Aspects on solar thermally driven heating and cooling and PV supported energy supply in buildings

Results from a comparative study within the EVASOLK project

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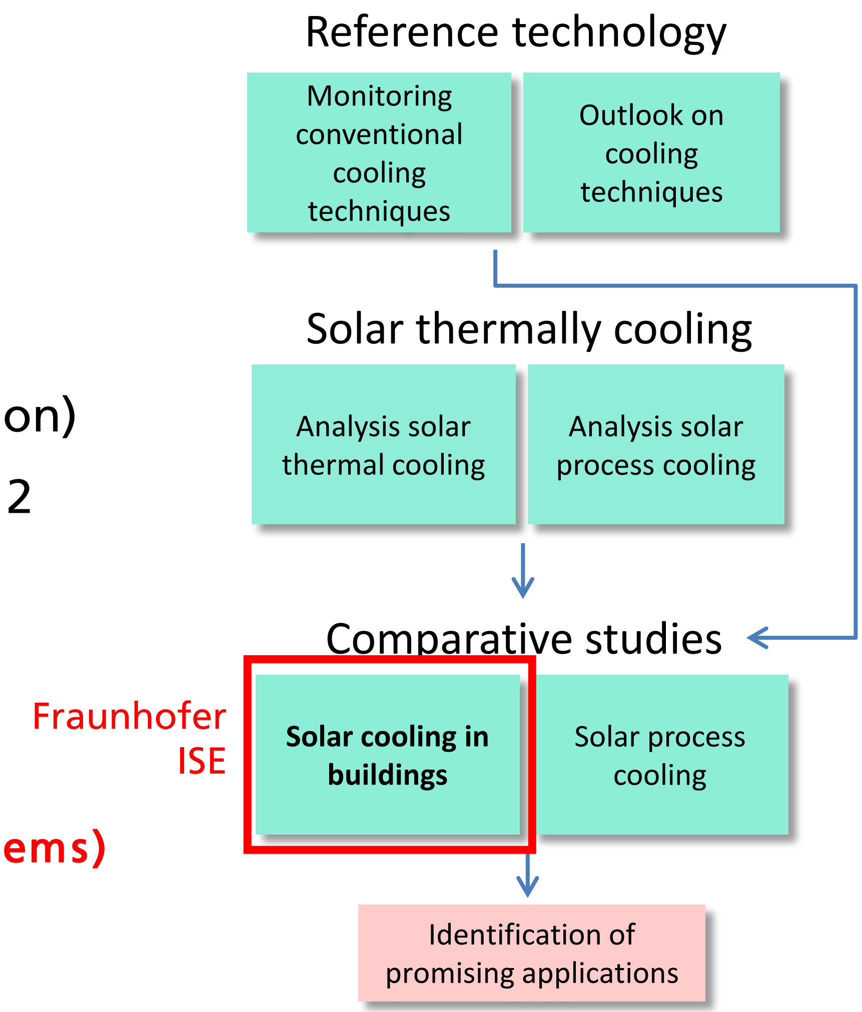
EvaSolK - Chances and perspectives of solar thermal cooling in comparison to Reference and PV-supported systems

- Funded by BMU*
- Partners:
  - ILK Dresden
  - ZAE Bayern
  - Fraunhofer ISE (Co-ordination)
- Duration: June 2010 – Dec. 2012
- Focus:
  - Reference technologies (e.g. monitoring)
  - Comparative study (buildings; closed cycle systems)

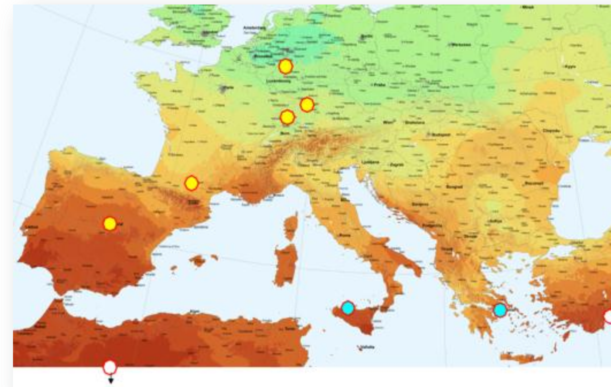


*Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Comparative study: Solar cooling in buildings
(closed cycle techniques)

How does solar cooling perfoms

- In different climate zones
  - Central-/South Europe, North Afrika



- In different utilisations
  - Cooling / Heating / Hot water
  - **A** (e.g. residential)
  - **B, B⁺** (e.g. office)
  - **C, C⁺** (e.g. hotel)

- In different configurations
  - Type of collector
  - type of chiller
  - heat backup type
  - with/without cold backup

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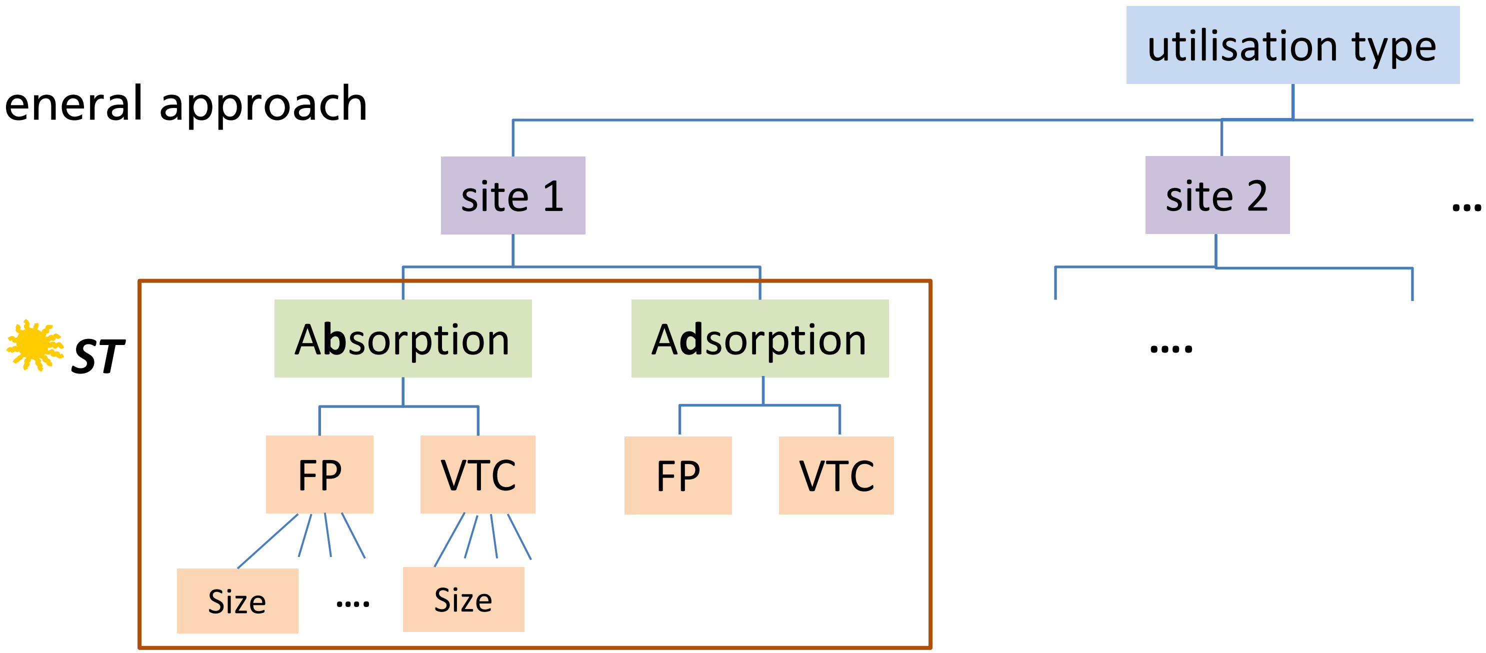
Comparative study: Solar cooling in buildings
(closed cycle techniques)

- General approach



FP : flat-plate collector
VTC : evacuated tube collector

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Comparative study: Solar cooling in buildings
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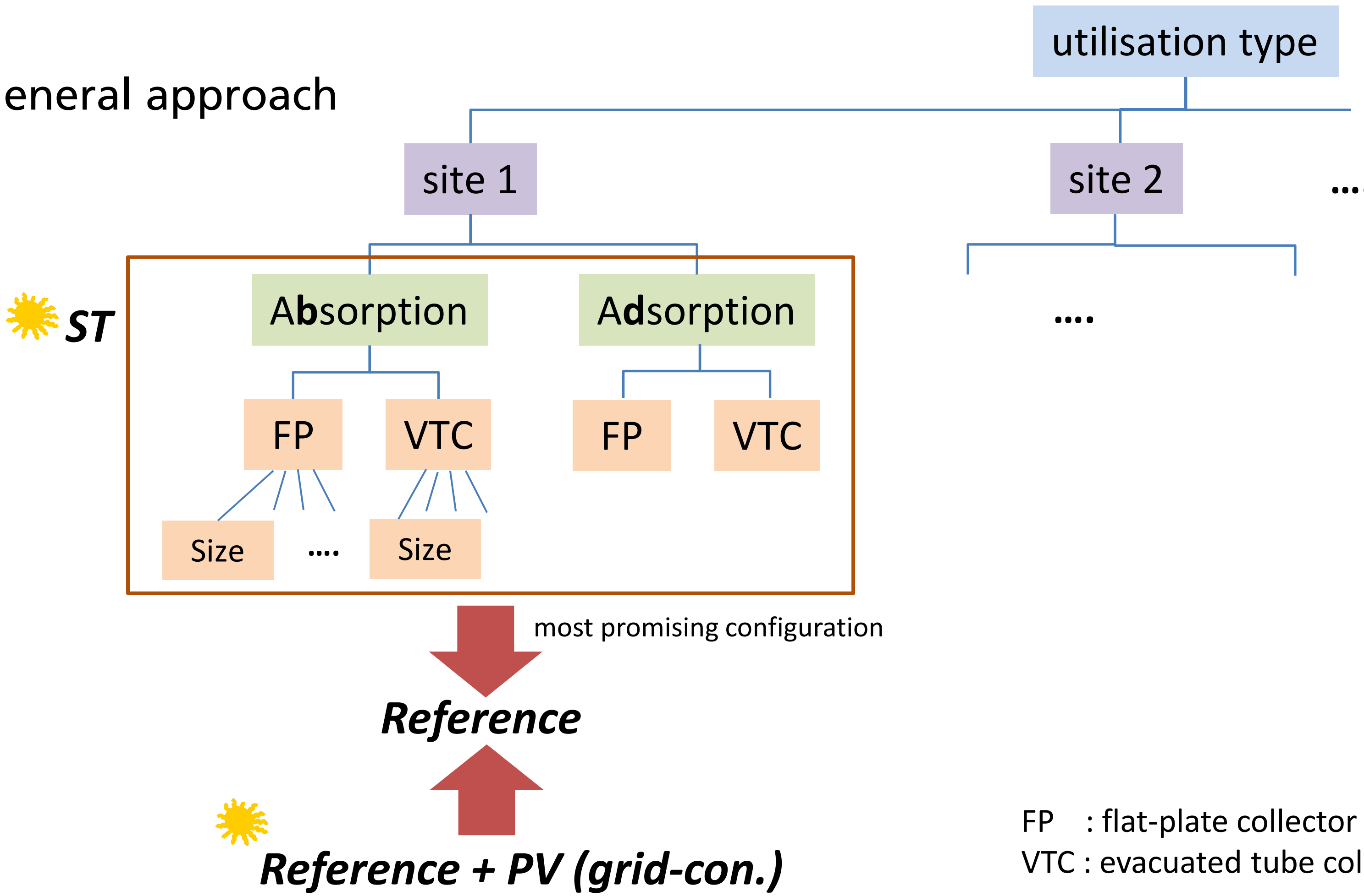

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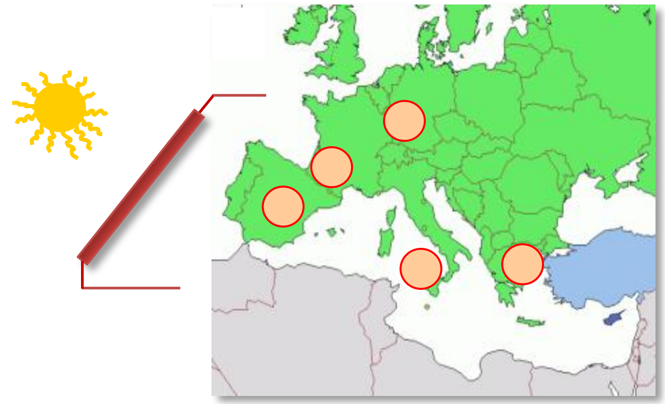
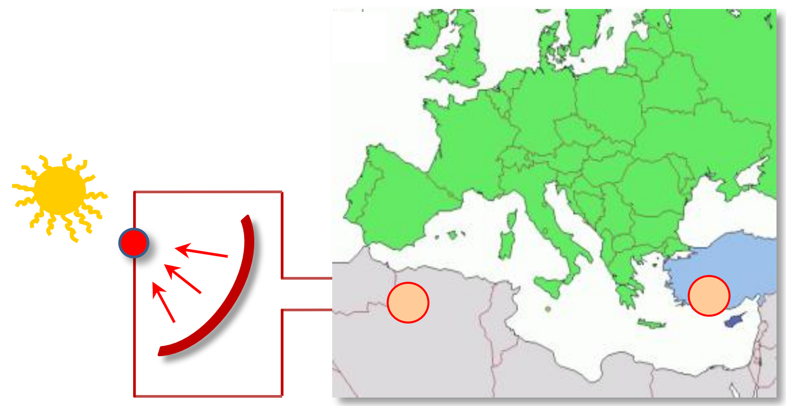
Sites

- Stationary collectors, 1-effect TDC
  - Freiburg (DE)
  - Toulouse (FR)
  - Madrid (ES)
  - Palermo (IT)
  - Athens (GR)



- Line concentrating collectors, 2-effect TDC (absorption)
  - Antalya (TR)
  - Bechar (DZ)



TDC : thermally driven chiller

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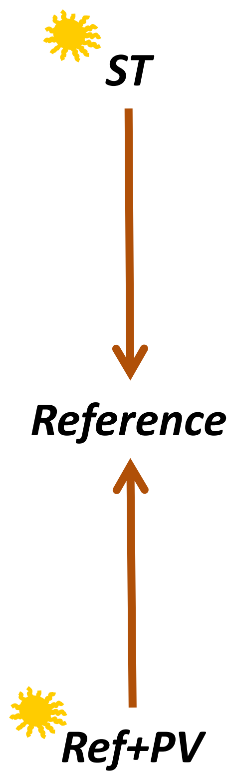
Configurations

- *Standard configurations with solar thermal system ST*
  - Cold backup (el. compression chiller: chilled water)
  - **A, B** : also considered without cold backup
    (in this case, solar thermal coverage of cooling load > 70%)
  - Heat backup: not used for operating thermally driven chiller
- *Reference*
  - Cooling:
    - multi split units (utilisations **A, B, C**)
    - electric driven compression water chiller (utilisations **B**$^{+}$, **C**$^{+}$)
- *Reference + PV*
  - Additional: grid-connected PV
  - Sizing of PV:
    PV$_p$ = 0.5 * nominal electric power demand of cooling system
    (→ 75-90% self consumption of PV electricity in building)



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Boundary conditions

- Investment cost
  - Cost curves for key components
  - No funding, no feed-in revenues
  - Installation, planning, maintenance: fixed %-rates of investment
- Other conditions
  - Country specific energy prices and conversion factors (primary energy, CO_2 emissions)
  - Increase of operation costs: electricity 5%/a; gas 3%/a
  - 20 years life cycle (Life Cycle)
    (life span of solar and thermal units: 20a, of el. compression based units: 15a)
- Evaluation: Standard approach *primary energy reduction cost*
  - Costs per saved primary energy within life cycle (CPE_{LCC})*
    - € per kWh saved primary energy
    - $CPE_{LCC} > 0$: additional costs compared to *Reference*

* Also defined for costs per avoided CO_2 emission within life cycle

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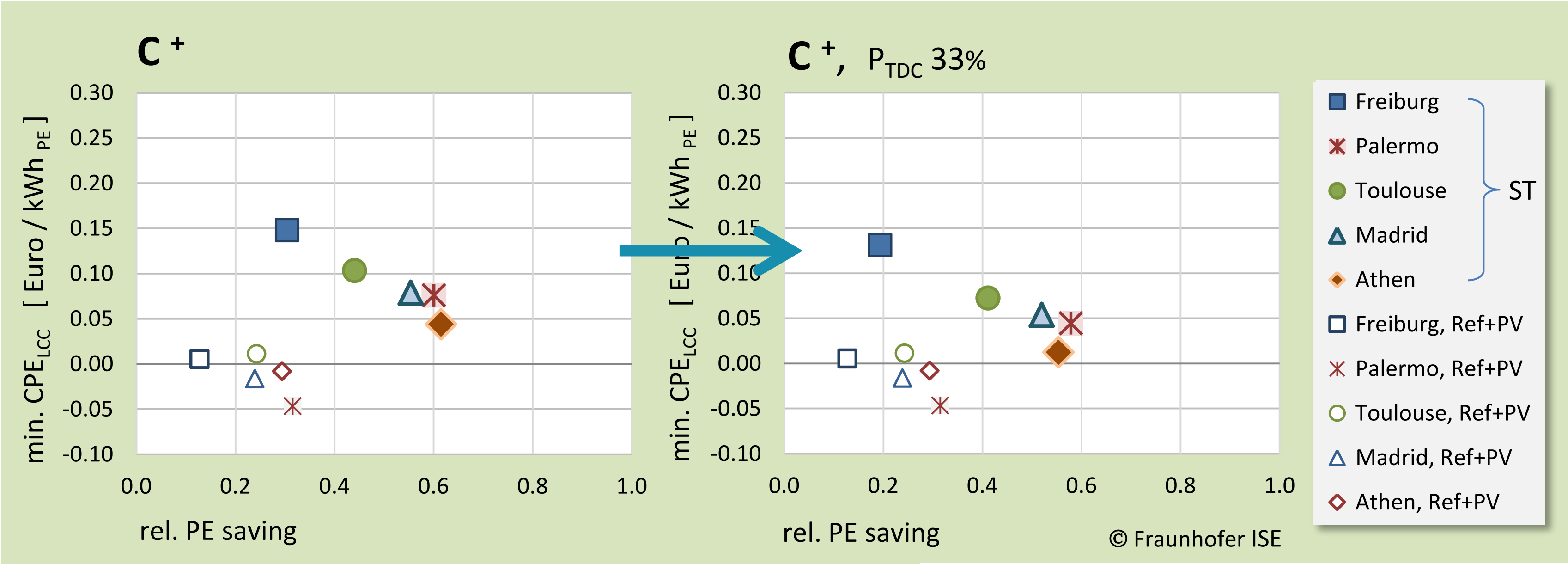
Results: costs and savings

A	Residential	
B	Office	
B⁺	Office, large	
C	Hotel	
C⁺	Hotel, large	

- Most promising for *ST*:
  Systems with additional large DHW demand
  - Example: capacity of TDC decreased from 75% of max. cooling load to 33%
  - Still high PE savings possible, specific cost decrease
  - → Avoid layout on peak load



TDC : thermally driven chiller

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Results: costs and savings

A	Residential	
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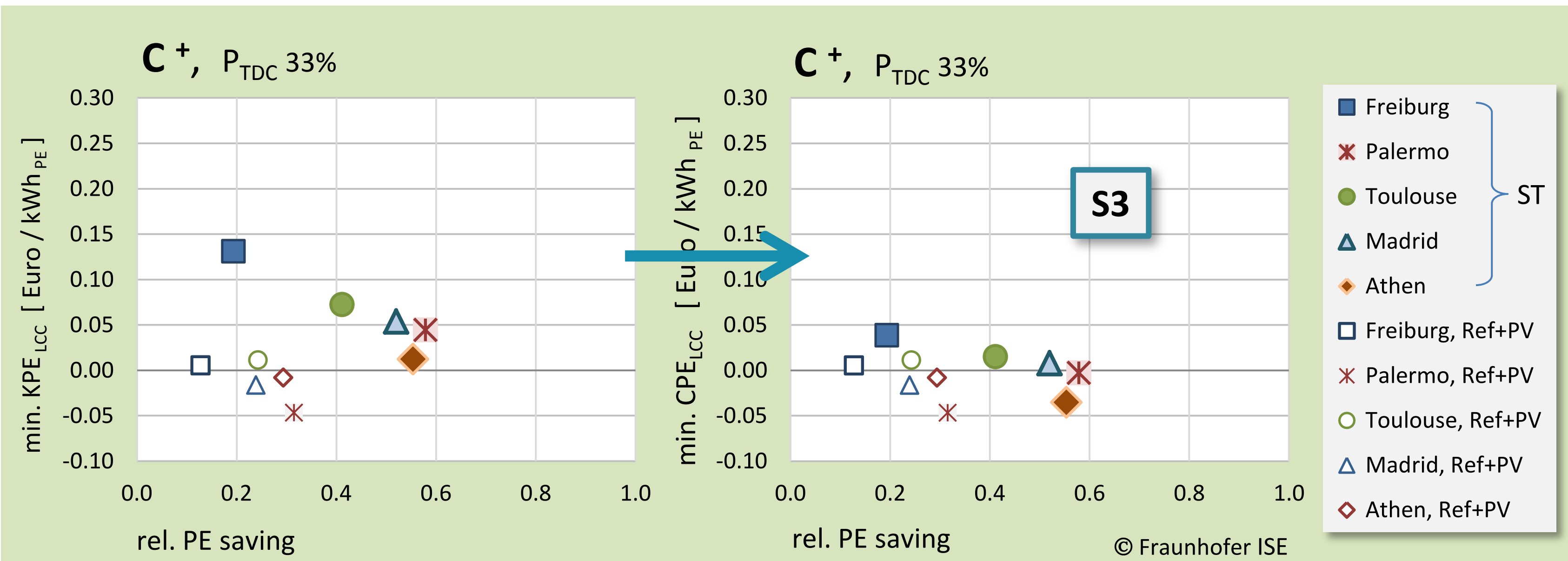
- Effect of cost projections
  - Different cost scenarios (decrease in component costs)
  - **S3**: strongest cost decrease prediction
    (Collector system: - 40%; TDC system: - 50%)
  - → economic competitive to *Ref+PV*, but higher environmental savings



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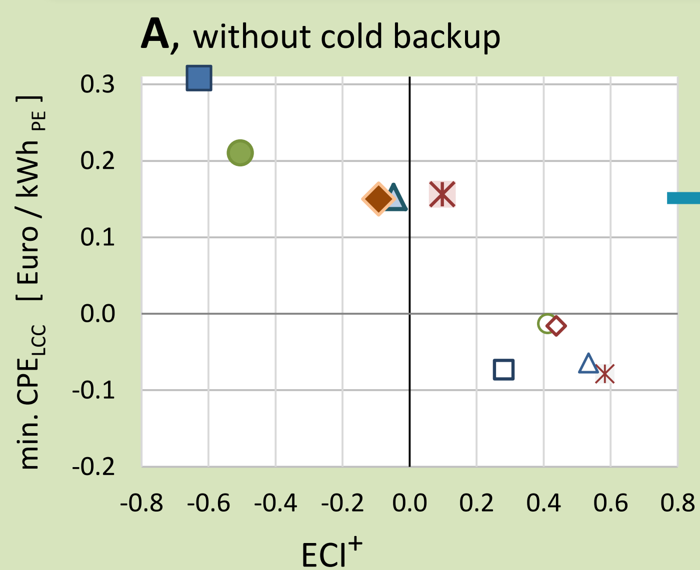
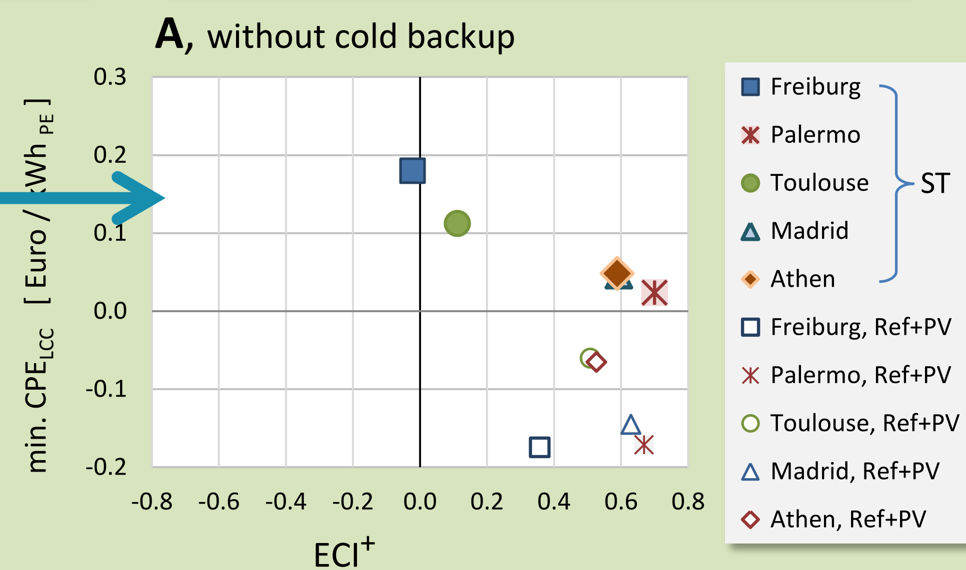
Example: Sensitivity

collector system -10%
TDC system -25%

increase electricity price	5 %/a
increase gas price	3 %/a
cost projection	none
life time multi-split unit (*Ref*)	15 a

increase electricity price	10 %/a
increase gas price	6 %/a
cost projection	**S2**
life time multi-split unit (*Ref*)	10 a





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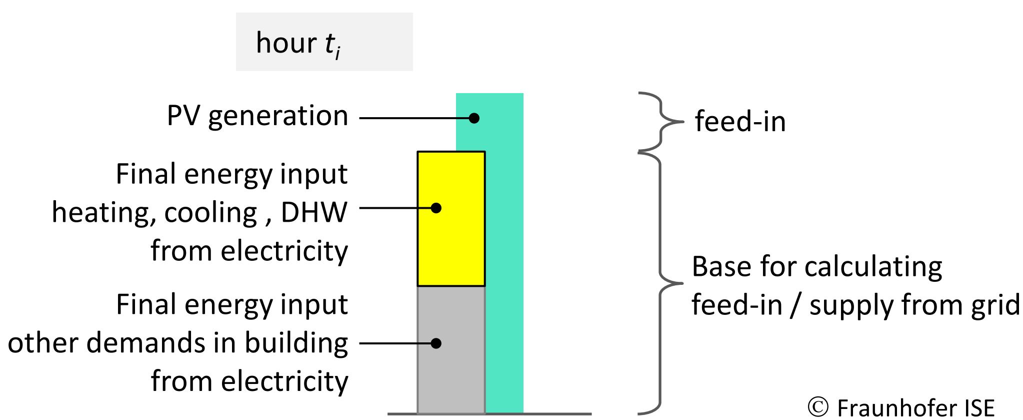
Estimations on grid interaction

- Physical effects on grid frequency and voltage in local supply node: not investigated within EVASOLK
- Approach similar to 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



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

** normalization different than in NZEB aproach

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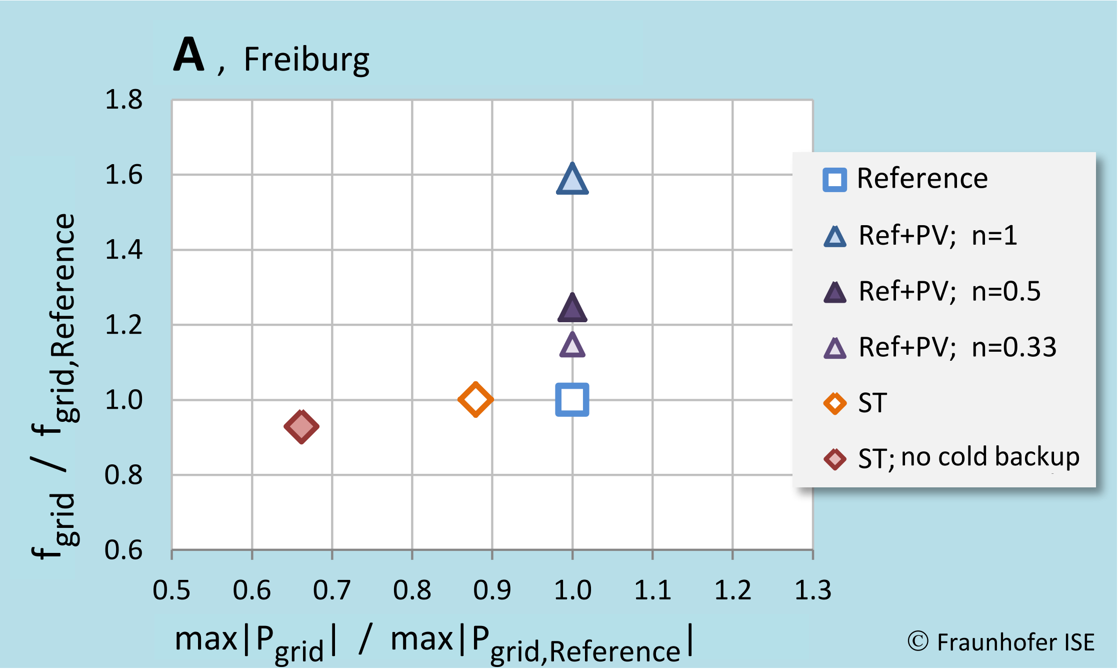
Grid interaction

- Utilisation type A
  - Decrease in peak-load from grid with solar thermal cooling, especially in configuration without cold backup
  - Increase of grid stress with Ref+PV



Configuration:

Gas boiler as heat backup

n … size of PV compared to chiller capacity

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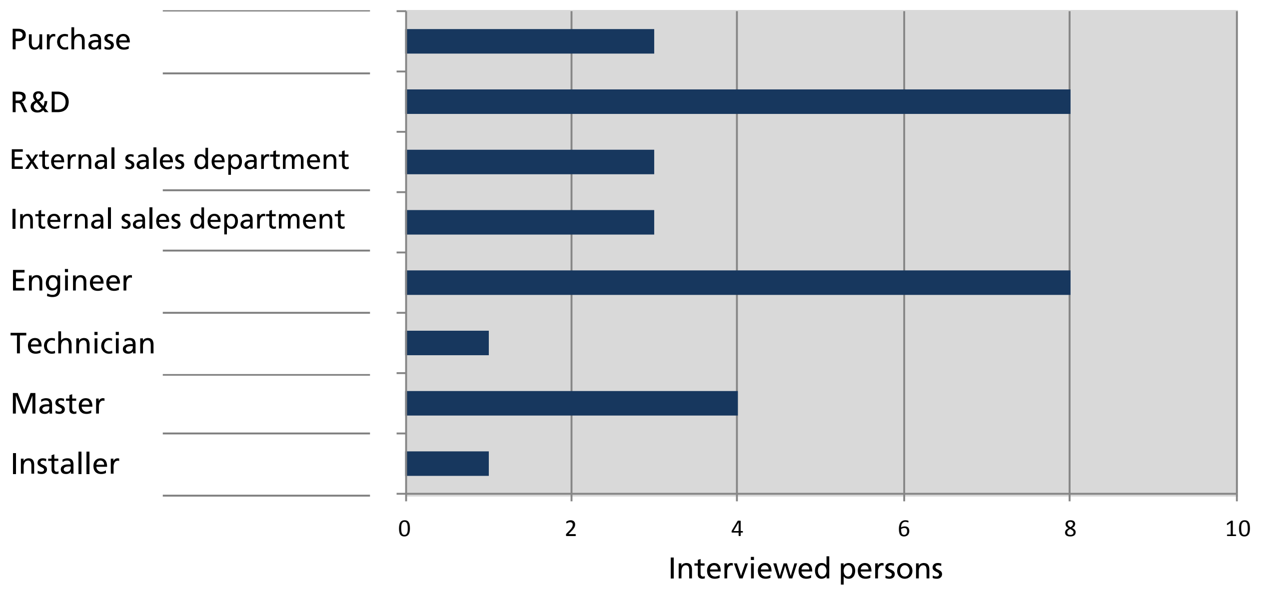
Expert survey (I)
"Trends and developments in cooling technologies"

- Conducted by ZAE Bayern and ILK Dresden (2012 – 2013)
- 30 experts of air-conditioning and refrigeration contacted, feedback from 19



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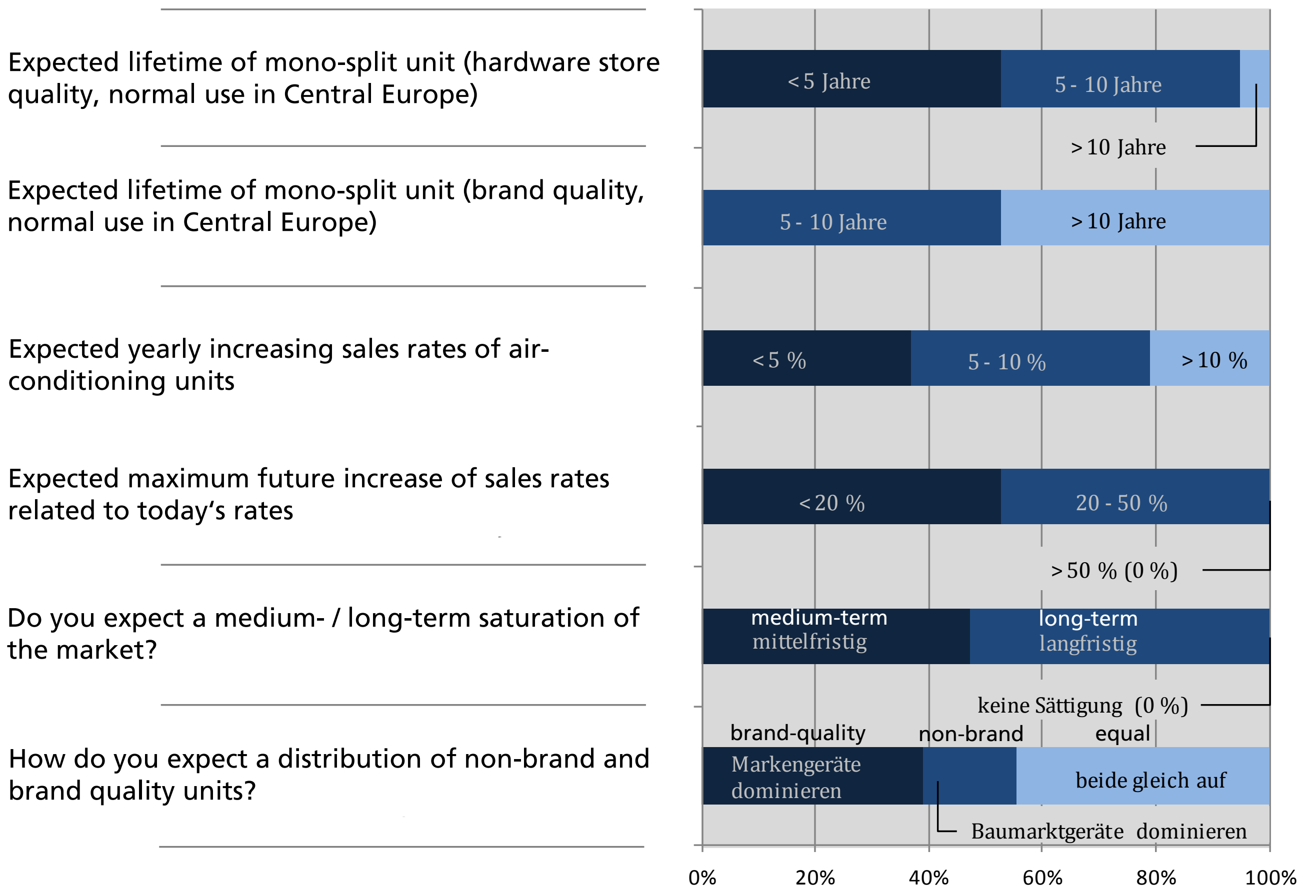
Expert survey (II)
“Trends and developments in cooling technologies”

- Market trends



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Expert survey (III)

- Technology trends

Expected technology (chilled water units or direct evaporation) for existing building stock in private household in Europe

Expected technology (chilled water units or direct evaporation) for hotel sector in Europe

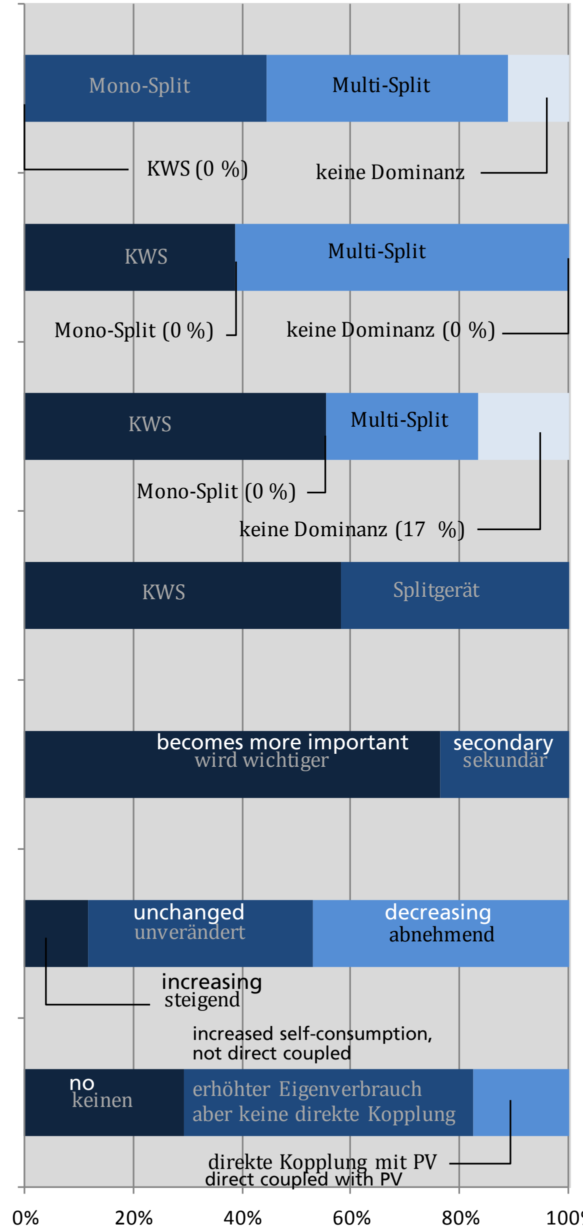
Expected technology (chilled water units or direct evaporation) for office sector in Europe

Which technology (chilled water units or direct evaporation) is expected to be advantageous concerning EER / COP?

Which future role plays the efficency in development and marketing?

Expected future leakage rates of refrigerants

Expected influence of permanently decreasing PV-module prices on the development of air-conditioning units



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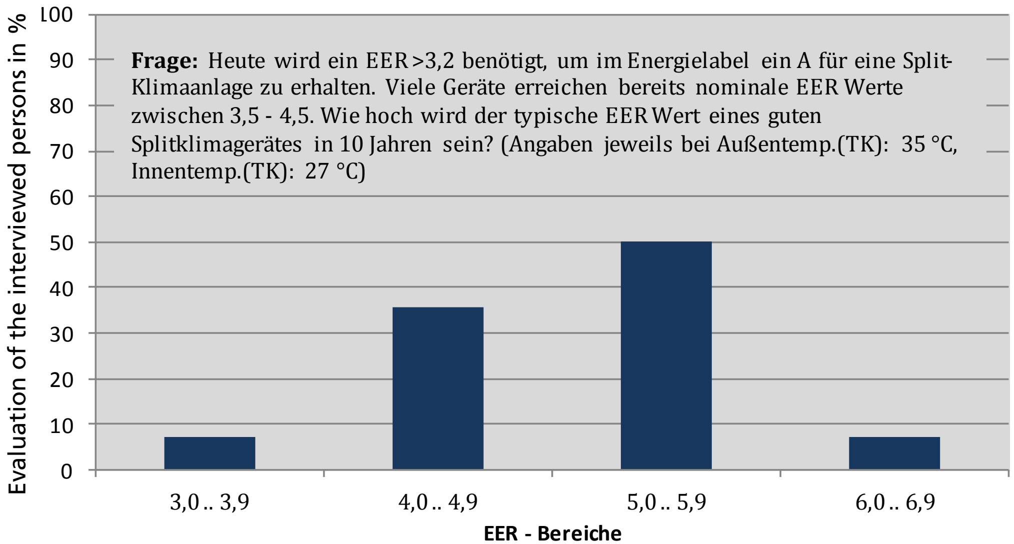
Expert survey (IV)
"Trends and developments in cooling technologies"

- Expected EER of split units in 10 years



Question:

Today, an EER>3.2 is required to get the A-rating for a split-unit. A large number of units already reach nominal values of EER between 3.5 and 4.5.

What do you expect as the typical EER of a split-unit in 10 years?

(boundary conditions: ambient temperature 35°C, room air temperature 27°C)

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Monitoring results of compression chillers
(by ZAE and ILK, operated in Germany)

System	Nom. cooling capacity	SEER	comments
	Equipment for room air-conditioning		
Mono-split (hardware store quality, not regulated)	2.6 kW	3.5 – 4.1	- 2 summer seasons
Mono-split (modulating)	5 kW	4.5 3.6	- Cooling season only - Whole year operation incl. standby
Multi-split (often part load operation < 5 kW)	40 kW	3.1 – 4.4	- 3 seasons operation - without internal unit
Chilled water system (with 2 units)	46.6 kW	3.6 / 3.1 3.0 / 2.5	- without chilled water pump - with chilled water pump
Chilled water system	54 kW	4.4 2.8	- without chilled water pump - with chilled water pump
	Equipment for cold storages		
Cooling chamber (<10°C)	2 kW	1.2	- overall system
Brine chiller	17.4 kW	2.3	- without brine pump

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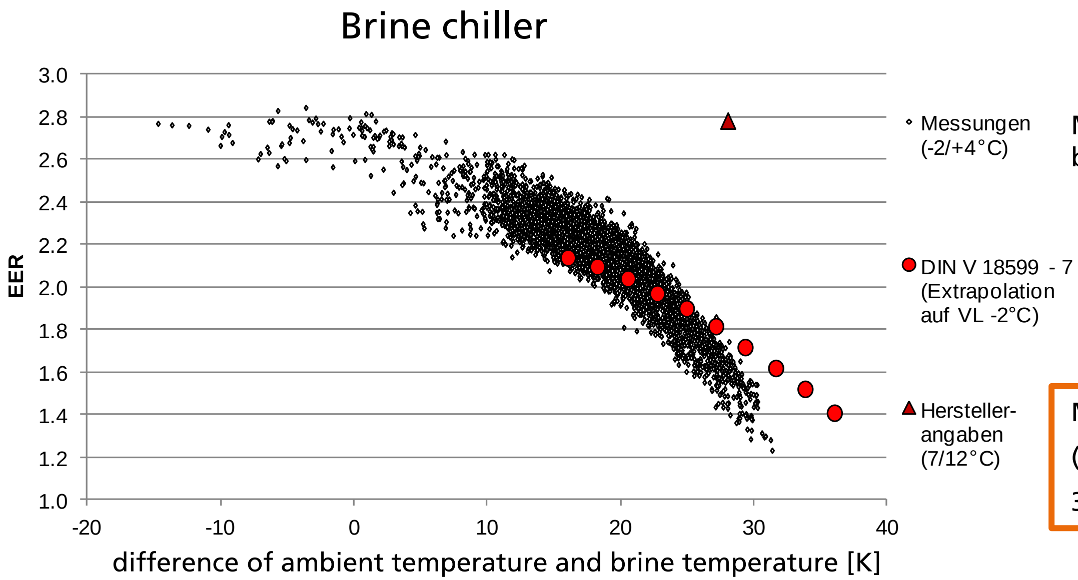
Monitoring results of compression chillers – example for cold storage applications
(by ZAE and ILK, operated in Germany)



Measurements, without brine distribution pump

Manufacturer's data
(2.78 @ 7/12 °C and
35 °C ambient temperature)

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Conclusions (I)

Solar thermally driven cooling is still not on a par with grid connected PV system technology due to the small market penetration, this results in comparatively high investment costs for thermal options.

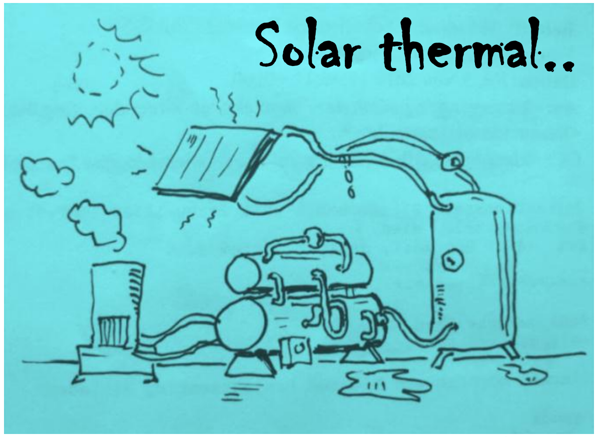
A differentiated evaluation of the technical approaches is necessary:

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 <u>electricity only</u> 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;

  pre-conditions for an economic use of solar thermally driven cooling are rathermore:

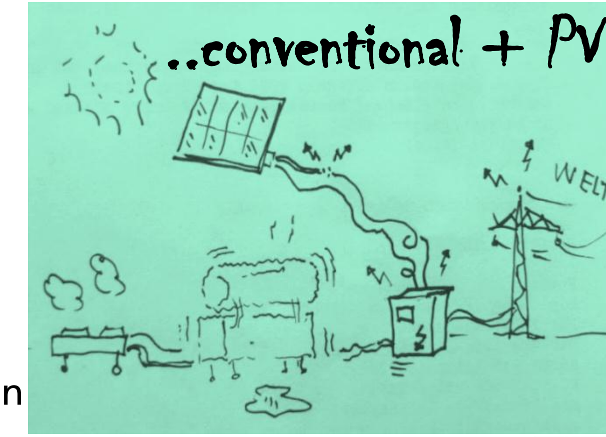
Conclusions (II)



Solar thermal driven system options

- Pre-conditions for an economic use of solar thermally driven cooling are rathermore:
  - 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
  - 2-effect cooling systems at appropriate sites
  - Whenever possible: use of heat rejection circuit for pre-heating feed water (large quantities, e.g., production facilities)

Conclusions (III)



Option Reference + PV

- A) regarding costs and environmental benefits
  - In applications with dominating electricity consumption (little fossil fuel input for heating only):
    → advantages of Ref+PV in economic and environmental terms
  - In applications with high additional thermal power demands (DHW):
    → lower environmental effects than solar thermal options; smaller differences in costs
- B) regarding grid interaction, grid-stress (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

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Conclusions (IV)

Monitoring of compression chillers

- Best results of SEER (equal to manufacturer's data) at systems without additional planning and installation demand
- Main reasons for worsening of SEER
  - Non-optimised operation (control) of cold water distribution pump and standby operation
  - Oversizing of the chiller results in inefficient part load operation or stop and go operation

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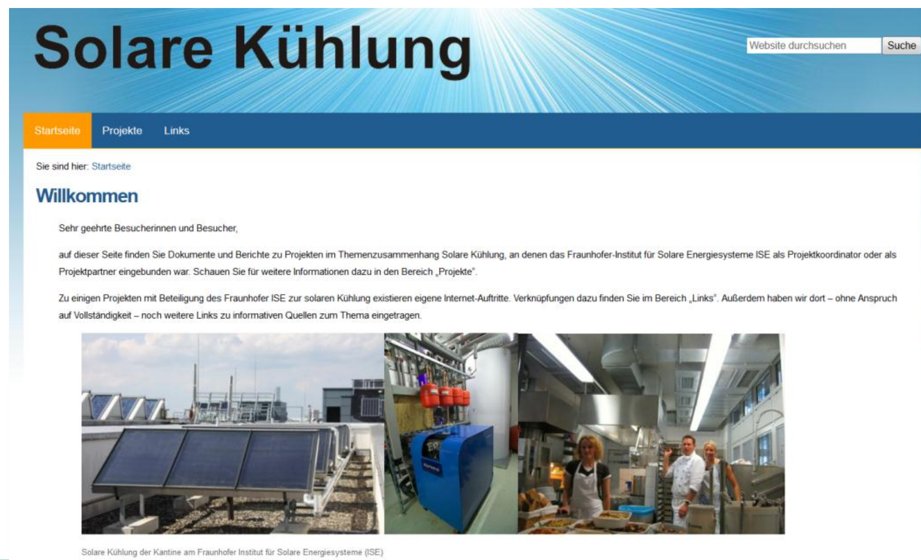
Final remarks

- EVASOLK was funded by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (FKZ 0325966ABC)

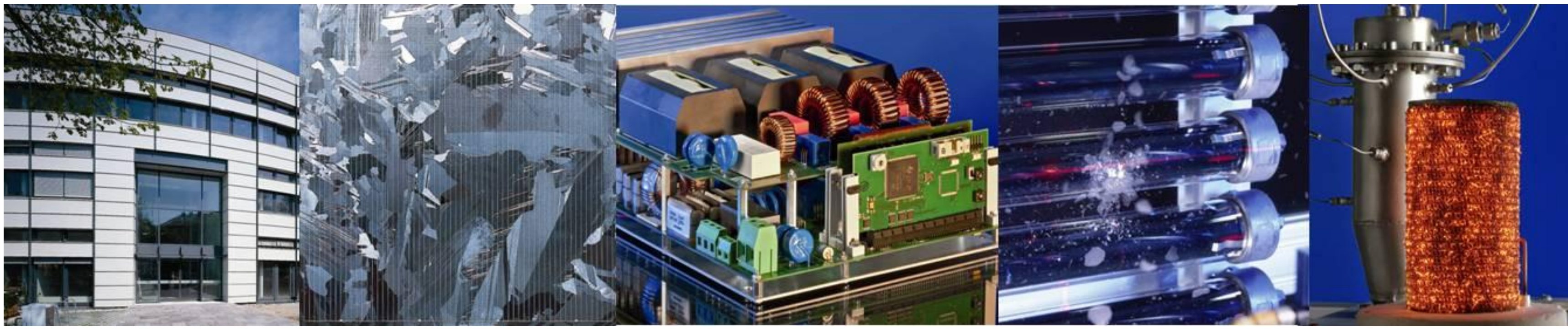
- Final public report (German language):
  - TIB (Technische Universitätsbibliothek Hannover)
    www.tib-hannover.de

    or

  - www.solare-kuehlung.info



Thank you for your attention!



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