

# CONTROL MODELS DEVELOPED FOR RESIDENTIAL SOLAR THERMAL SYSTEMS USING MODELICA

„Different approaches applied in heat supply system modelling“



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Mini-Workshop on Optimal Control of Thermal Systems in Buildings using Modelica

Freiburg, 24<sup>th</sup> March 2015

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# AGENDA

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- Solar combi-system
- Control system
  - Hysteresis
  - PID control (Matched-flow)
  - Determination of mass flow rate by energy-balancing
  - Flip-flop control
  - ON/OFF Valve control
- Parameter optimization of solar thermal system

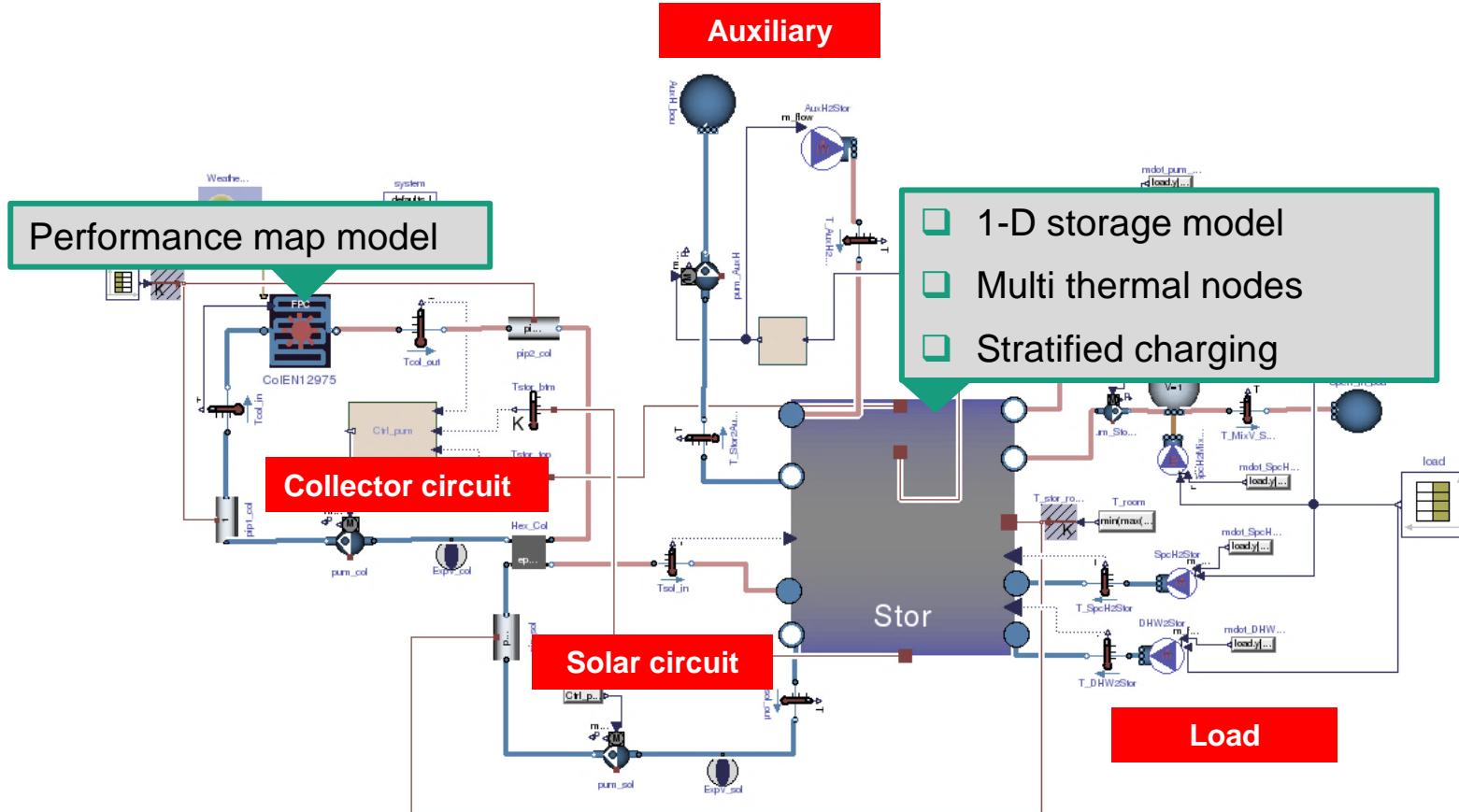
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# Solar combi-system

Solar combi-system provides both space heating and DHW load



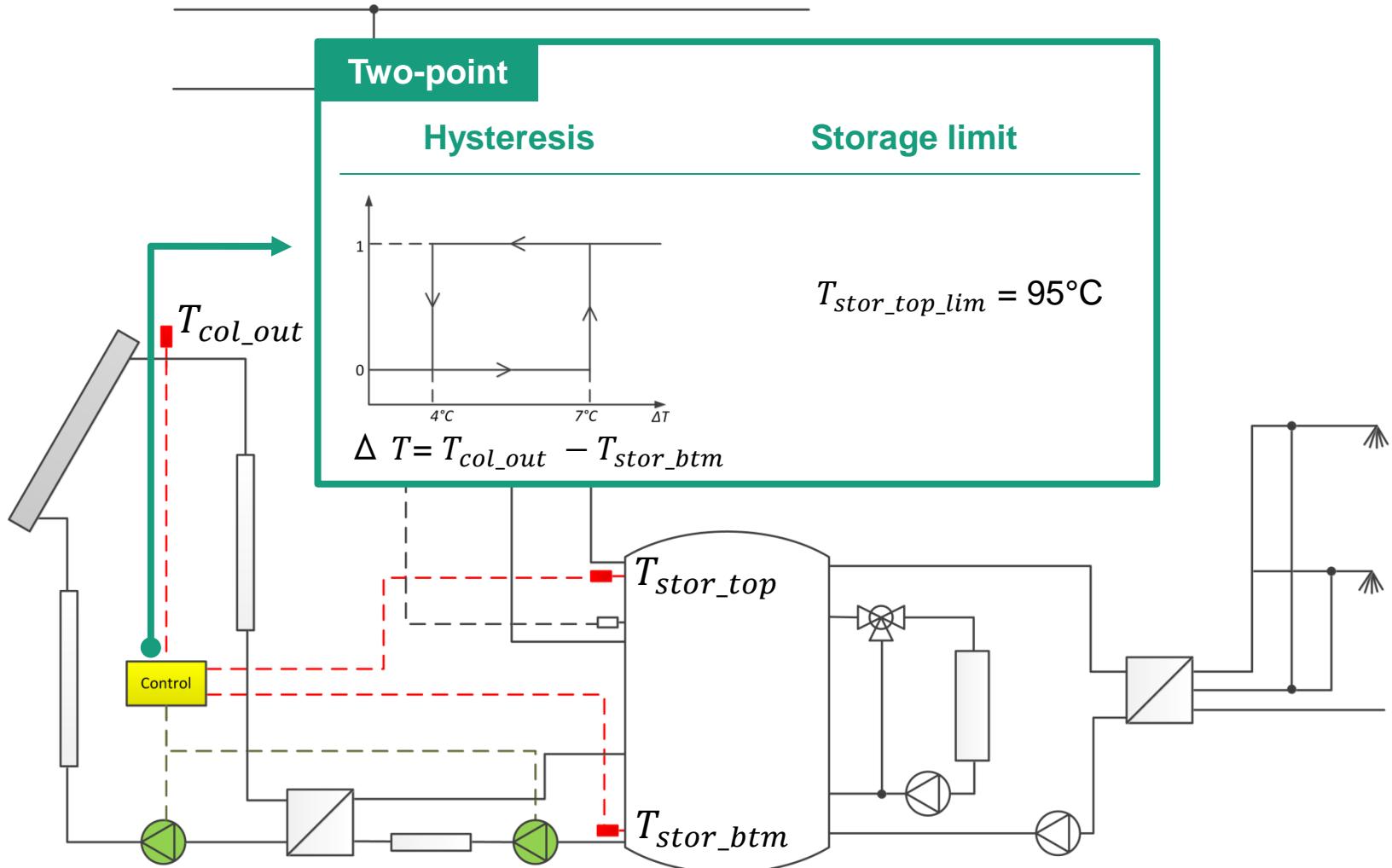
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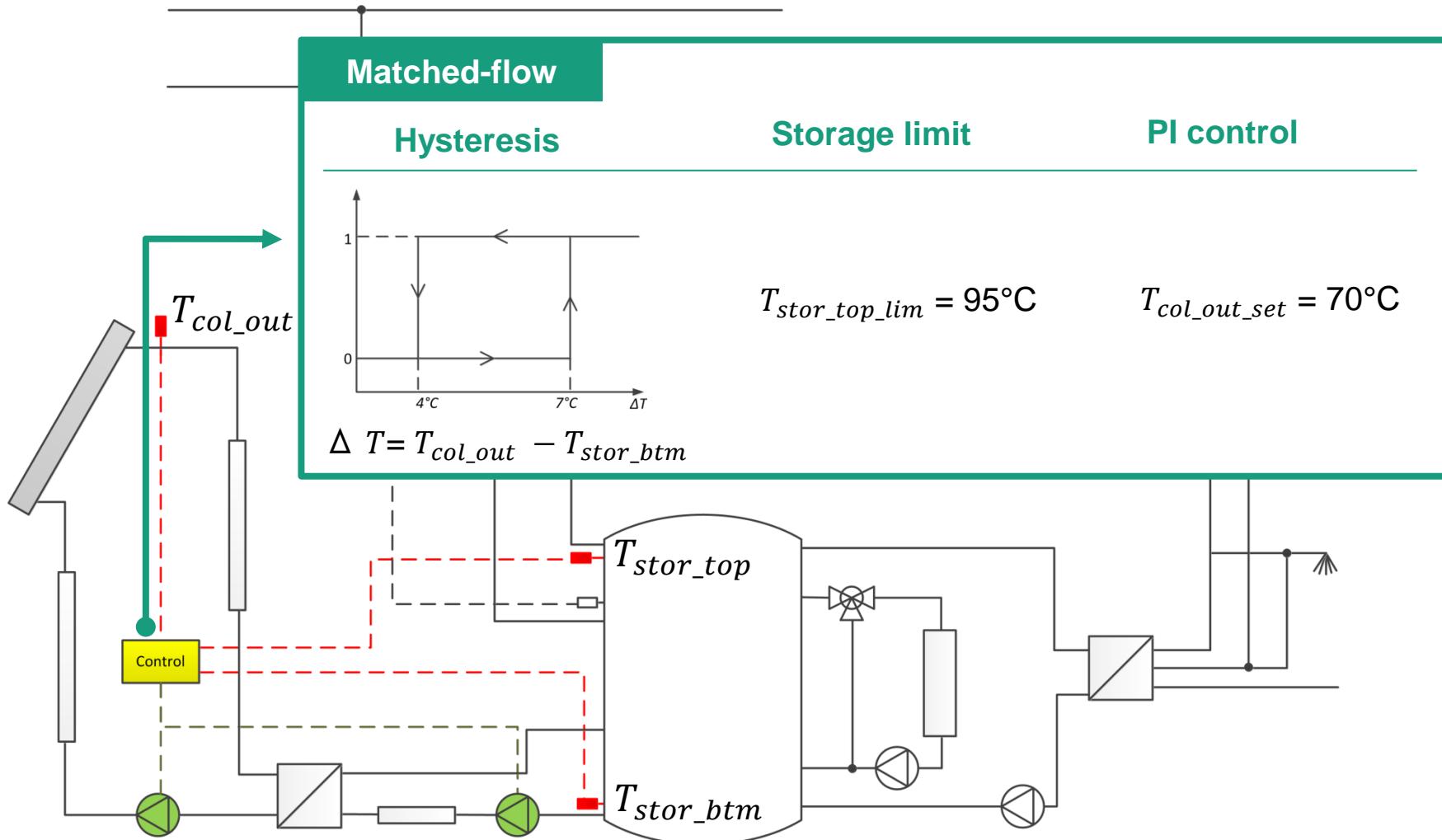
# Control system

## Hysteresis



# Control system

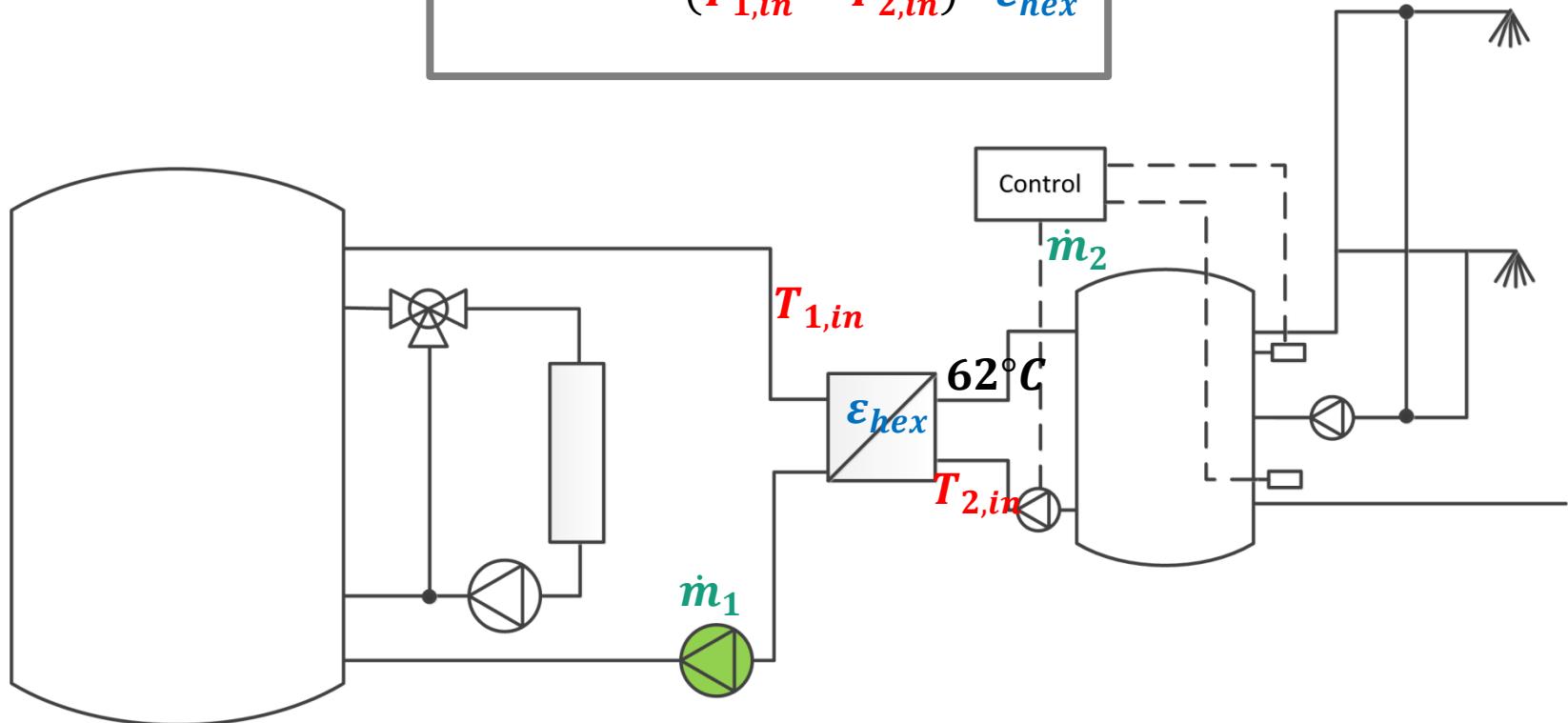
## PID control (Matched-flow)



# Control system

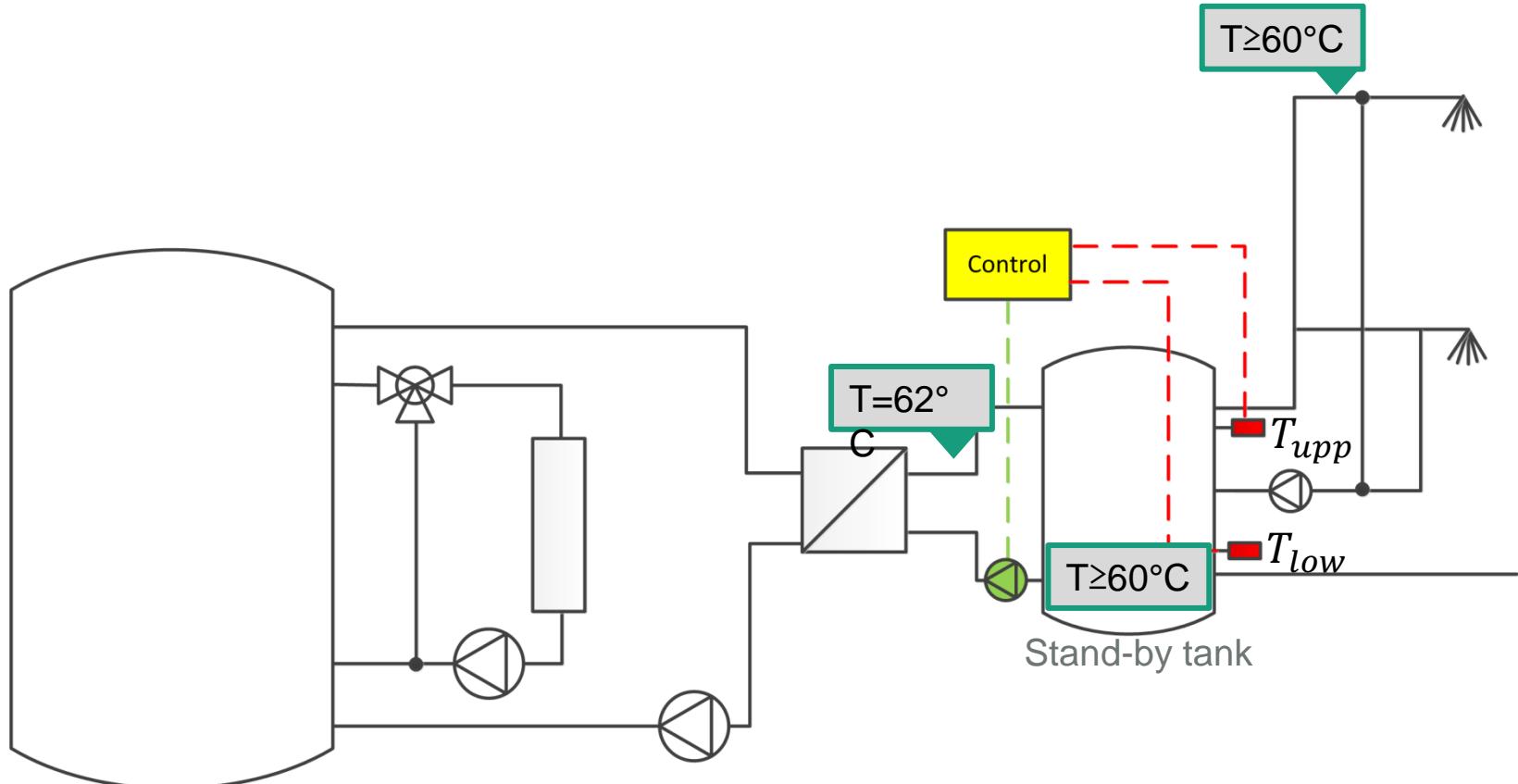
## Determination of mass flow rate by energy-balancing

$$\dot{m}_1 = \dot{m}_2 \cdot \frac{(62^\circ C - T_{2,in})}{(T_{1,in} - T_{2,in})} \cdot \frac{1}{\varepsilon_{hex}}$$



# Control system

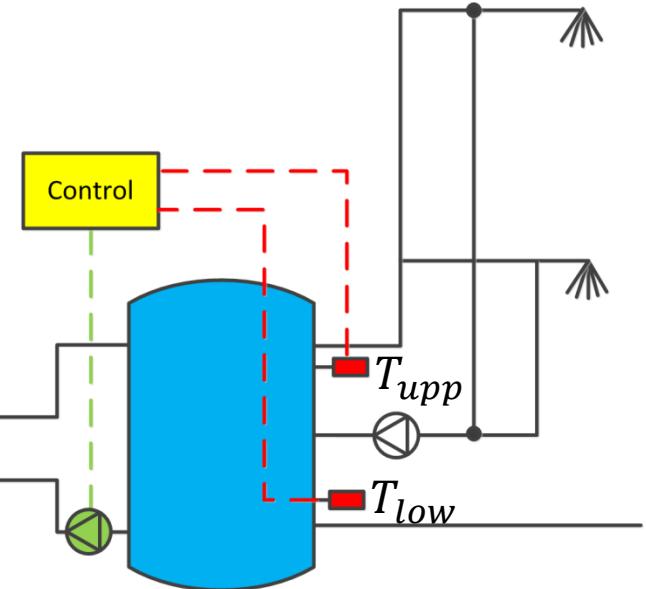
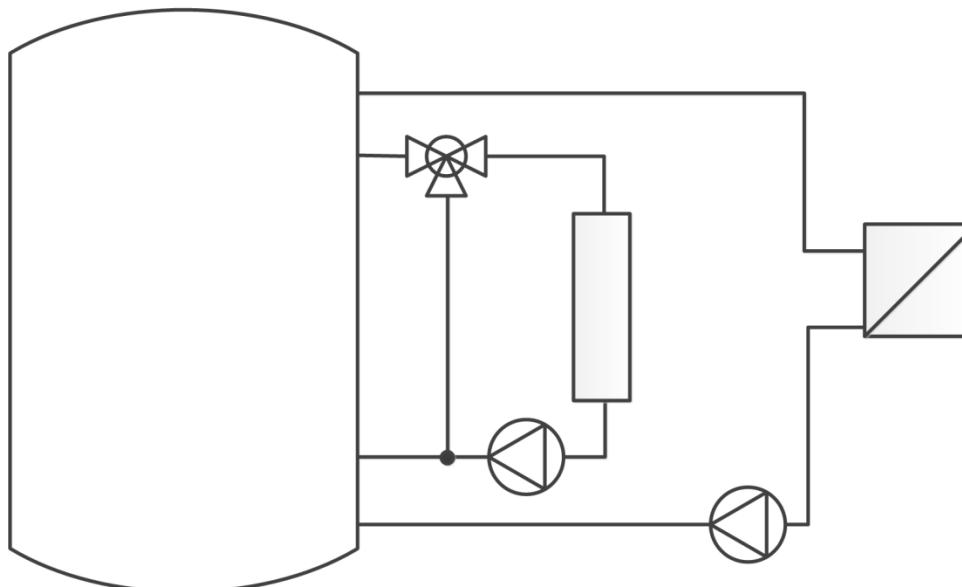
## Flip-flop control



# Control system

## Flip-flop control

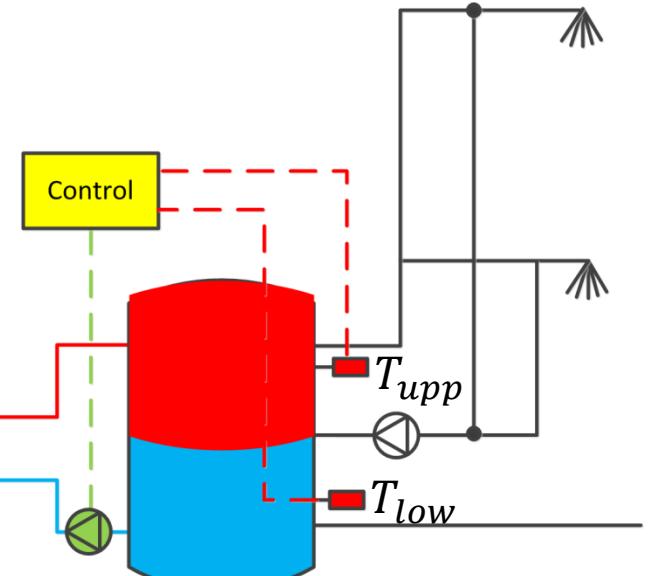
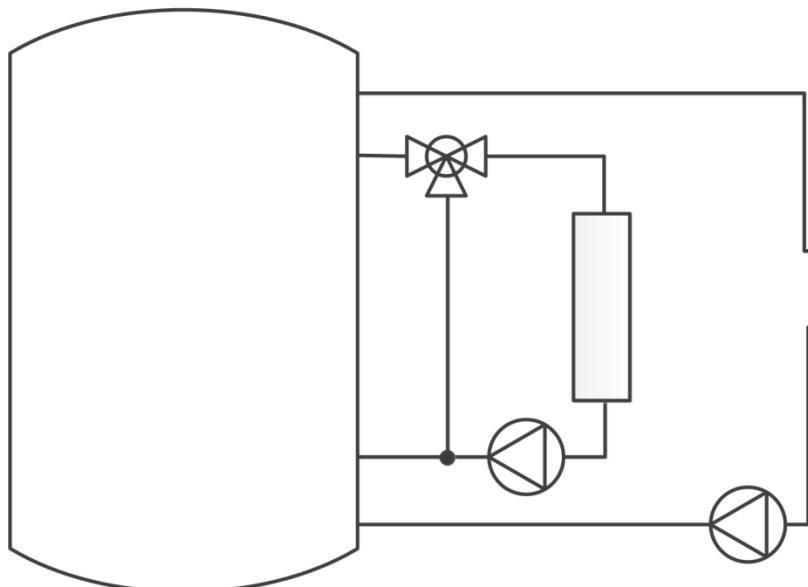
$T_{upp} \leq 60^{\circ}C ?$	$T_{low} \leq 60^{\circ}C ?$	Ctrl
True	True	ON



# Control system

## Flip-flop control

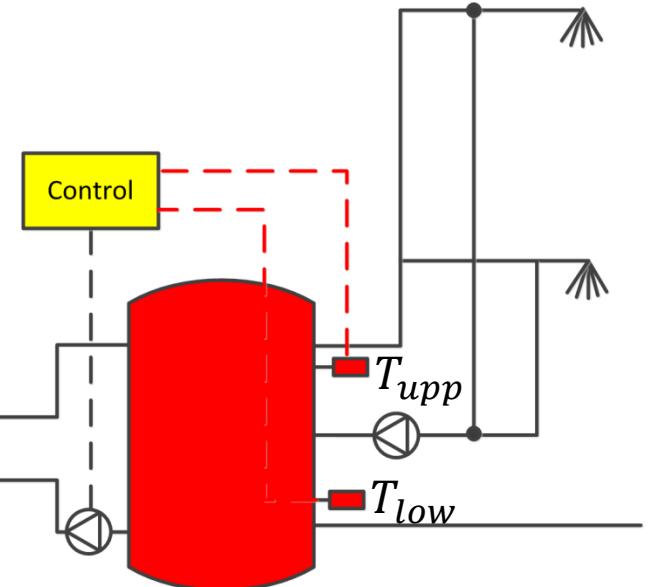
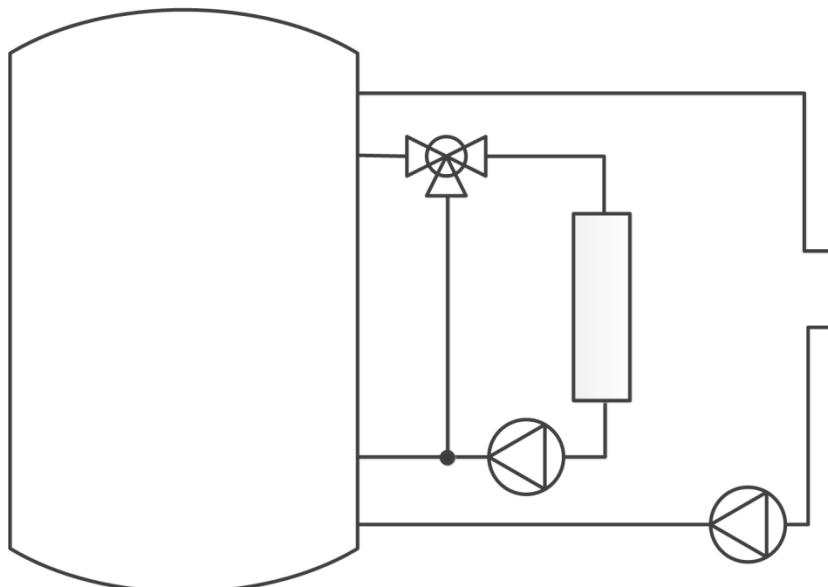
$T_{upp} \leq 60^{\circ}C ?$	$T_{low} \leq 60^{\circ}C ?$	Ctrl
False	True	ON



# Control system

## Flip-flop control

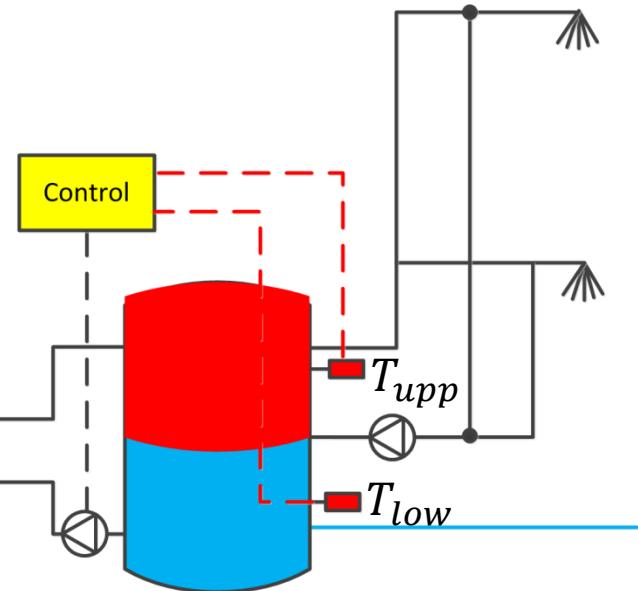
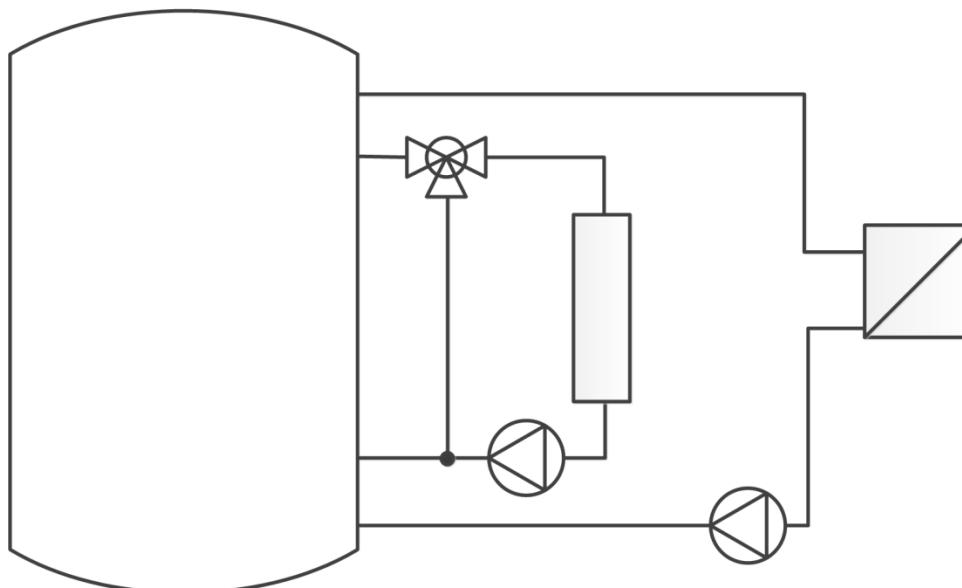
$T_{upp} \leq 60^{\circ}C ?$	$T_{low} \leq 60^{\circ}C ?$	Ctrl
False	False	OFF



# Control system

## Flip-flop control

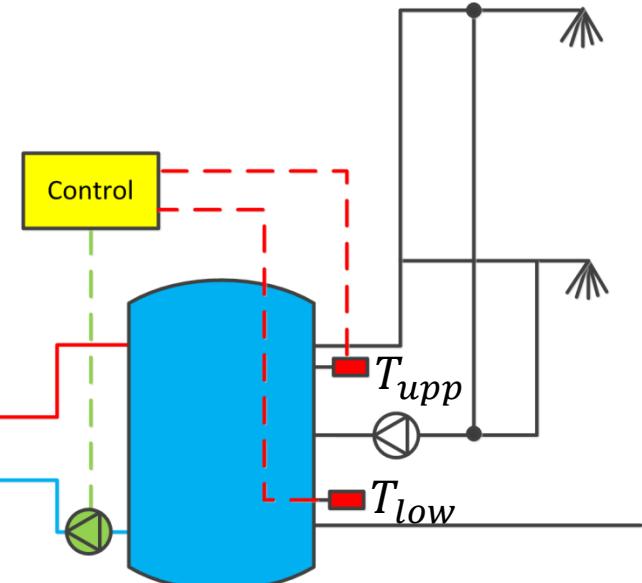
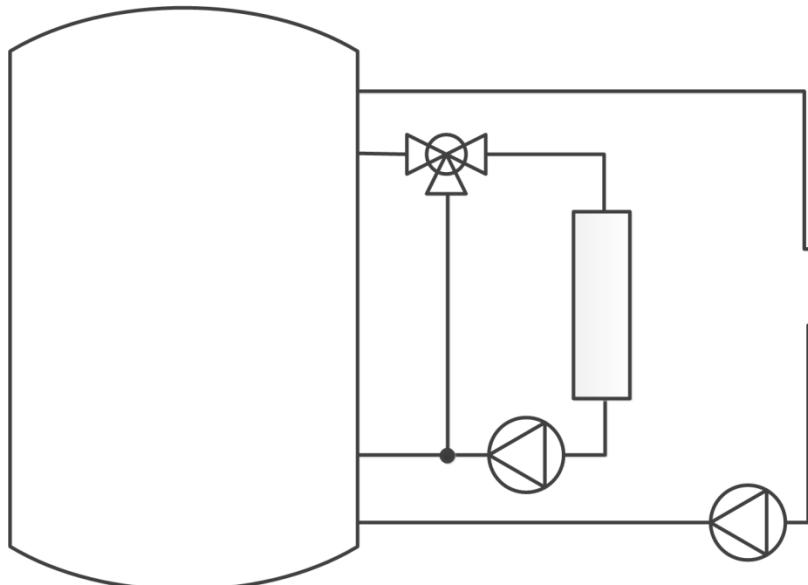
$T_{upp} \leq 60^{\circ}C$ ?	$T_{low} \leq 60^{\circ}C$ ?	Ctrl
False	True	<b>OFF</b>



# Control system

## Flip-flop control

$T_{upp} \leq 60^{\circ}C ?$	$T_{low} \leq 60^{\circ}C ?$	Ctrl
True	True	ON



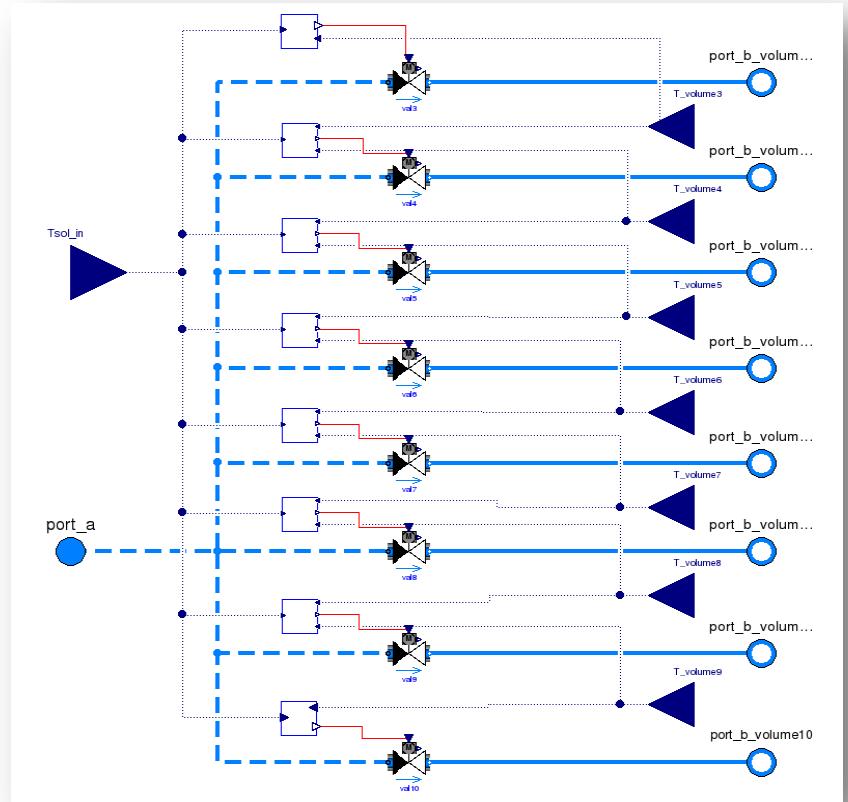
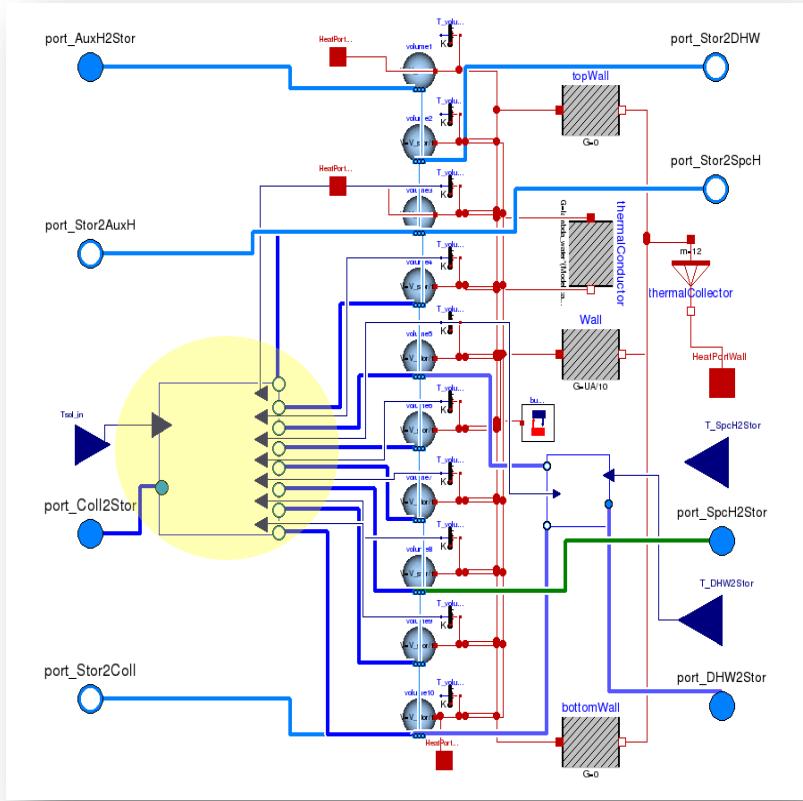
# Control system

## Flip-flop control

$T_{upp} \leq 60^{\circ}C ?$	$T_{low} \leq 60^{\circ}C ?$	Ctrl
True	True	<b>ON</b>
False	True	<b>ON</b>
False	False	<b>OFF</b>
False	True	<b>OFF</b>
True	True	<b>ON</b>

# Control system

## ON/OFF Valve control (stratified charging)



	Open criteria (otherwise the valve is closed)
Valve 3	when $T_{sol\_in} \geq T_{stor\_vol[3]}$
Valve i (for $4 \leq i \leq 9$ )	when $T_{stor\_vol[i]} \leq T_{sol\_in} < T_{stor\_vol[i-1]}$
Valve 10	when $T_{sol\_in} < T_{stor\_vol[9]}$

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# Parameter optimization of solar thermal system

## In context of grid interactivity

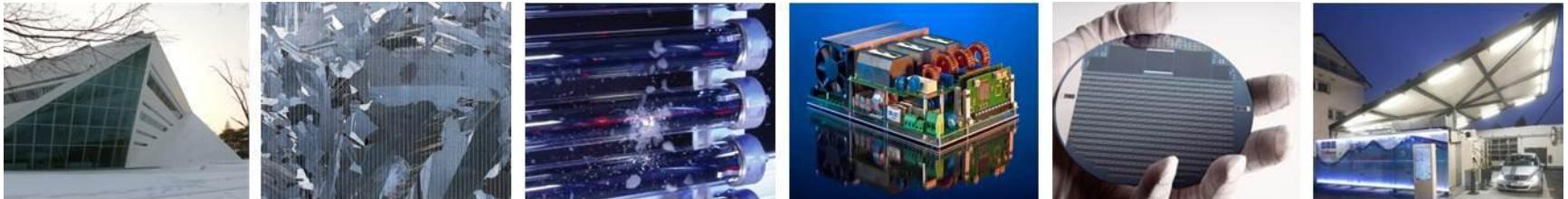
### ■ Objective parameters for optimization

- Specific collector aperture area per resident (heated floor area)
- Collector orientation (tilt and azimuth angle)
- Specific thermal capacity of store
- Specific auxiliary volume of store
- Design of other components of heat supply system  
(efficiency, temperature level,...)
- **Control parameters** (hysteresis, set-point values,..)

### ■ Cost function ( $\text{€}/\text{kWh}_{\text{useful energy}}$ )

- **Useful thermal energy gain of solar system** (building, district,..)
- Investment, operation **cost €** (heat generating and supply system, fuel consumption)

# Thank you for your attention!



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