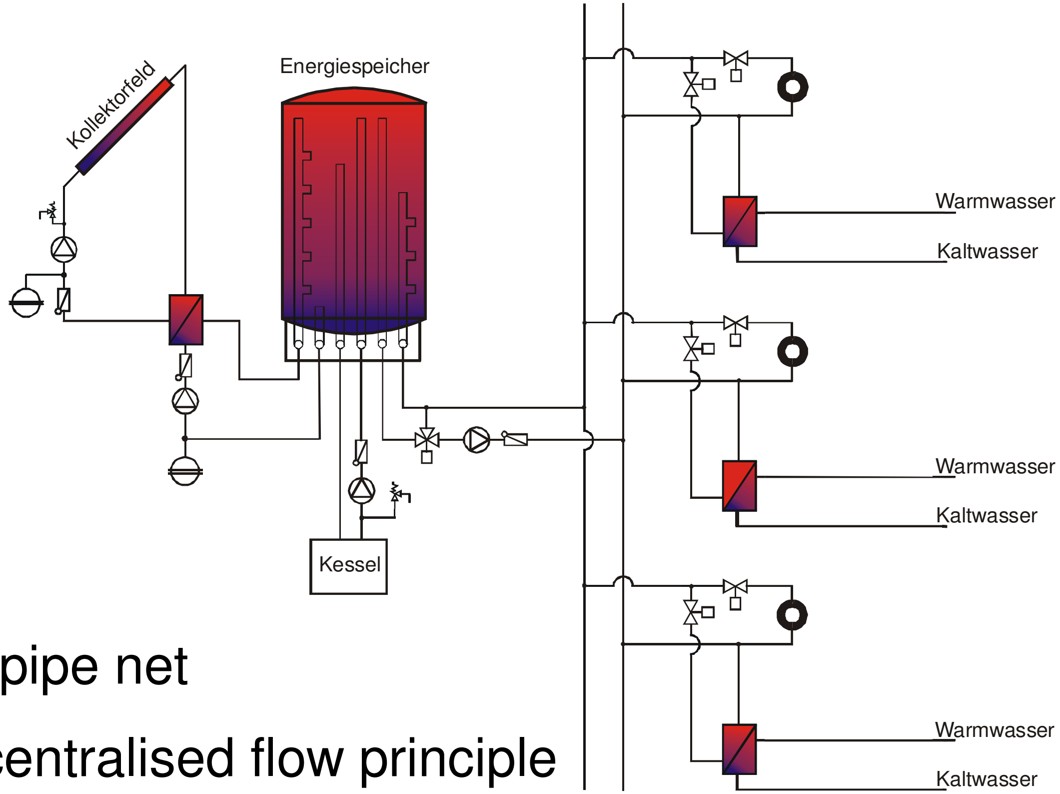
# Solar supported heat nets of the 3rd generation




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

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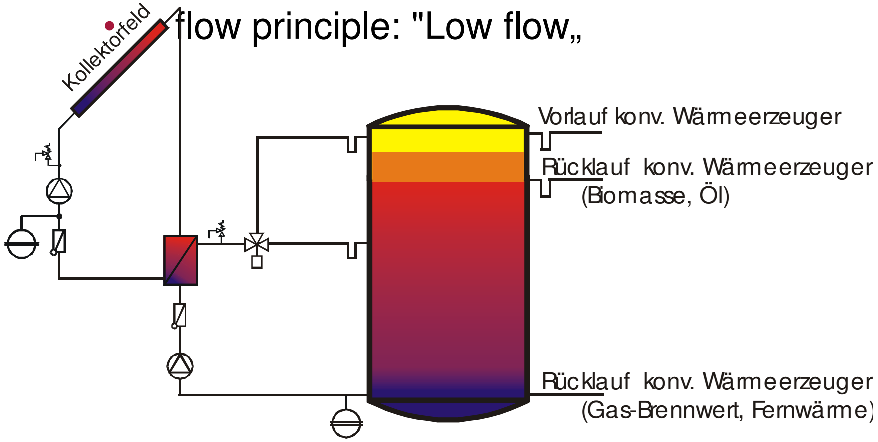
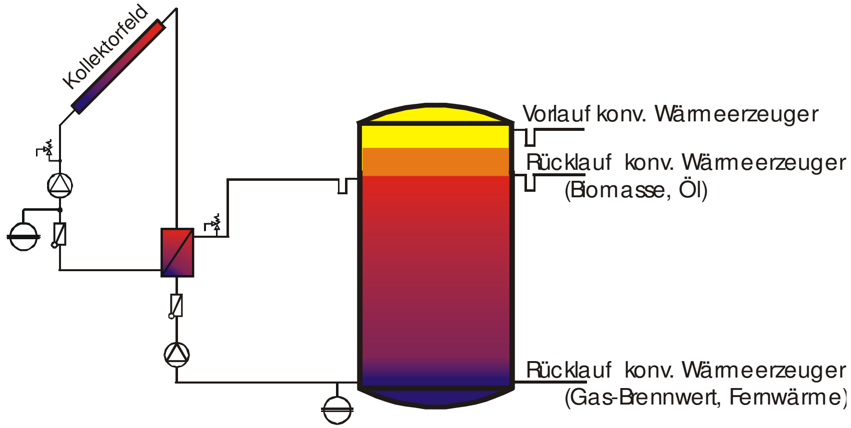
# Advantages of 2-pipe nets

- Distribution losses are reduced to a minimum
- Dependent on the system a space heat supply can be achieved automatically
- Cheaper heat prices compared to 4-pipe systems
- An increase in comfort and absolutely harmless water hygiene
- Reduction of the error frequency in industrial manufactured housing stations and no auxiliary energy is needed

# Integration of conventional heating systems

• flow principle: "Low flow„



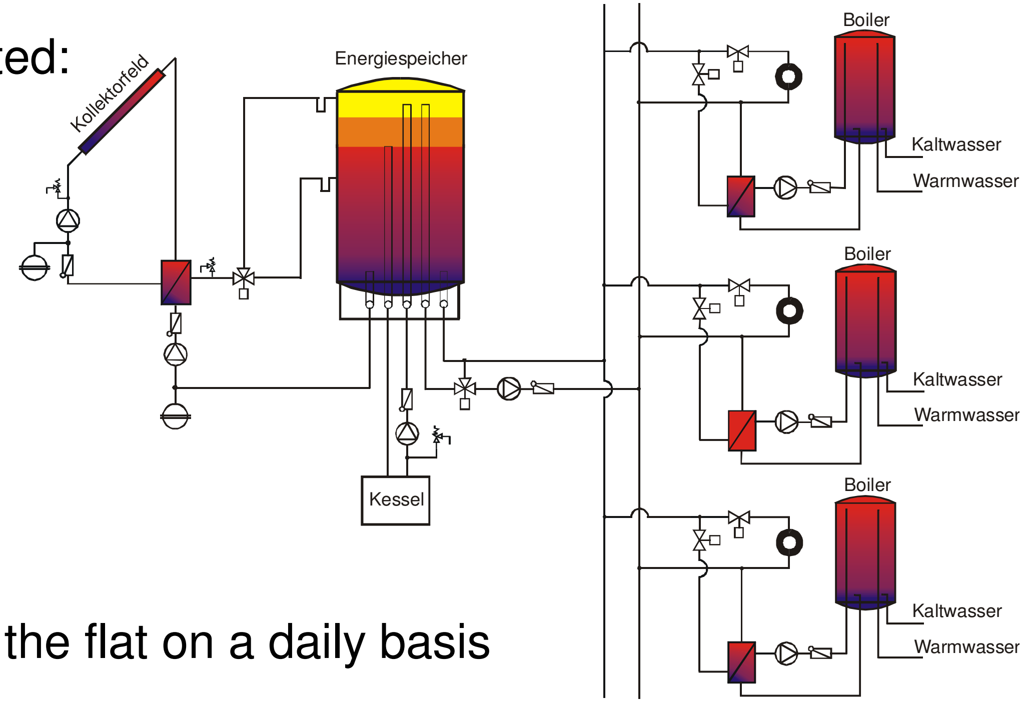

- Integration of the solar system
  - No need for a layer load device in large plants→ small impact on solar covering degree
- Application
  - Need appropriate speed regulation and economical loading strategies
  - ➢ 1 feeding height (beyond the readiness and switching volume)
  - ➢ 2 feeding heights (one at the top, one at 2/3 of the height)

  The change is effected by the temperature and made by a 3-way valve

- Integration of conventional boilers
  - Net supply: upperst part of the storage
  - Return: upper part of the storage (can be used for biomass, oil, gas)
  - Return in the lower third of the storage (can be used for condensing boilers and district heating)

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

- Solar system
  - If an energy storage is integrated:
    - 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 the flat on a daily basis



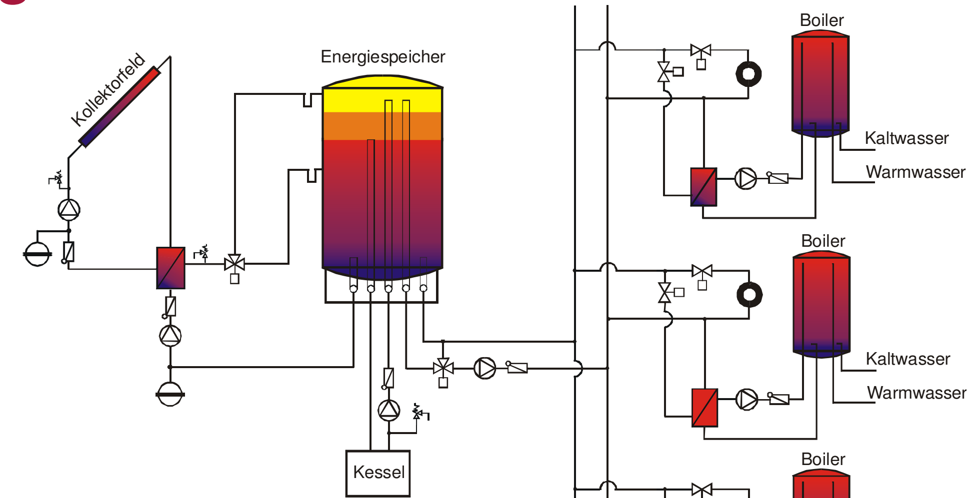

**<u>Important</u>: The distribution net is used 22h to 23h for the heat supply and just 1h to load the boiler**

**<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 nets: 2-pipe systems with decentralised hot water storage

- Important components:
  - Mixing valve
  - Pump
  - Decentralized load substations
- Application:
  - New building, residential buildings in compact building method, reconstruction (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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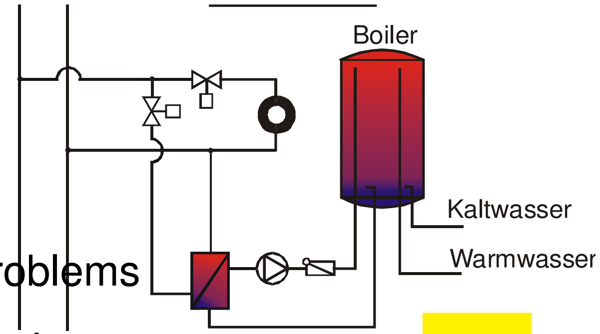
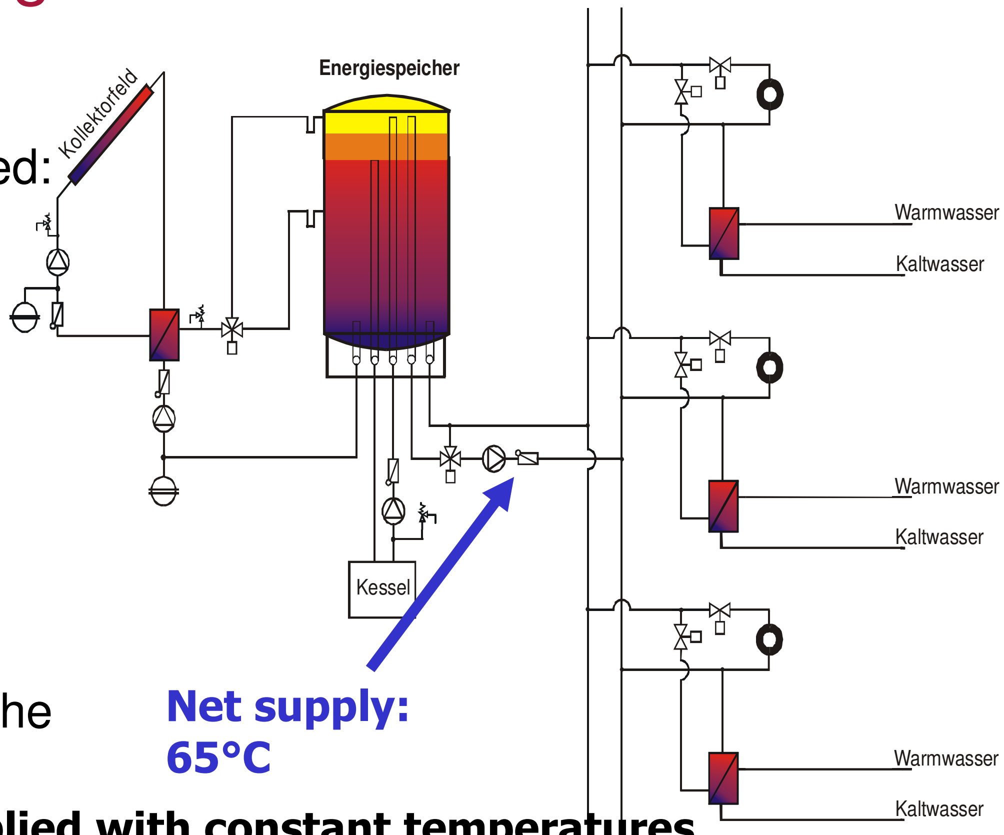
# Hot water preparation / Space heat supply

- 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



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

- Solar system
  - If an energy storage is integrated:
    - 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 the flat



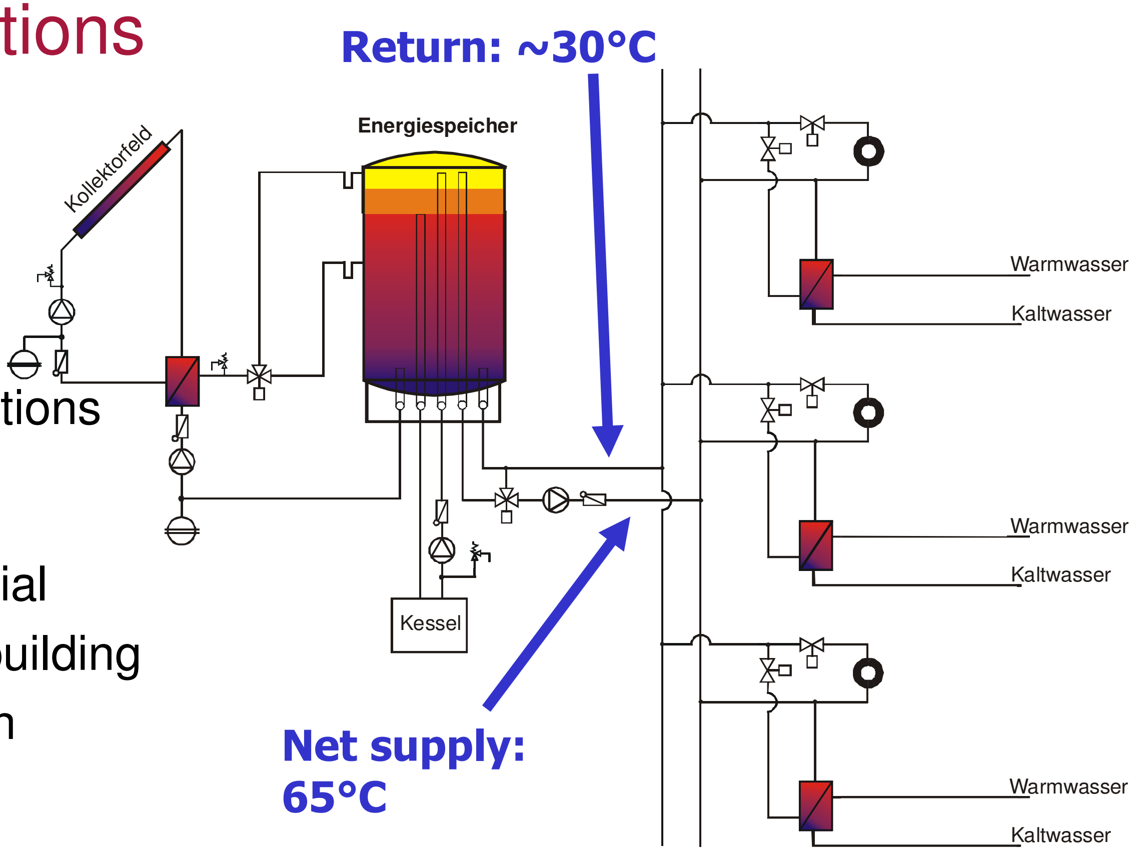

**<u>Important</u>: The distribution net is supplied with constant temperatures (approximately 65 °C) during summer and winter**

**<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 nets: 2-pipe nets with decentralised district heating substations

- Important components:
  - Mixing valve
  - Pump
  - District heating substations
- Application:
  - New building, residential buildings in compact building method, reconstruction




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

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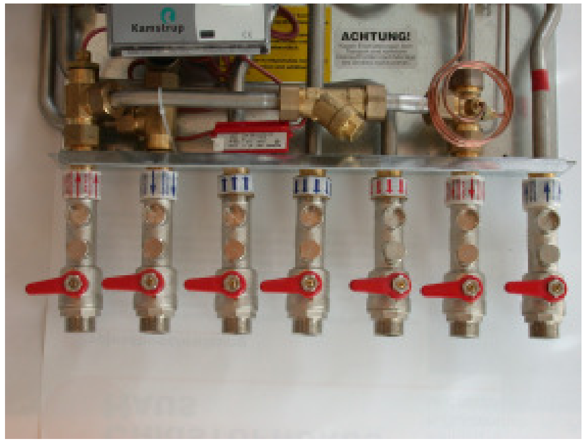
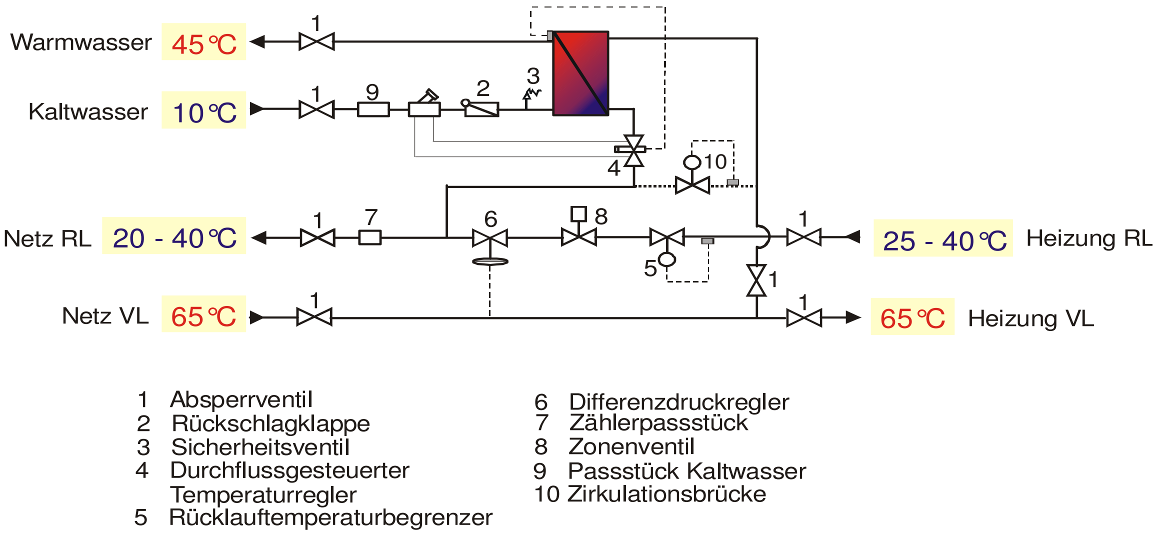
# Substations

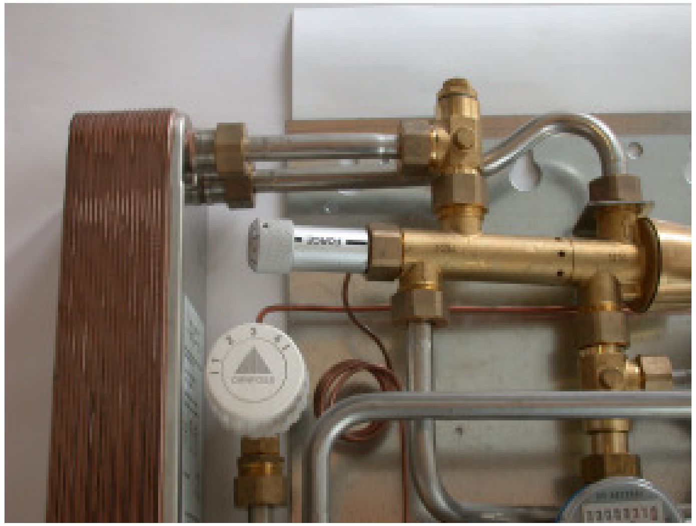
- Advantages of substations:
  - Industrial manufacturing
  - Highest quality criteria
  - No external energy requirement
  - Low investment costs
  - Individual design (finery, in the wall, different geometry)

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



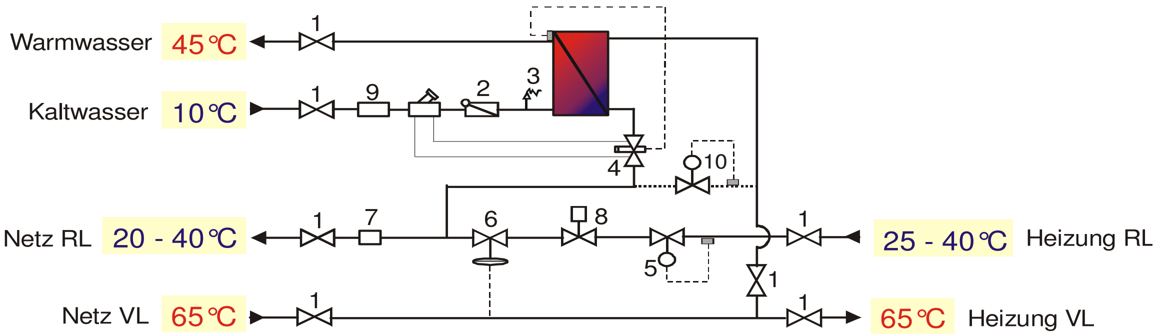
# Functions of substations



- 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

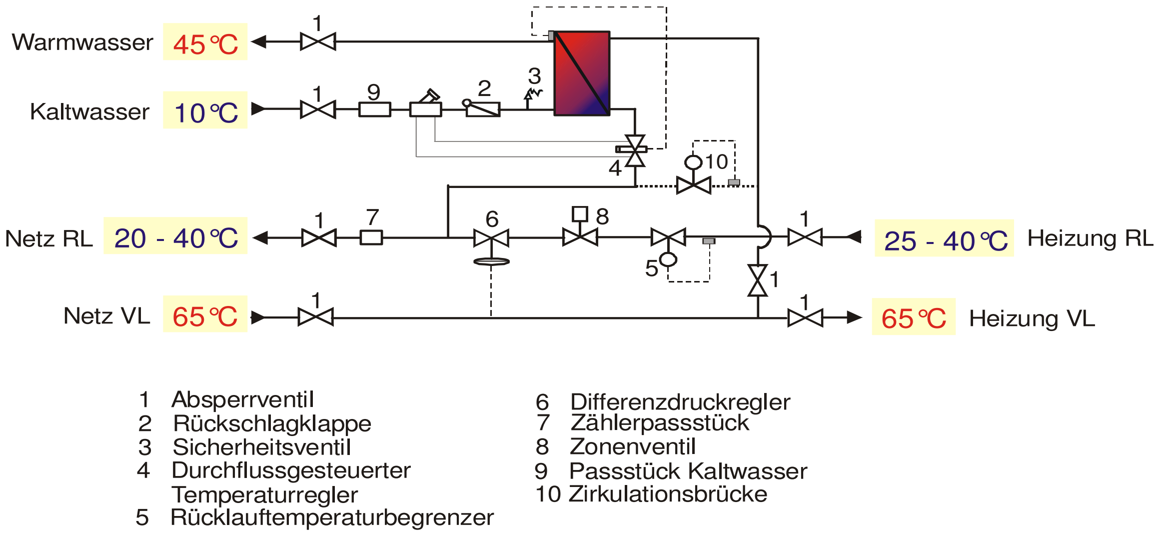
# Functions of substations




1 Absperrventil
2 Rückschlagklappe
3 Sicherheitsventil
4 Durchflussgesteuerter Temperaturregler
5 Rücklauftemperaturbegrenzer
6 Differenzdruckregler
7 Zählerpassstück
8 Zonenventil
9 Passstück Kaltwasser
10 Zirkulationsbrücke

- 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

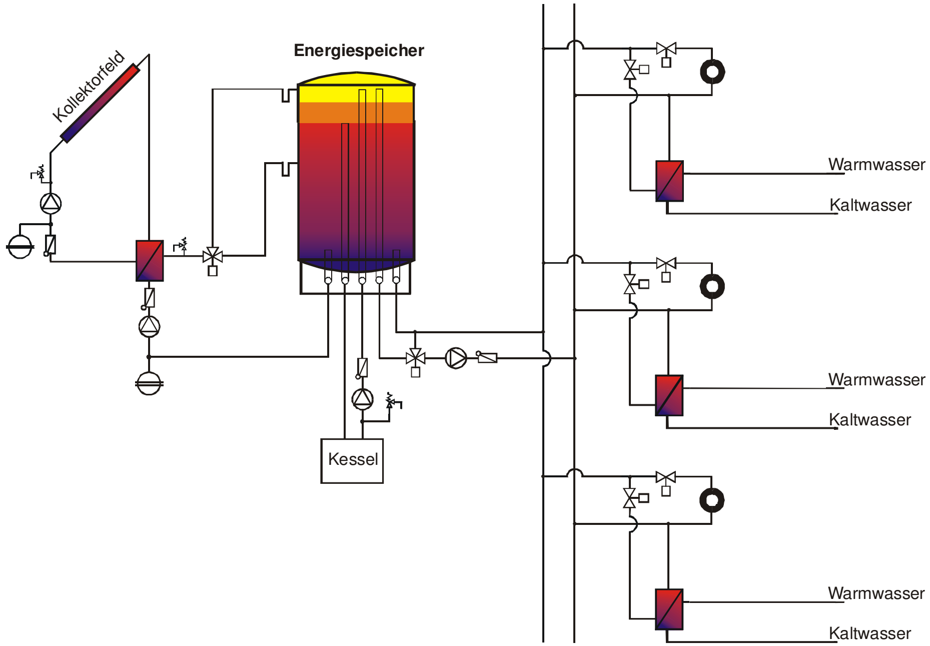




- Important components for measuring the demand:
  - Water meter
    - measures the total amount of hot water used in a unit
  - Heat meter
    - measures the total amount of hot water and heat used in a unit
  - Can be read out manually or via a bus-sytem

# 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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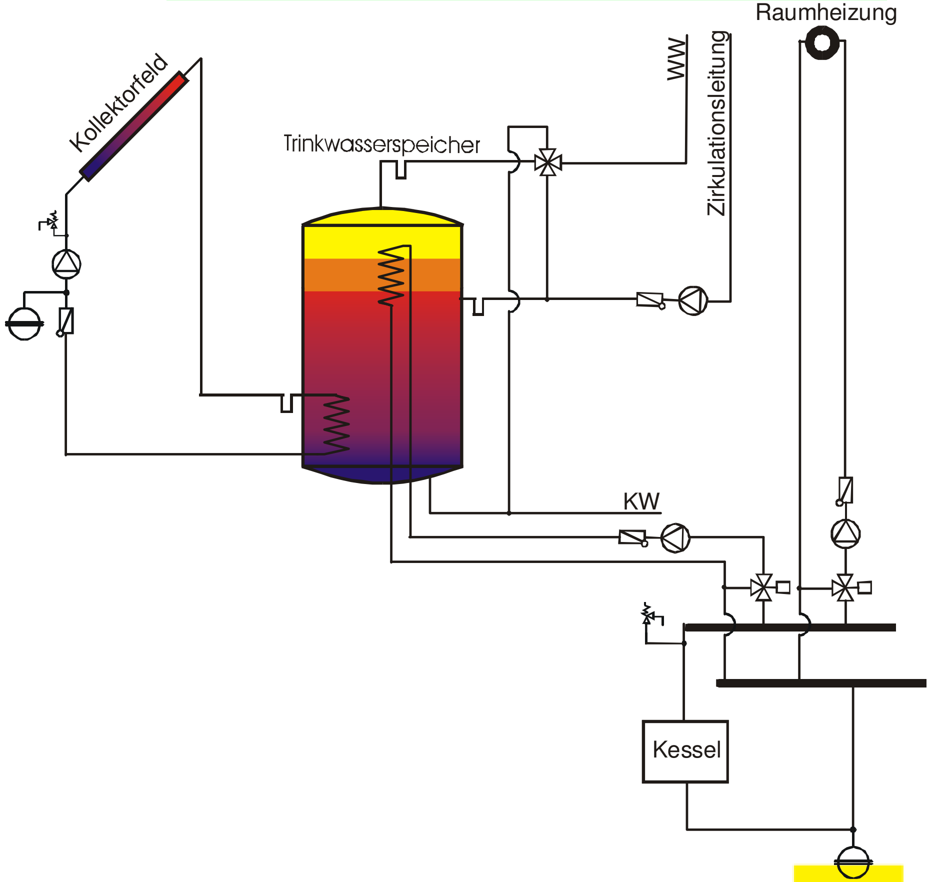
# 4-pipe nets with hot water storage

- 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 exchange

**Systeme with hot water storage**

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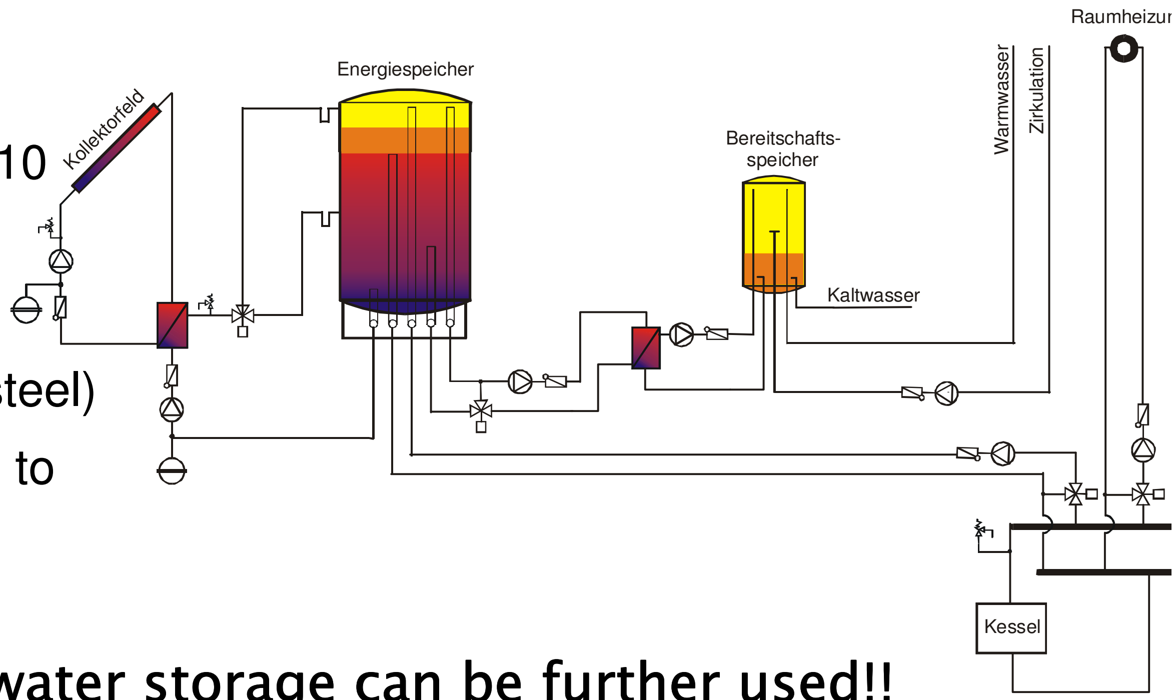
# 4-pipe nets with two-storage systems

- Application
  - For large hot water consumption (more than 10 flats)
- Layout
  - Central energy storage (steel)
  - Central hot water storage to cover peak loads




An already existing hot water storage can be further used!!

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

# Connection of large collector areas

# Requirements on collector connections

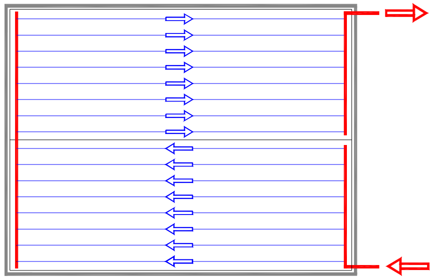
- Heat transfer between absorbers and heat distribution media as good as possible
- Pressure losses by the collector flow as small as possible
- Standard dimensions from the manufacturers should be used
- To reduce the calorific losses, the material and assembly costs a small cross section of pipes is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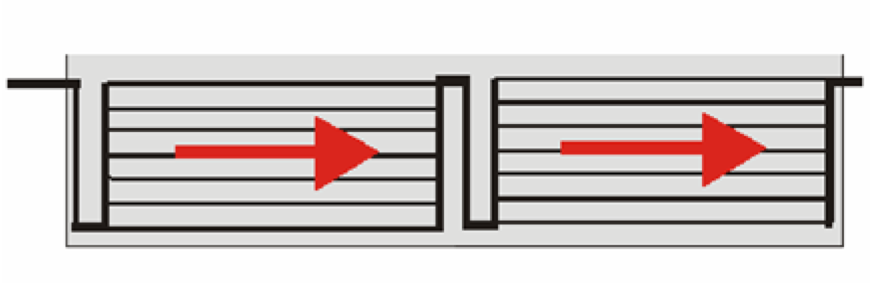
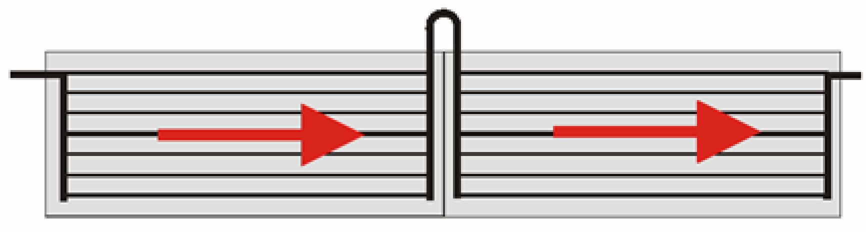
# Expansion Compensation

**Copper with 200 K $\Delta T$: 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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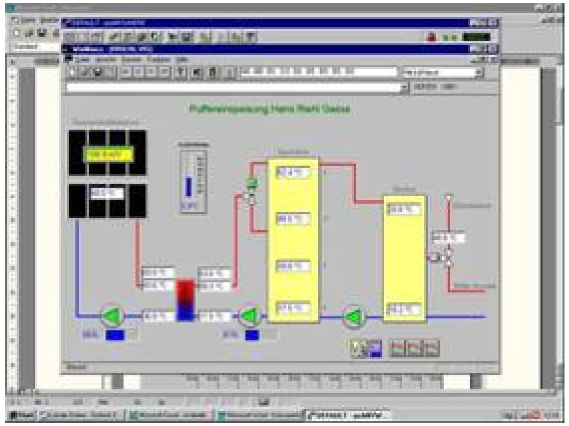
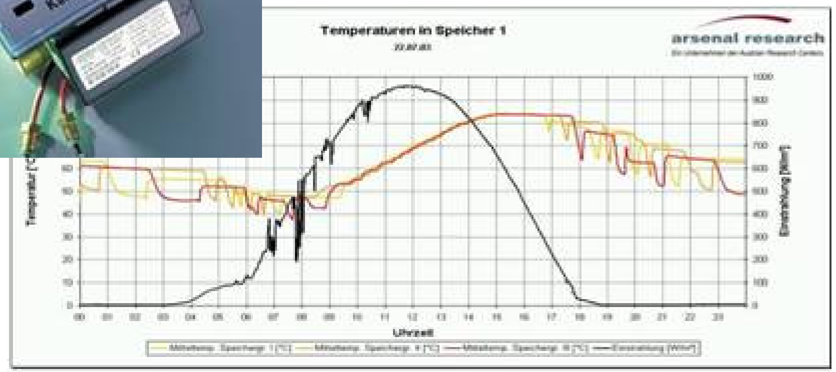
# Functional and yield control

*„monitoring“*



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- What is a functional and yield control?
- For what reason are they used?
- Different quality standards of a functional and yield control

# Functional Control

- Manual visual control – control of the plant operator
  - Selective system temperatures, pressures
  - Heat insulation condition
  - Connection control
  - Selective control of the system operation
  - Optionally readjustment of the system operation after some months

**During the maintenance all points should be covered!!**

- Automatic functional control
  - intelligent regulation (easily programmable)
  - automated error message (SMS, email, call, etc..)
  - continuous monitoring of the plant operation (temperatures, pressures, etc..)

# Yield control

- Manual yield control
  - Readout of heat meters (monthly, annually...)

- Automatic yield control
  - Automatic readout of heat meters and further sensors (M-Bus, pulse out,..)
  - Can serve also as rough functional control

# For what reason are they used?

- In Germany the use of heat meters in solar systems is demanded
- In some parts of Austria it is a condition for funding
  - Minimum solar yield: 350 kWh/m²y
- Some companies which build dwellings ask for a specific solar yield where
  - Achievement and/or quality profile is prescribed
  - Guaranteeing is taken over by the installer (mostly common together with the collector supplier)
  - less yield is determined in the first three years and projected on life span
  - disadvantage: guarantee is void from the planer!
  - Mostly manual heat meter readout

# Different quality standards of a functional and yield control

- Minimal plant monitoring
  – Use of a heat meter
  – Regularly maintenance
  – heat meter should regularly be readout

  – Optional: Use of a „simple" heat meter combinable with the control device (→ amount of heat, flow and return temperatures are saved in the control device; possible readout; for small applications additional also with the pump running time conceivably)

**→Usage: mainly in single family houses**

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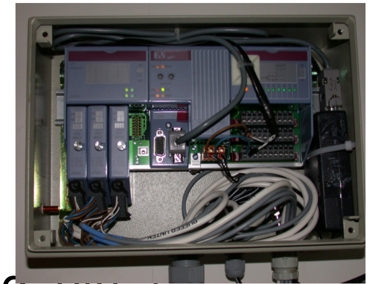
# Large solar applications



- Routine monitoring (failure safety )
  – Alarm-steered monitoring of the plant operation
  – By means of appropriate control devices (EMC 2000, Schneid, etc..) or control systems
  – Error message in consequence of programming logic or logic in the data analysis
  – Criterion: temperature and radiation conditions, system pressure
  – No evaluation of plant yields

  – <u>Conditions</u>: easily programmable control device or control system (with the ability to mail alarms automatically), modem, alarm acceptance place)

# Large solar applications

- **Detailed plant monitoring (optimize and research)**
- Flow rate and pair of temperatures in each hydraulic circle (energy balances), storage temperatures, running times, etc..
- By means of appropriate control device or own data logger; bus systems are only conditionally suitably, because:
  - Memory interval periods mostly much too roughly (max. 1x daily; e.g. m-bus)
  - Compatibility to other measure systems is only conditionally given
- Error reporting criterion: Temperature- and/or radiation conditions, system pressure
- Error message "on-line" or from logic of the daily automatic data analysis
- Detailed analysis of operational behaviour (energies, temperatures, losses, etc..) in appropriate temporal resolution

- <u>Conditions</u>: easily programmable control devices or control systems with the ability to buffer data sets and to spend it in an appropriate format and/or to mail alarms automatically, modem, alarm and data acceptance place

# Optimization measures to increase the entire plant efficiency

- → A technical deficiency recognized in the plant monitoring is not only concerning the solar system but also the entire heat supply or hot water system!
- → The recognized technical deficiencies are mostly not acute/serious (save money)

→ **The arising technical deficiencies are often very similar and can partly be repeated in individual plants**

→ **Early recognition can minimize negative effects on the plant efficiency and the solar yield!**

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# Thank you for your attention!