Optimisation of a solar combisystem including a thermochemical storage

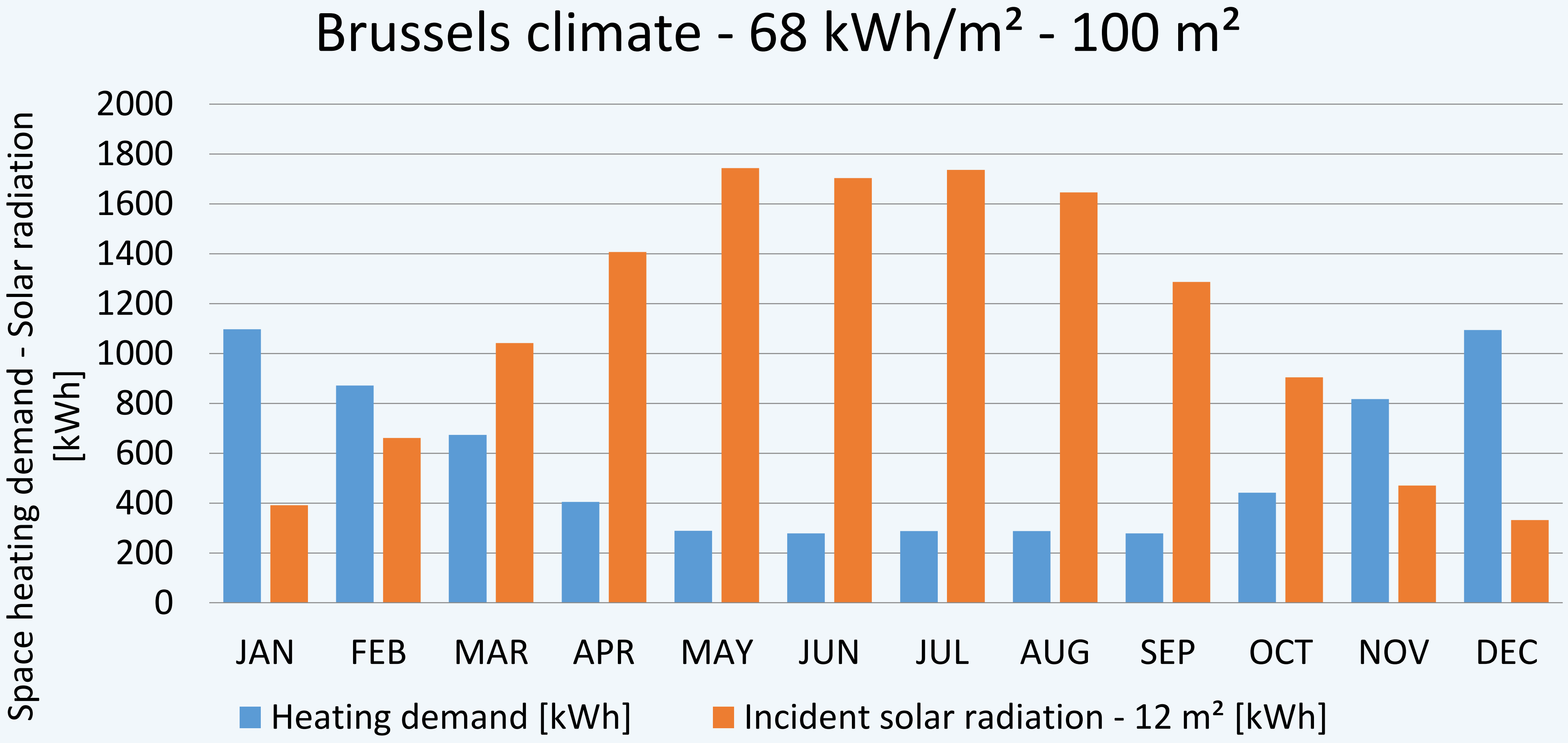
Focus on TRNSYS Tips and Tricks

Samuel Hennaut - BEMS

University of Liège – Arlon Campus Environnement

February 25th – TRNSYS Experience 2016 - TUK

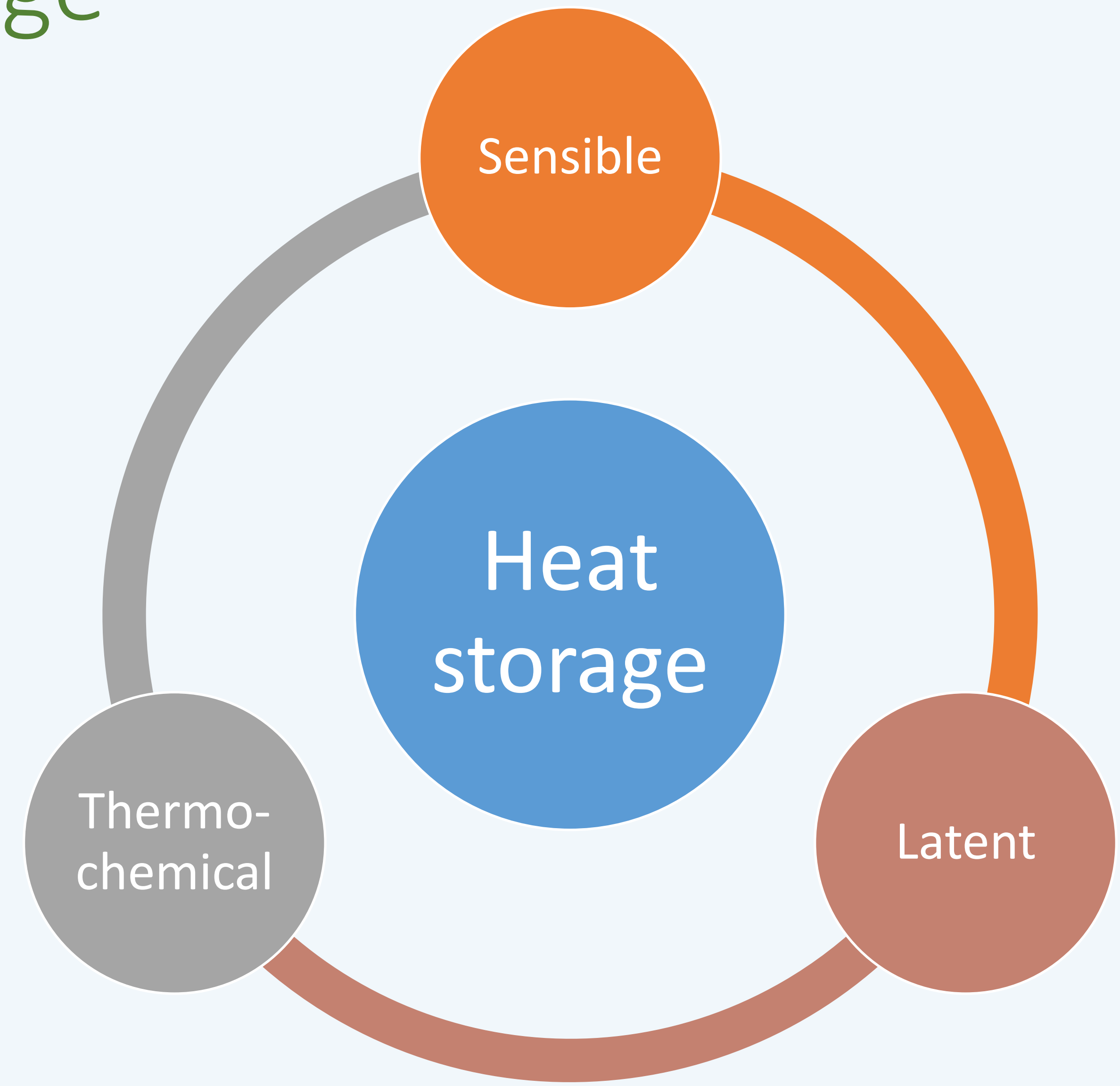
Heat your building with solar heat in winter?



Content

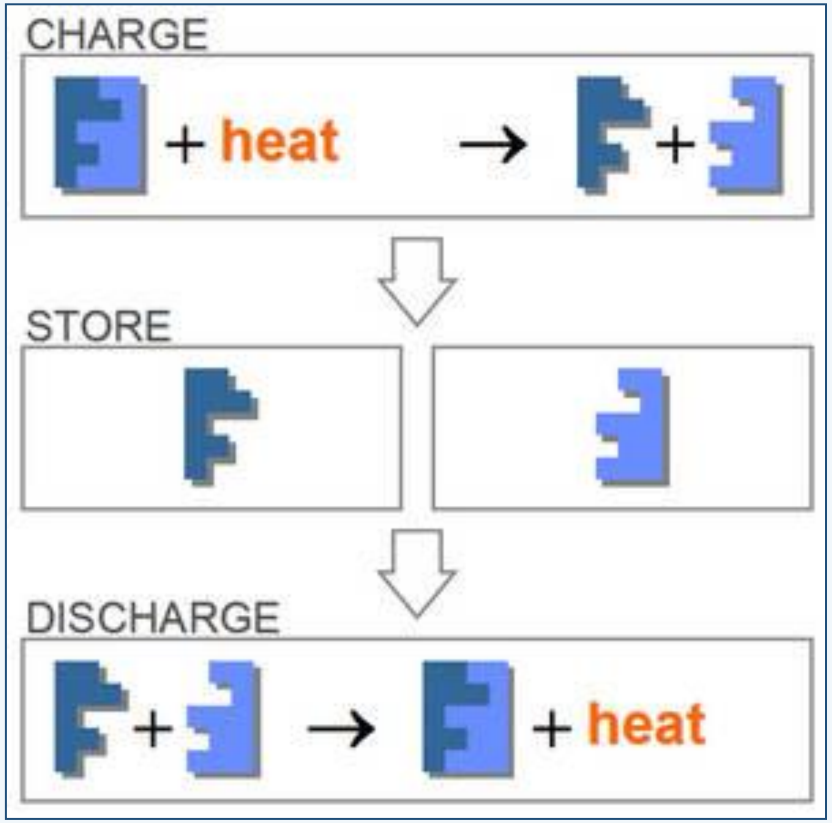
- Context
- TRNSYS simulation
  - Automatic parameters adaptation
  - Reactor model
  - Pipe model
  - Tank model
  - Parametric analysis
- Conclusion

Heat storage



Thermochemical storage of solar heat

Summer: excess of solar heat



Source: ECN (2009)

Winter: space heating needs

Thermochemical storage: pros and cons

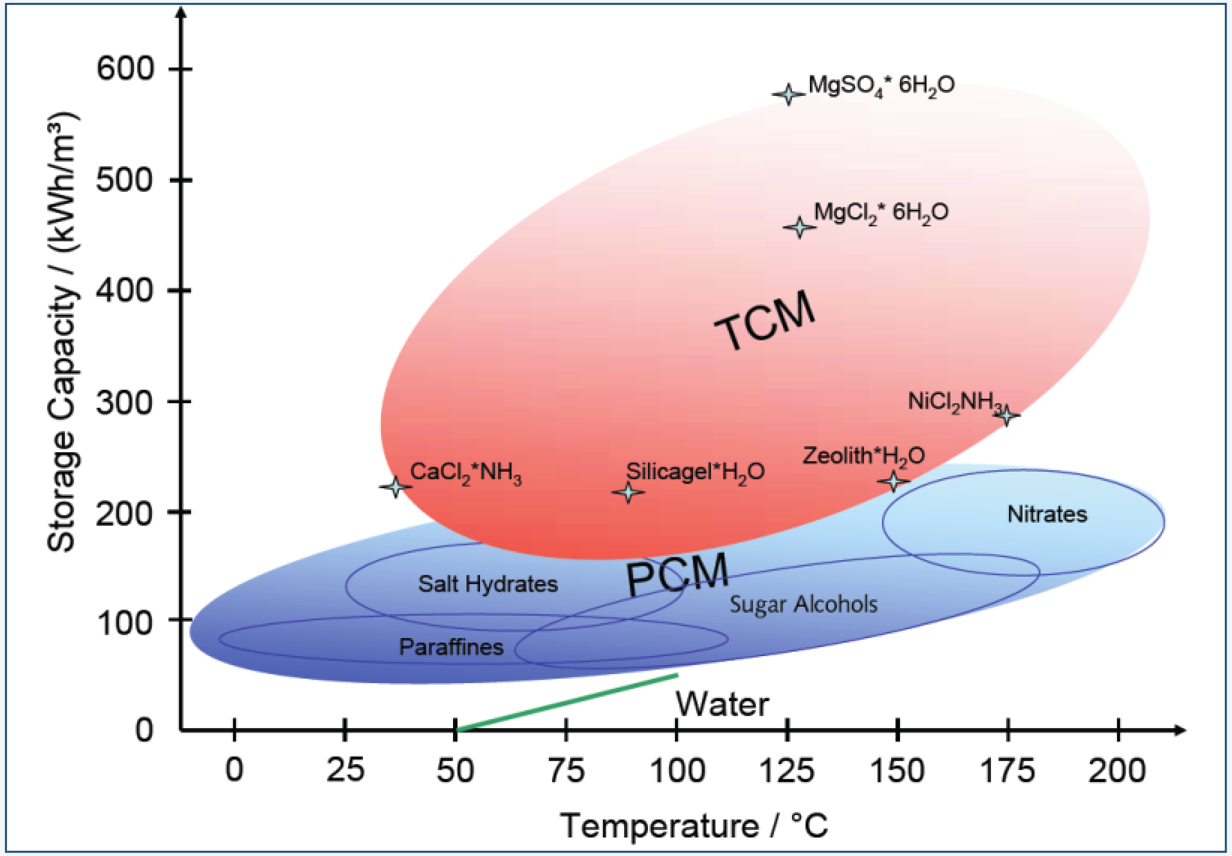
Advantages

- Big energy density
- No thermal losses
- Adaptable temperatures

Disadvantages

- Complex technology
- Subject to ambiant conditions

Storage density



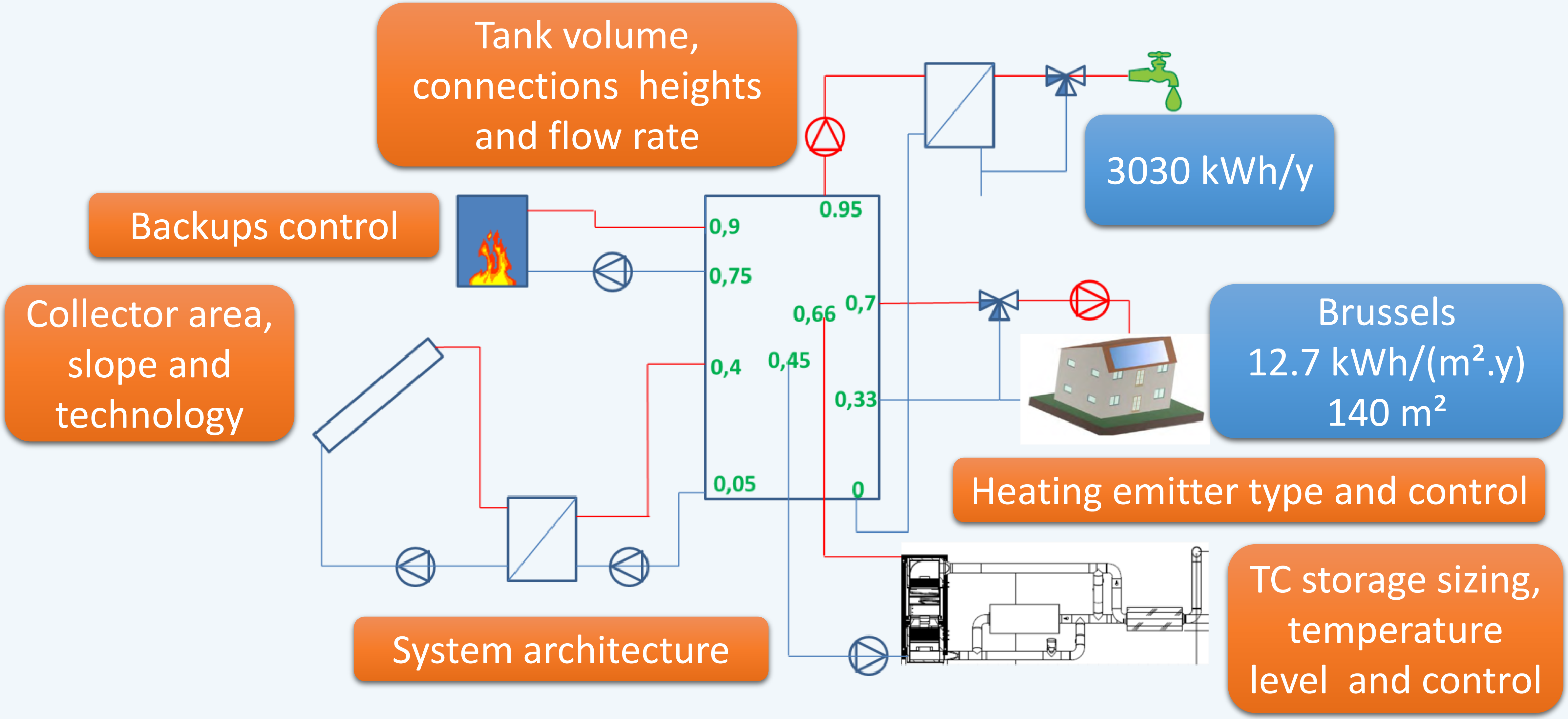
Source: Hauer (2010)

Sotherco research project

Solar direct heat + Solar excess Heat + Storage: solid-gas sorption = 100% Heat demand

$SiO_2\text{-}CaCl_{2\,(s)} + H_2O_{(g)}$

System sizing and control



System optimization

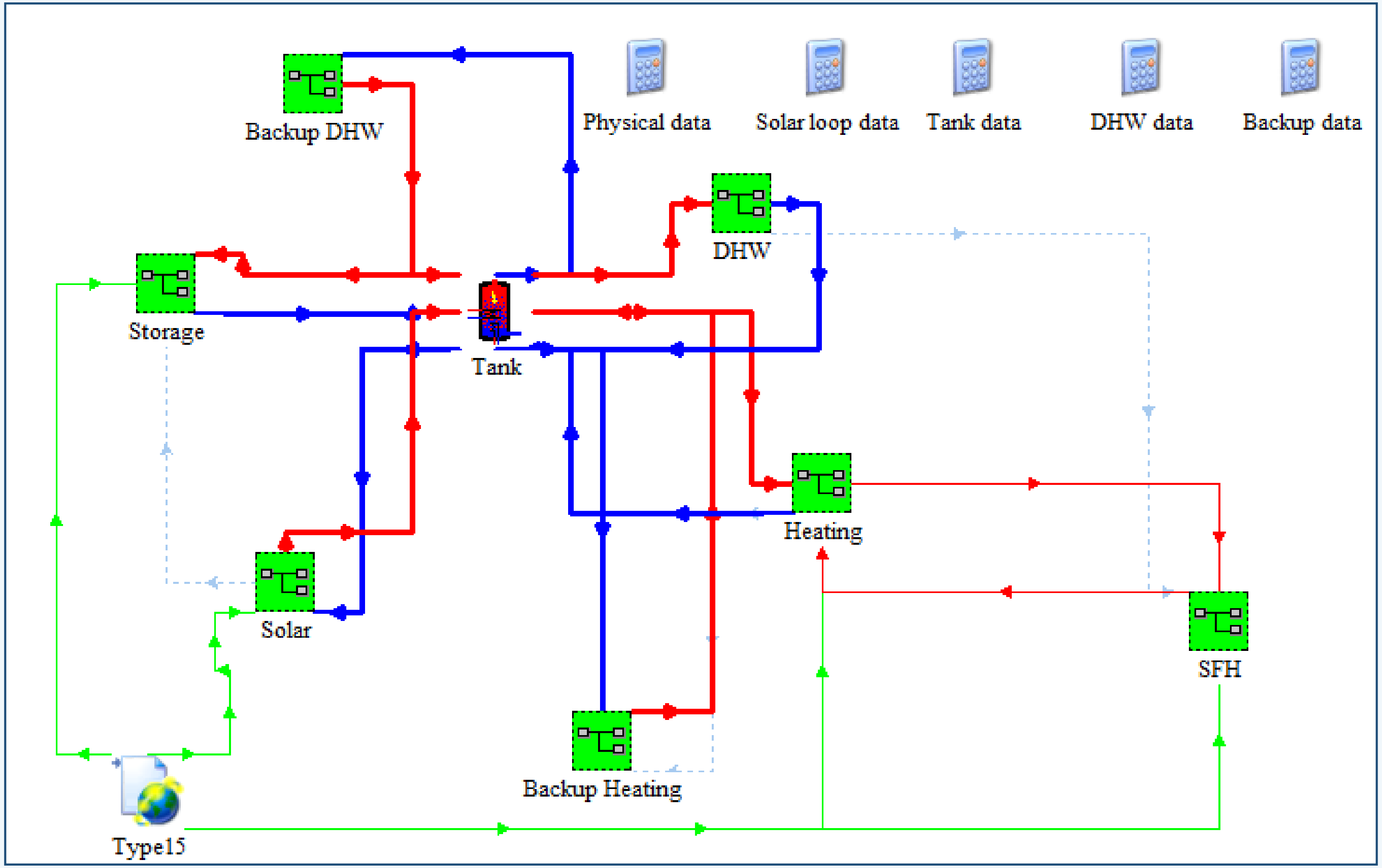
Parametric analysis for system sizing

- Tank volume
- Collector area
- Cold source temperature (water vaporization)
- Air flow rate in the reactor

Focus on

- Solid mass for chemical storage
- Backup energy needs: DHW + space heating (from TCS)

TRNSYS model



Automatic modification of parameters

What ?

- Define relations between parameters
- Ex: $\dot{m}_{solar} = \dot{m}_{specif} \cdot A_{coll}$

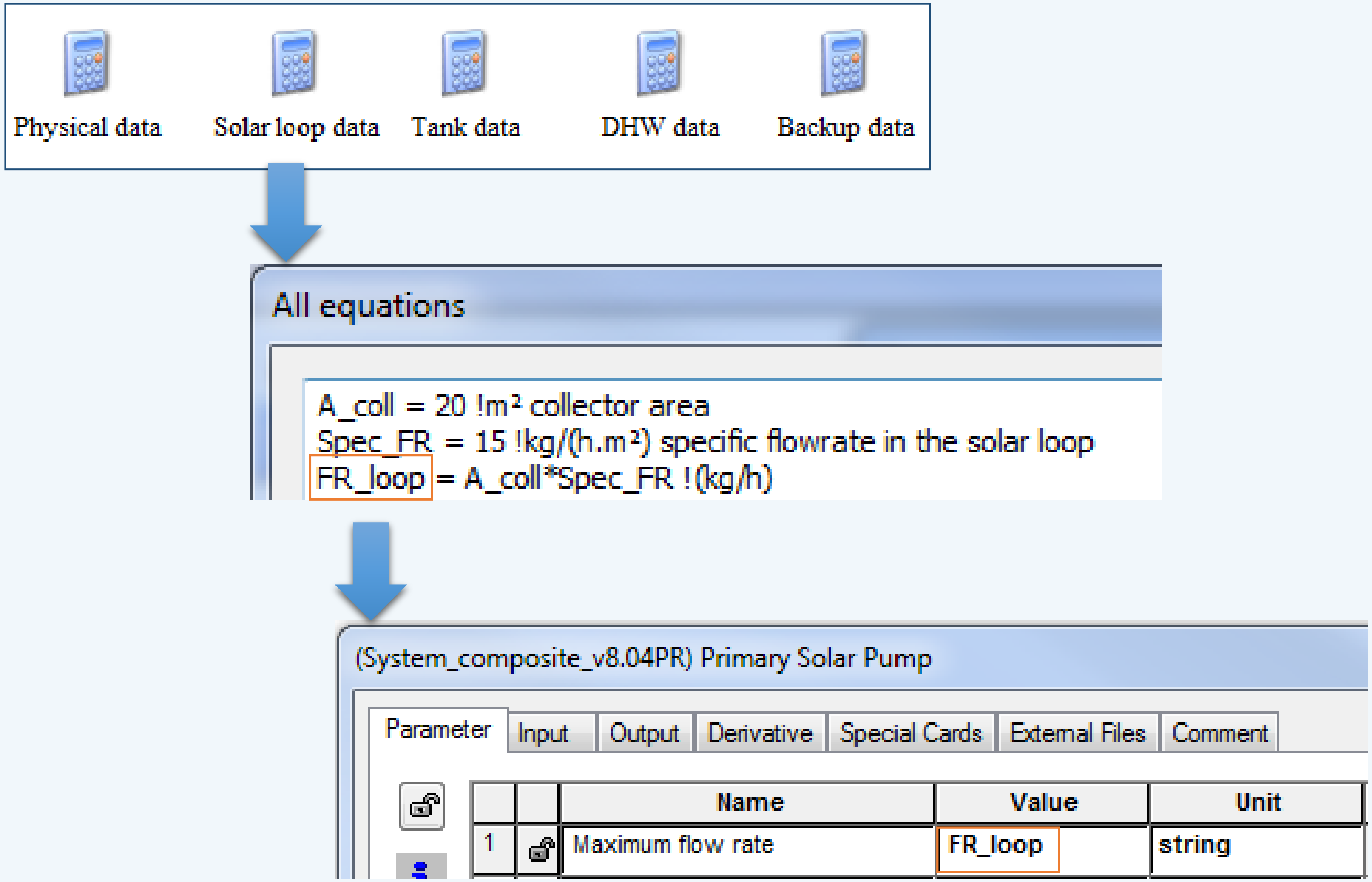
Why?

- Modify automaticaly linked paramaters
- Avoid bias during parametric runs

How?

- Using TRNSYS Equation Editors
- Parameters defined as « String »

Example: Solar loop flow rate
Automatic modification of parameters



Objectives:

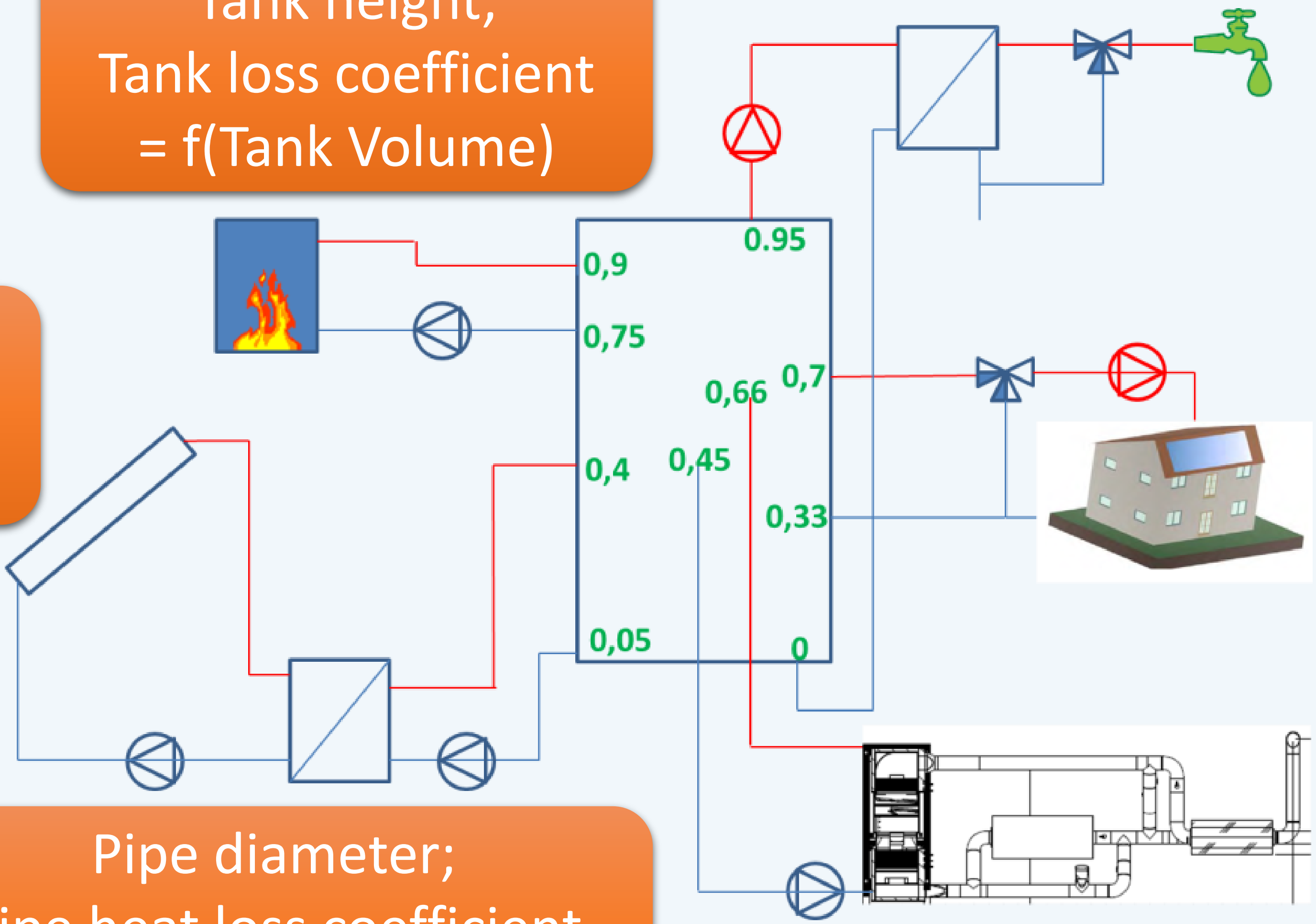
1 -Modification of flow rate **with** collector area

2 - Modification of flow rate in primary **and** secondary loop

Automatic modification of parameters

Tank height;
Tank loss coefficient
= f(Tank Volume)

Solar loop flow rate
= f(collector area)

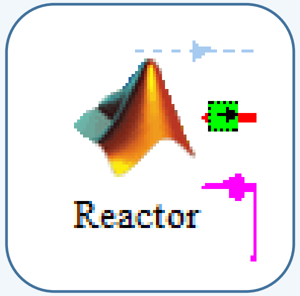


Pipe diameter;
Pipe heat loss coefficient
= f(solar loop flow rate)

Source:
Tank height;
tank loss
coefficient

IEA-SHC Task 32,
Report A2, Heimrath
et al., 2007

Thermochemical reactor model

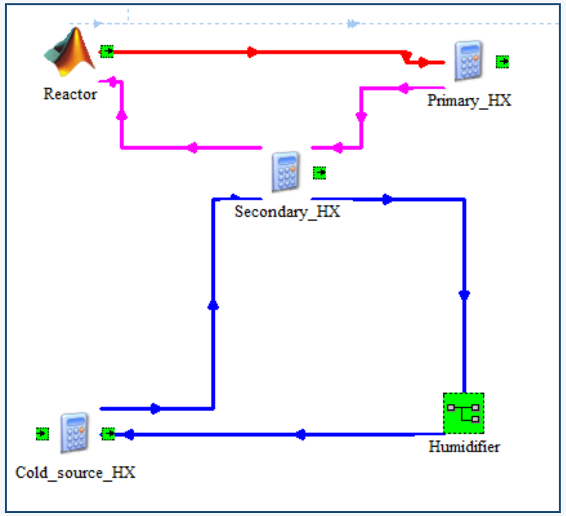


- TRNSYS Type 155: calling MATLAB

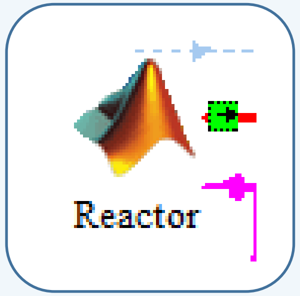
- Objective: Use « powerful » MATLAB solvers

```
% solving main system
out_main      = fsolve(@system_of_equations_main,y_ini_main,optimset('TolFun',1e-6));
%
```

- Integration similar to other TRNSYS models
  - Linked to « external » *.m file



Type 155 – Interaction Matlab ↔ TRNSYS



- *.m file code architecture similar to classical type:
  - Respect specific TRNSYS calls

```
% First call of the simulation: initial time step (no iterations)
if ((trnInfo(7) == 0) && (trnTime - trnStartTime < 1e-6))
```

- Import model inputs in Matlab

- Export model outputs to TRNSYS

- Increase calculation time

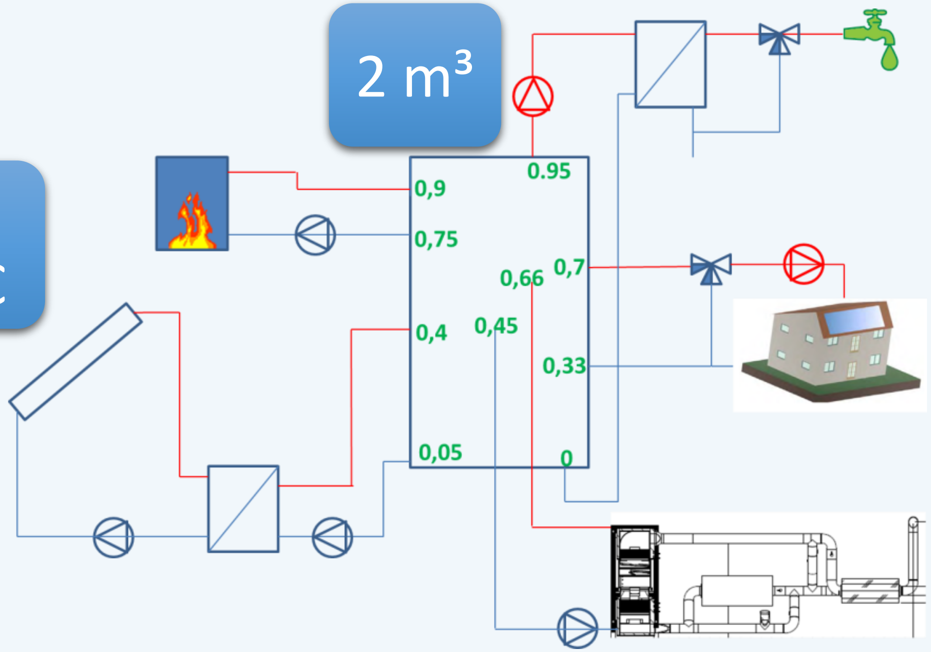
```
% reactor inlet temperature
Tin_r       = trnInputs(1); % [°C]
% reactor inlet humidity ratio
Xout_ev     = trnInputs(2); % kg/kg
% dry air fow rate in the system
m_dot_air   = trnInputs(3); %kg/s
% enthalpy of chemical reaction
h_reaction  = trnInputs(4); %kJ/kg
% initial solid state
x_s_ini     = trnInputs(5); %kg/kg
%total salt quantity in the reactor
m_solid     = trnInputs(6); %kg
%kinetics coefficient - water mass transfer coef.
coef_w_trnf = trnInputs (7);%s-1
```

Level of detail in TRNSYS HVAC simulation

- Is it necessary to simulate pipes or not?
- Influence of tank thermal losses accuracy?

20 m² ETC
Slope 40°C

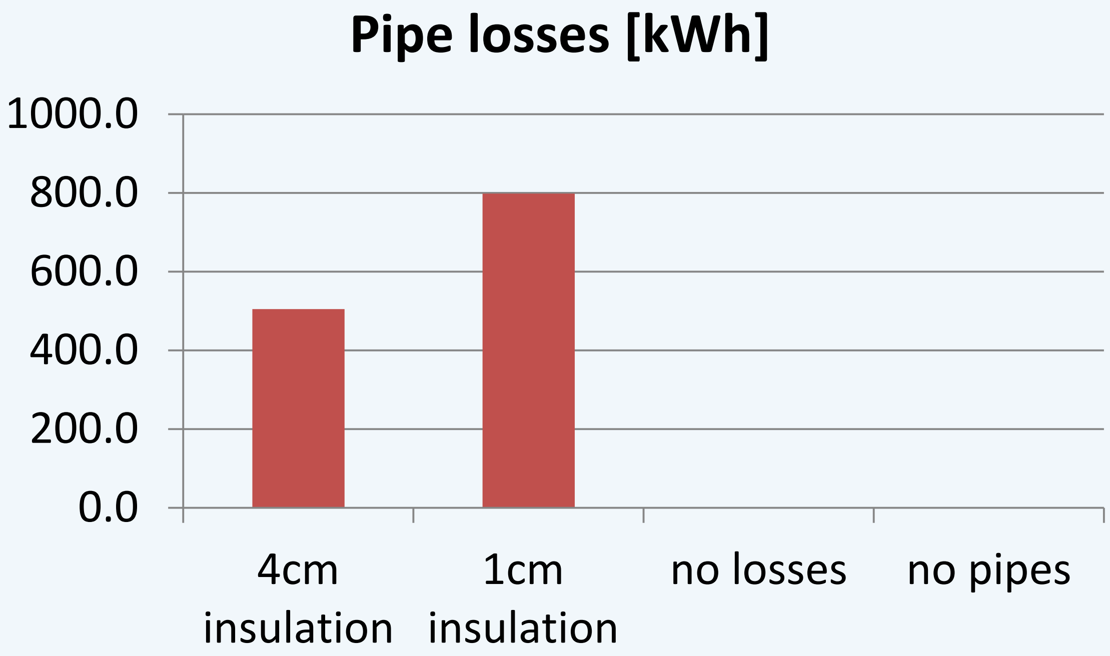
2 m³

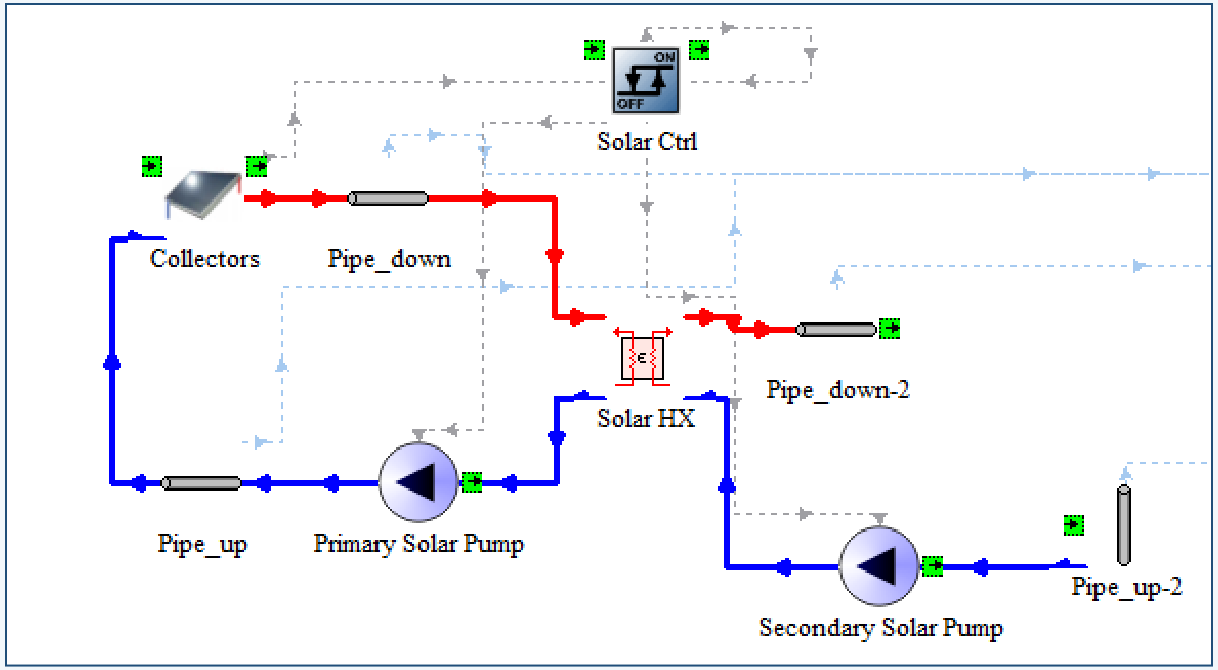


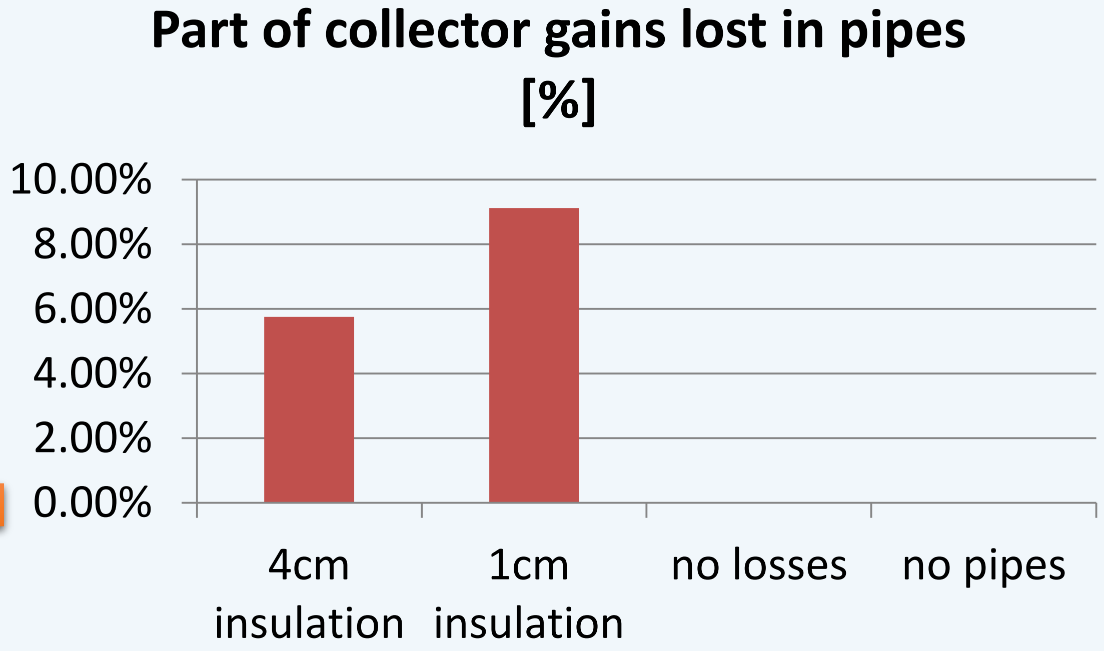
5 °C
0.5 kg/s

Objective:
Give an order of magnitude!

Pipe simulation or not?

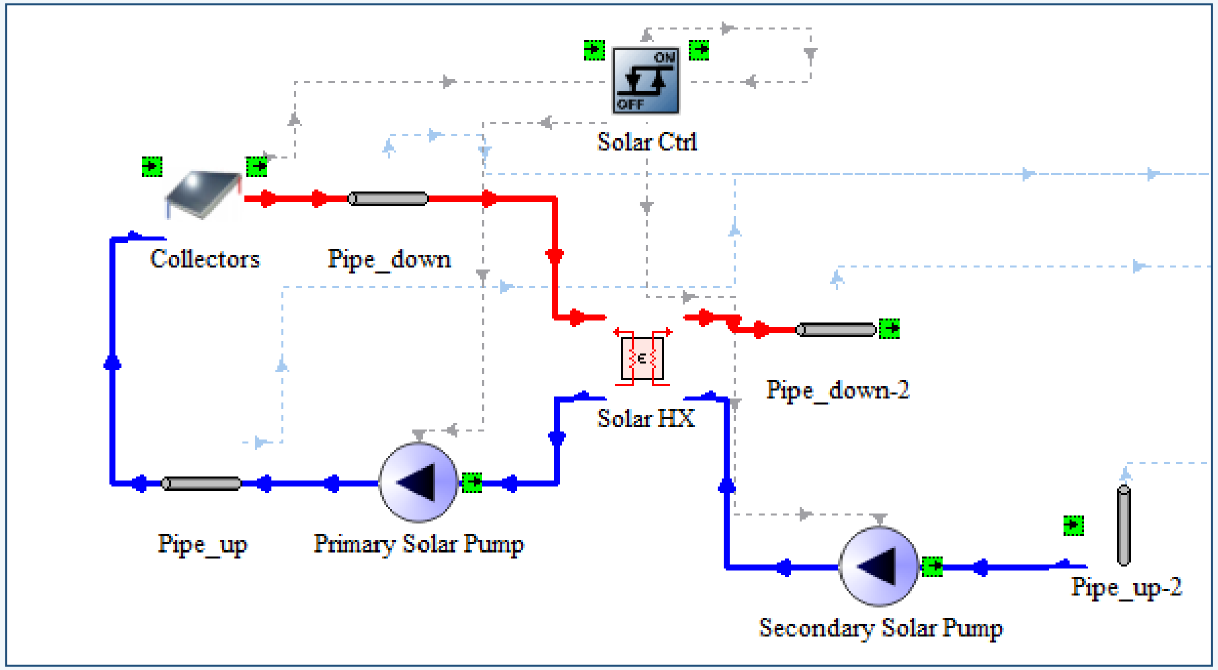


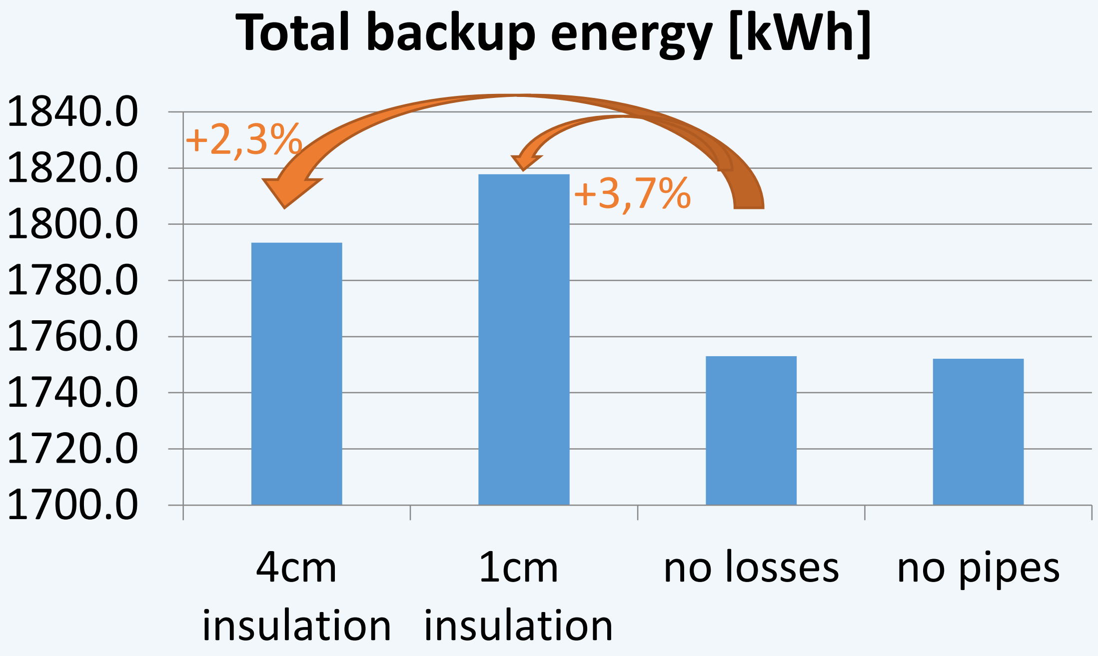


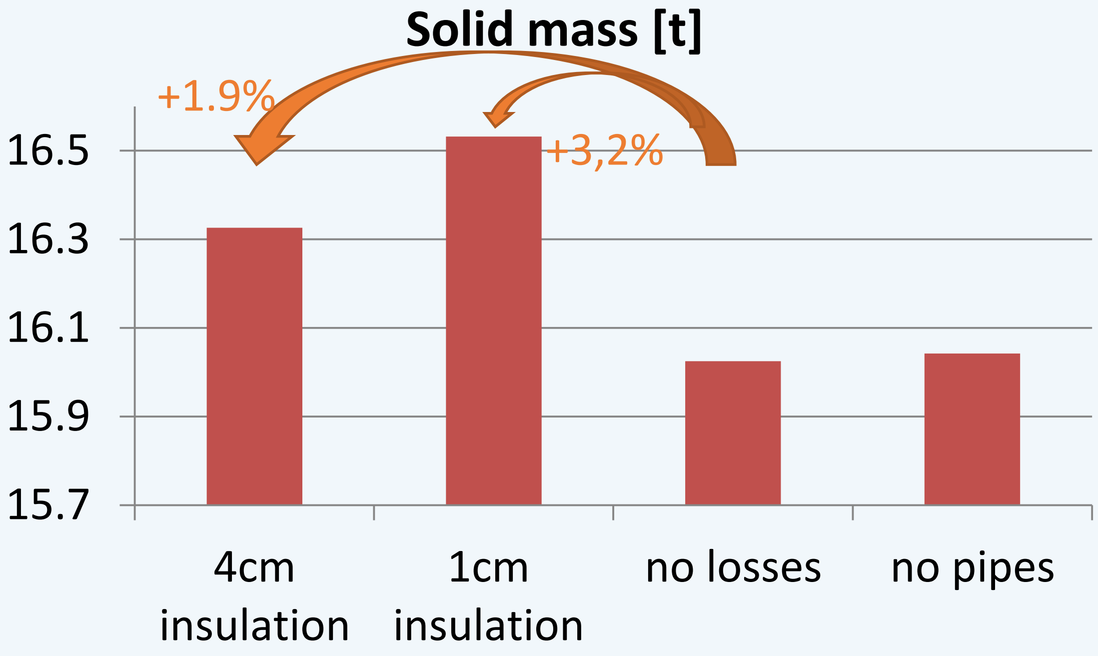


Influence on collector sizing

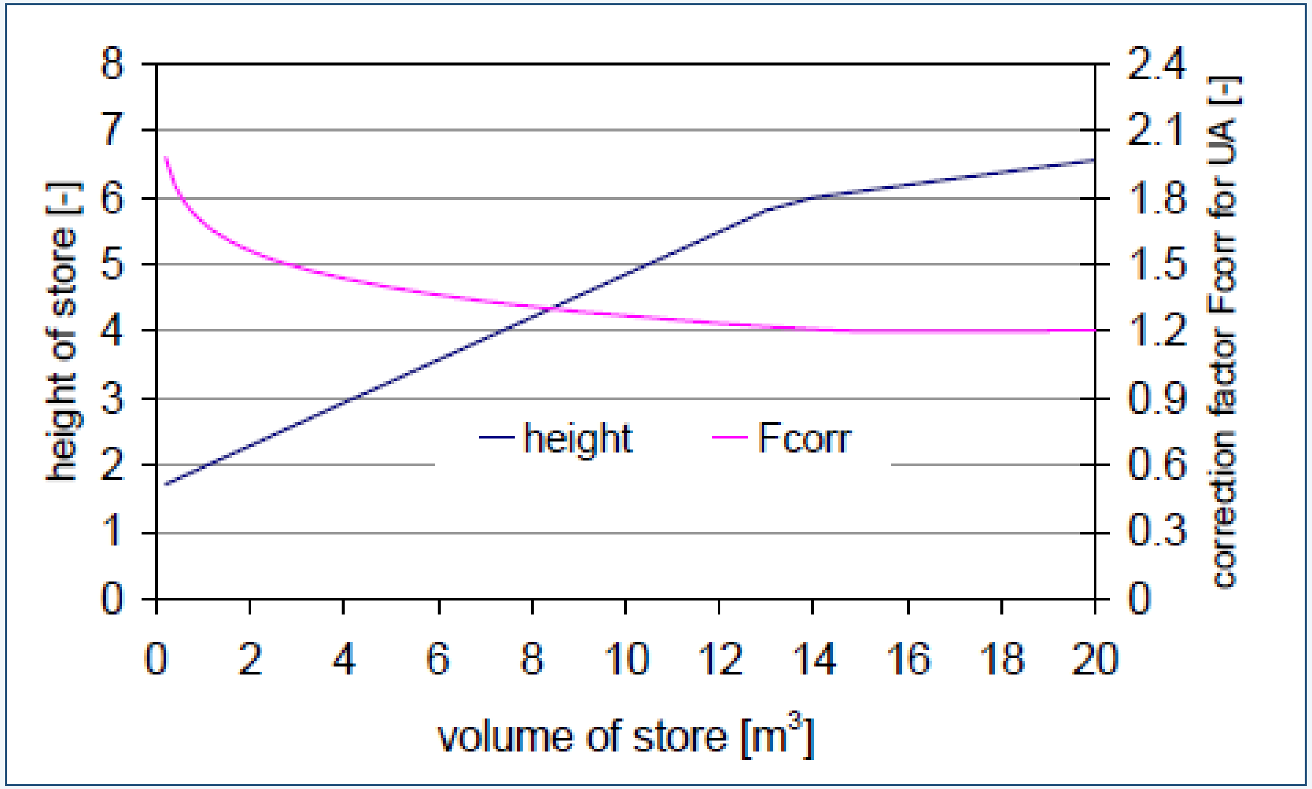
Pipe simulation or not?







Tank insulation correction factor

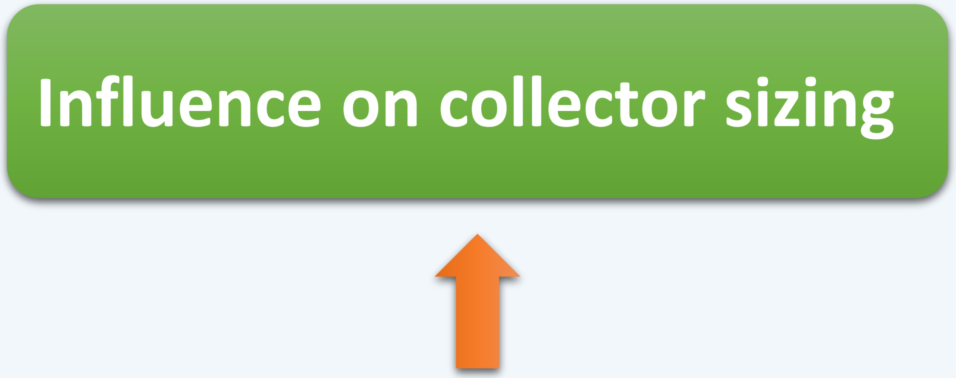


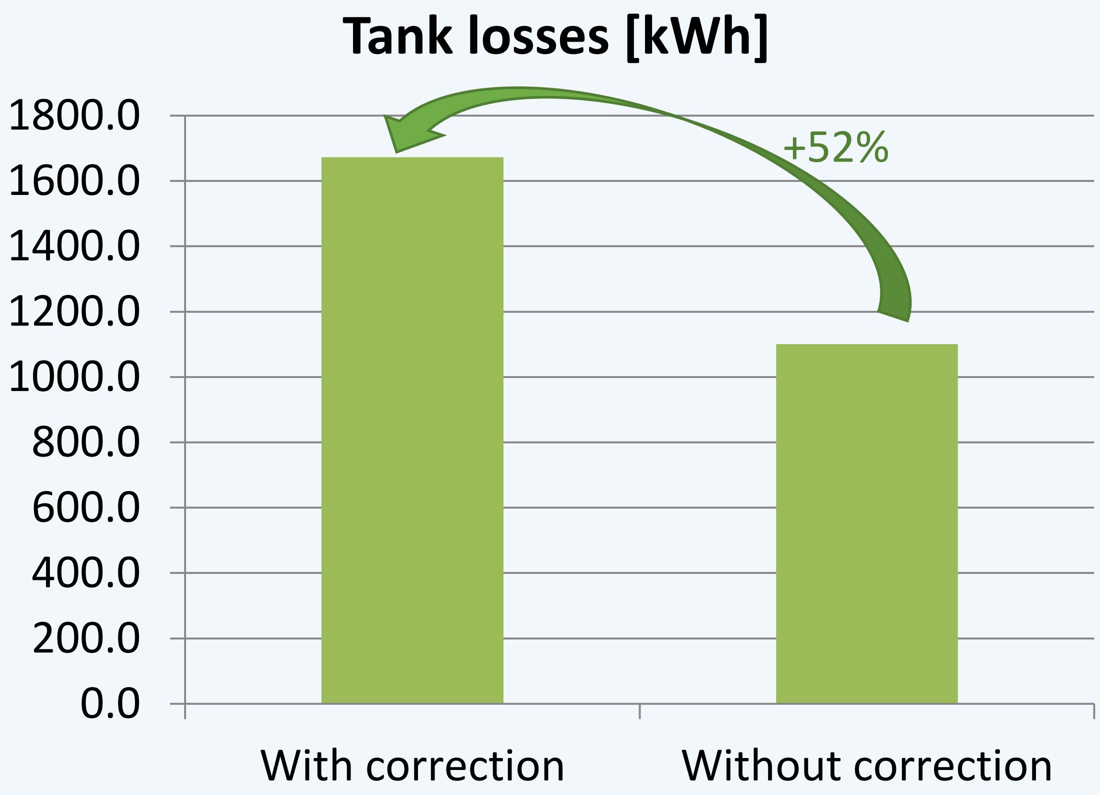
$$UA_{tank,corr} = F_{corr} \cdot (UA_{tank,insulation})$$

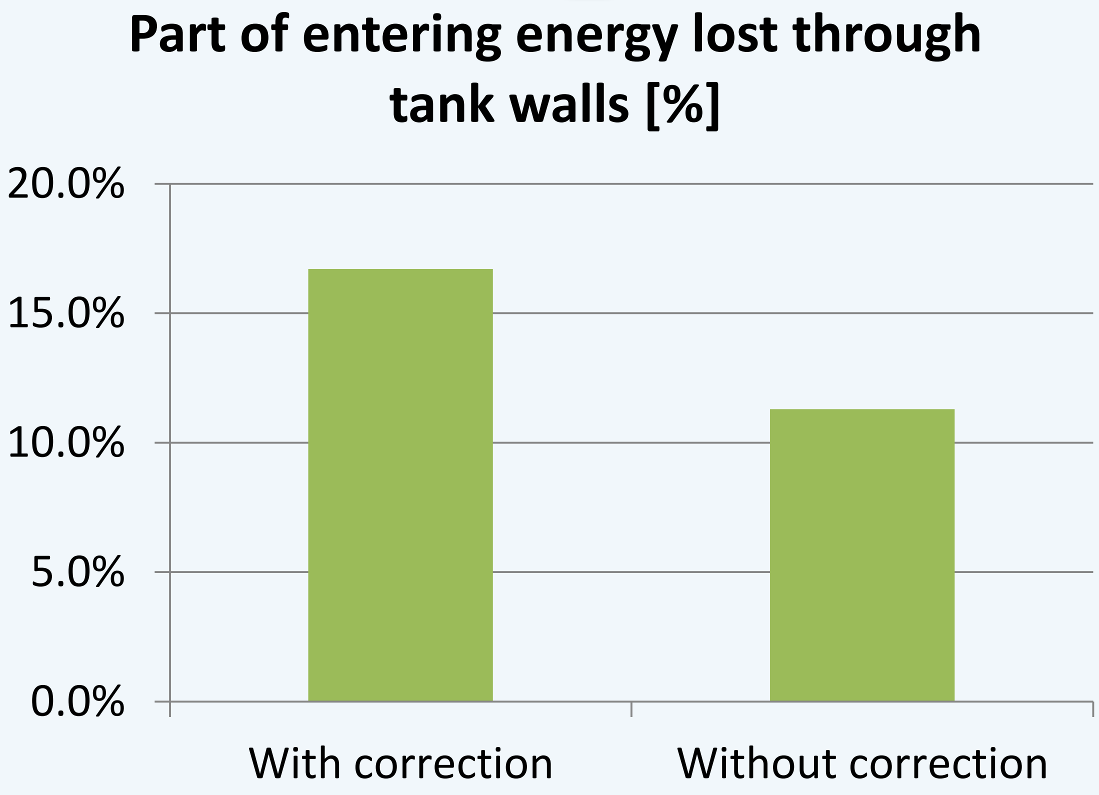
$$F_{corr} = MAX(1.2; -0.1815\, LN(V_{tank}) + 1.6875)$$

Source: IEA – SHC
Task 32

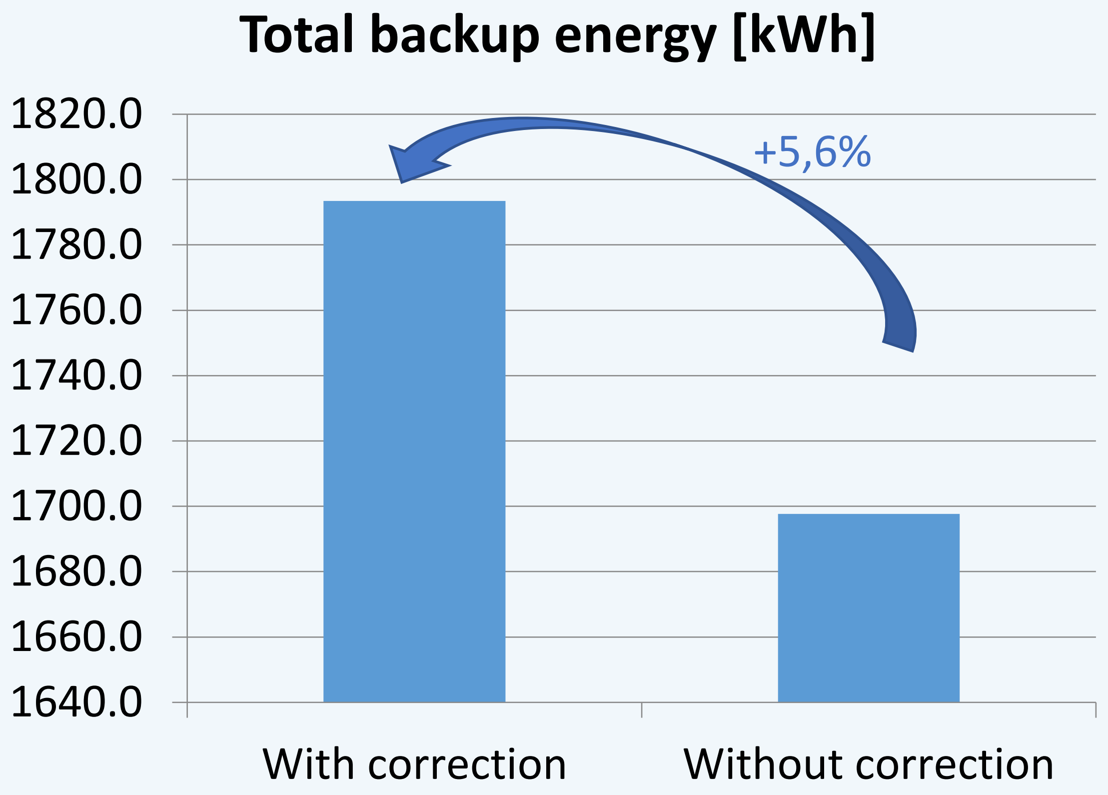
Tank insulation

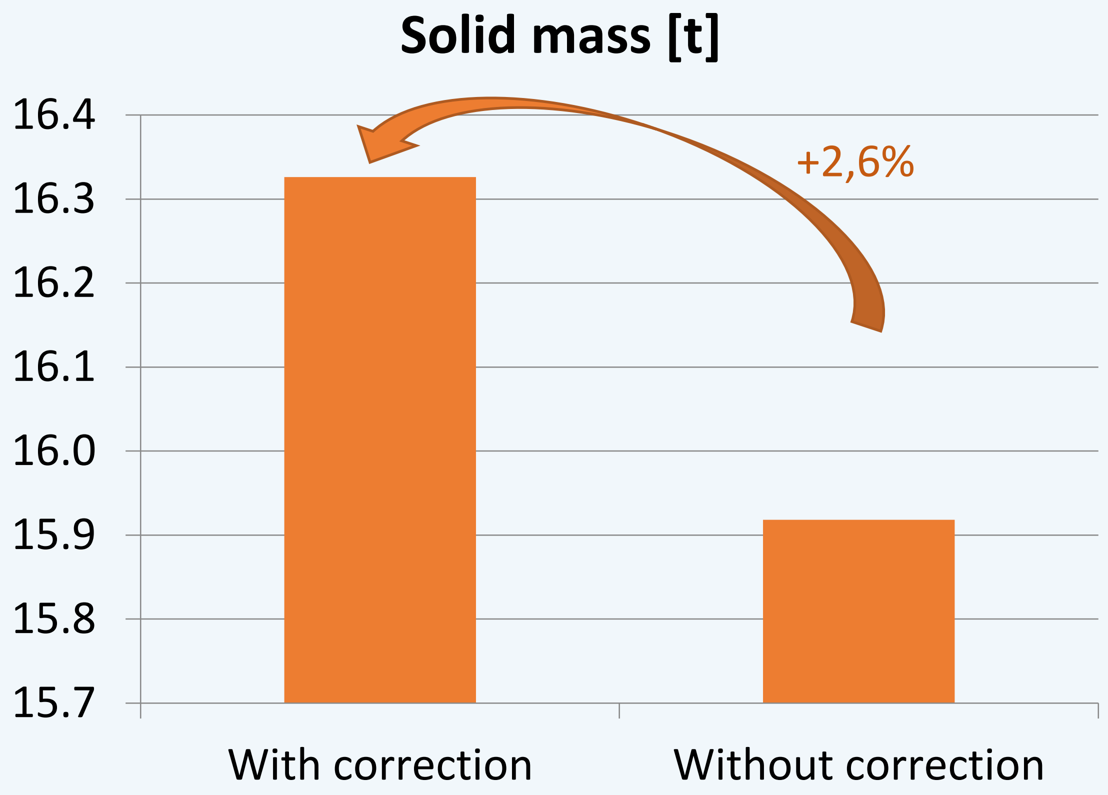






Tank insulation

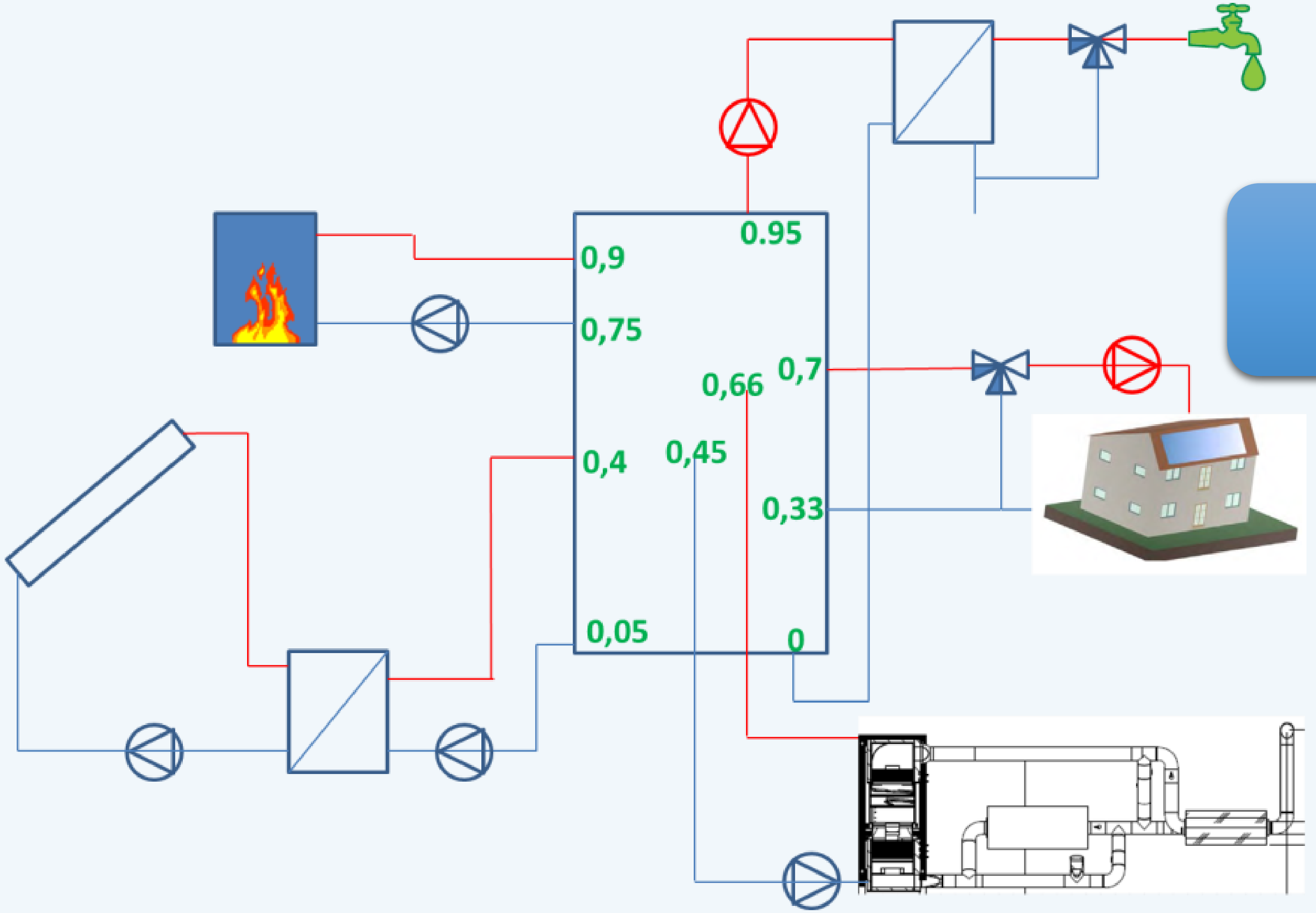




Parametric study definition

Cold source temperature	• 2; 5; 8 °C
Collector area	• 15; 20; 25 m^2
Air flow rate in the reactor	• 0.25; 0.5; 0.75 kg/s
Tank volume	• 0.5; 1 ;2 m^3

Analysed variables



Comfort penalty [°h]

Mass of solid necessary for autonomous space heating system[t]

First results

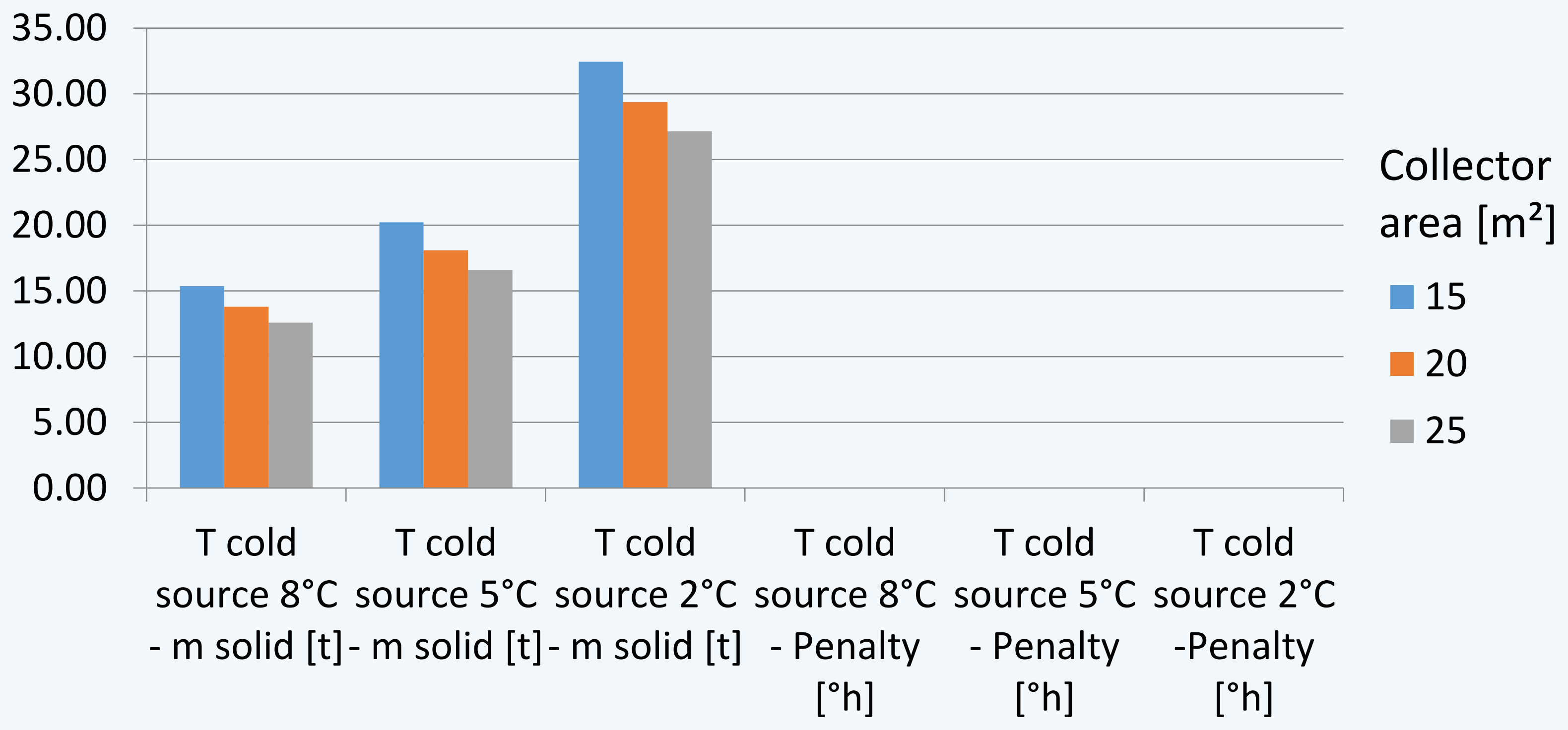
- Minimal solar collector area= $f(T_{cold\ source})$
  - 2°C: At least 25 m²
  - 5°C: a bit less than 20 m²
  - 8°C: around 17.5 m²

- Minimal air flow rate in the reactor = $f(T_{cold\ source})$
  - 2°C: around 0.75 kg/s
  - 5°C: around 0.5 kg/s
  - 8°C: around 0.25kg/s

- $V_{tank} = 2m^3$ → always minimum mass of solid

First results

- Minium of solid mass
  - Tank volume = 2m³
  - Air flow rate: 0.5 kg/s if T_{CS}= 8 or 5 °C; 0.75 kg/s if T_{CS}= 2°C



Conclusion

- Level of detail: depends on simulation objective and precision needed
  - ➢ Define the objective before starting the simulation
  - ➢ Decision depends of the « quality » of system components: quality of insulation, size of the tank, temperature difference

- Thermochemical storage is a quite promising solution to increase heat storage energy density and for seasonal storage, especially with a « hot » cold source