EVASOLK

Evaluation of Solar Cooling in Comparison to Reference Technologies

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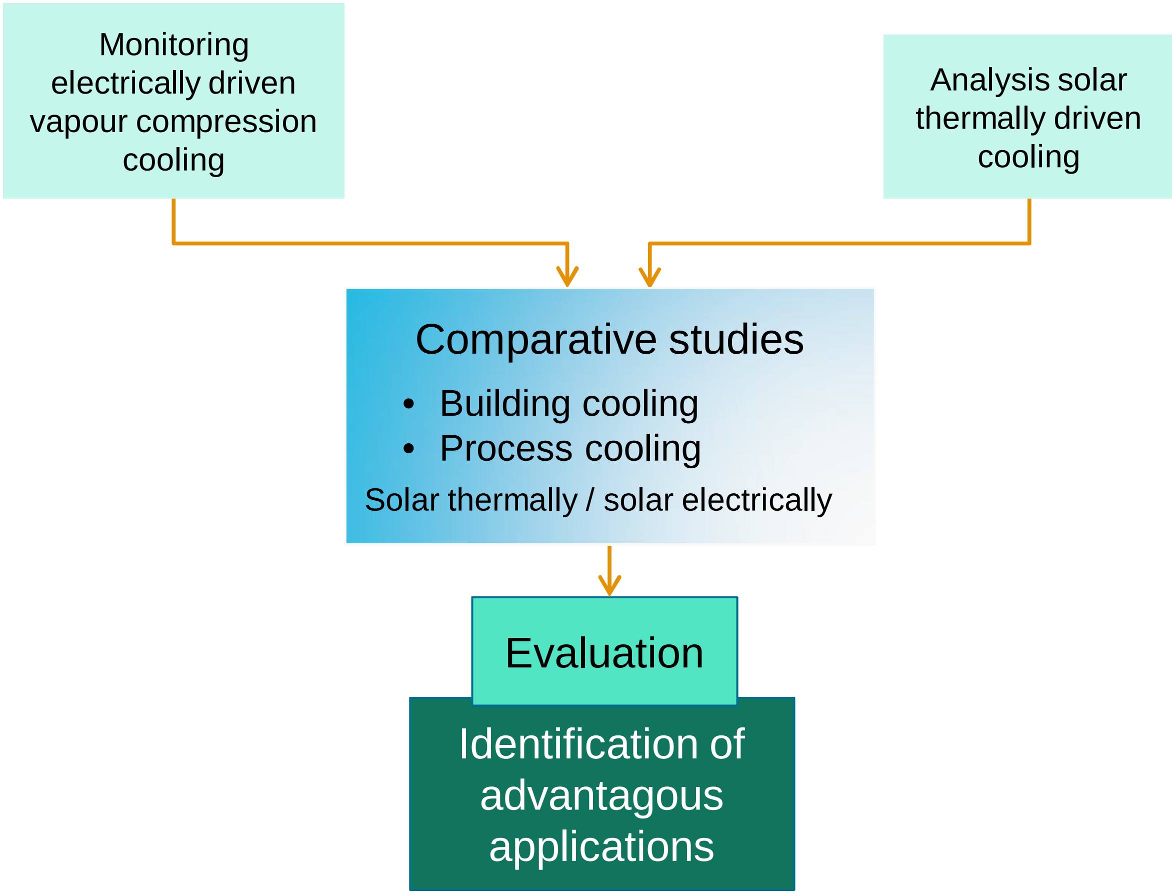
EVASOLK - Perspectives of solar cooling
(closed cycle systems)



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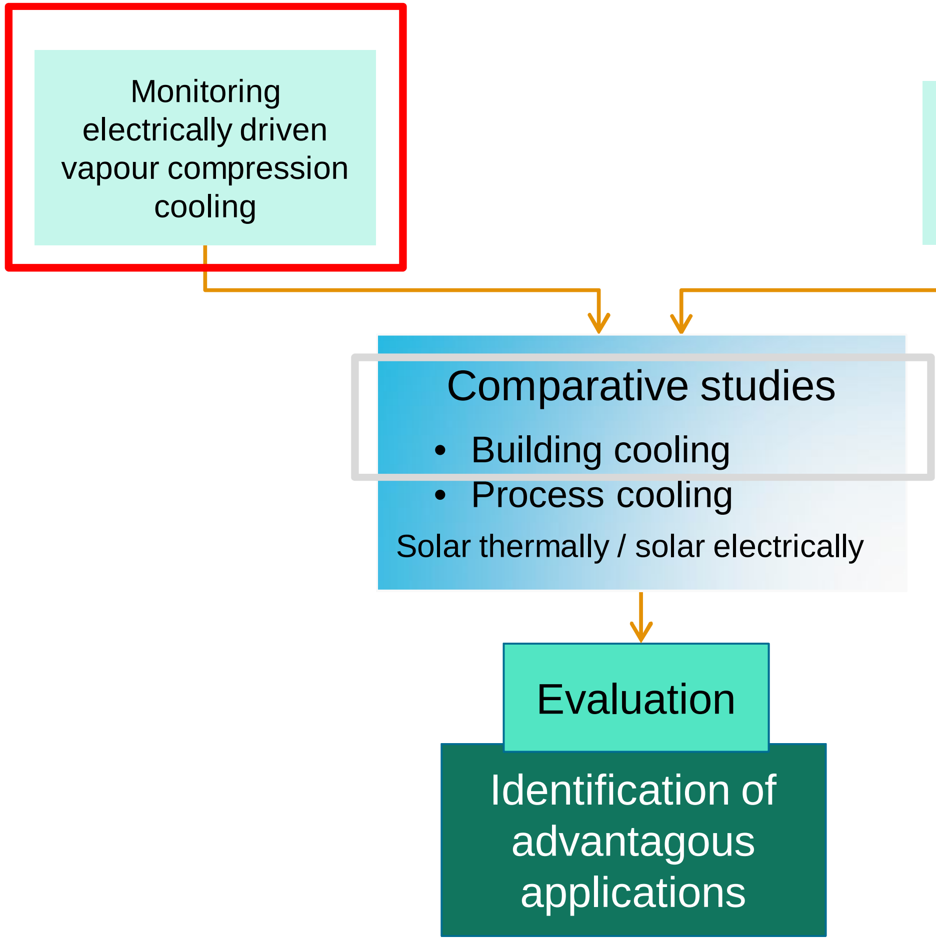
(closed cycle systems)



Reference technology: monitoring

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- Conventional installations; cross-section of technologies
- Monitoring by ILK Dresden, ZAE Bayern

	Technology	Rated capacity [kW]	Distribution	Monitoring status	Remark
Building cooling (comfort air-conditioning)					
1	Chilled water	13.1	Fan coils	running	
2	Chilled water	46.6	Ventilation	running	
3	Chilled water	60	Ventilation	running	
4	Mono-split	2.65	Fan coils	running	Type: hardware store
5	Mono-split	5.0	Fan coils	running	Type: brand supplier
6	Multi-split	40	Fan coils	running	6 condensor units
Commercial / process cooling					
7	Normal cooling	17	Cooling cell	running	brine system
8	Normal cooling	2	Cooling cell	running	direct evaporation

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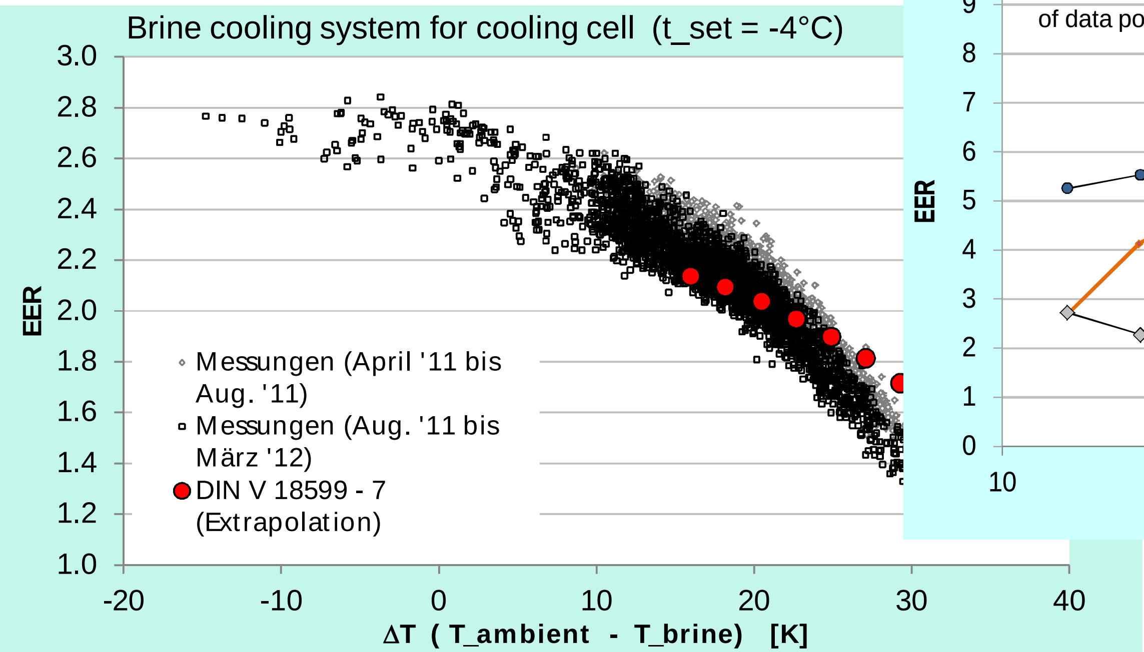
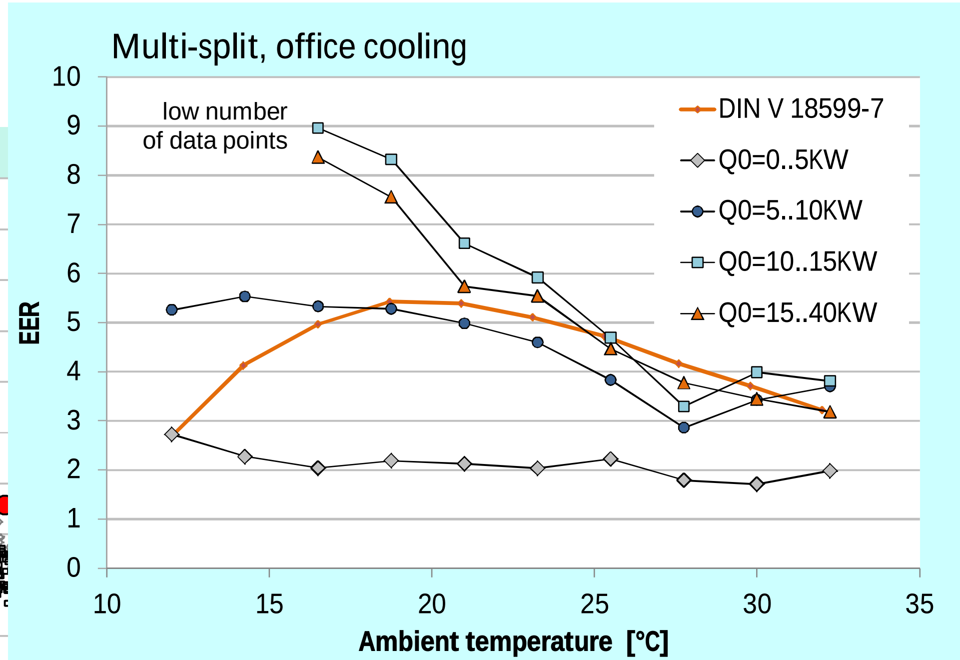
Reference technology: monitoring

- Performance of conventional installations
- Data base for models in comparative study
- ongoing





Source: ILK Dresden

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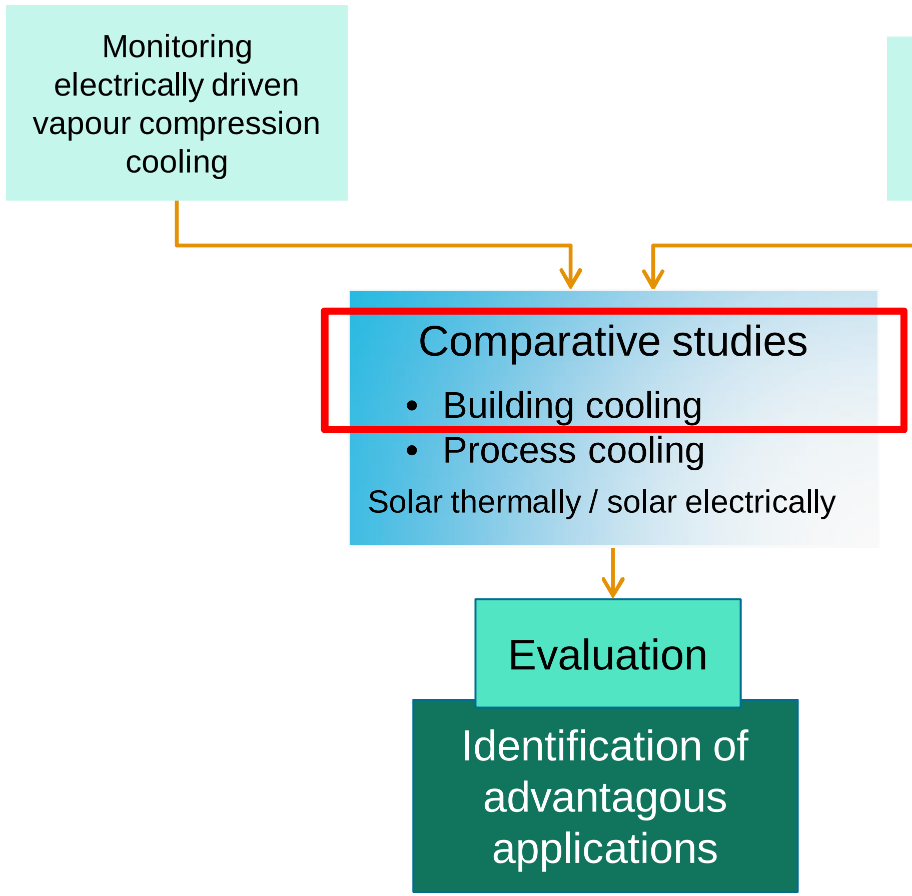

Comparative study: solar cooling in buildings

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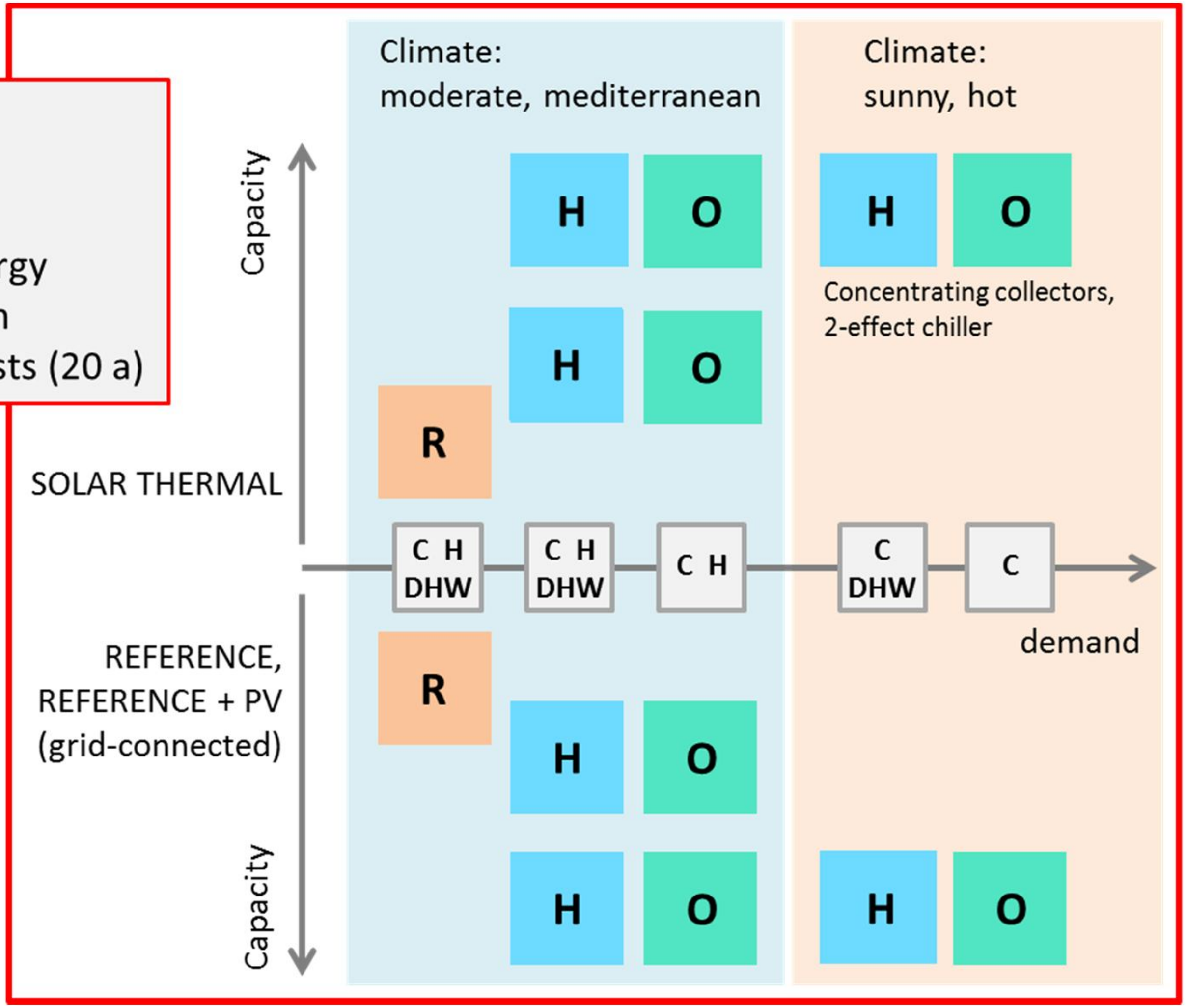
Balance:
- electricity,
- fuel,
- primary energy
- CO_2 emission
- Life cycle costs (20 a)



R Residential (Multi-family house)

H Hotel building

O Office building

Use:

C = cooling

H = heating

DHW = domestic hot water

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Comparative study: solar cooling in buildings

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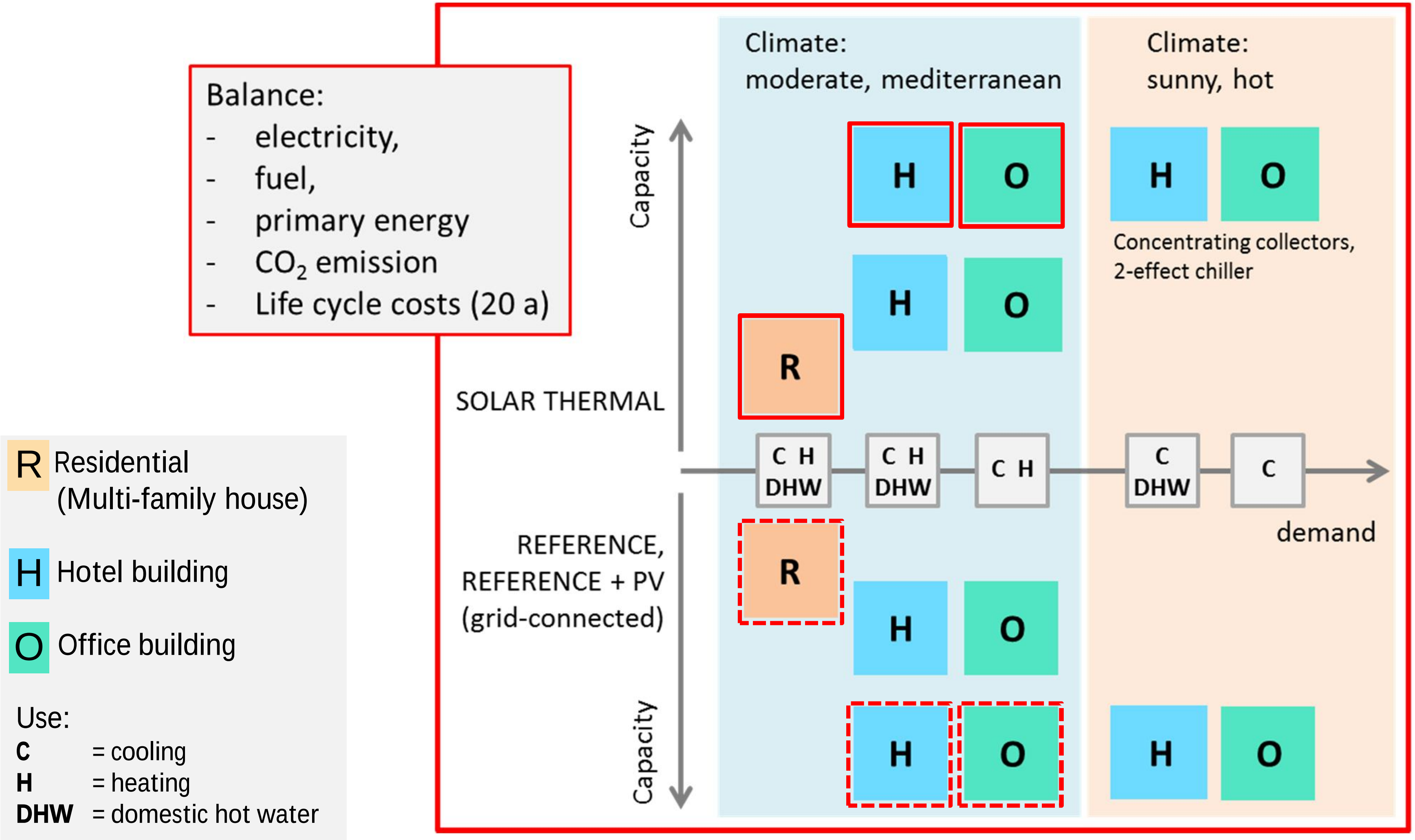

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Comparative study: solar cooling in buildings

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- Basic approach:
  - Annual simulation with TRNSYS;
    generic models (TDC, CCH, HP, collectors, ..)
  - Cost curves for key components (present costs)
  - Country specific energy prices
  - Primary energy savings and CO_2-avoidance calculation in comparison to reference with country specific conversion numbers
  - Including emissions of typical refrigerant losses
  - Life cycle: 20a (collectors, TDC); 15a (CCH, HP)
  - Capital costs: rate of interest 5%
  - Annual energy price increase: 5% (electricity), 3% (natural gas)

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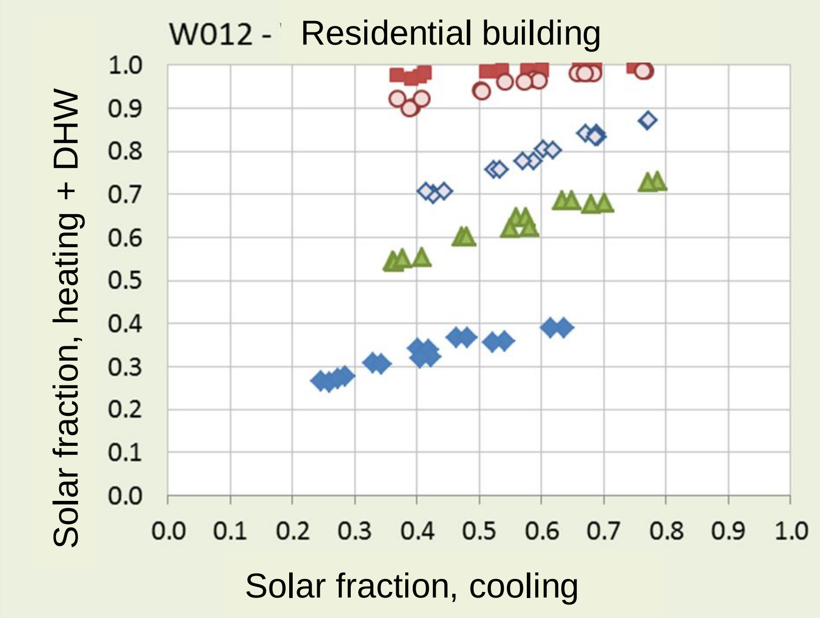
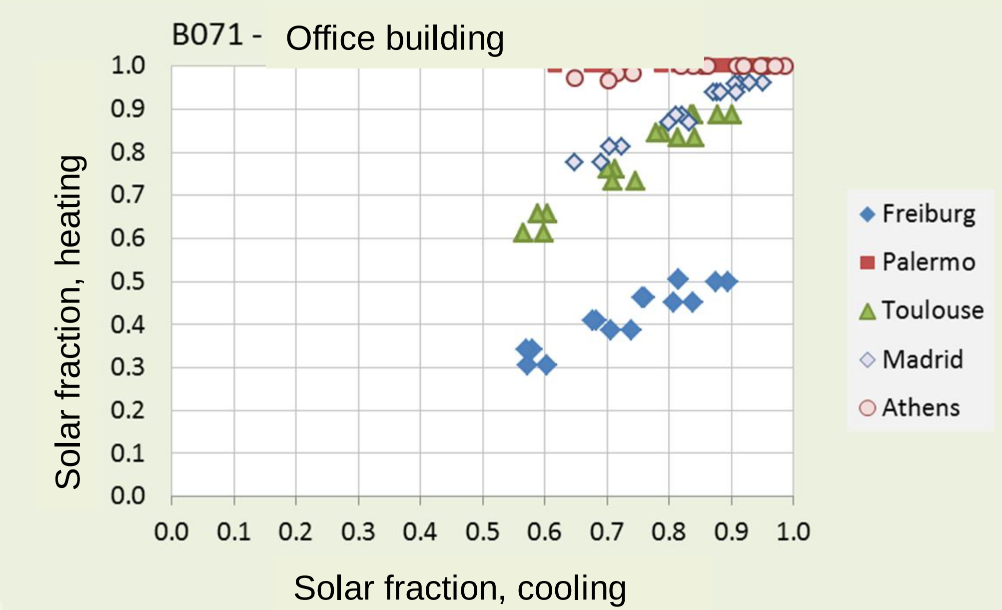
Overview solar fractions



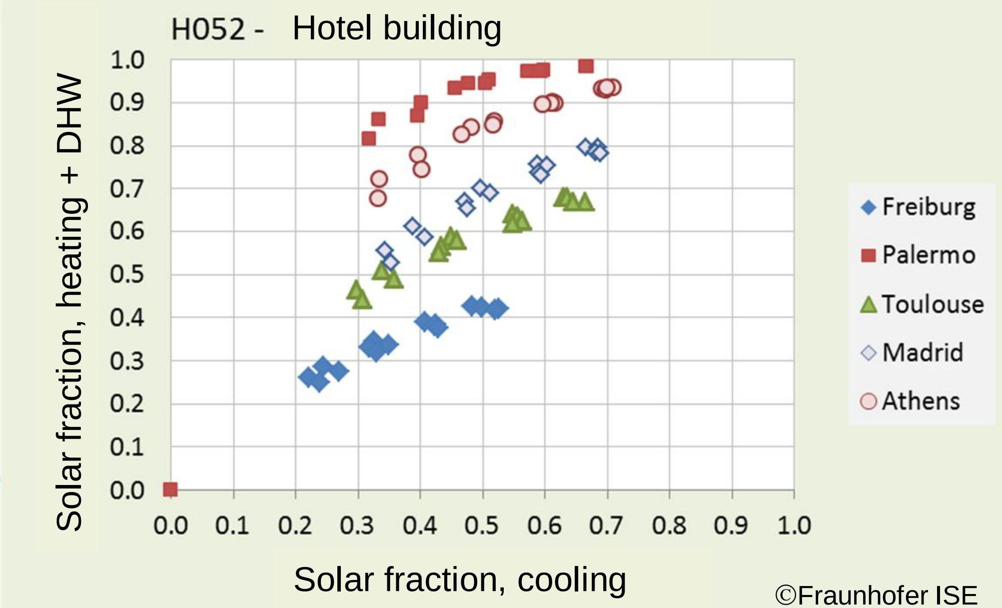


Variations:

- location
- TDC-Type
- FPC: 3…6 m²/kW$_{P_TDC}$
- ETC: 2.5…5.5 m²/kW$_{P_TDC}$

Cold backup: Air-cooled chiller

Reference: Multi-Split-System



Evaluation

- Combined economic – primary energy related evaluation figure:
  - Costs of saved Primary Energy

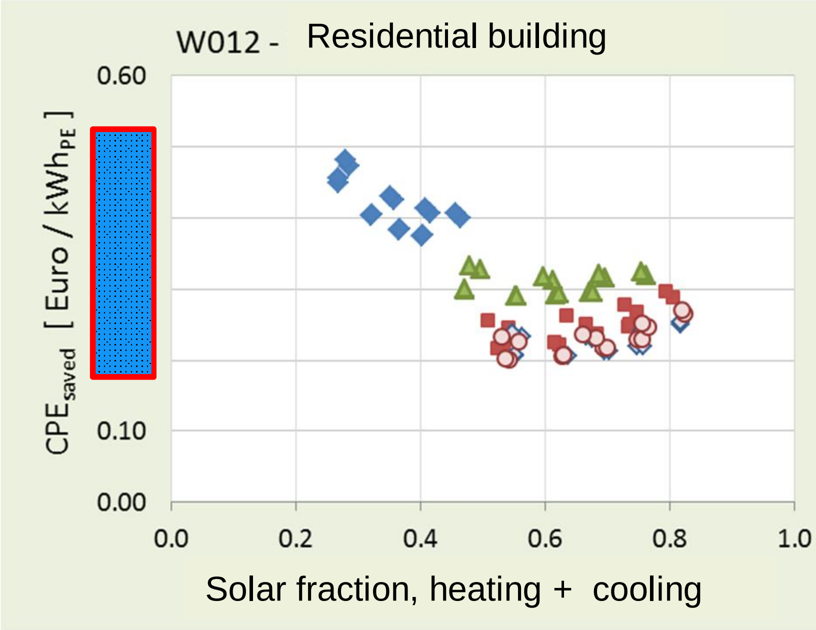
$$\mathbf{CPE_{LCC}} = \Delta LCC / (PE_{Ref} - PE_{Sol}) \qquad € / kWh_{PE\_saved}$$

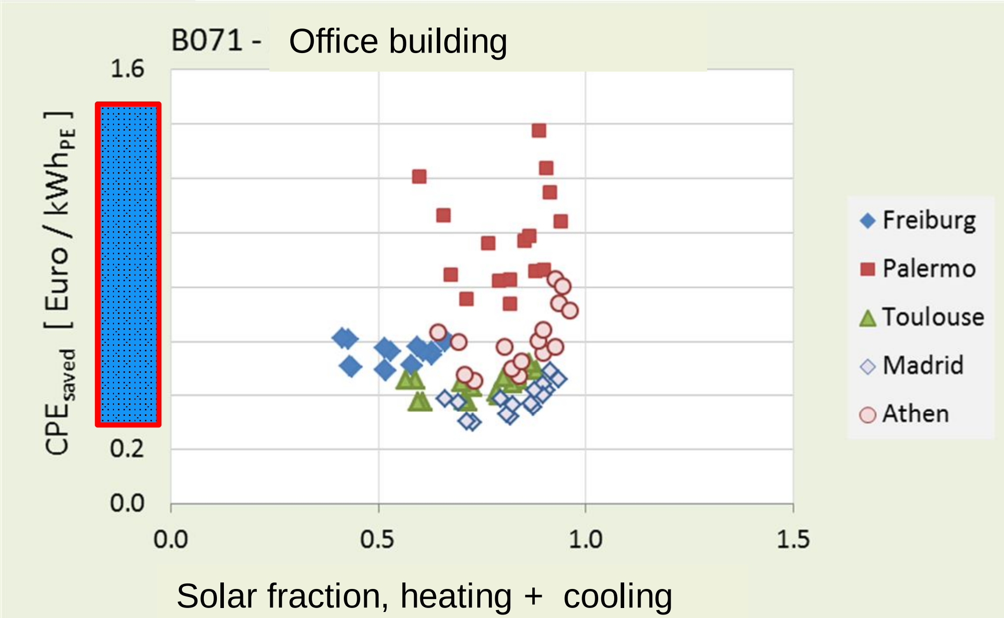
with

ΔLCC	=	(Life cycle cost, Solar system – Life cycle cost, Reference) LCC include investment and capital costs, operation and maintenance costs of 20 years life cycle
$(PE_{Ref} - PE_{Sol})$	=	difference in PE demand between Reference and solar configuration within life cycle (20a)

  - Precondition: primary energy is saved $\Rightarrow (PE_{Ref} - PE_{Sol}) > 0$
  - then: CPE_{LCC} is <u>positive</u> in case of higher life cycle costs of solar based system
  - In case, solar based system shows lower life cycle costs than reference:
    CPE_{LCC} is negative
    (divison of one benefit by another: not useful)

Übersicht Kosten der Primärenergieeinsparung





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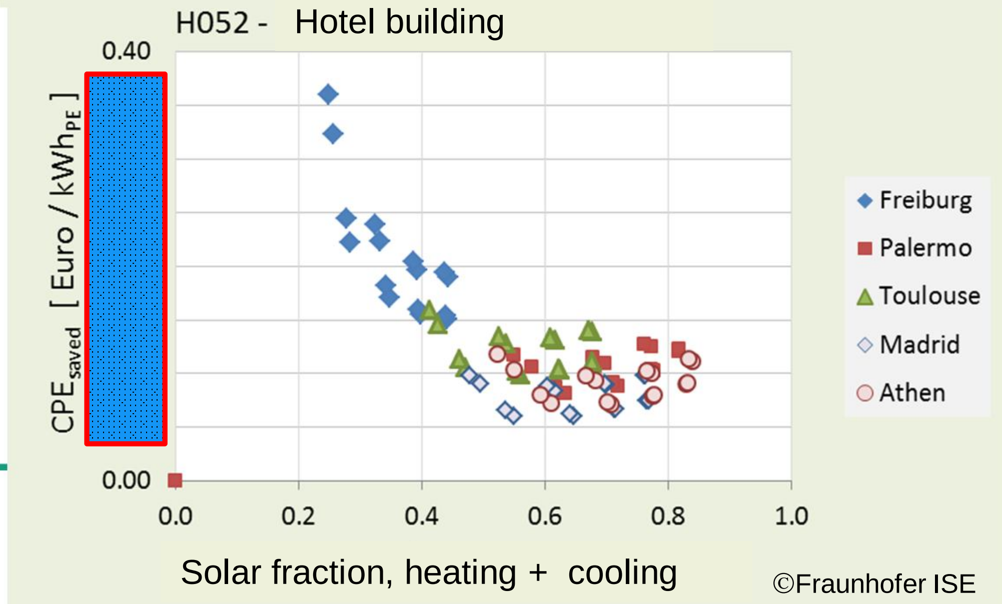
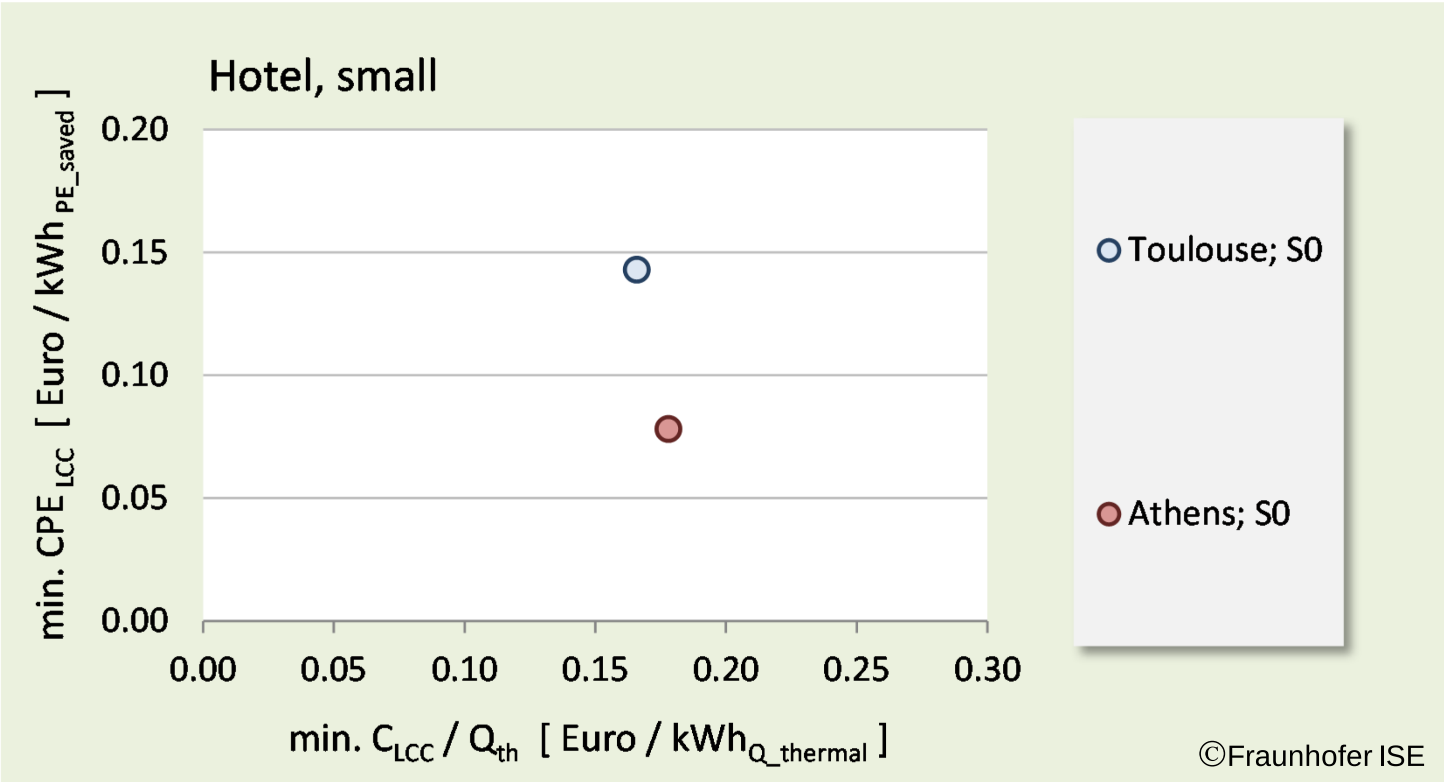


Effect of investment costs

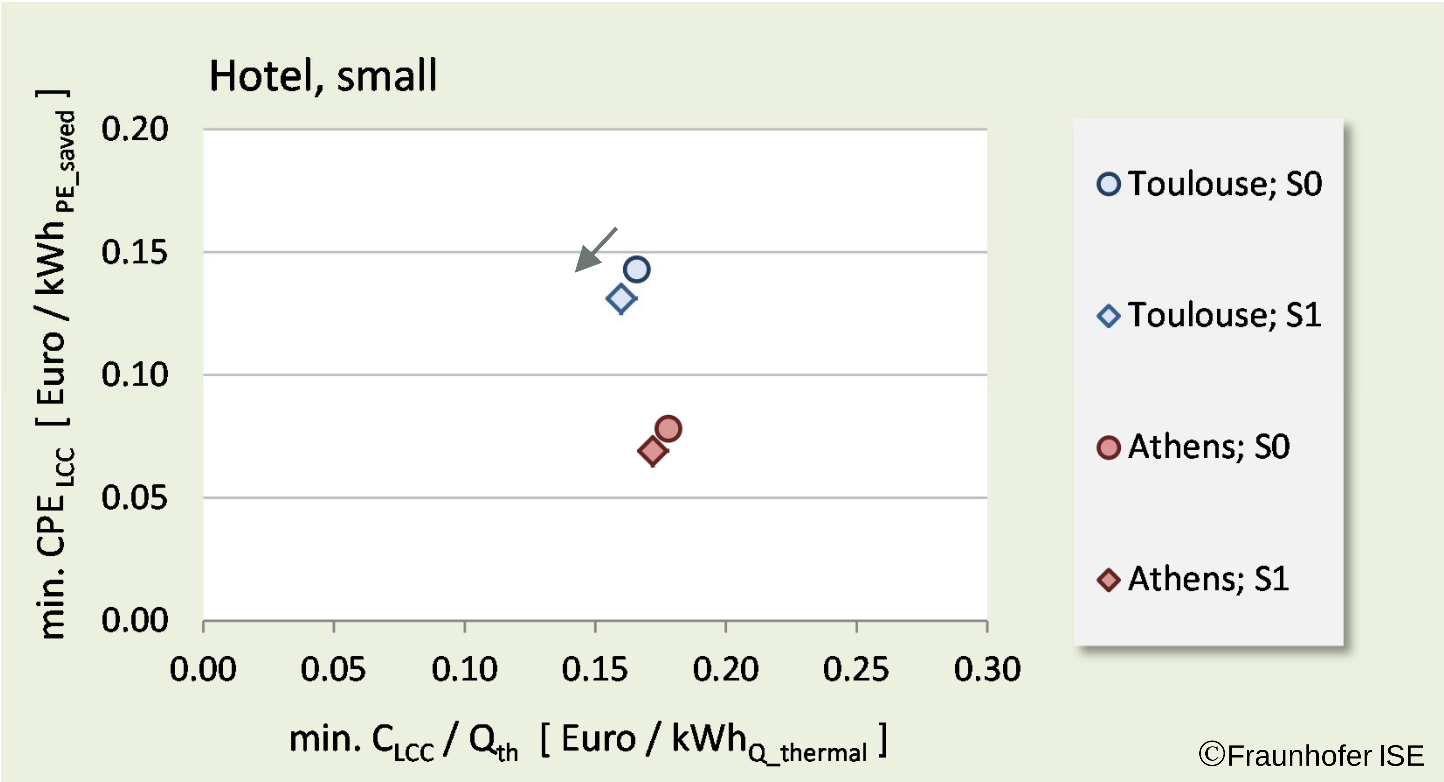
- Configuration with lowest PE-avoidance costs
- **S0** : present cost situation
- C_{LCC} / Q_{th}: costs per kWh thermal useful energy
  Q_{th}: thermal useful energy [Σ ($Q_{Heating}$, $Q_{Cooling}$, Q_{DHW})] within life cycle



Effect of investment costs

- **S1** : collector system costs: -10% *

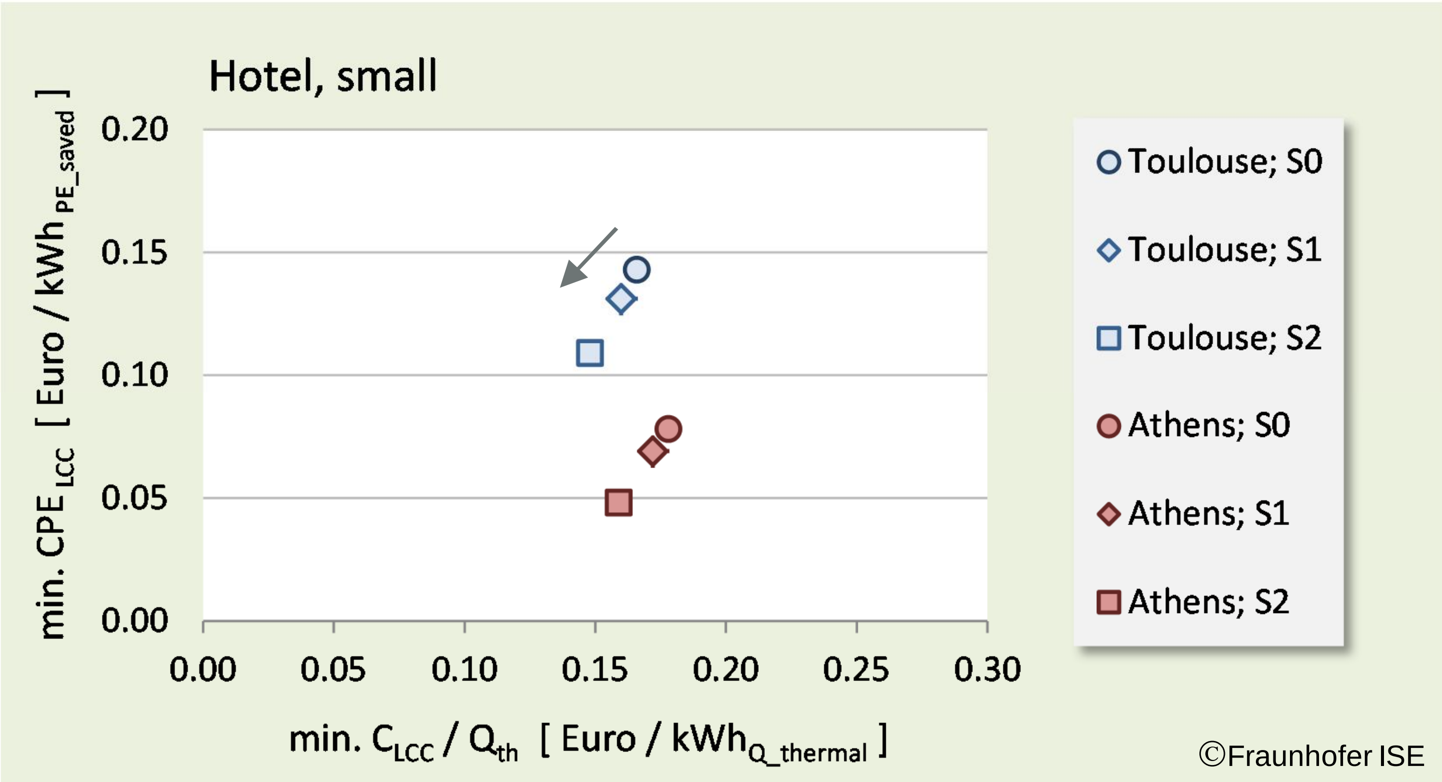
* goal Roadmap of BSW: Solar thermal system costs -14% until 2020



Effect of investment costs

- **S2** : collector system costs: -10%, TDC system costs -25% *

* goal Roadmap of BSW: Solar thermal system costs -14% until 2020;
forecast small/medium TDC-systems: -35% until 2020 (Dr. U. Jakob, Green Chiller)



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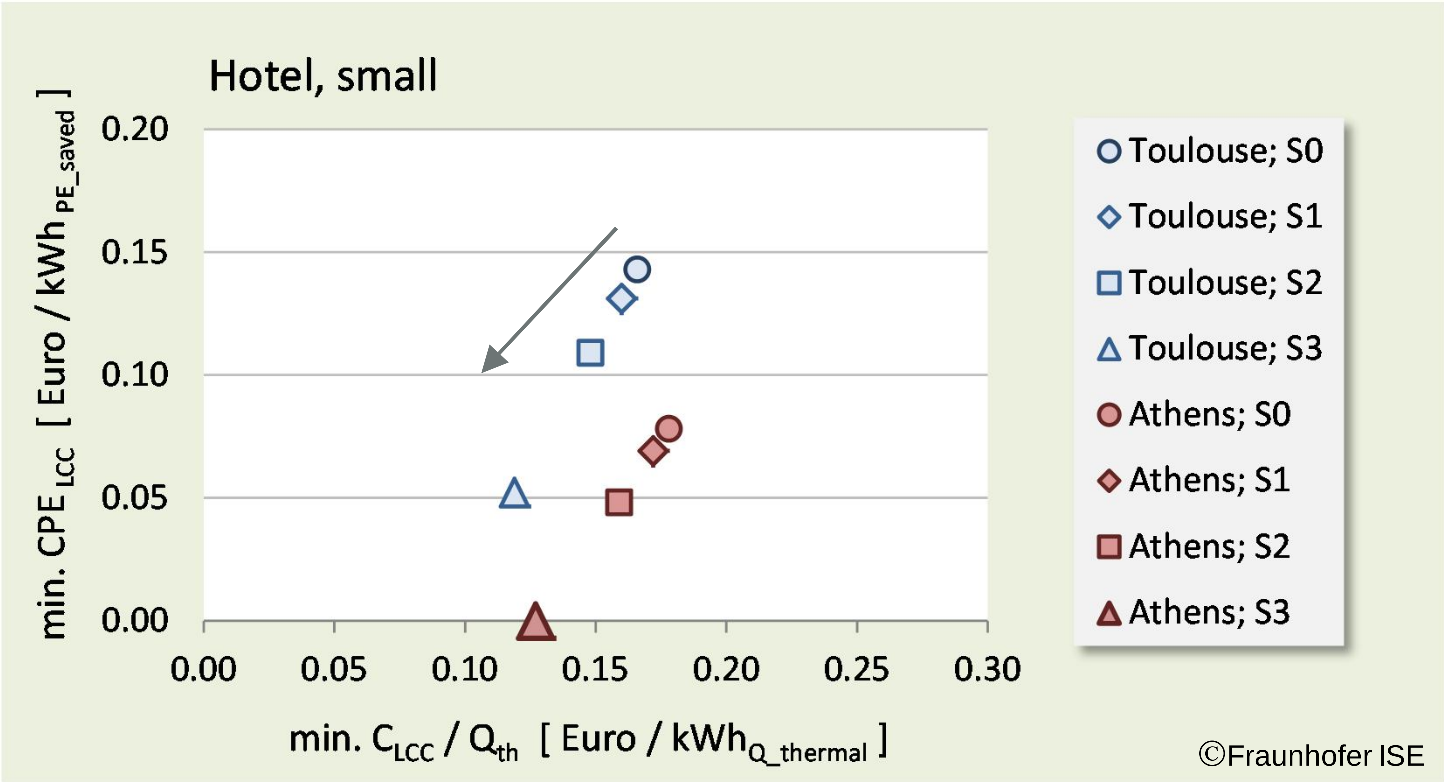
Effect of investment costs

- **S3** : collector system costs: -40%, TDC system costs -50% *

* goal Roadmap of BSW: Solar thermal system costs -43% until 2030;
forecast small/medium TDC-systems: -50% until 2030 (Dr. U. Jakob, Green Chiller)



Effect of thermally driven chiller capcacity

- Reducing capacity of thermally driven chiller (backup chiller size remains constant)
- P_TDC: **75%** of max. cooling load (regular layout in case study)

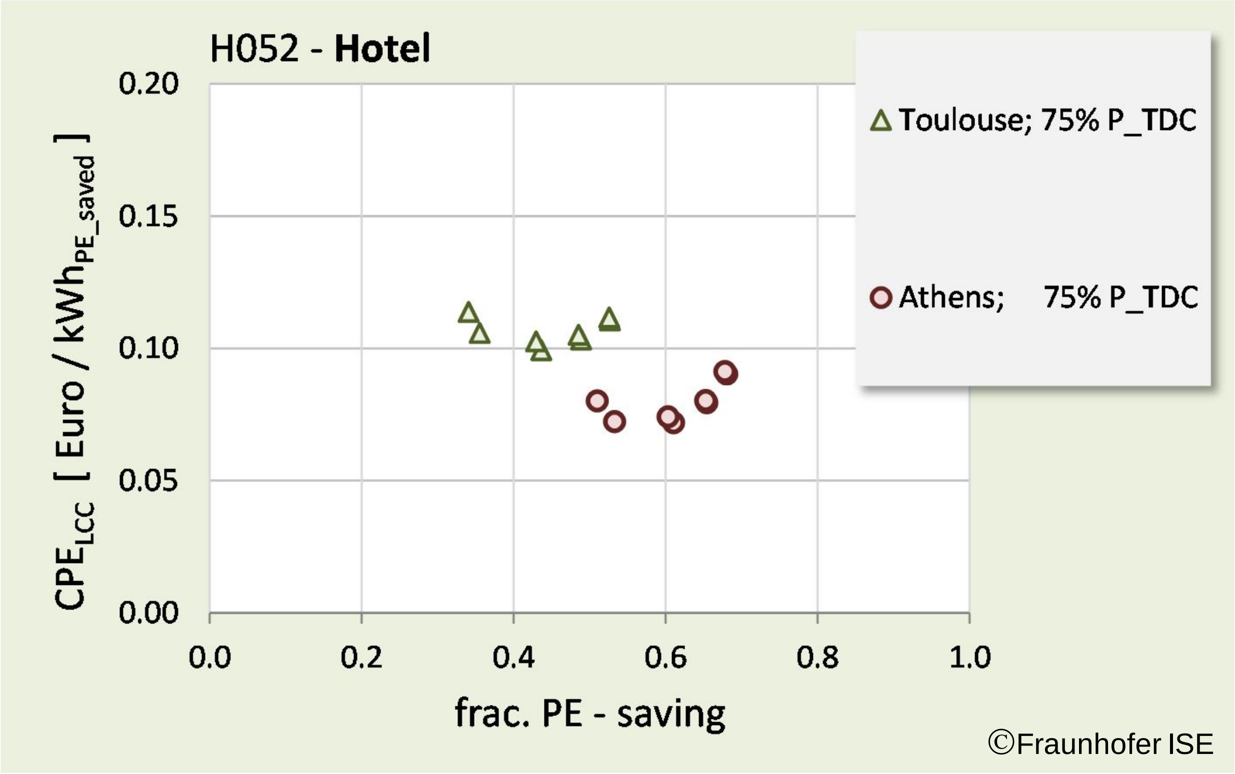
P_TDC:

85 kW (Toulouse)
94 kW (Athens)

flat-plate collector
3-6 m² per kW $_{P\_TDC}$

cold backup:
el. compr. chiller

heat backup:
gas boiler



Effect of thermally driven chiller capcacity

- Reducing capacity of thermally driven chiller (backup chiller size remains constant)
- P_TDC: **50%** of max. cooling load

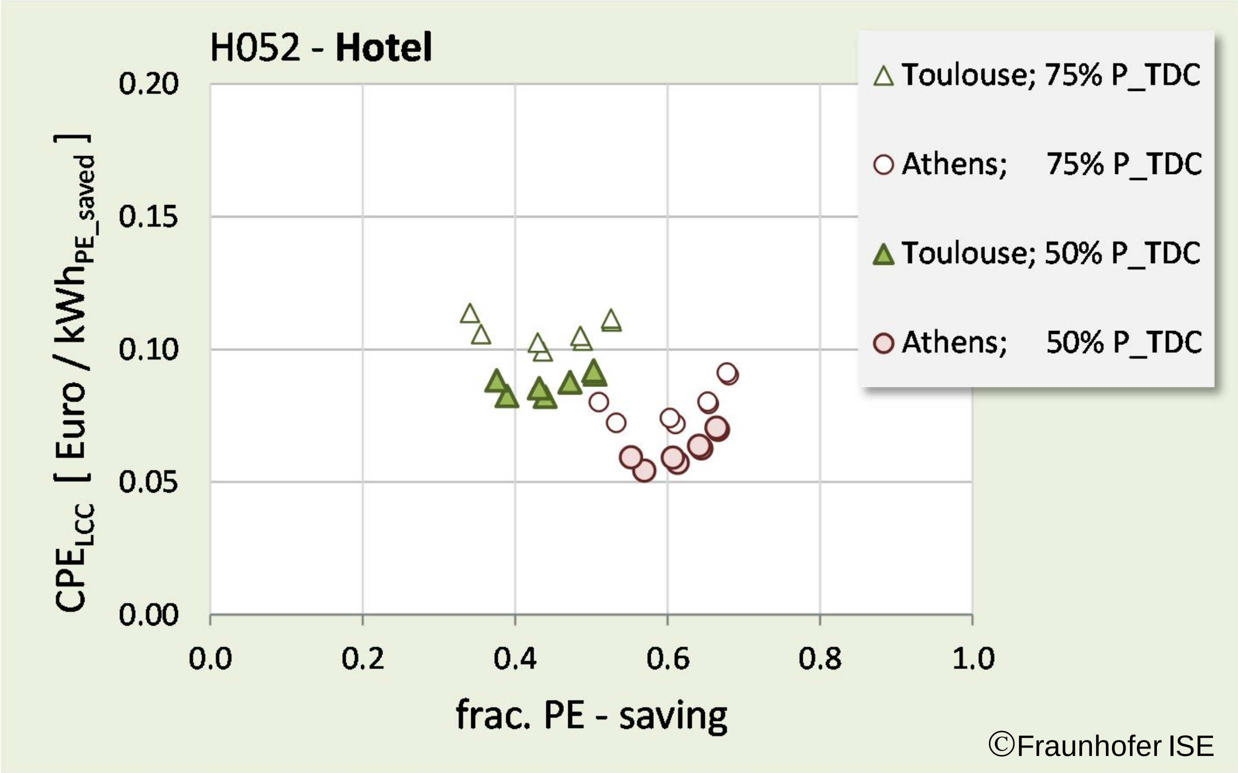
P_TDC:

56 kW (Toulouse)
62 kW (Athens)

flat-plate collector
5-8 m² per kW $_{P\_TDC}$

cold backup:
el. compr. chiller

heat backup:
gas boiler



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Effect of thermally driven chiller capcacity

- Reducing capacity of thermally driven chiller (backup chiller size remains constant)
- P_TDC: **33%** of max. cooling load

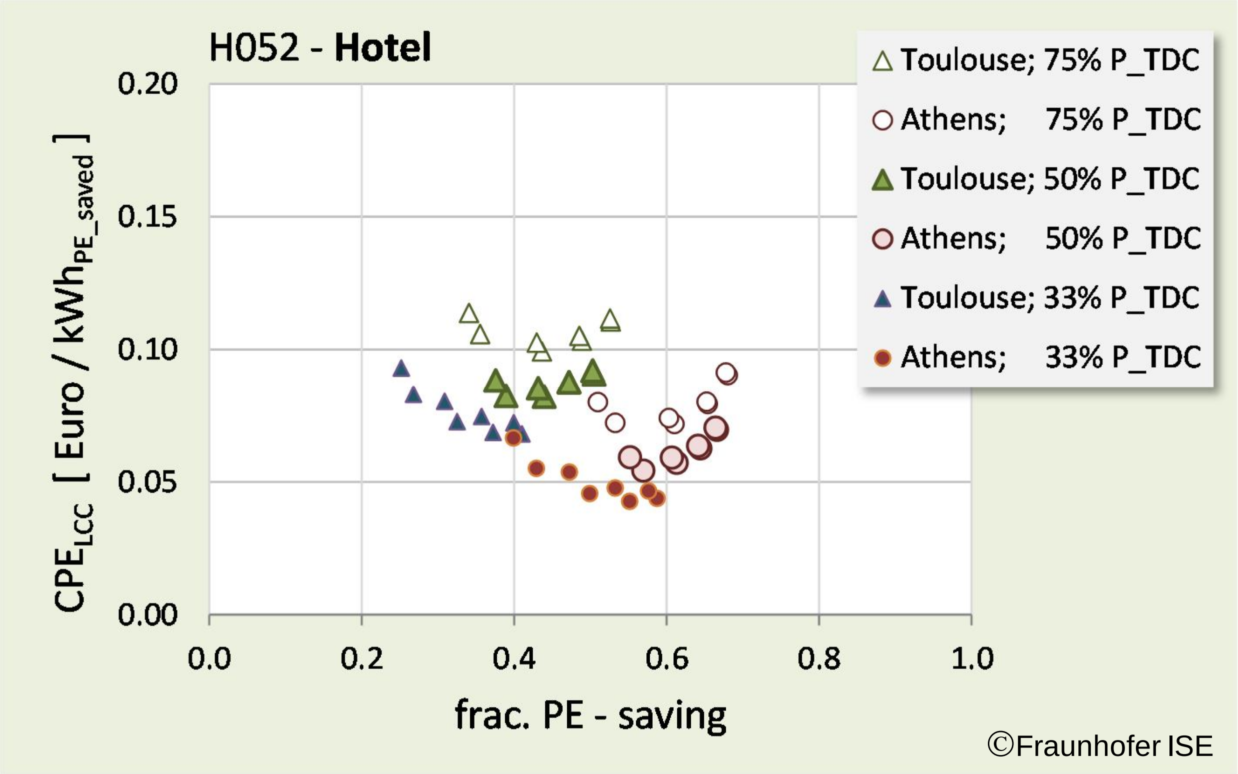
P_TDC:

38 kW (Toulouse)
42 kW (Athens)

flat-plate collector
5-8 m² per kW $_{P\_TDC}$

cold backup:
el. compr. chiller

heat backup:
gas boiler



Costs of PE-saving: Sensitivity

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- Effect on CPE by variation of +/- 10% relative of governing factors

Hotel, small

flat-plate collector

cold backup:
el. compr. chiller

heat backup:
gas boiler

Sensitivity to Cost per saved kWh primary energy: **Hotel, Palermo**, flat plate collector of size 5 m² per kW chilling capacity of thermally driven chiller (absorption)		
	Relative change % of rated value	Influence to CPE_{LCC} in %
Electricity price	+ 10	**– 3**
	– 10	**+ 3**
Fossil fuel price	+ 10	**– 3**
	– 10	**+ 4**
Seasonal efficiency of cooling system in reference	+ 10	**+ 15**
	– 10	**– 12**
Cost of collector	+ 10	**+ 8**
	– 10	**– 7**
Cost of thermally driven chiller (TDC)	+ 10	**+ 6**
	– 10	**– 6**
Installation cost	+ 10	**+ 4**
	– 10	**– 3**
Interest rate	+ 10	**+ 6**
	– 10	**– 6**
Annual increase energy cost (electricity + fuel)	+ 10	**– 3**
	– 10	**+ 3**

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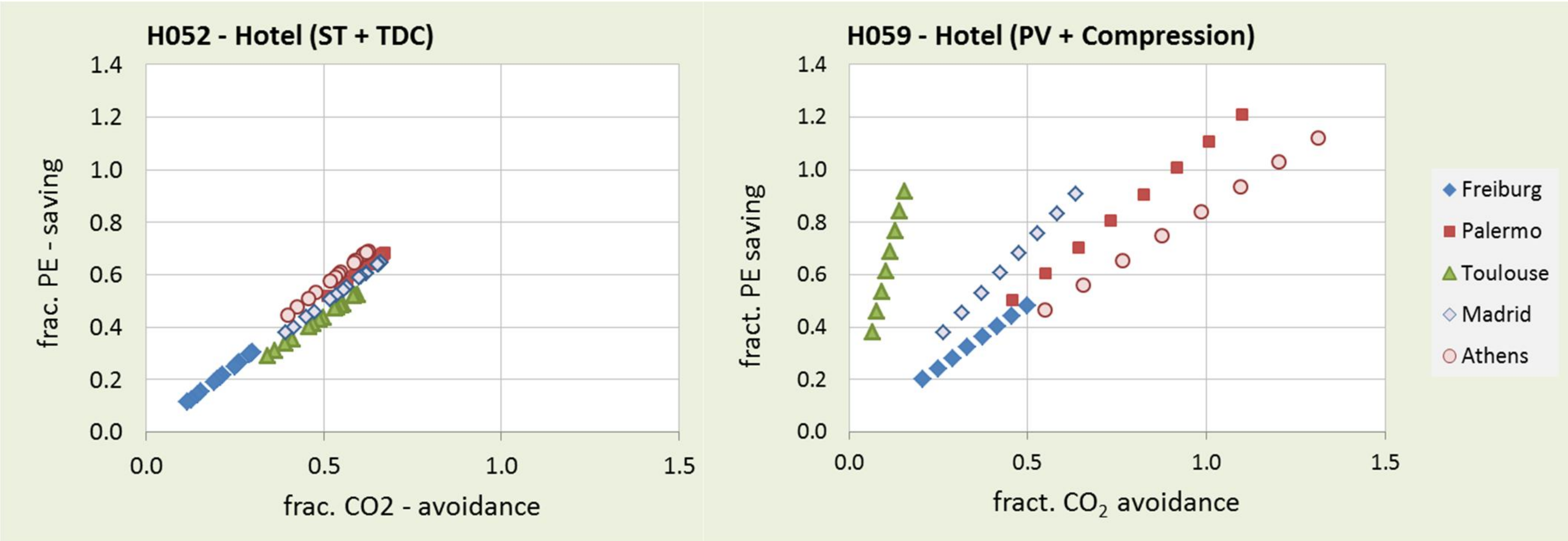
Comparison ST - PV

- 2.5…6 m²/kW$_{P_TDC}$ for ST and PV
- PV: grid connected (unlimited storage)



Summary (1)

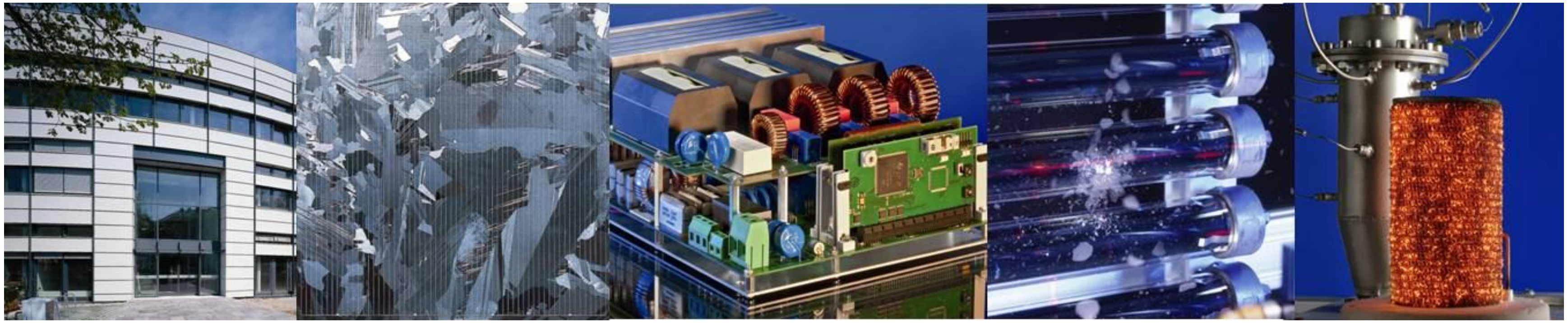
- Investigated so far: solar cooling with 1-effect thermally driven technology in standard configurations
- At appropriated sites, high PE savings and solar fractions possible
- Most promising: applications with additional use of solar thermal system (e.g., high DHW demand)
- Life cycle costs still higher than reference (no funding considered)
- To compete economically with reference systems: pronounced decrease in component costs (collector, thermally driven chiller) is necessary
- With cost projection of industrial associations: economic equality to reference obtained, but not in a short term
- High sensitivity to EER in reference:
  efforts necessary to increase electrical efficiency of solar cooling systems
  (with cold backup: no comfortable distance to reference)
- Sensitivity to energy price: small

Summary (2)

- Further measures for optimization
  - avoidance of cold backup, where compatible with comfort requirements
  - careful decrease of TDC capacity (no peak-load design)
  - use of medium-temperature heat (e.g. for DHW pre-heating, not studied)
- Next steps
  - Comparison with reference + grid connected PV
  - Systems with heat pumps
  - Systems with concentrating collectors, 2-effect TDC
  - Comparative study on solar process cooling (ILK Dresden)
  - Evaluation of reference technology (ZAE Bayern, ILK Dresden)

EVASOLK is supported by the federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety (FKZ 0325966 A)

Thank-you for your attention!



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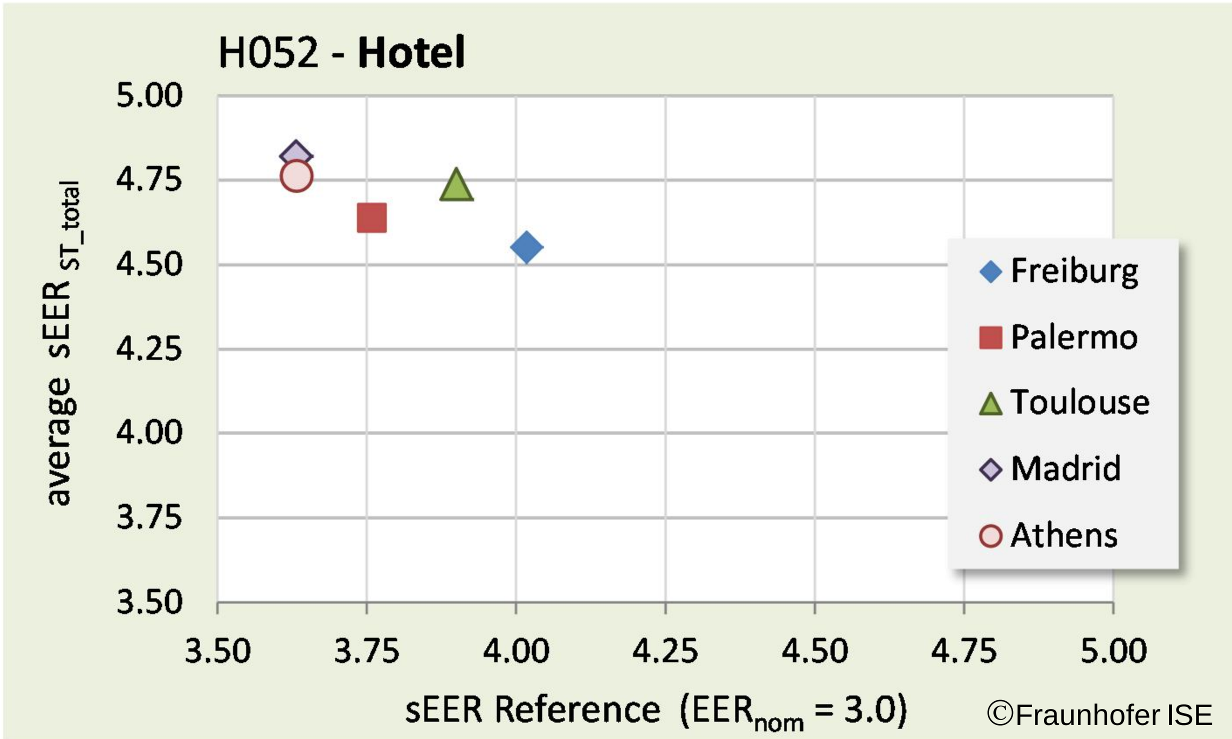
EER

- sEER of solar thermal systems (H052 configurations) : 7.5 – 8.9
  (collector and TDC system with pumps, heat rejection)
- average $sEER_{ST\_total}$: total system incl. backup chiller, chilled water pump
  (average of configurations per site)

sEER:

$$\frac{\text{cold production}}{\text{electricity input}}$$



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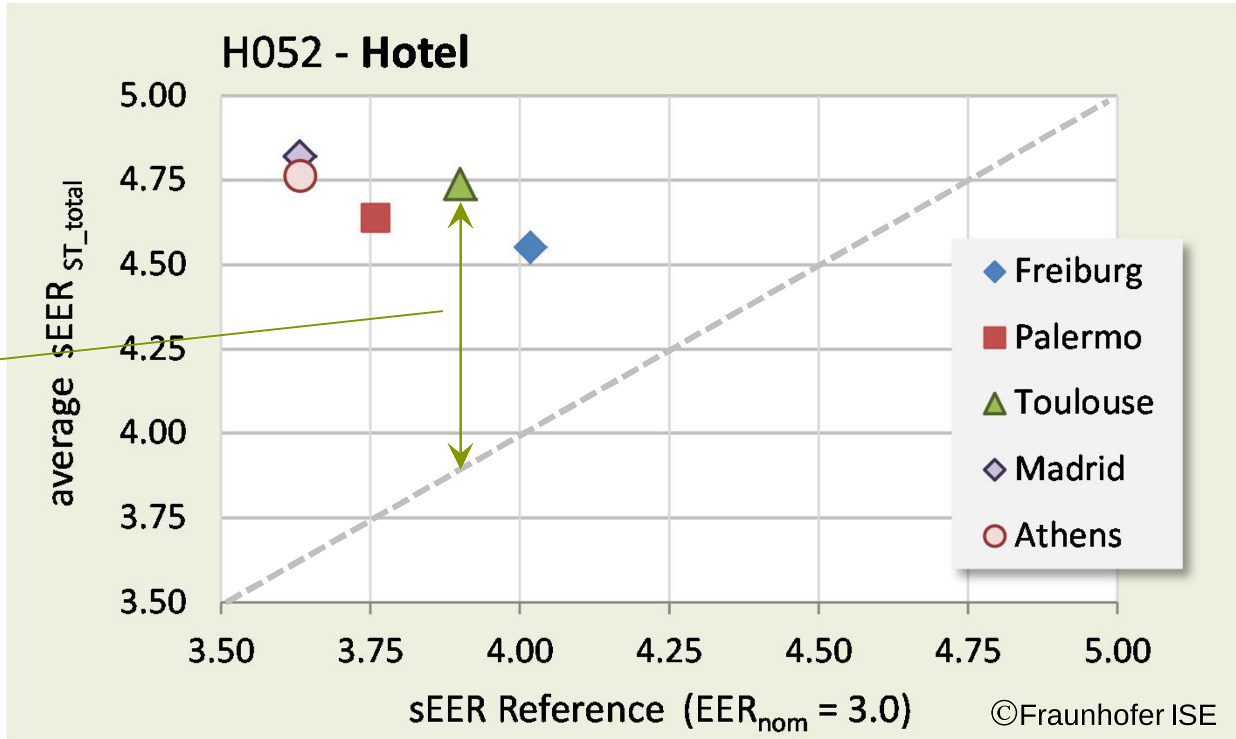
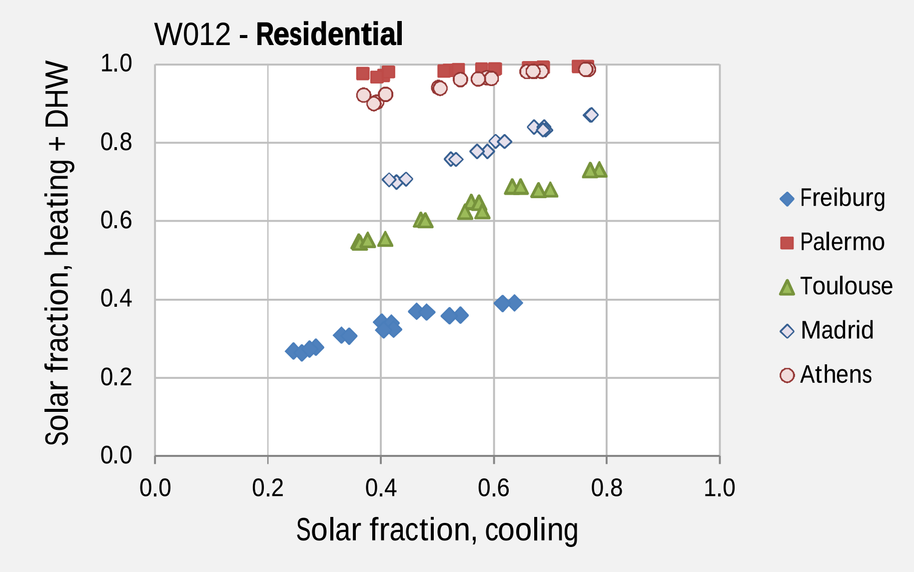
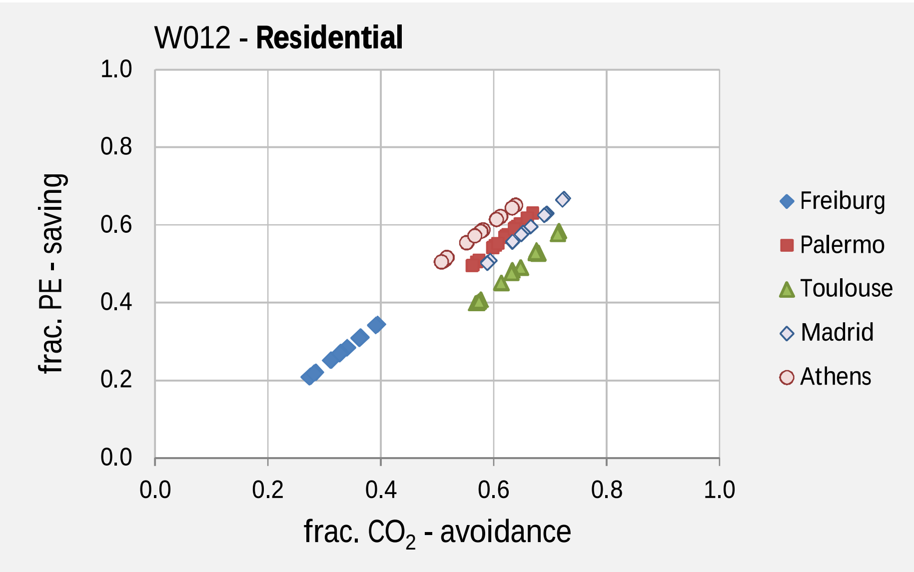
advantage of electric performance



Example: Residential (1)





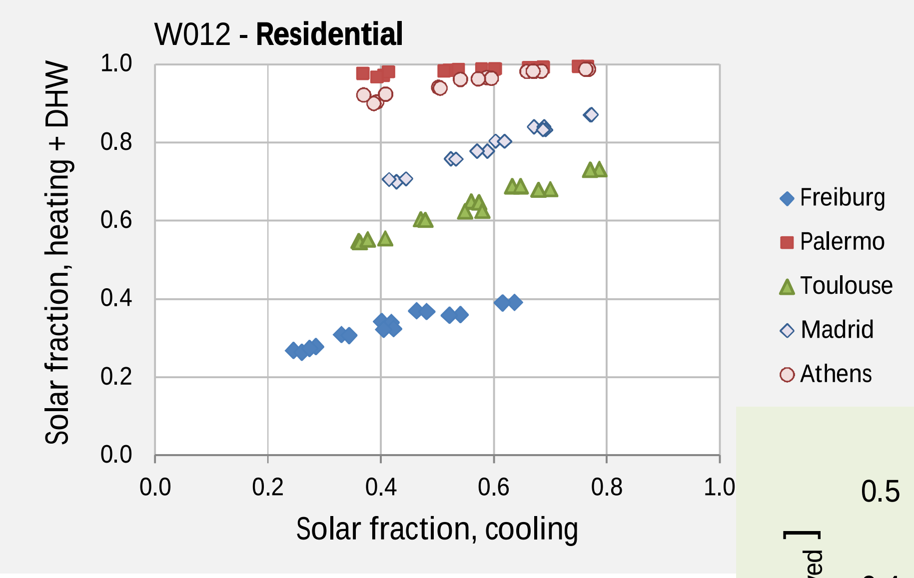
- Small application: multi-family building (< 20 kW capacity TDC)
- Cold backup: el. compression
- Reference: multi-split system

- Variations:
  - Collector size
  - Collector type
  - Ab-/Adsorption chiller

specific collector area:

3	4	5	6	m² / kW TDC_capacity	: FPC
2.5	3.5	4.5	5.5	m² / kW TDC_capacity	: ETC

Example: Residential (1)



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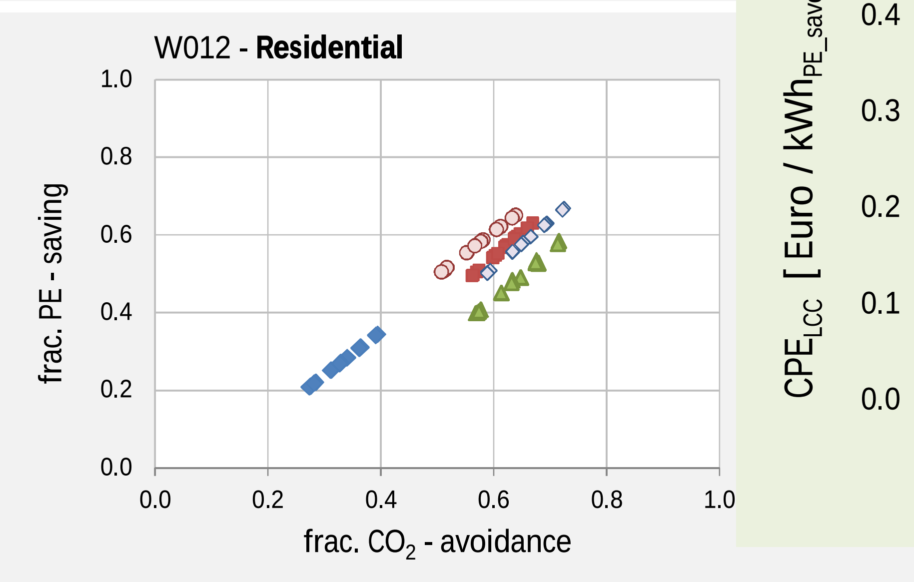

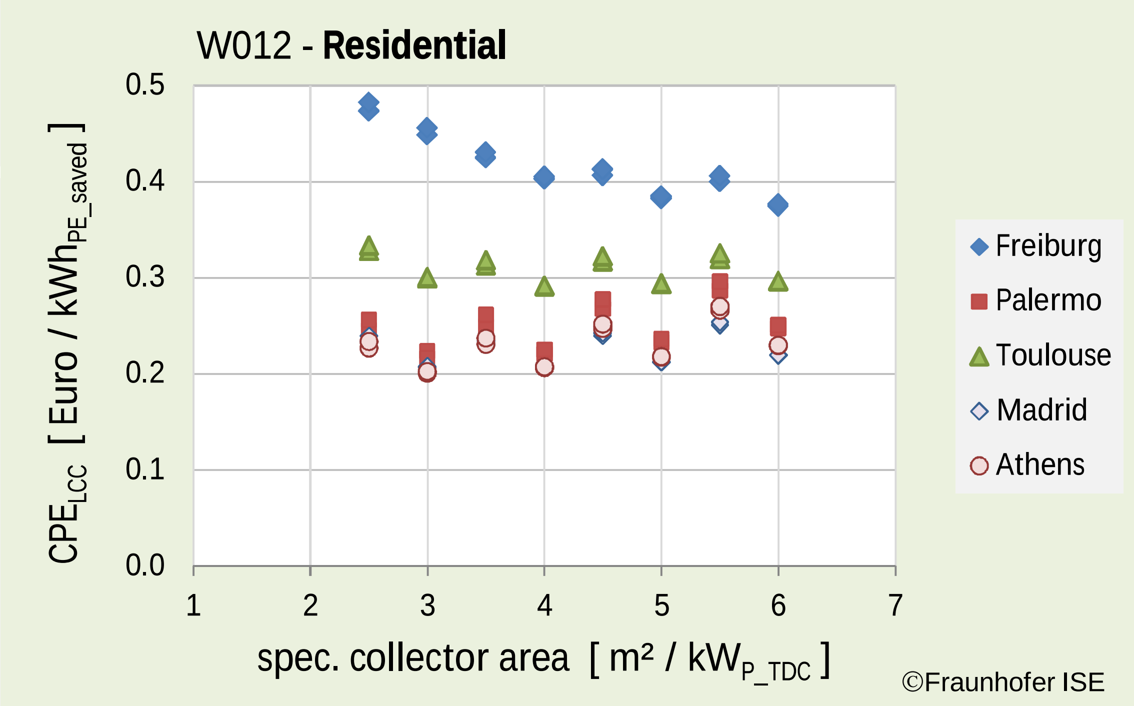

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Example: Office

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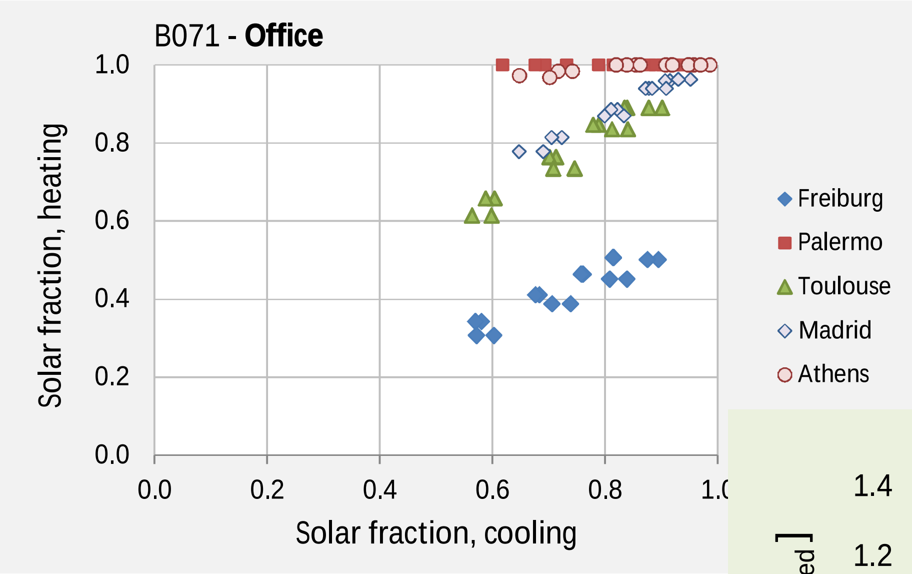
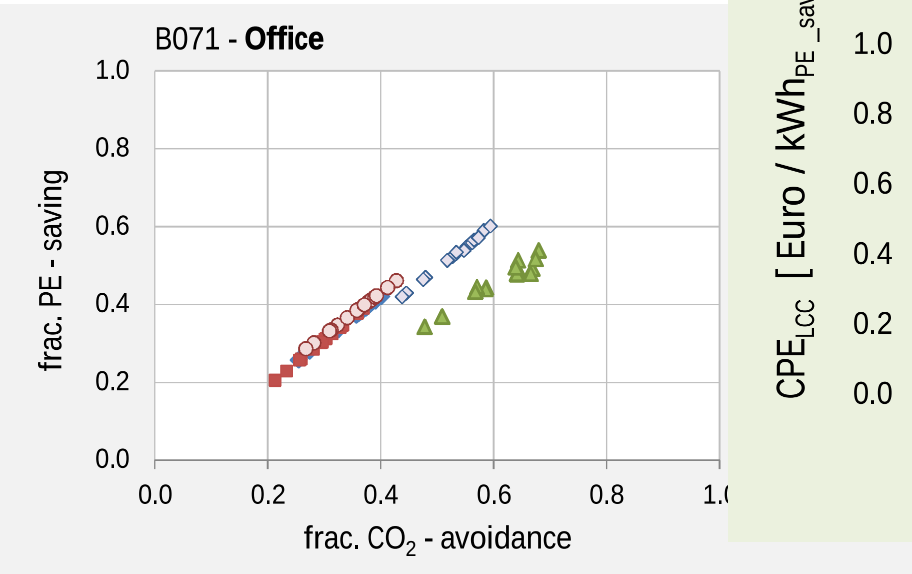
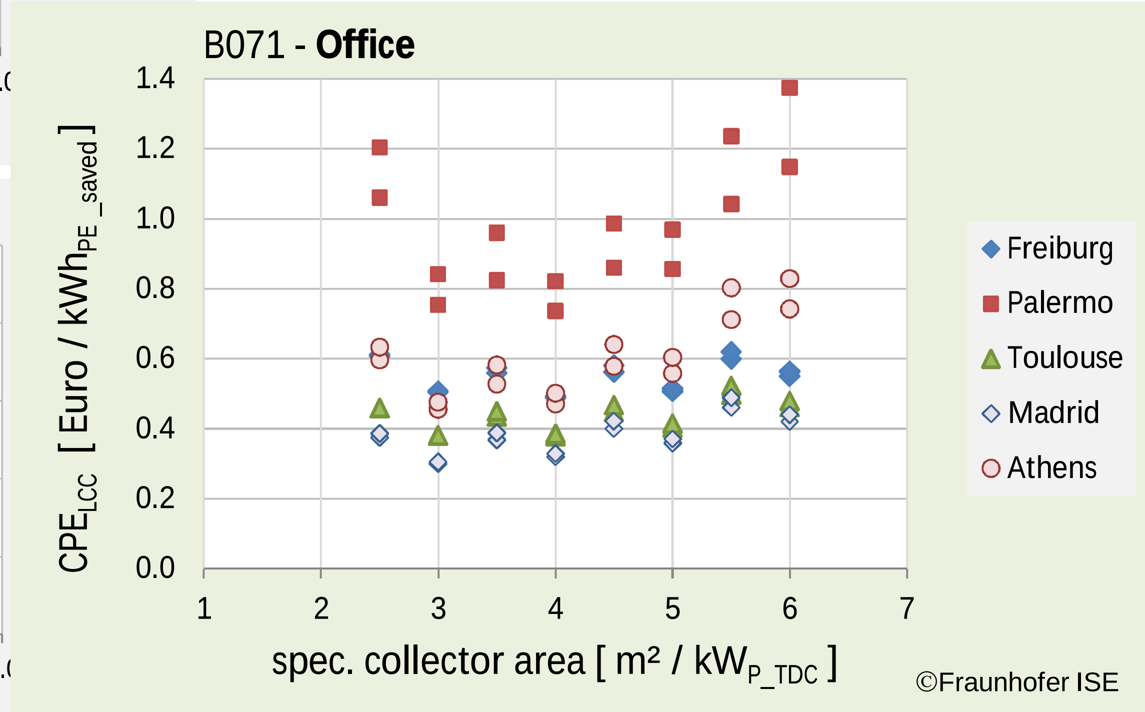


- Office building
  (> 100 kW capacity TDC)
- Cold backup: el. compression
- Reference: multi-split system





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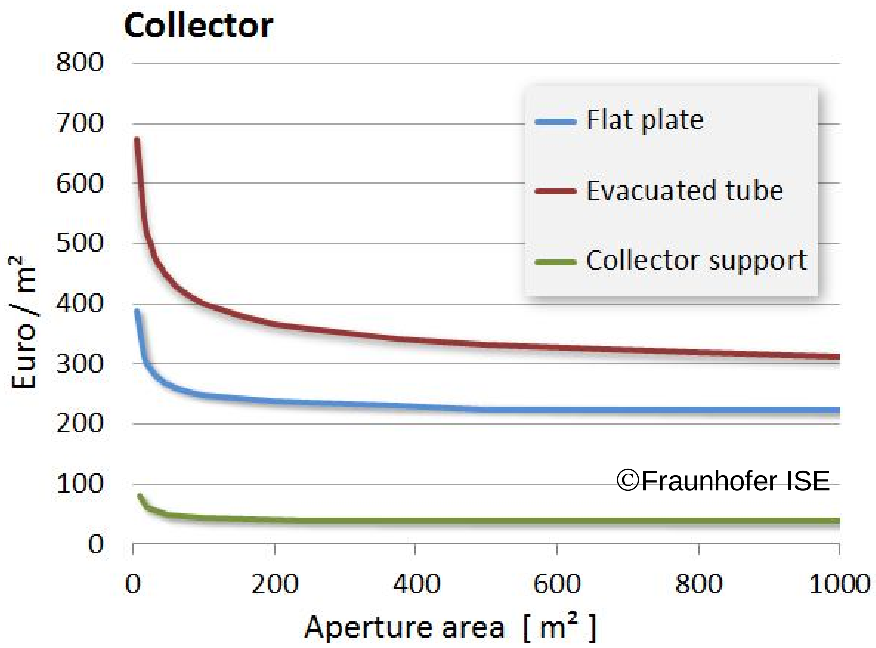
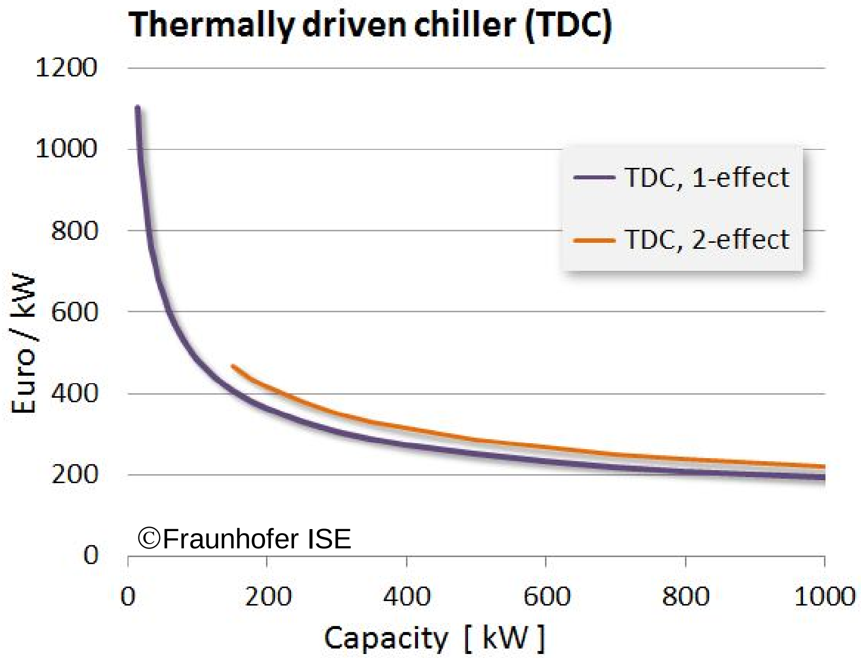
Comparative study: solar cooling in buildings

- Base for cost curves components:
  - Survey in IEA SHC Task 38
  - Realised systems, own queries
  - Catalogue sales prices





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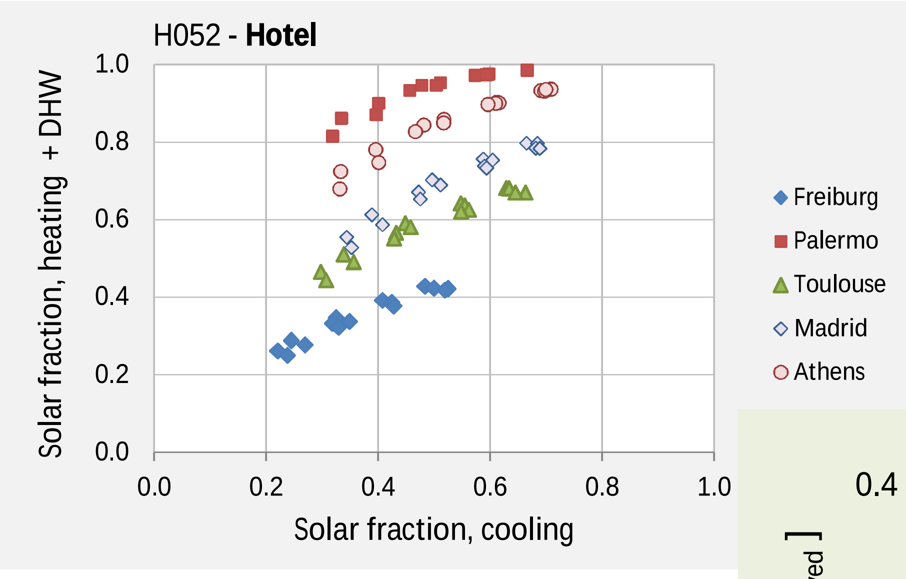
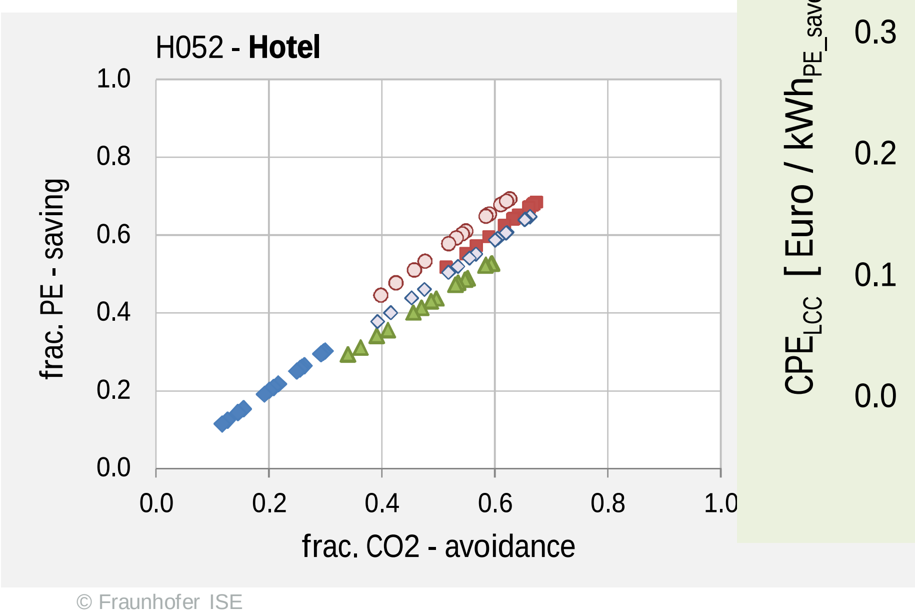
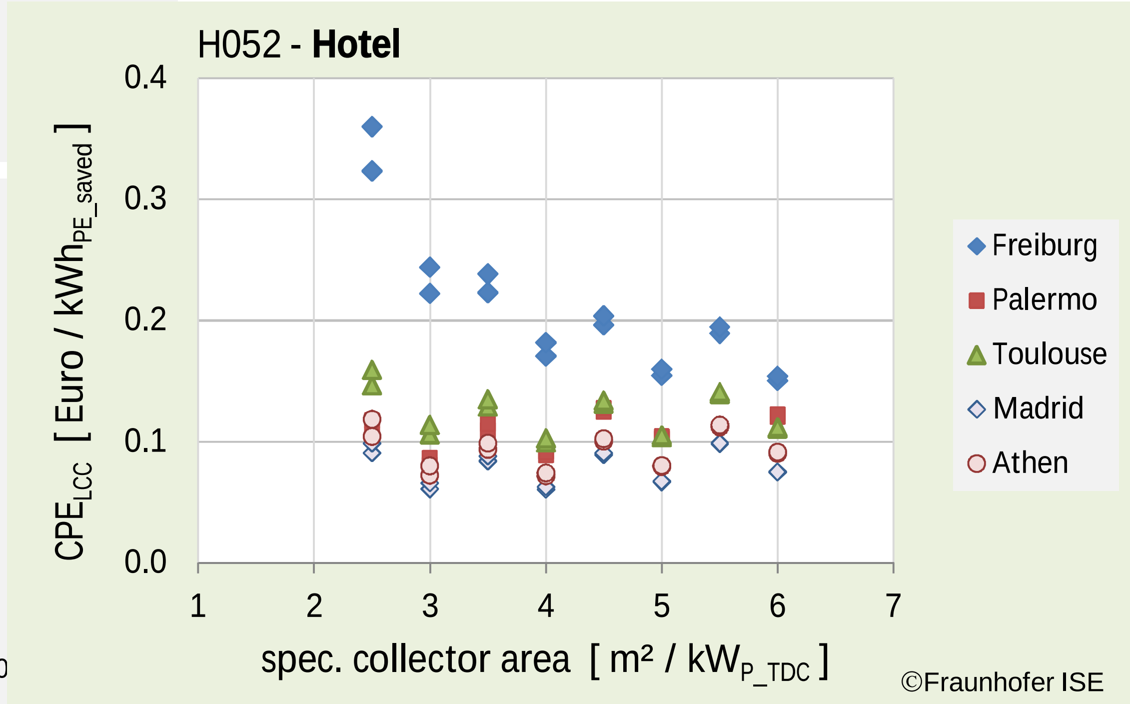
Example: Hotel





- Hotel building
  (> 70 kW capacity TDC)
- Cold backup: el. compression
- Reference: multi-split system



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