SAMSSA

Sugar Alcohol based Materials for Seasonal Storage Applications

Performance assessment through a case study

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Definition of storage requirements

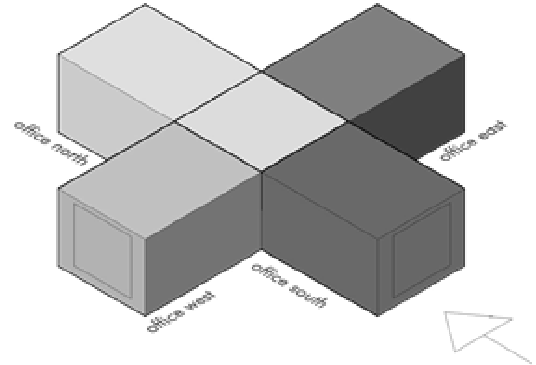
Aim: definition of storage requirements

Tool: Simulation study in TRNSYS:

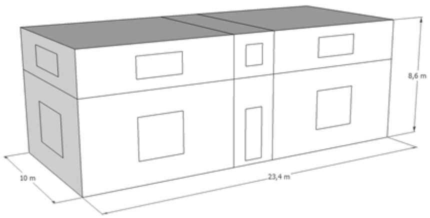
1. Definition of heating loads
2. Definition of storage requirements by system simulation
   - Storage volume
   - Power density
   - Melting temperature
   - Number of storage cycles

Definition of heating load: building type

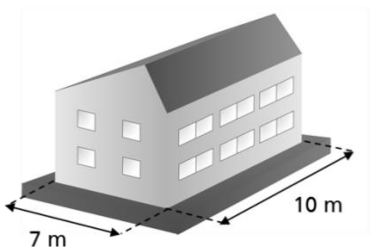
- Office building (584 m²)

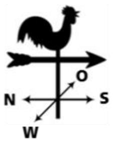


- Multi family house (612 m²)



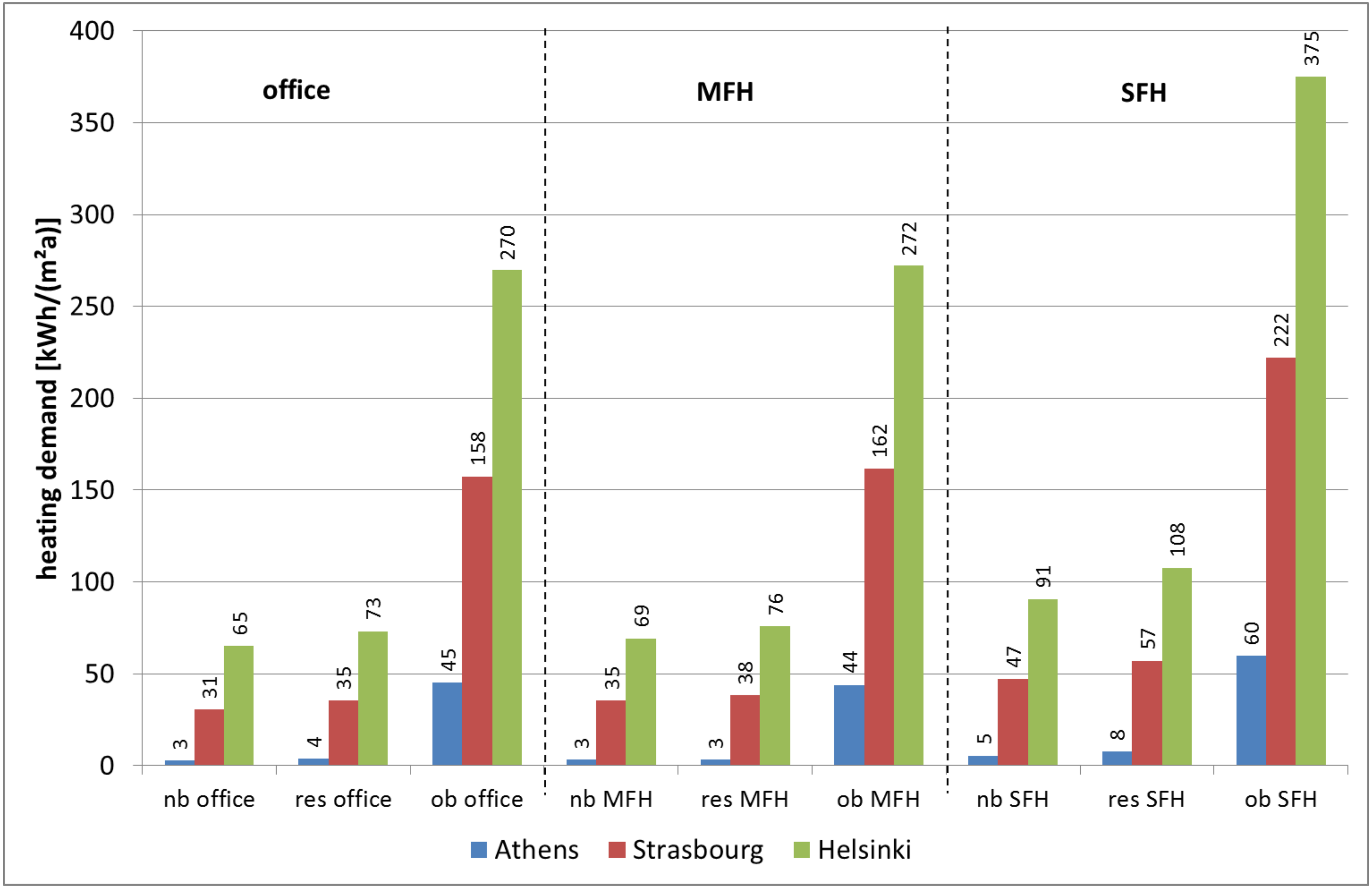
- Single family house (140 m²)





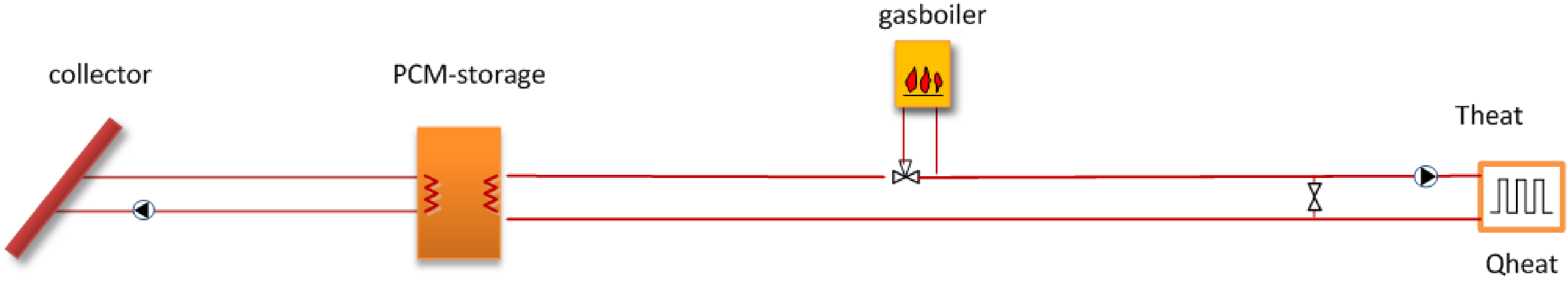
Three Climates: Helsinki, Strasbourg, Athens
Three building standards: new, retrofitted, old

Definition of heating load: results

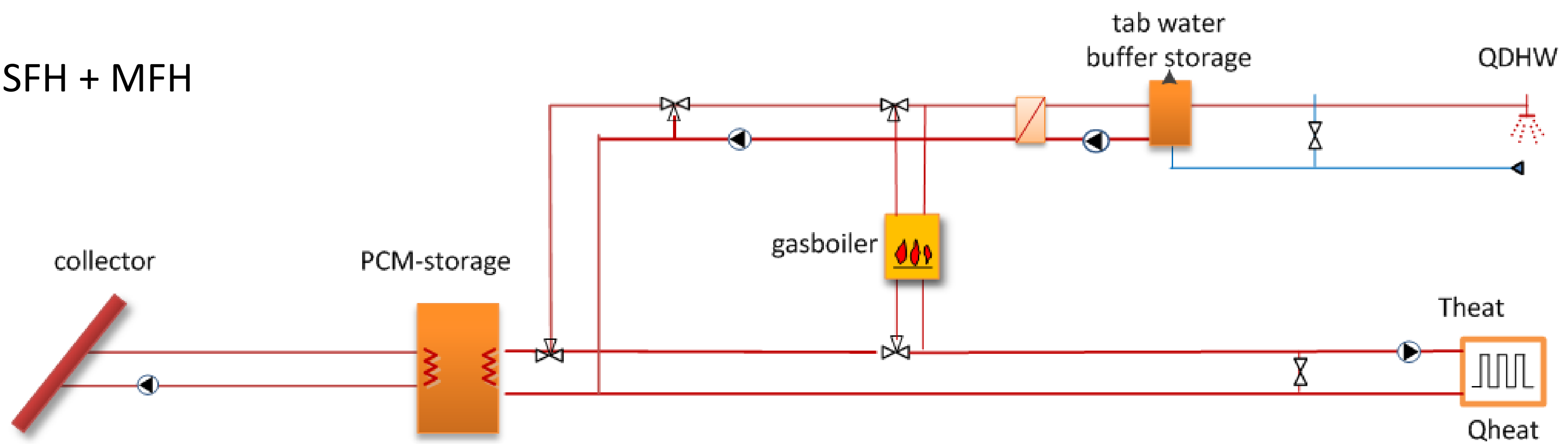


Solar thermal system

Office

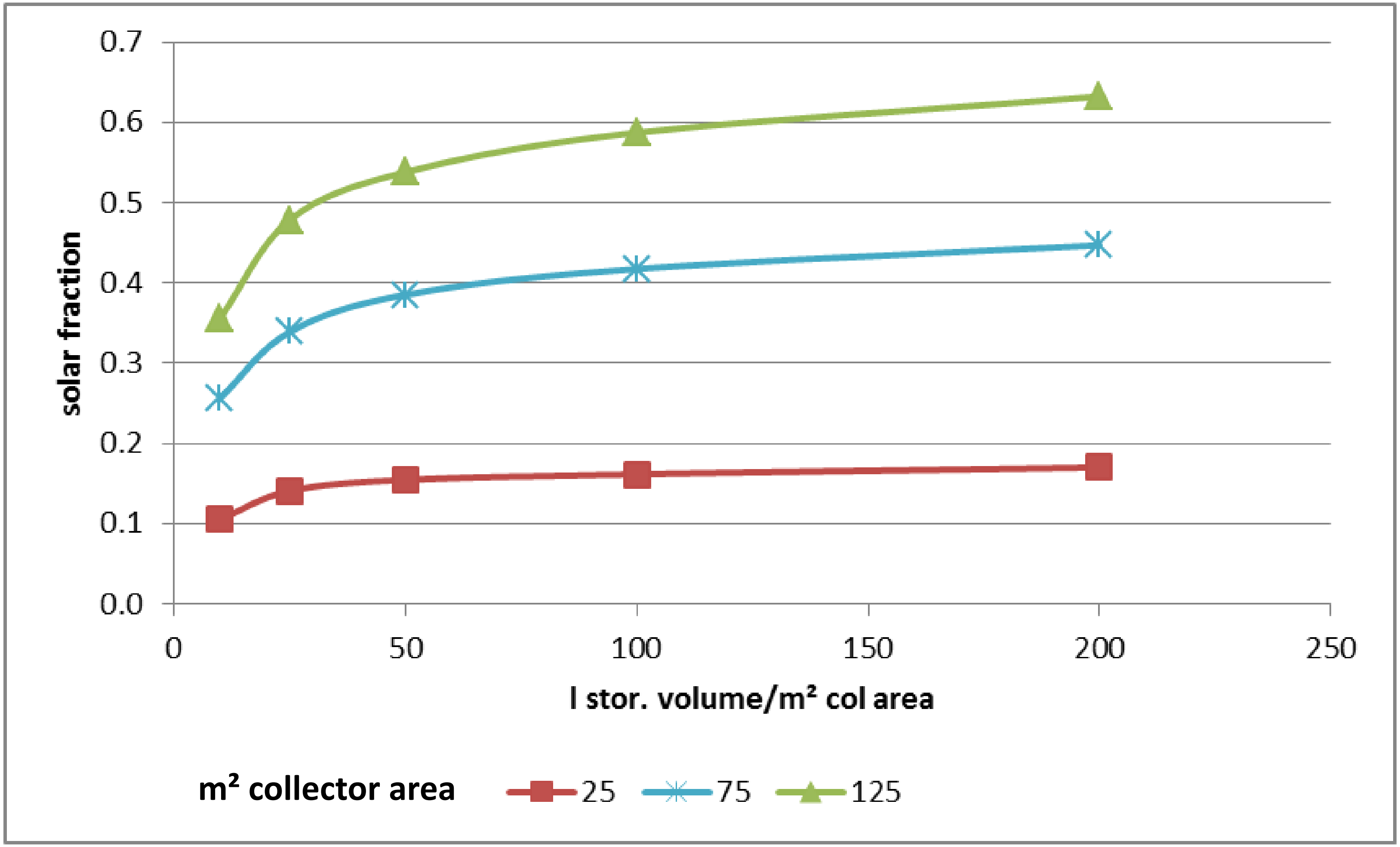


SFH + MFH



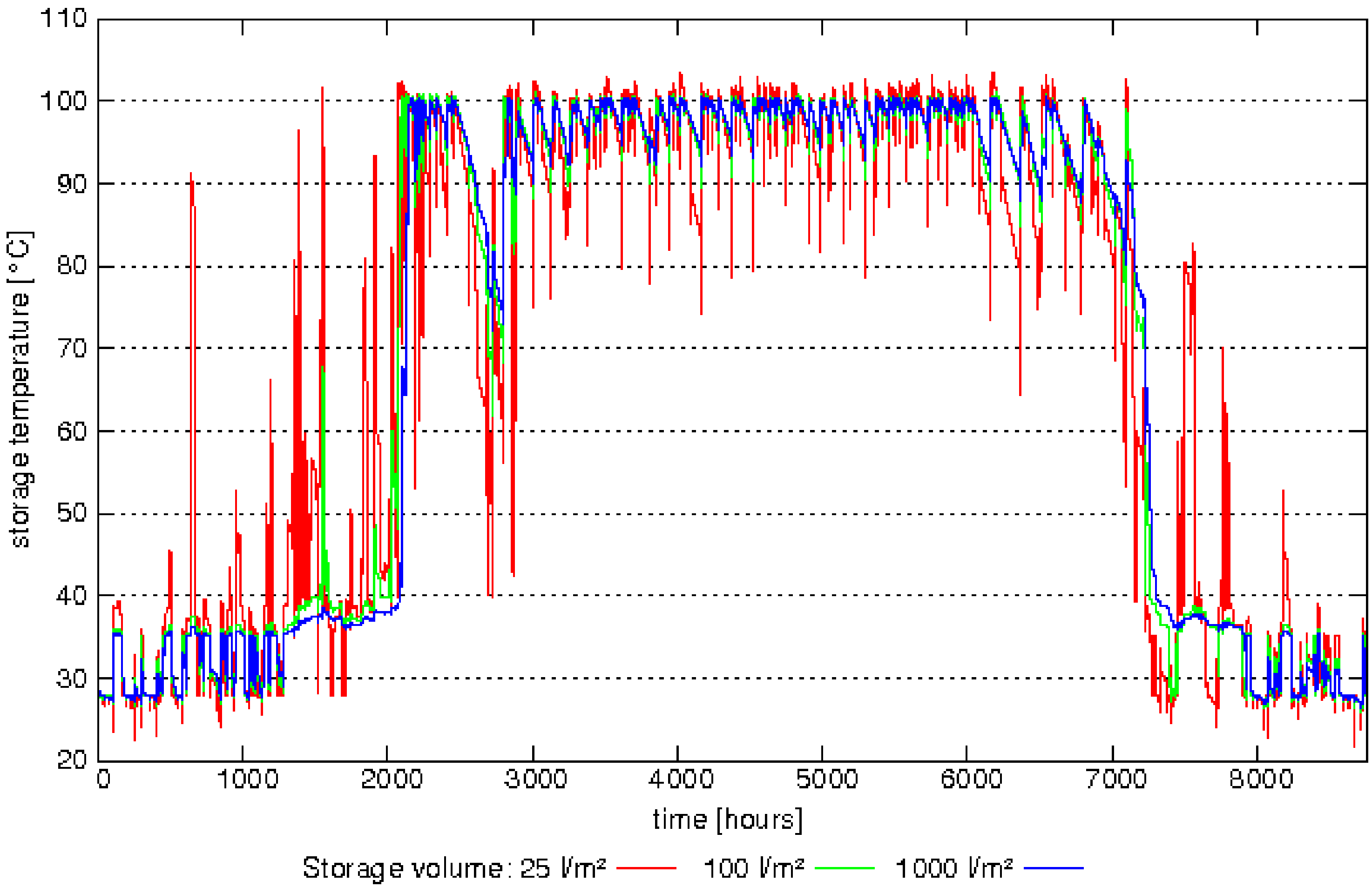
Simulation study: Strasbourg, office, new building

- Results solar fraction
- Floor heating



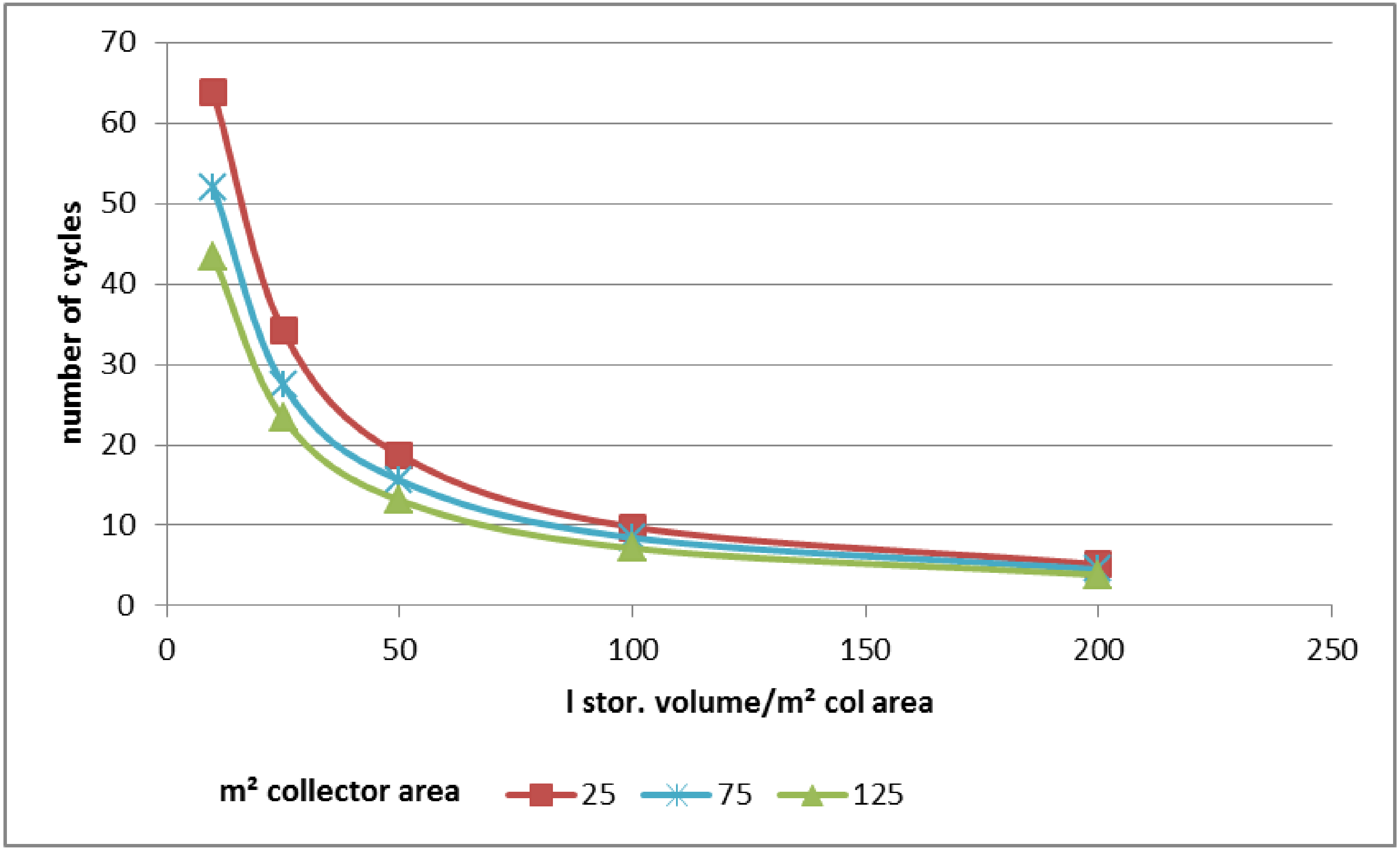
Simulation study: Strasbourg, office, new building

- Yearly storage temperature
- Floor heating, 75 m² collector area



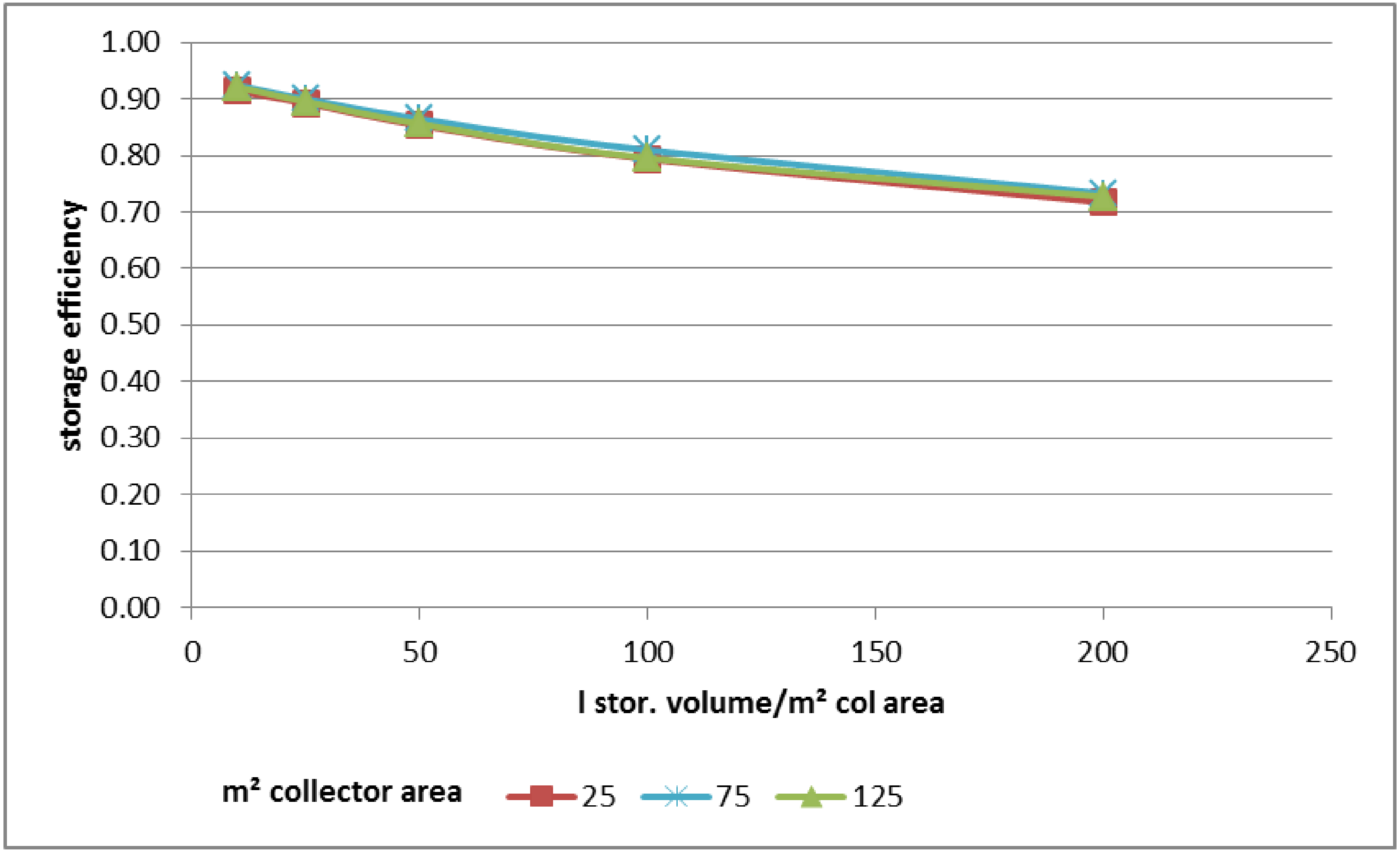
Simulation study: Strasbourg, office, new building

- Results number of storage cycles
- Floor heating



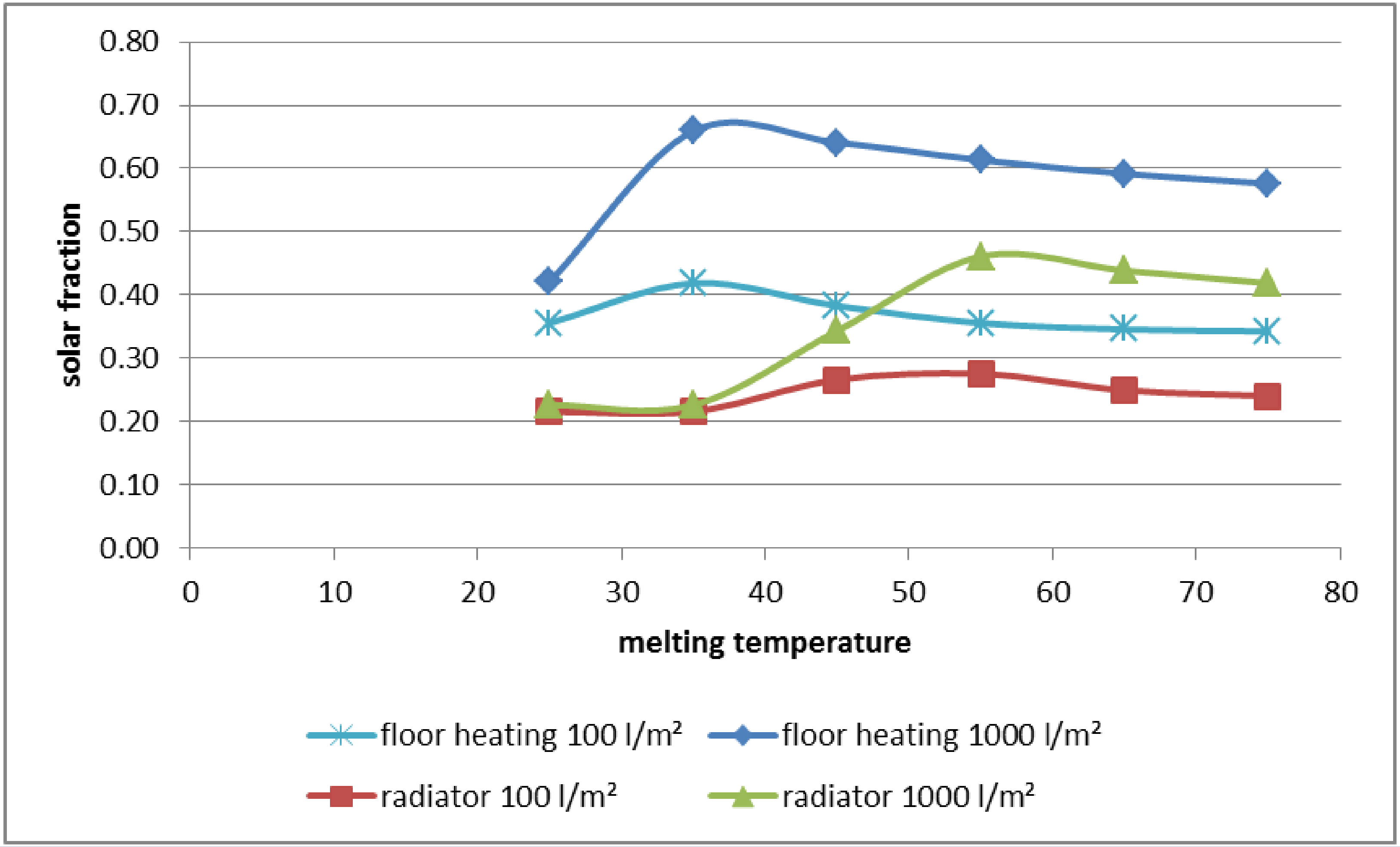
Simulation study: Strasbourg, office, new building

- Results storage efficiency
- Floor heating



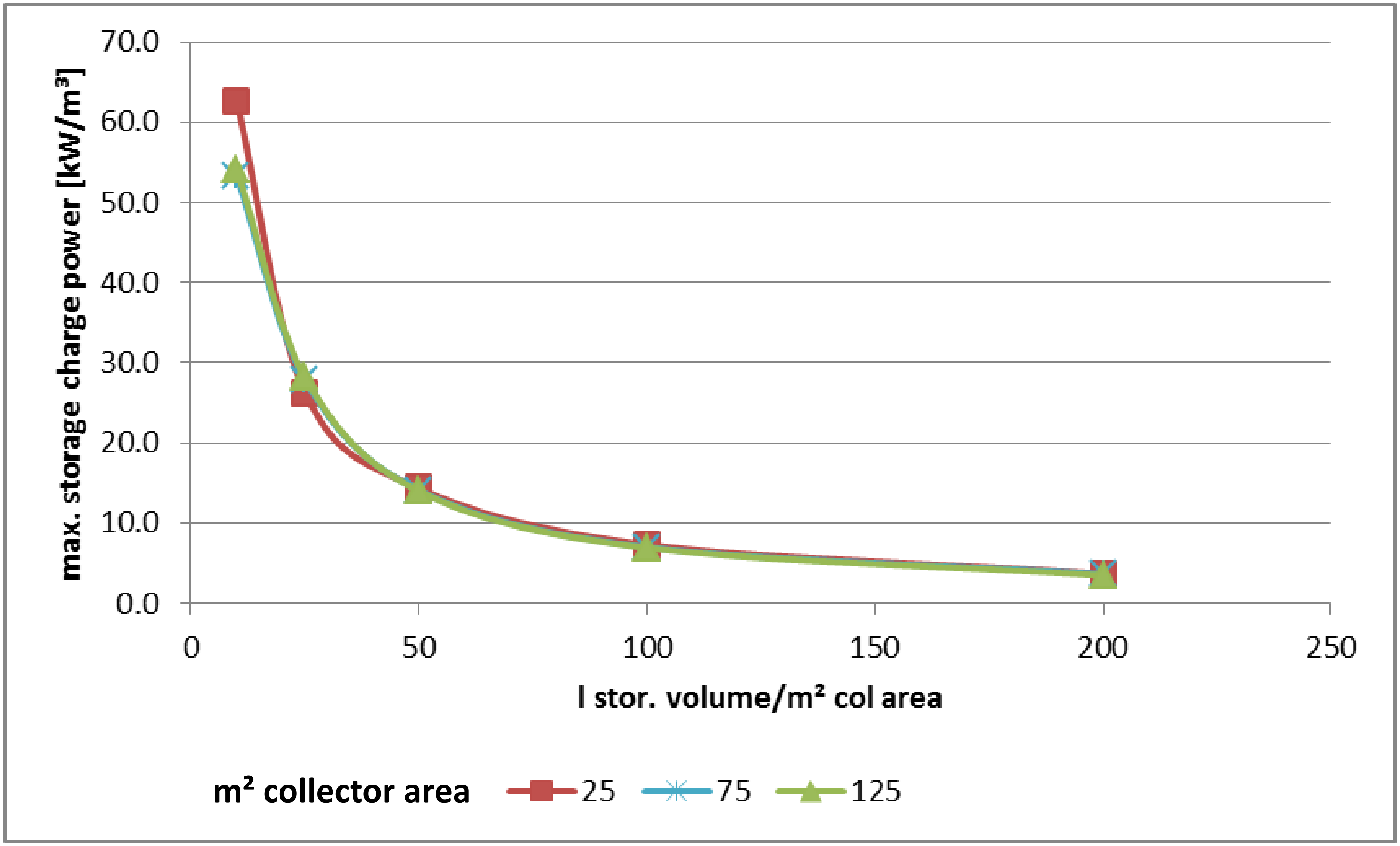
Simulation study: Strasbourg, office, new building

- Melting temperature variation: results solar fraction
- 75 m² collector area



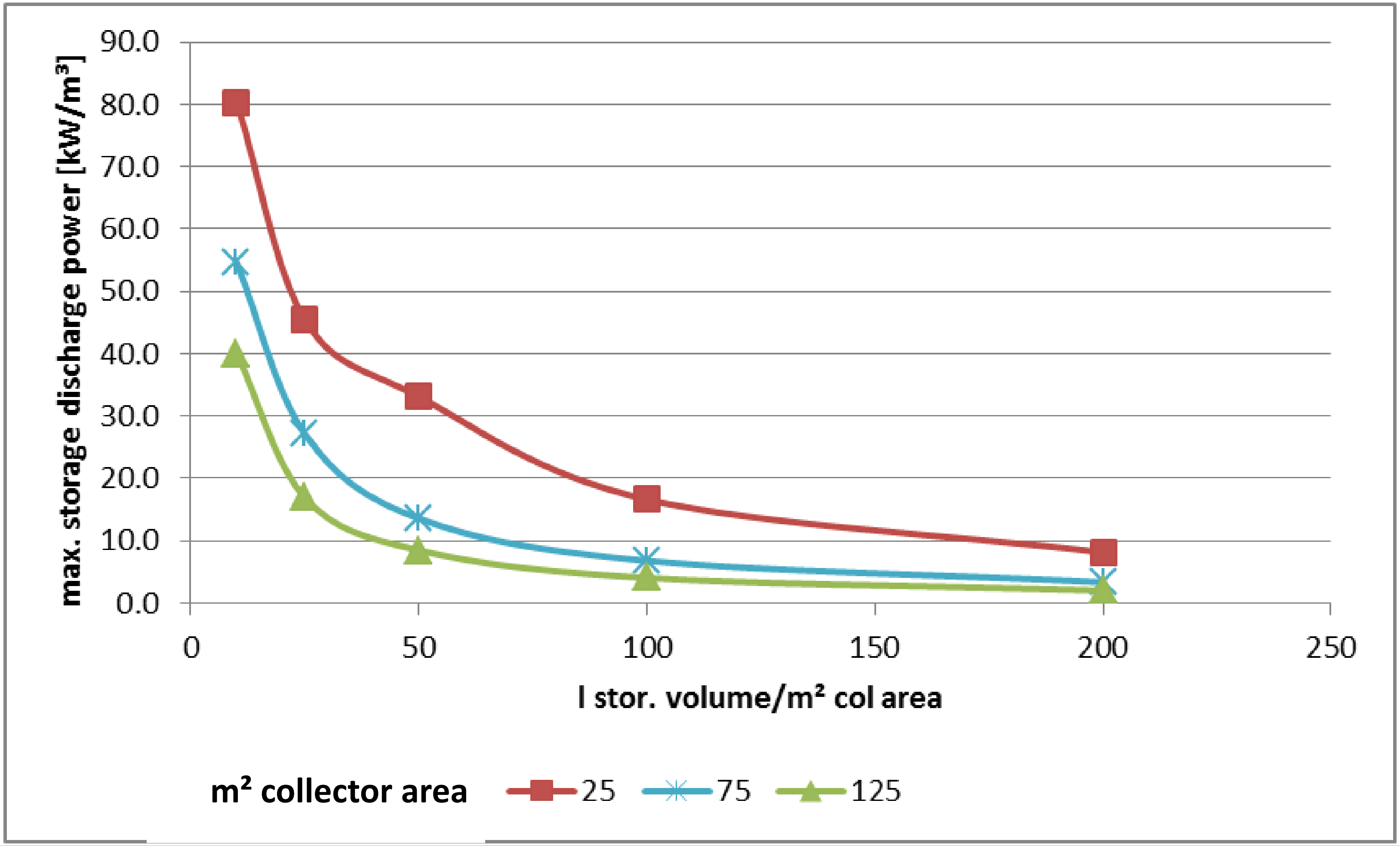
Simulation study: Strasbourg, office, new building

- Max. storage charge power
- Floor heating



Simulation study: Strasbourg, office, new building

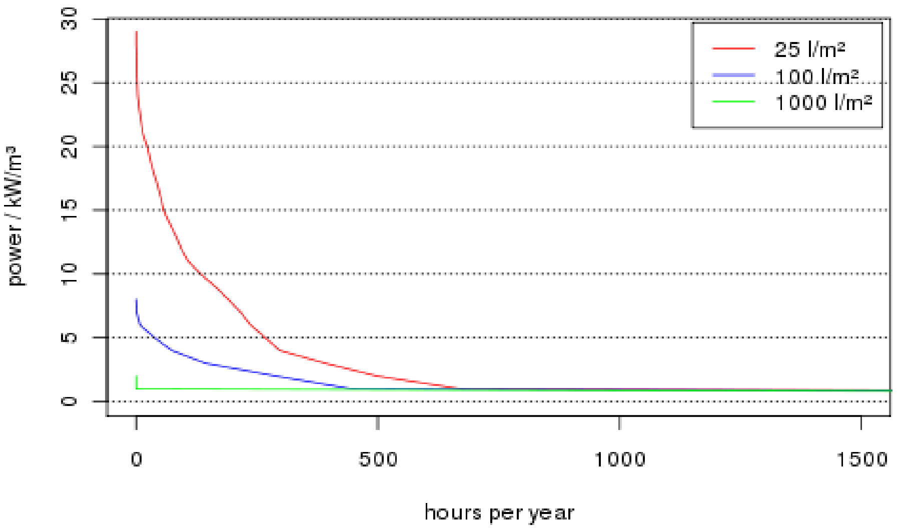
- Max. storage discharge power
- Floor heating



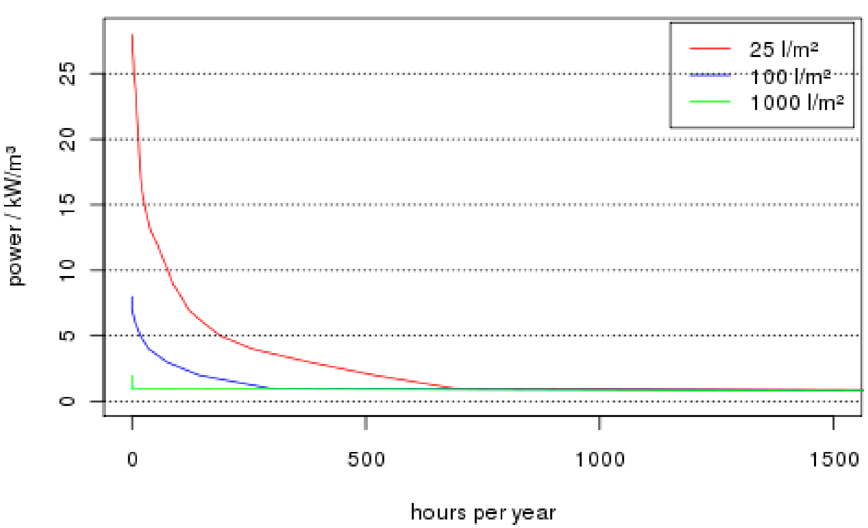
Simulation study: Strasbourg, office, new building

- Charge and discharge power
- Floor heating, 75 m² collector area

Storage charge power per m³ storage volume



Storage discharge power per m³ storage volume



Final case study

- Summary of simulation study for Strasbourg, office, new building standard, 75 m^2 of collector area
- Maximum discharge power (only appear during < 5h per year):
  29 kW/m^3 for 25 l/m^2 storage
  8 kW/m^3 for 100 l/m^2 storage
  1 kW/m^3 for 1000 l/m^2 storage
- 80 % of the maximum power:
  23.2 kW/m^3 for 25 l/m^2 storage
  6.4 kW/m^3 for 100 l/m^2 storage
  0.8 kW/m^3 for 1000 l/m^2 storage
- Most realistic storage size: 100 l/m^2
  => most important range: 4 – 8 kW/m^3
  => base for project design

Material costs: Carbon foam & micro encapsulation

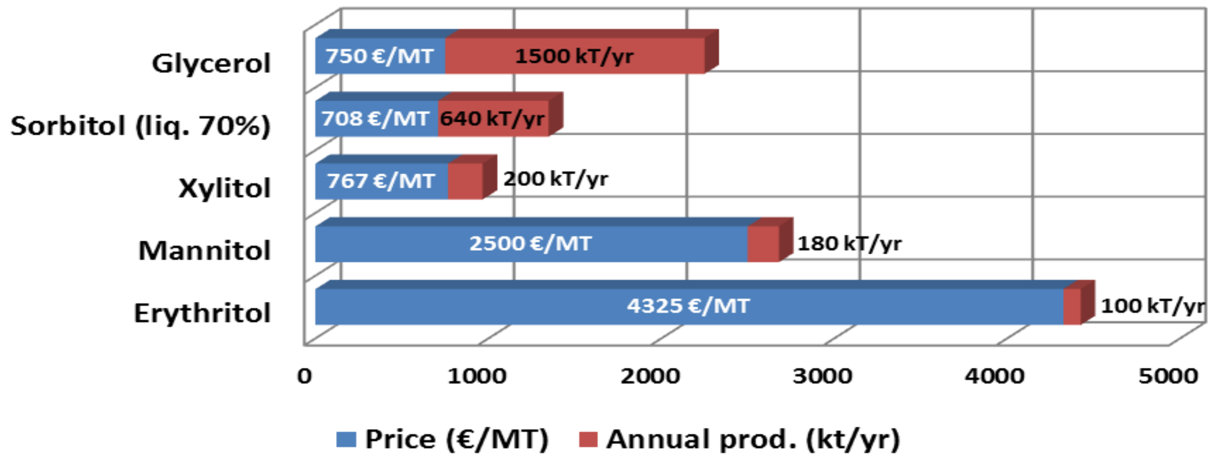
- Raw material based on information collected from the partners:
  - CNRS (A. Celzard)
  - IMNR (R. Piticescu)
  - Cice (M. Karthik)
  - Aidico (M.D. Romero)
- Raw material cost was multiplied by 2 to account for energy costs, fixed costs and depreciation

Product	Price /Ton
Raw sugar	300 €
Graphite powder	770 €
Nickel Nitrate (hexahydrate)	3,000 €
Urea	513 €
Zinc Nitrate (hexahydrate)	760 €
Resin	2,760 €
Synthetic graphite	770 €
PU foam	1,380 €

Material	Lab	Porosity %	Density kg/m3	Raw material price / kg foam or shell	Price / kg SA (SA = 1€/kg)	Price / kg SA (SA = 2€/kg)	Price / kg SA (SA = 3€/kg)
Carbon foam	CNRS	85-86	330-380	1.2	1.7	2.7	3.7
Carbon foam + ZnO	CNRS + IMNR	85-86	560	2.1	2.9	3.9	4.9
Carbon foam	Cice	75	350-400	3.0	2.9	3.9	4.9
Micro encapsulation	Aidico			2.3	4.5	5.5	6.5

- For other materials developed in the project, no information has been received.

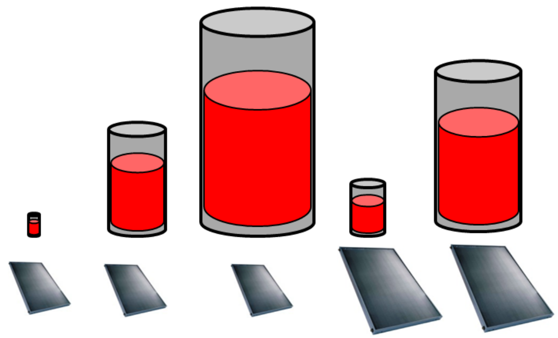
Material costs: sugar alcohols (SA)



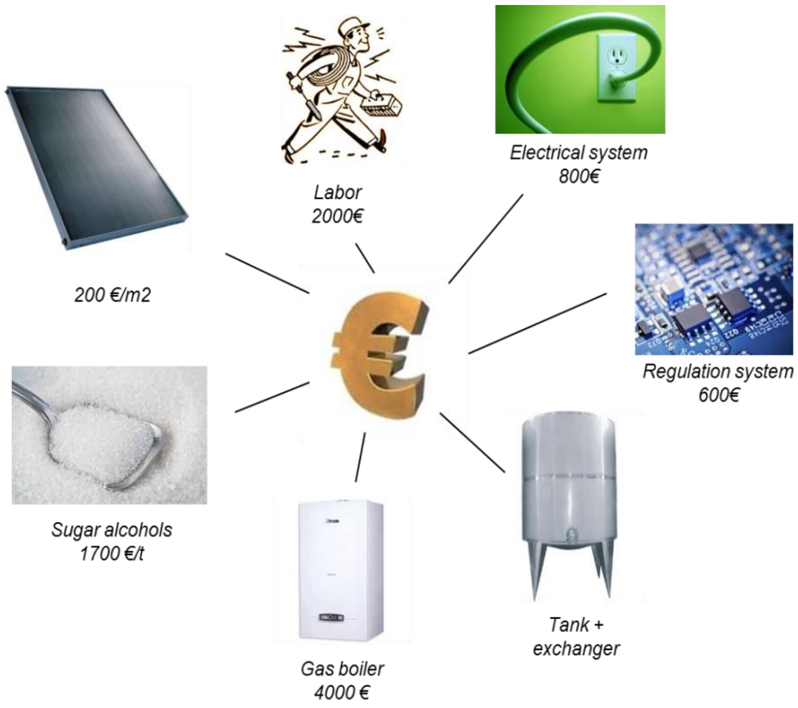
- SA are mainly sourced from starch
- Price depends on offer/demand, purity, type of process …
- A price between 1000 and 3000€/T is assumed for the SA blend

- By selecting CNRS carbon foam a material price ranging from 1.7 to 3.7 €/kg is assumed

Configuration selection for economic estimation



	PCM1	PCM2	PCM3	PCM4	PCM5
Collector area (m2)	25	25	25	75	75
Storage volume (m3)	0,25	1,25	2,5	0,75	1,88
Storage capacity (kWh)	34	170	339	102	254
Energy delivered (%)	11	16	17	26	35
Materials (k€)	0.6	3.2	6.4	1.9	4.8
Pannels (k€)	5.0	5.0	5.0	15.0	15.0
Other costs (k€)	8.3	9.1	10.4	8.6	10.1
Total system (k€)	13.9	17.3	21.8	25.5	29.9



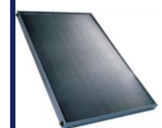
- System cost ranges from 14 to 30k€
- Material cost represents less than 16% of total
- Panels cost ranges from 36 to 50% of total cost

Other technologies





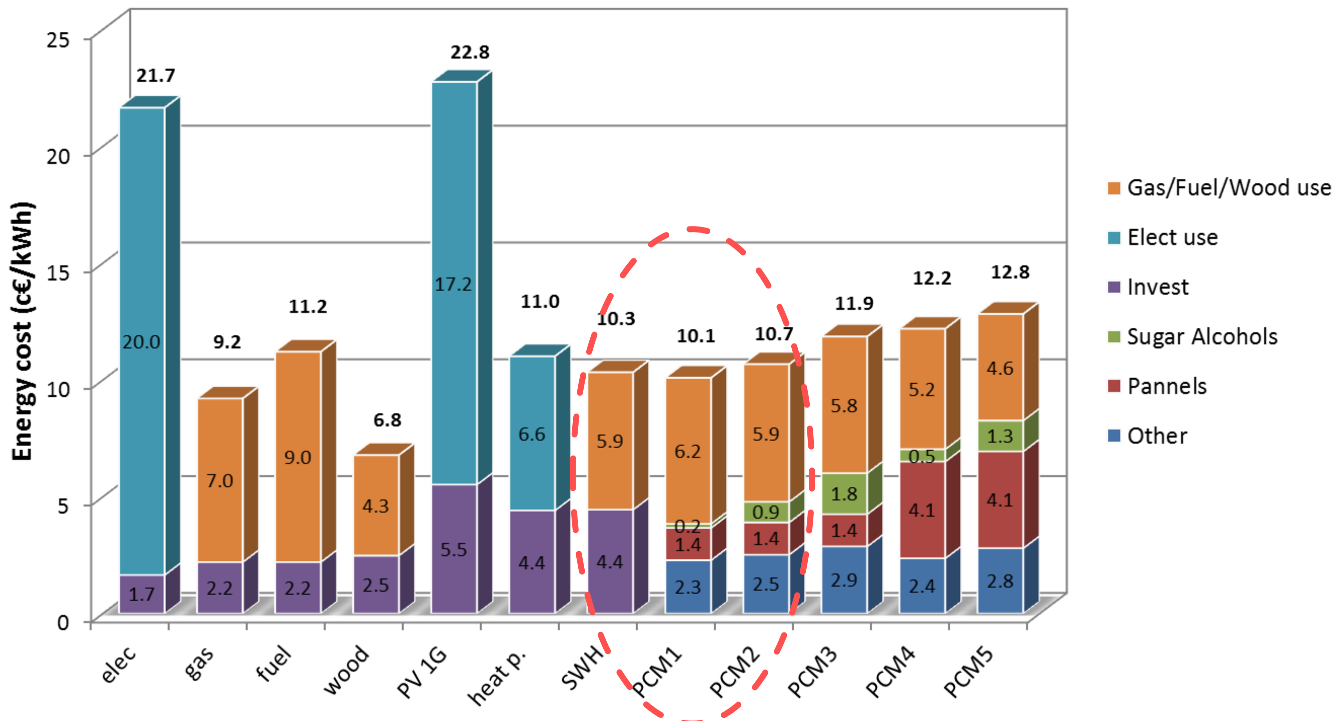




	Elect.	Gas	Fuel	WBS	PV 1G	Heat pump	SWH
Invest. (k€)	6	8	8	9	20	16	16
Use (c€/kWh)	20	7	9	4	20	20	7

- Gas boiler and SWH are selected as benchmark technologies

Energy cost benchmark

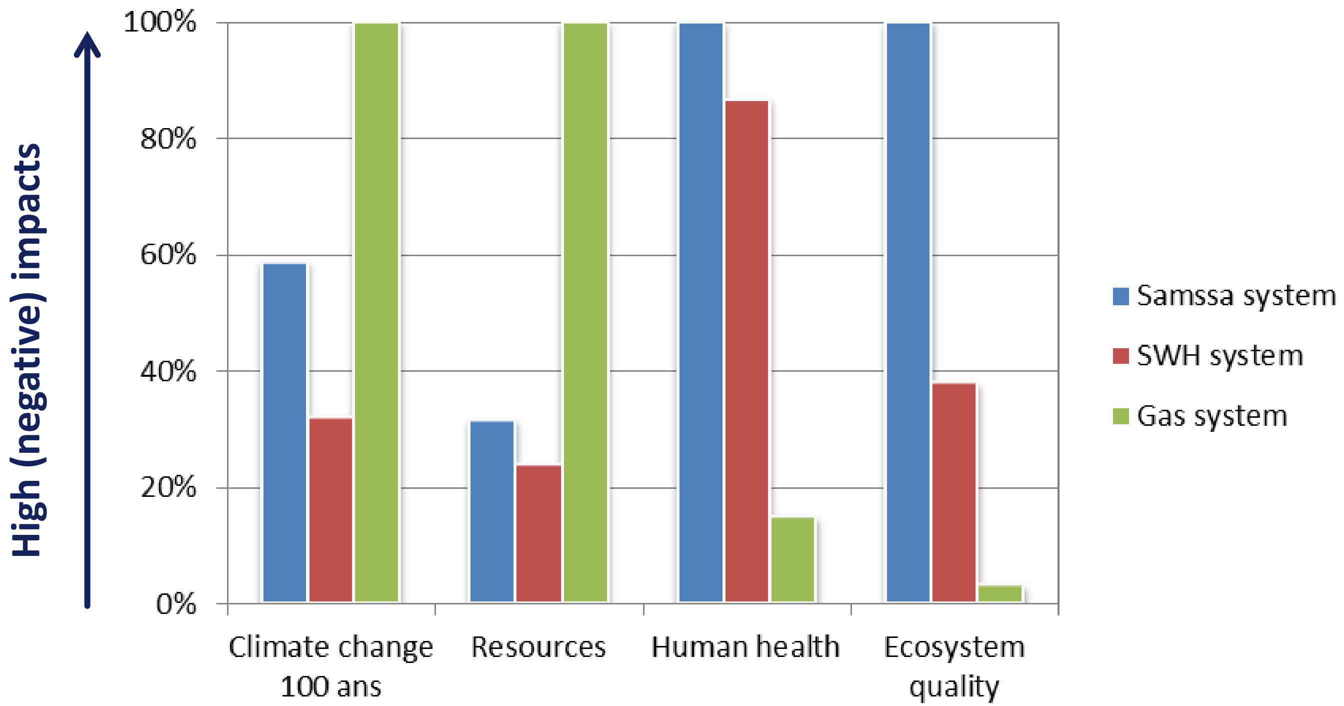


- PCM1 and PCM2 are cost competitive versus SWH
- Sugar alc. cost contribution is low (weak impact with expensive sugar alc.)
- Solar panel cost contribution is important
- Full electrical and PV1G (w/o incentives) are too expensive

LCA (Life cycle assessment) on the system

- Functional unit:
  - Deliver 2880 kWh per year of thermal energy to a heating system during 20 years in a new office building located in Strasbourg
- 3 Reference systems can provide 2880 kWh:
  - PCM energy storage system
    - 25m2 collectors, 1875 kg of sugar alcohols, storage tank (1.5m3) – **PCM2**
  - SWH storage system
    - 25m2 collectors, 4000 kg of water, storage tank (4m3)
  - Gas boiler system
    - 16% of a gas boiler, 2880 kWh of natural gas per year

LCA: Damage categories



- Less impact than gas in climate change and resources
- But higher impact on human health and ecosystem quality due to <u>starch production</u> and <u>copper used in collectors</u>

Conclusions/Perspectives

Cost analysis

- Phase changed materials is today a competitive technology versus SWH <u>without any incentive</u>
- Solar collector is significant weight of the system cost
- PCM cost don't have much impact of the cost

Live Cycle Assessment

- SAM.SSA offer the best compromise in Climate change and resources (damage categories) vs. gas or SWH system
- Solar panel is the main contributor for human health (Cu)
- Produce sugar alcohols from 2G biomass (wood vs. corn or potato) will be the key perspectives to minimise ecosystem impact

Perspectives

- Potential interest of sugar alcohols as PCM is confirmed from technico-economical analysis
- Others heat storage applications need to be evaluated with this promising materials (natural, no toxic, no hazard).