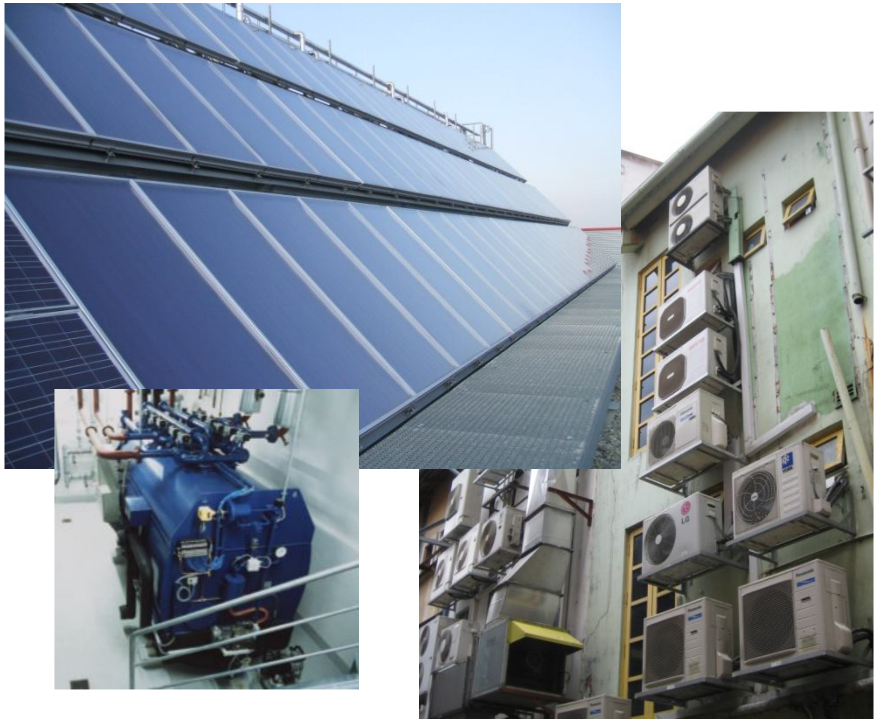
EVASOLK: Chances and perspectives of solar cooling in comparison to reference technologies

Work package: comparative study on solar cooling in buildings



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Cooperative project

Coordination: Fraunhofer ISE

Partners: ILK Dresden, ZAE Bayern

4th Expert meeting IEA SHC Task 48

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Newcastle, Australia

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

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Motivation

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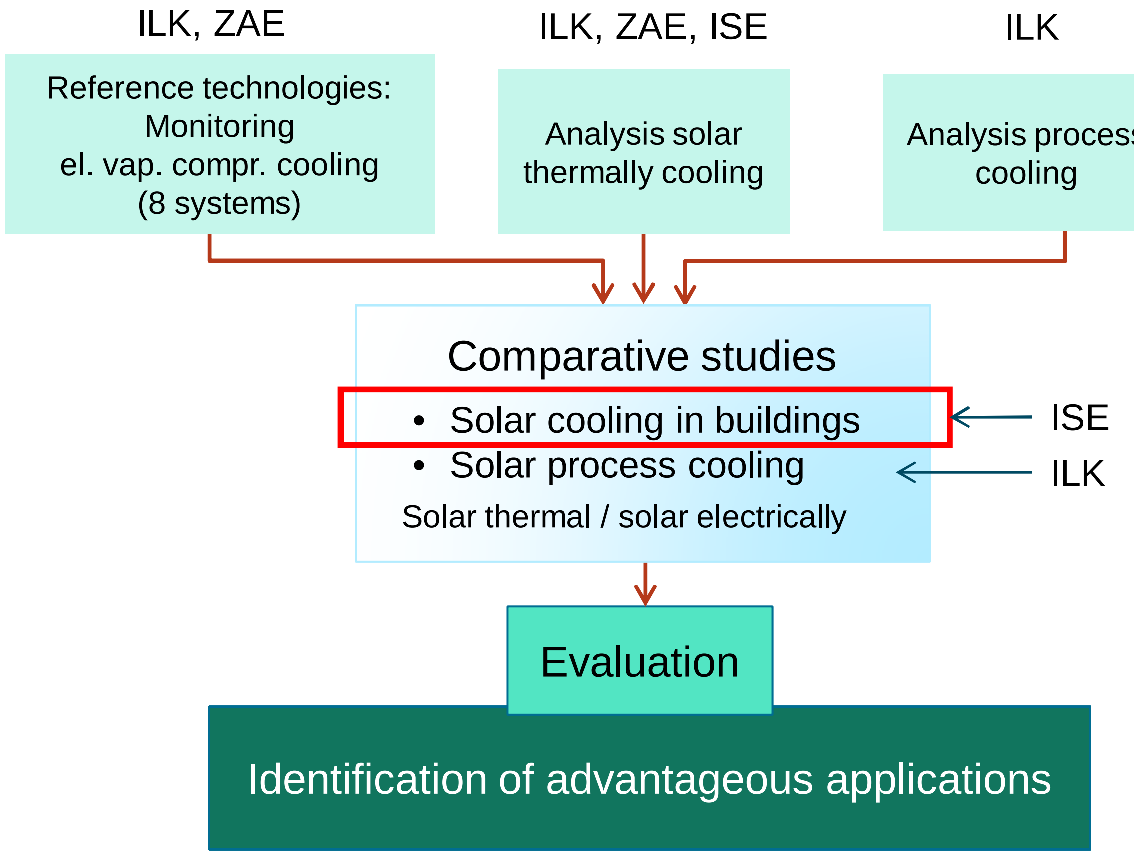
Solar thermally driven cooling

- Low movement in costs (components, planning, installation)
- High complexity
- Low market growth ↔ no mass production
- In target countries: market collapse due to economic problems
- Other benefits often not perceived (heating support, sanitary hot water production)

<u>At the same time:</u>

- Distinct price decline of PV systems (grid-connected)
- Attractive: conventional building energy supply with grid-connected PV
  - simple planning; no interaction with building supply systems
  - no interaction of heat/cold supply with PV
- Focus in public discussion on electricity based appliances

EVASOLK



Partner:
Fraunhofer ISE (Koordination)
ILK Dresden
ZAE Bayern

Comparative study: Solar cooling in buildings
(closed cycles)

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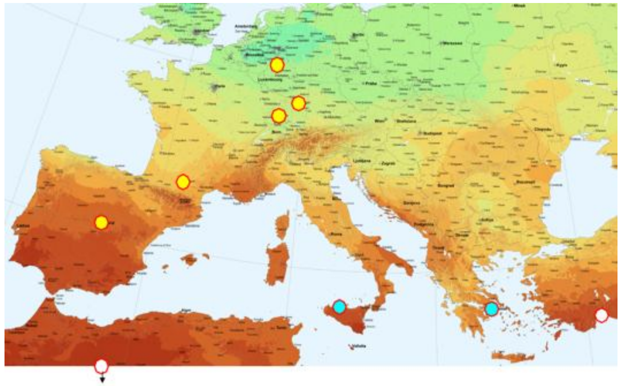
How does solar cooling perform…

- In different climate regions
  - Central / South Europe, North Africa
- In different applications
  - 3 types of buildings and user demand profiles (e.g., multi-family house, office and hotel buildings)
- In different configurations
  - collector, thermally driven chiller (TDC), Back-up, gas boiler / heat pump
- In comparsion to reference system (+ PV)
  - el. driven compression chiller, gas boiler / heat pump



Comparative study: Solar cooling in buildings

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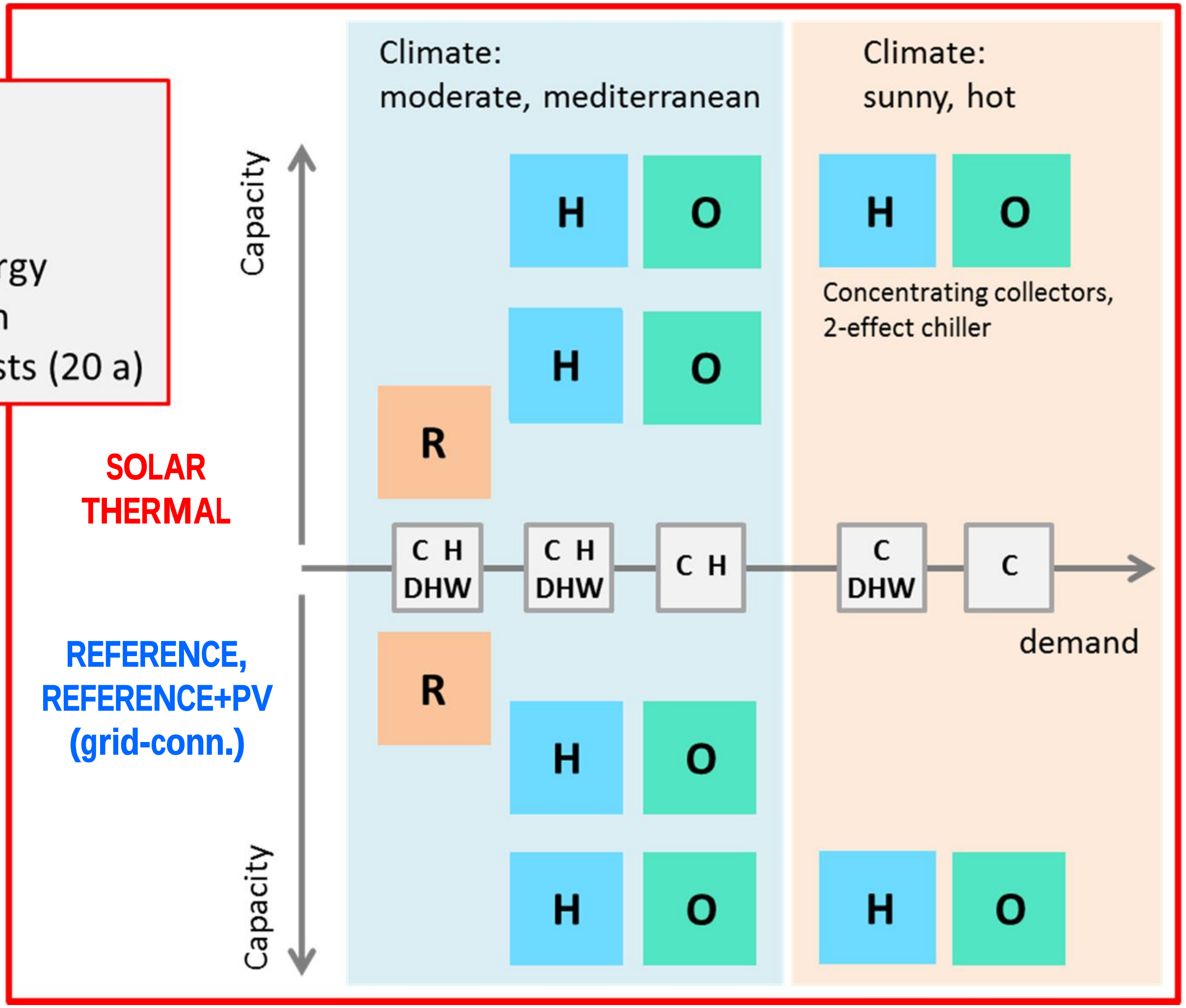
Balance:
- electricity,
- fuel,
- primary energy
- CO_2 emission
- Life cycle costs (20 a)



R Residential (Multi-family house)

H Hotel building

O Office building

Use:

C = cooling

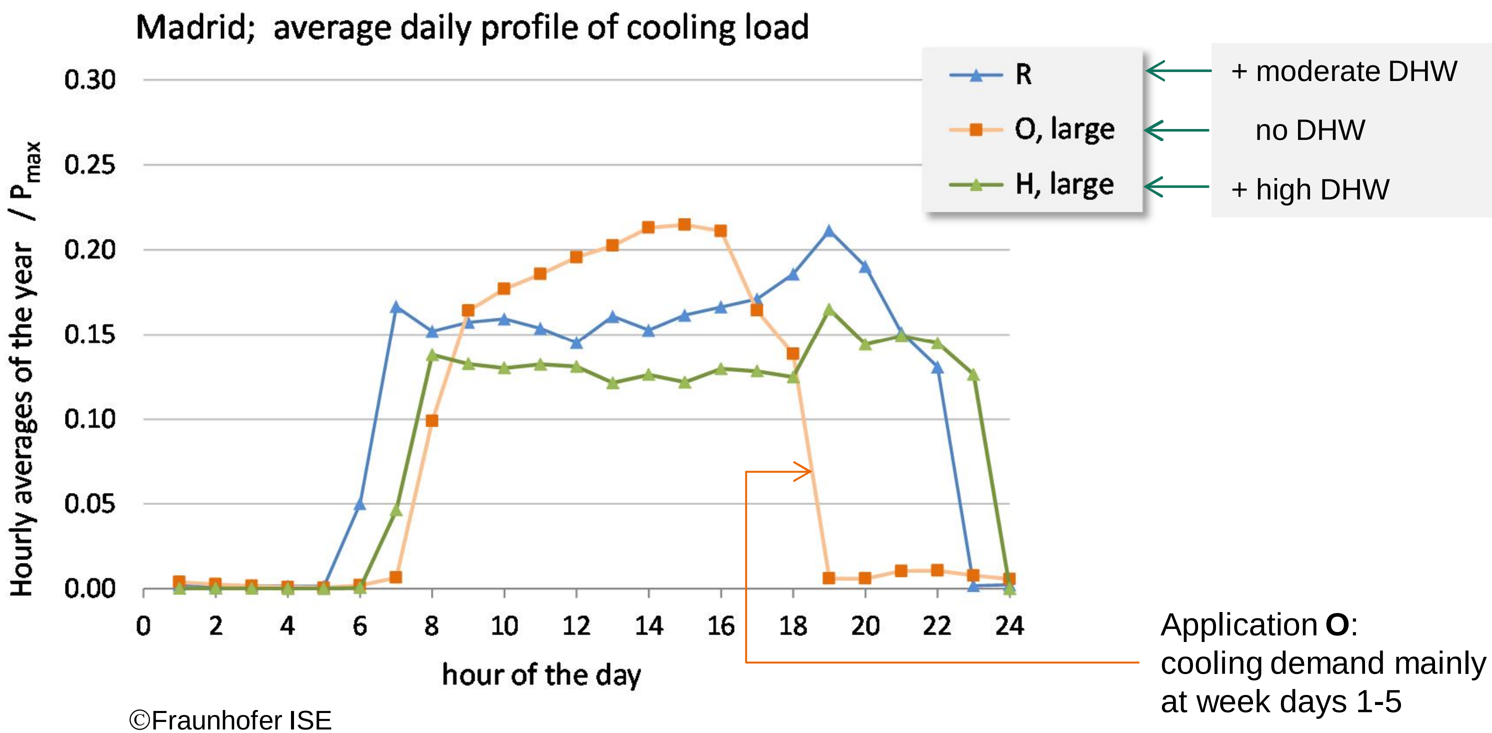
H = heating

DHW = domestic hot water

Comparative study: Solar cooling in buildings

- Example for Madrid site: average daily cooling load profile, shown as fraction of max. load

  + heating demand and in R,H: DHW demand



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Comparative study: Solar cooling in buildings

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- Standard configuration solar thermal cooling
  - cold-backup (el. compression chiller, cold water)
  - residential, small office: also configuration without cold-backup
  - heat-backup: gas boiler, heat pump (el.); not used for TDC driving heat
  - variation: collector area,
    flat-plate coll., evacuated tube coll. (line focus collector)
  - absorption, 1-effect (2-effect); adsorption
- Reference
  - Cold supply:
    - multi-split-units (small capacity range R, O, H)
    - chilled water unit (large capacity range O, H)
  - Heat supply: gas boiler, heat pump (el.)
- Reference + PV
  - Conventional heat and cold supply (as in reference)
  - PV: conventional inverter; base of PV modules: multi christalline Si

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Comparative study: Solar cooling in buildings

- System modelling in TRNSYS®
  - Considering the total thermal (cooling, heating, domestic hot water) and electrical (air-conditioning, equipment, …) energy demand

- Solar thermal systems
  - Variation of collector type, collector area, TDC type, …

- Referenz + PV
  - Installed peak-power of PV- Generator
    = nominal electrical power demand of compression chiller CCH (100%-dimensioning)
  - PV system: only self-consumption of PV-electricity considered in primary energy and cost calculation. Reason:
    - high uncertainty of future feed-in tariff regulations
    - in the long term with cont. increasing electricity costs, self-consumption is high attractive
    - better comparison to thermal systems (no funding, no use of surplus thermal energy)
  - No special measures to increase self consumption due to interaction with air-conditioning system (storages etc., → leading to higher cost of PV-approach)

Comparative study: Solar cooling in buildings

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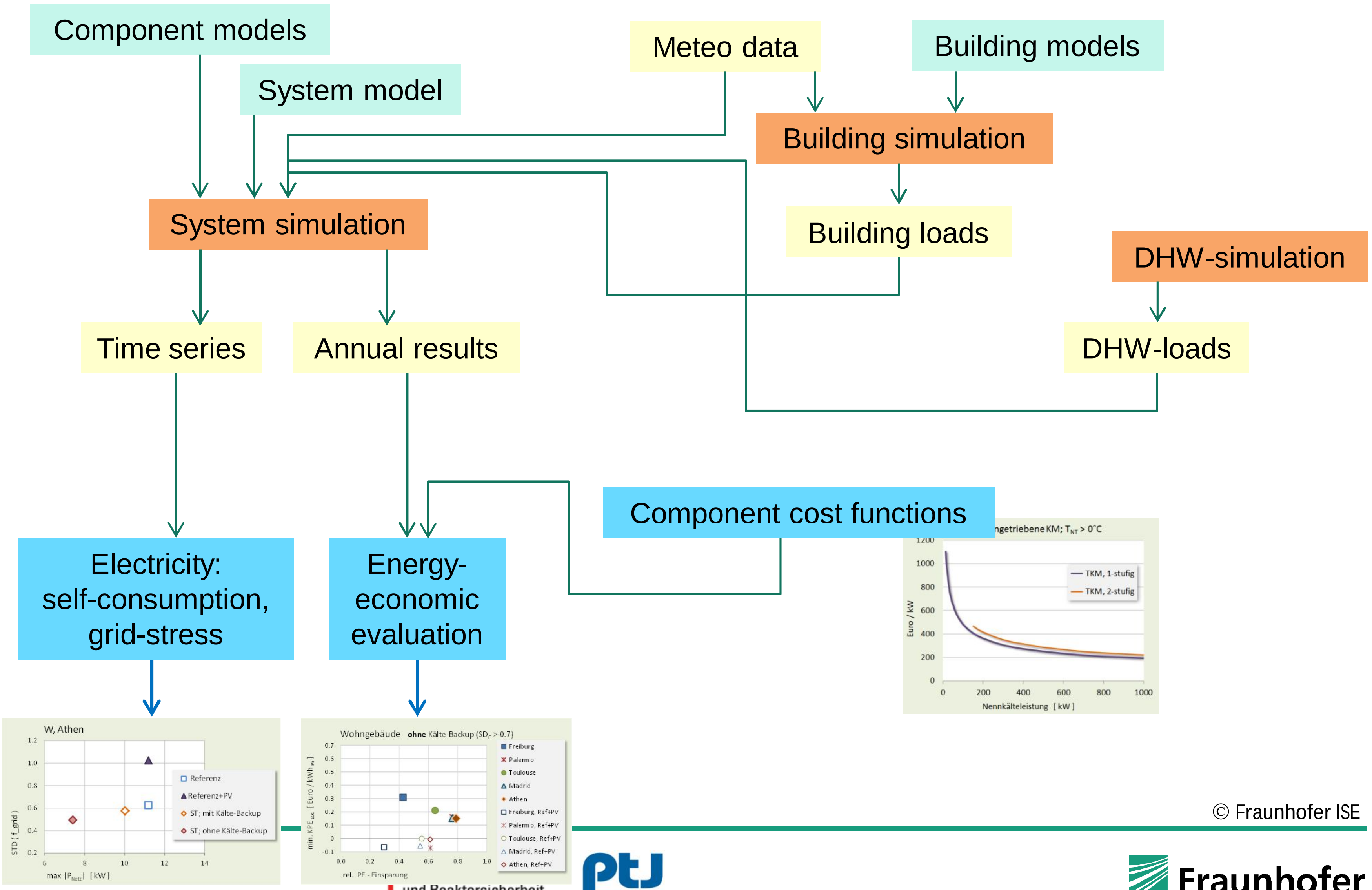
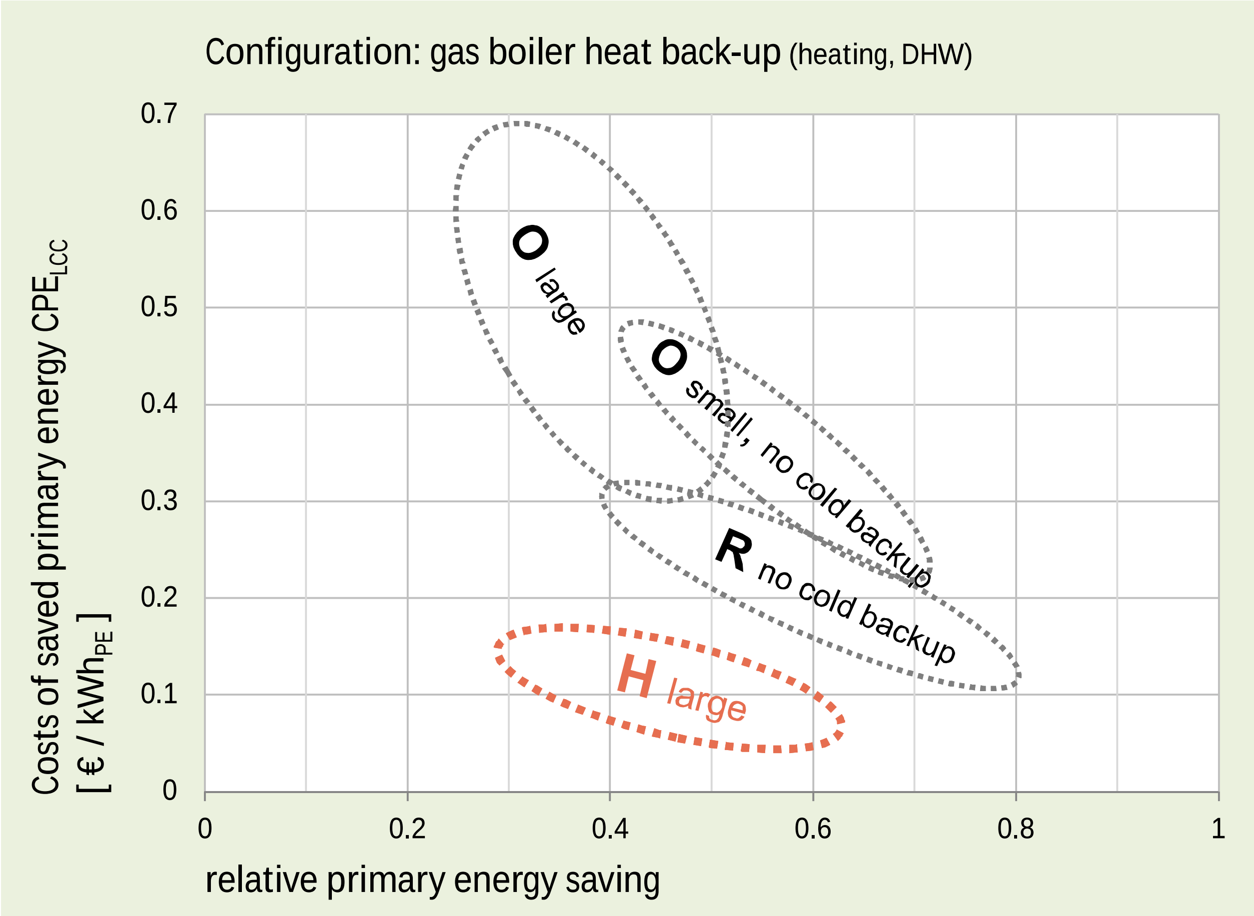
- Investment
  - Key components: cost-curves on base of present costs
  - no funding
  - Fixed %-rates for installation, planning, maintenance
- Other boundary conditions
  - Country specific energy prices and conversion factors (primary energy, CO_2-emission)
  - System operation: 20 years (life cycle LC)
  - Interest rate: 5%
  - Annual increase of operation costs: electricity 5%/a; gas 3%/a
- Evaluation
  - Costs of primary energy saving within LC (CPE_{LCC})
    - € per kWh saved primary energy
    - CPE_{LCC} values > 0: additional costs compared to reference
  - Saved primary energy
  - Also calculated for CO_2 savings (not presented here)

Comparative study



Results: standard configuration

- CPE_{LCC} * versus PE savings for solar thermal driven applications



* Site dependent range of minimum CPE_{LCC} values from collector size and type and TDC type variation

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Results: standard configuration

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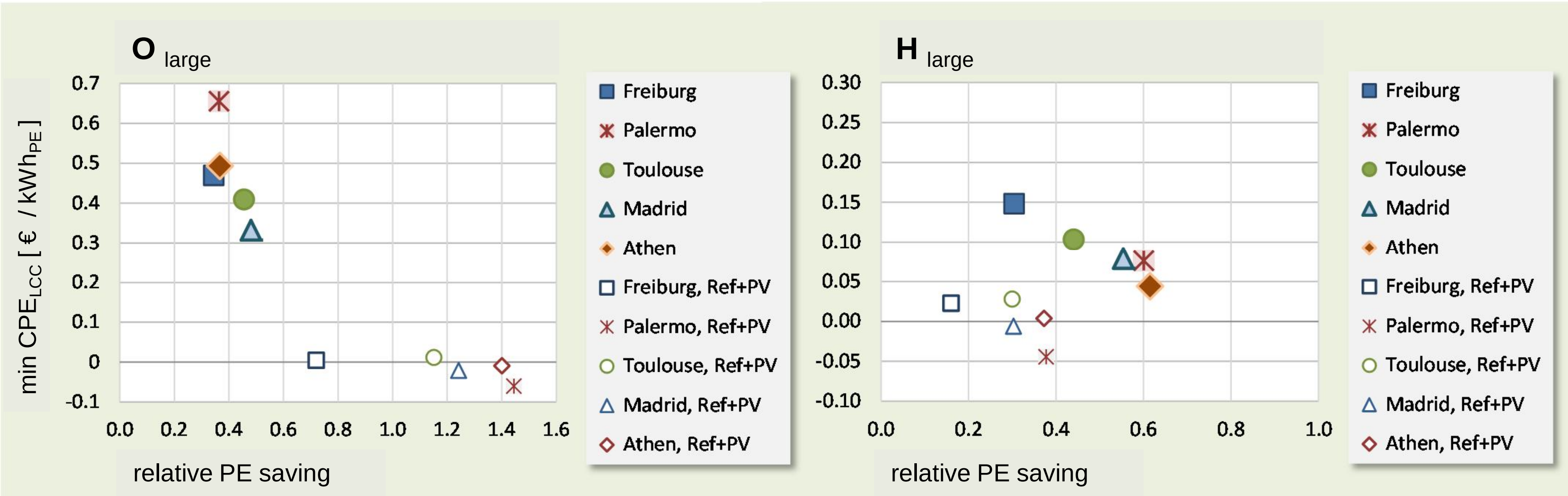
- Application type Office building:
  - Good correlation between cooling loads in summer and PV-electricity generation
    → high rates of self consumption and thus PE savings
    → difficult for solar thermal solutions, to approach to cost and PE performance of Ref+PV
- Application type Hotel building:
  - Extended use of solar thermal plant due to sanitary hot water production
    → substitution of fossil fuels for DHW preparation
    → higher PE savings, but still higher costs than Ref+PV option



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Influcence: TDC sizing

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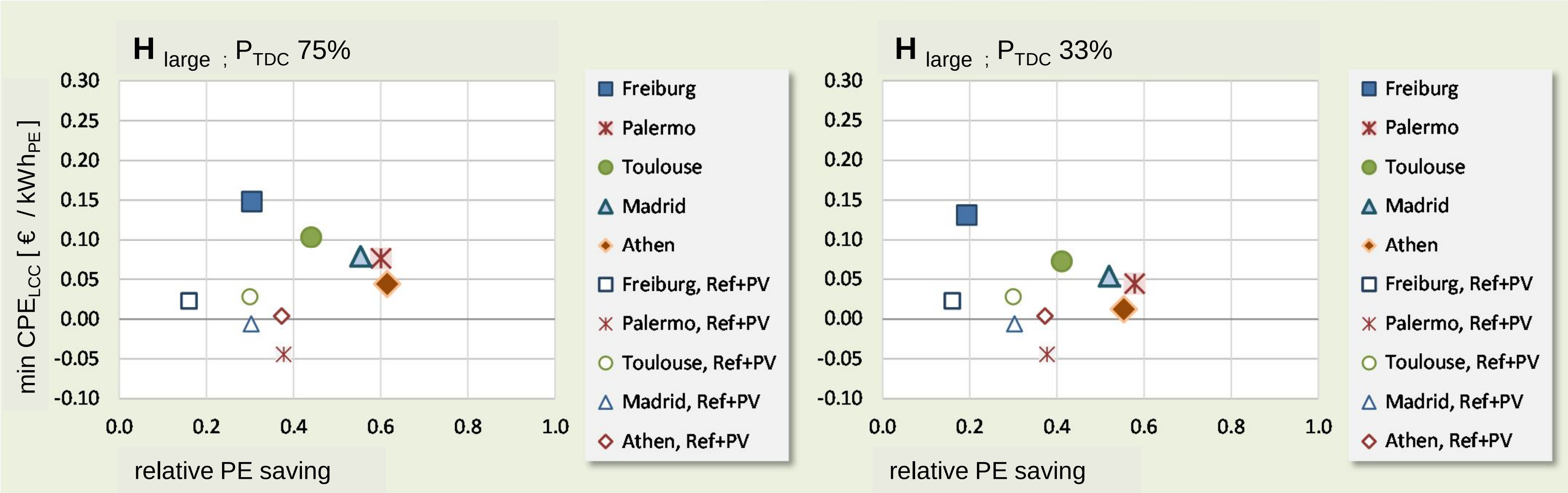
- Application **H**: reduction of TDC capacity
  - Regular sizing of TDC in comparative study: 75% of max. cooling load
  - Down sizing of 50%, 33% of max. cooling load
  - ⇒ avoiding peak-load sizing improves economics with acceptable losses in PE-saving
  - Still higher costs than Ref+PV system, but higher PE-savings



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Influence: Investment costs

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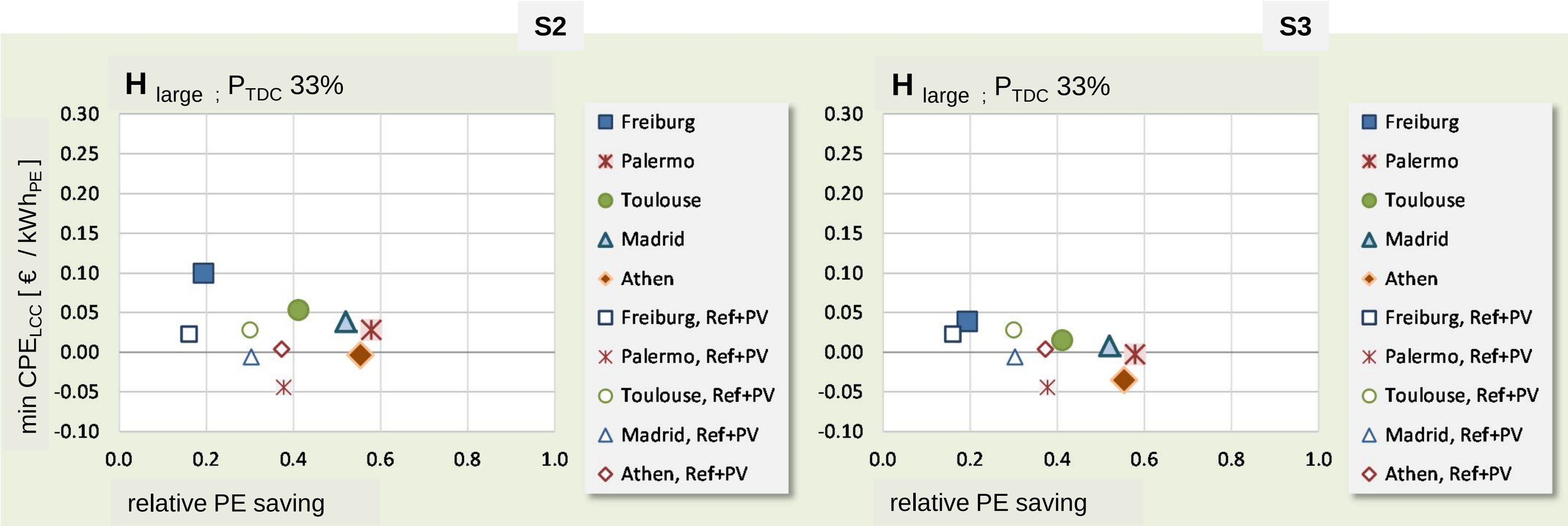
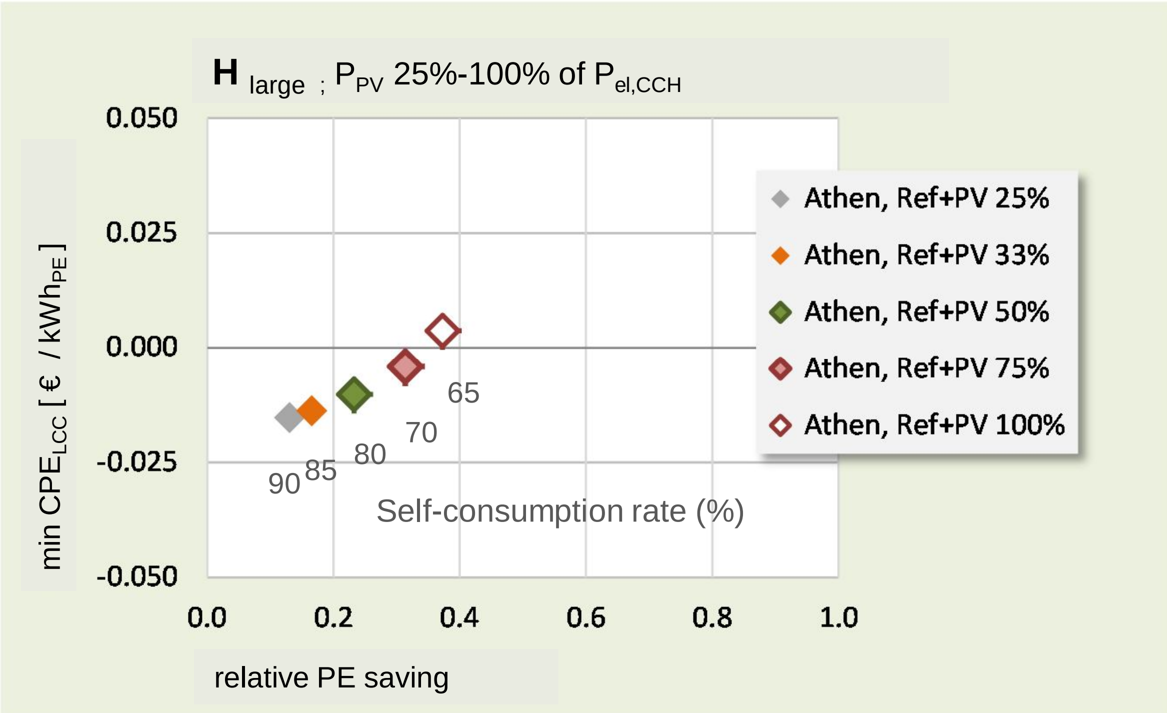
- Collector system and TDC system costs
  - S2: Collector system -10%, TDC system -25% (investment)
  - S3: Collector system -40%, TDC system -50% (investment)
    ⇒ costs comparable to Reference + PV, but higher environmental benefits



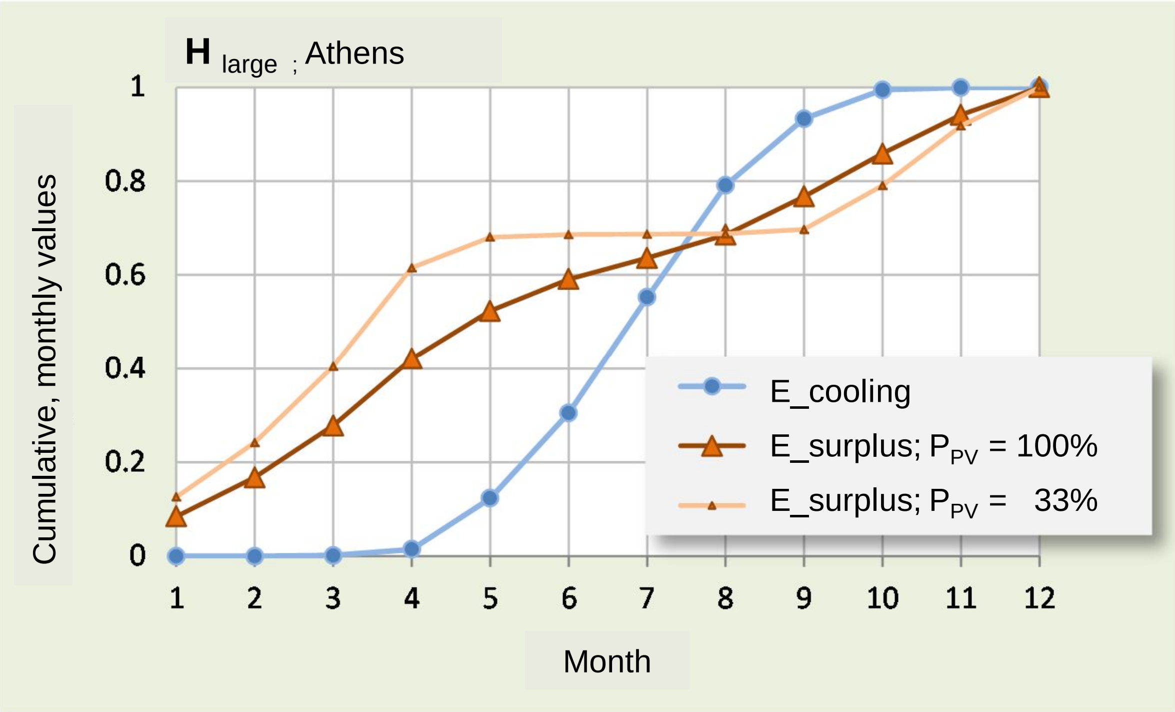
Influence: PV capacity on self consumption rate

- 100% - sizing:
  Peak-power of PV generator = nominal electricity demand of compression chiller
  - Reminder: no special measures to increase self consumption
  - Smaller PV capacities improve self consumption rates and costs, but decrease environmental savings



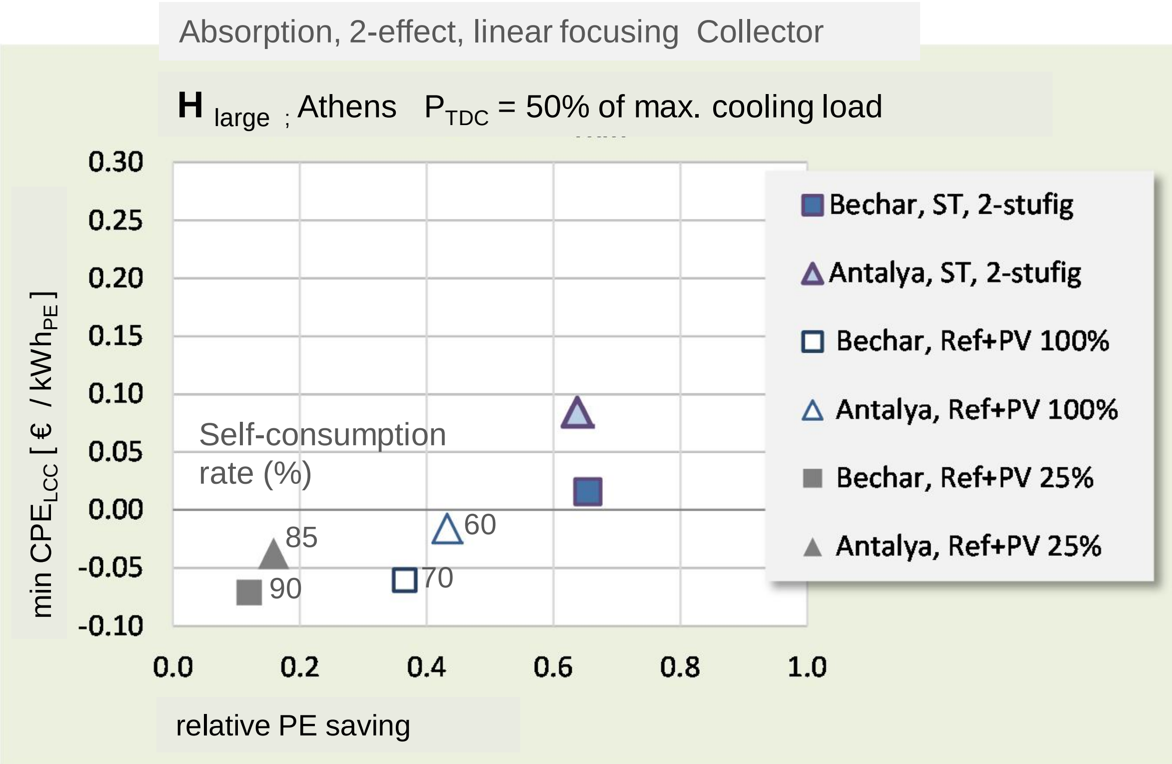
Influence: PV capacity on self consumption rate

- Load curves
  - Site dependent; Example Athens, **H**otel application:
    - 100% layout: < 40% of surplus appears in cooling season (limited benefits through further installation of storages etc.)
    - 33% layout: marginal surplus in cooling season only



Influence: PV capacity on self consumption rate

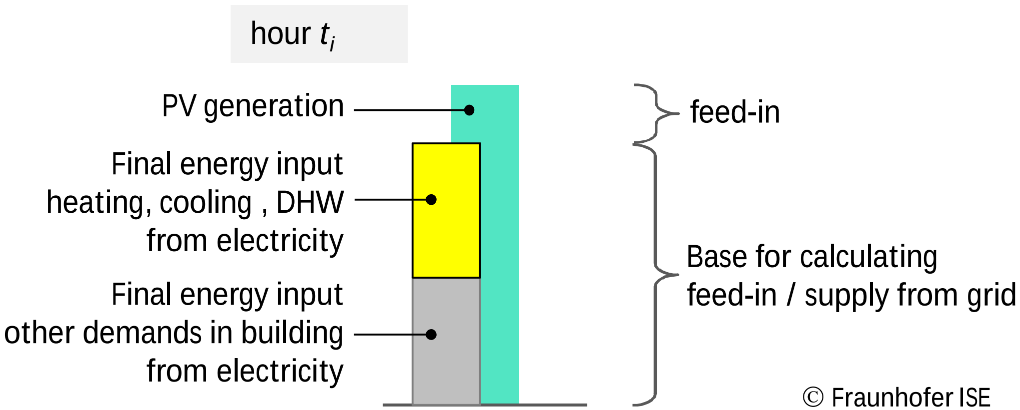
- Sunny areas, 2-effect solar thermal driven option and PV-option
  - Good energy and cost performance of solar thermal system, however still additional costs due to very low electricity prices
  - Ref+PV option: advantegous in cost, but small PE savings, especially when feed-in is not allowed



PV layout 100%:
$P_{peak,PV} = P_{el,nom}$
of compression chiller

With PV electricity feed-in: grid interaction

- Physical effects on grid frequency and voltage in local supply node: not investigated within EVASOLK
- Assessments on the basis of the approach in Net Zero Energy Buildings (NZEB):
  - Grid interaction index f_grid (annual value)*: standard deviation of grid exchange fluctuations (normalized to average of grid load)**
  - The less f_grid, the smaller the 'stress' on the grid



* $f\_grid = \sigma \left[\frac{P_{Grid,i}}{\langle |P_{Grid}|_i \rangle} \right]$

** In the NZEB approach the grid exchange is related to max$|P_{Grid}|$, but this leads to a distortion of the results compared to variations with lower maxima of grid load

Grid interaction

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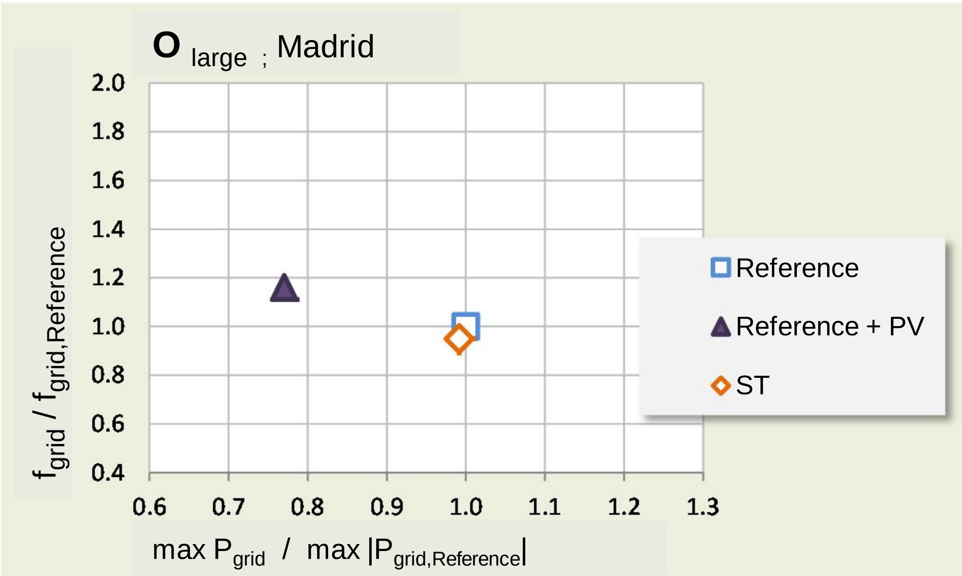
- Qualitative: Application type **O**
  - Due to high correlation between Irradiation / load profile: decrease in peak power demand from grid with option Ref+PV
  - Moderate increase of grid stress with option Ref+PV
  - Solar thermal option: comparative to Reference (more advantages with solar thermal cooling without backup)

Configuration:

Heat backup gas boiler

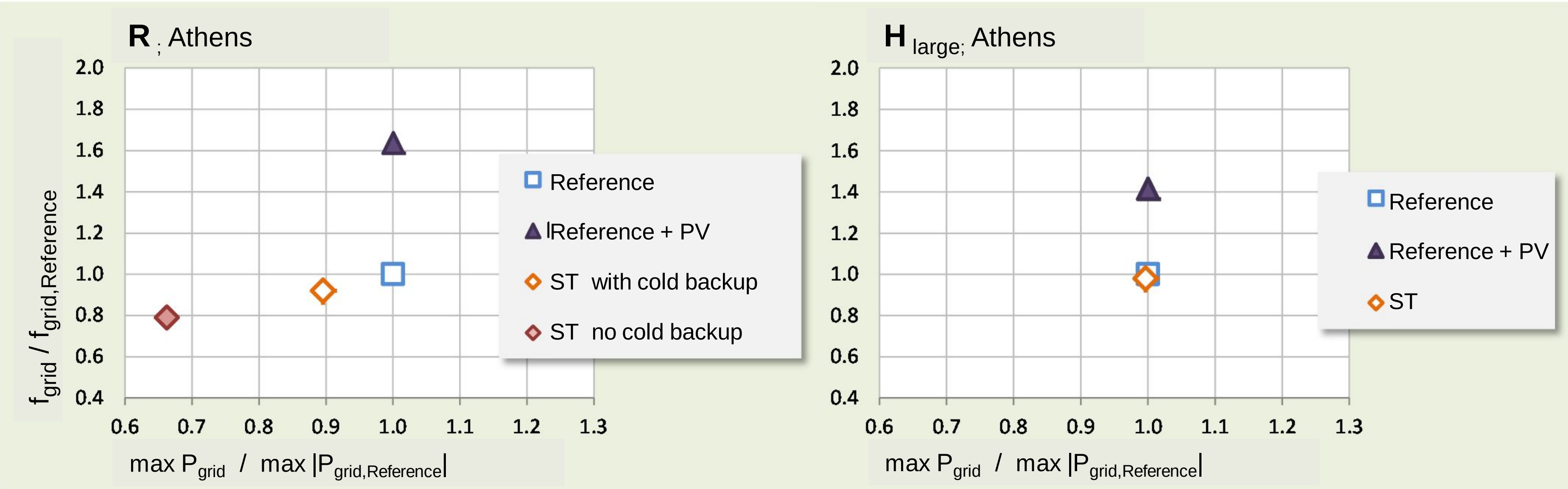


Grid interaction

- Qualitative: Application type **R**
  - Decrease in peak power demand though solar thermal configuration
  - Significant effect with solar thermal cooling without cold-backup
  - Increasing grid stress with Ref+PV
- Qualitative: Application type **H**
  - Comparative to Reference
  - Increasing grid stress with Ref+PV

Configuration:

Heat backup gas boiler



Preliminary conclusions

Solar thermal driven system options

- Environmental beneficial effects are high
  $\rightarrow$ high primary energy and CO_2 savings are possible
- Favourable applications: high full load hours of cooling equipment (>> 500 h/y), high radiation sums
- Compensation of electricity only with solar thermal options are difficult in terms of economics with present costs (and even with moderate cost decrease forecasts), especially in comparison to the option Ref+PV;

* Solare Kühlung = solarthermische Kühlung

Preliminary conclusions

Solar thermal driven system options

- Pre-conditions for an economic use of solar thermally driven :
  - Optimised use of collector system throughout the year covering additional heat demands, e.g., high domestic hot water demand (hotels, hospitals, production, ..) $\Rightarrow$ utilisation chain of solar heat
  - Accurate planning and layout in large capacity systems $\Rightarrow$ no layout of thermal driven cooling components on peak-load
  - Whenever compatible with requirements on room air states: waiving of cold-backup installation
  - Moderate to distinct cost decrease (or proportional funding) in collector and thermally driven cooling system
  - Whenever possible: use of heat rejection circuit for pre-heating feed water (large quantities, e.g., production facilities)
  - 2-effect cooling systems at appropriate sites (however, limited cost effects through extreme low (subsidised) electricity prices in e.g. North African countries)

Preliminary conclusions

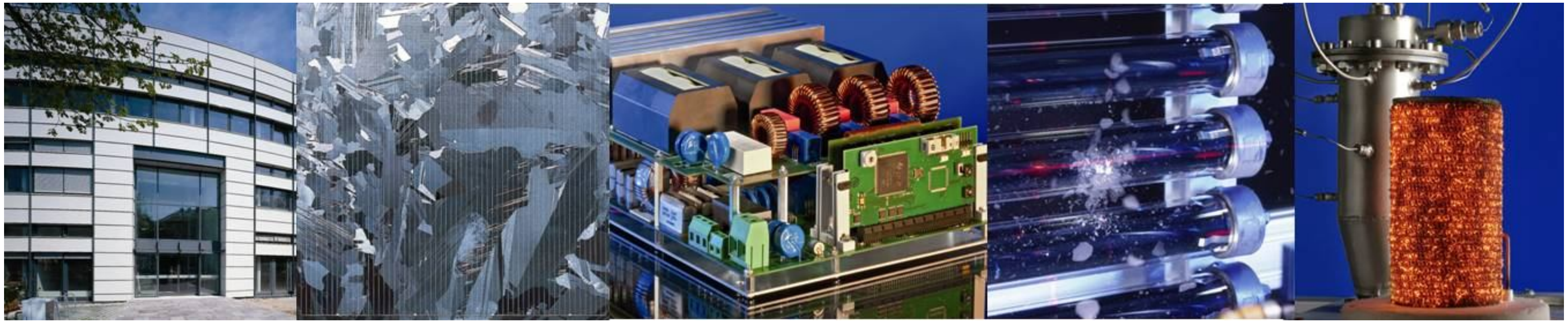
Option Reference + PV

- A) considering self-consumption of produced electricity
  - Considering the above mentioned conditions on favourable applications of solar thermal cooling:
    economic figures comparable to solar thermal cooling, but partially lower environmental benefits with Ref+PV options
  - Otherwise: advantages of Ref+PV in economic and environmental terms
- B) considering grid interaction with feed-in (qualitative)
  - In general: increase of grid stress → to be considered in 'weak' public grids
  - In some application types: higher peak electricity exchange with grid compared to solar thermal driven option → to be considered in 'weak' public grids

Please, note:

- Only standard, marketable solar cooling solutions and configurations are considered
- Comparative study is not fully completed

Thank you for your attention!



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