Development demand on solar cooling

A technology view from cooperations with industry partners and optimisation studies

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Solar Cooling - Lessons Learned

Technology view

- Solar thermal systems are complex and expensive compared to PV-driven cooling systems … could make sense if cold and heat is needed in parallel (examples: Montpellier, UWC Singapore, …)
- Solar thermal systems still have optimization potential in electrical COPs
- PV-driven systems are more simple but in direct competition to green electricity driven systems

Market perspective

- Solar thermal driven cooling systems … hardly still in the realisation
- But what about the PV-powered systems? Are the numbers increasing?
- As greener the grid becomes as less “solar” each system must be
- A cautious trend to autonomous/off grid systems is noticeable, but system requirements are very high – pressure of energy grid still not high enough

Pilot project on solar cooling of cold stores (2012)

- Pilot project of industrial partner: company Kramer GmbH, Umkirch
  - 12 kW NH_3/H_2O Absorption chiller, air-cooled
  - 88 m² Fresnel collector
  - 0.6 m³ Ice storage, 100 m³ cold store
  - Load simulations
  - Site of pilot plant: near Freiburg
  - Aim: Pilot for realisation of large systems in sunny, hot climates

Source: Kramer

addhome - Innovative air conditioning systems for mobile living and work (2015)

- Pilot project of industrial partner: company Kramer GmbH, Umkirch
- Monitoring of the office module
  - Energy demand and comfort
- System components
  - Ventilation unit Vitovent 300c, with heat recovery
- Split-heat pump Mitsubishi Heavy SRK
  - Cooling capacity: 5 kW
  - Heating capacity: 5,8 kW
- PV: 3 kWp, grid parallel without feed in
- Battery: 6,4 kWh (130Ah, 48 V, C10)
- Grid: 230 VAC, control unit for uninterrupted switch of power supply
- Test of passive measures (shadings, blinds, green facade)

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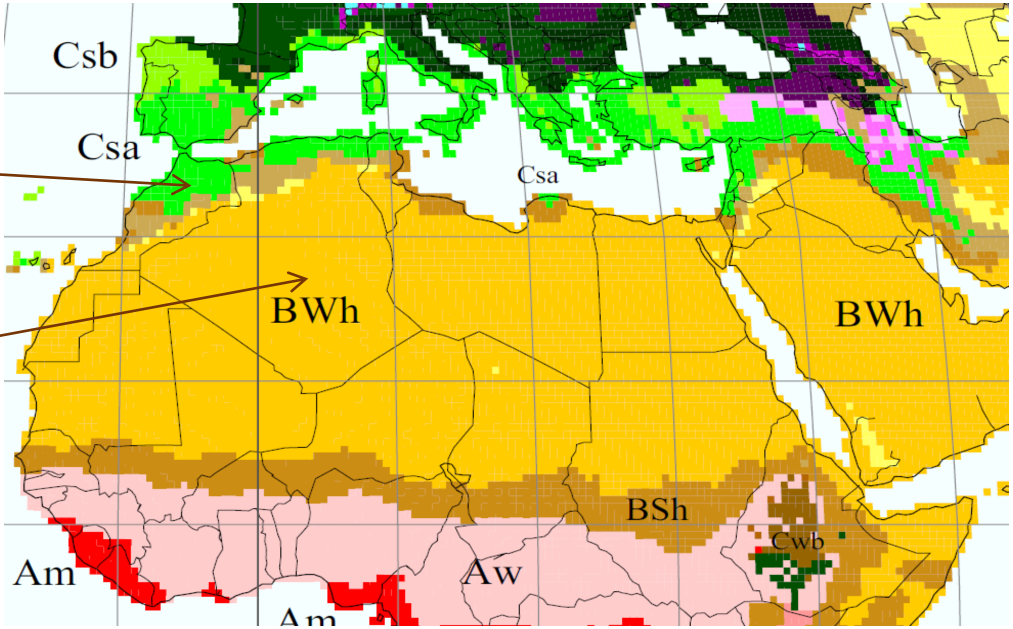
Cold storages in warm and sunny regions

South Europe, North Africa and aride climates:

- High technically demands
  - Systems run at high ambient temperatures and are exposed to sun
    → increased cooling load and reduced efficiency of conventional refrigeration technology
  - Weak / instable grids or off-grid systems with electricity generation at high prices

Warm
dry, hot summer

Desert climate, hot

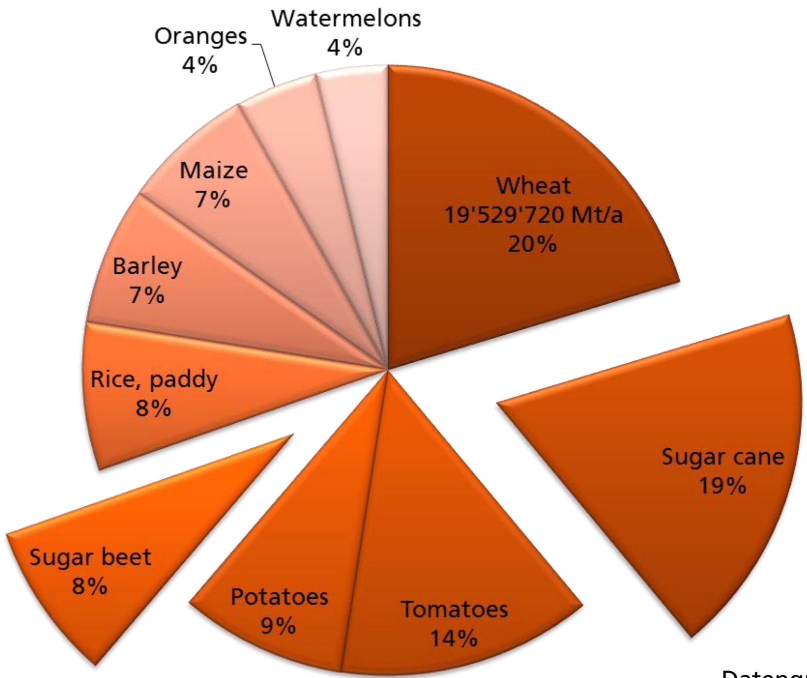


Auszug aus Klimakarte
Köppen-Geiger; nach Kotteck et al., 2006

Cold storages in warm and sunny regions

Example: Egypt, Tunesia, Algeria, Morocco

- Relevance: about 70 millionen tons of goods per year to be cooled
- Cold storage temperature about 0 -10 °C
- Assumption: low electric efficiency of conventional refrigeration with compression chillers* → unfavorable environmental footprint**



Datenquelle: FAOSTAT

* Monitoring of two cold storages / brine cooler in Germany: EER only at about 2
** Africa: about 90% of electricity generation with gas, oil or coal
(World Energy Outlook, OECD/IEA 2011)

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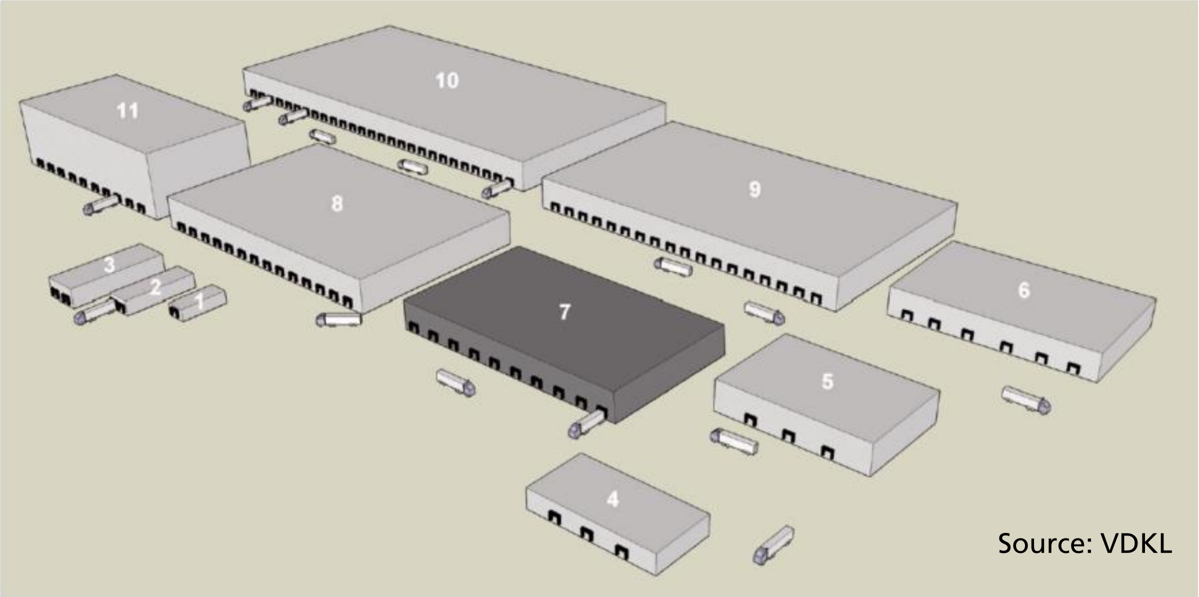
Demand on cold storages

- Big demand of: temperaure controlled storage of food in
  - industry (ice houses / cold storages) and
  - trade (refrigerated warehouses)
- Ice houses: storage temperature below 0°C
- Cold storages: storage temperature at about or above 0°C
- Market for standardised cold storages



Source: VDKL

Normkühlhäuser des VDKL

(Verband Deutscher Kühlhäuser und Kühllogistikunternehmen e.V.)

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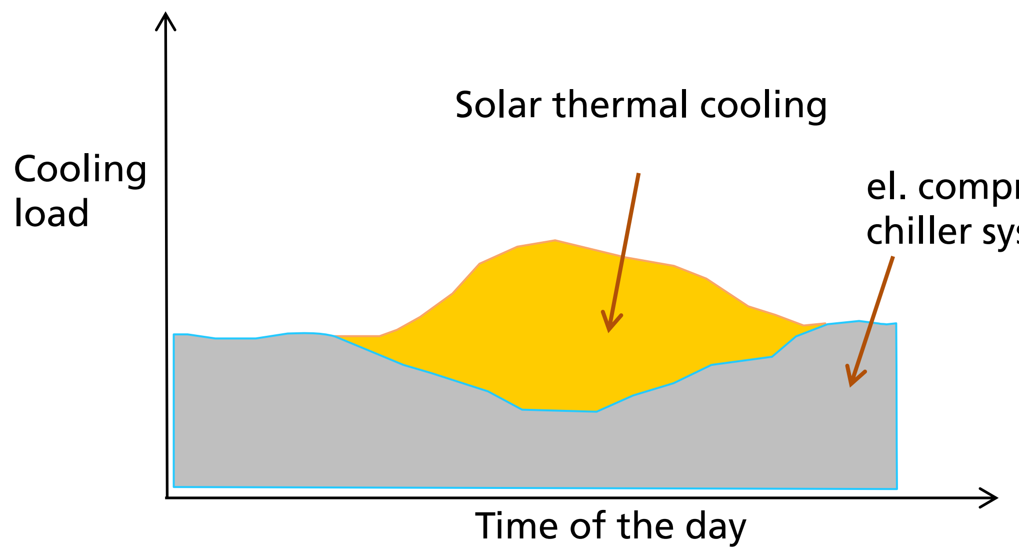
Approach

Cold storages with solar (thermal) cooling technology

- Increase of overall efficiency:
  - Base load system (compression chiller) runs during the day (highest ambient temperature) with reduced performance
  - Solar thermal system can cover peak load for many hours during the day with high electrical efficiency
  - Bridging of critical grid situations with (phase change) storages



Source: Fraunhofer ISE

Demand / request from industry

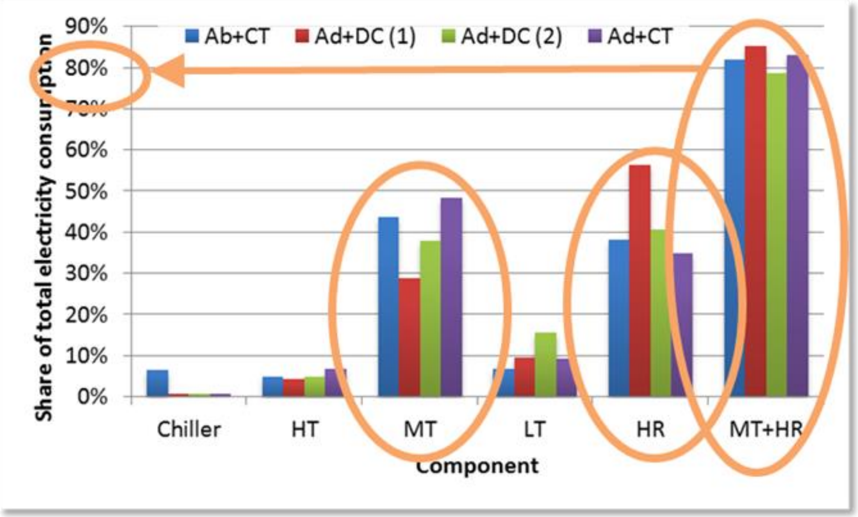
- Increasing demand / aim of companies in food sector
  - Cooling chain regenerative and sustainable (solar autonomous) for operation in rural areas or off-grid operation
- So far no big players on the market
- Still a lack of broad availability of good DC compressors, especially for small applications (beside Chineese products)
  - → room for new developments

Optimisation potential of solar thermal cooling systems – results of an optimisation study

- Motivation
  - SEER (seasonal energy efficiency ratio) of field measurement data significant lower compared to design data

$$SEER_{tot} = \frac{\int_{t0}^{t1} \dot{Q}_{LT}\ dt}{\int_{t0}^{t1} P_{el,tot}\ dt}$$

- Analysis
  - Absorption chiller operation in part load or in intervals → losses at low capacity demand
  - Circulation pumps (Ab-/Ad-chiller) mostly not speed-regulated → high power consumption also at low heat fluxes
  - 80 % of electricity consumption in heat rejection circuit MT and cooling tower (fan)

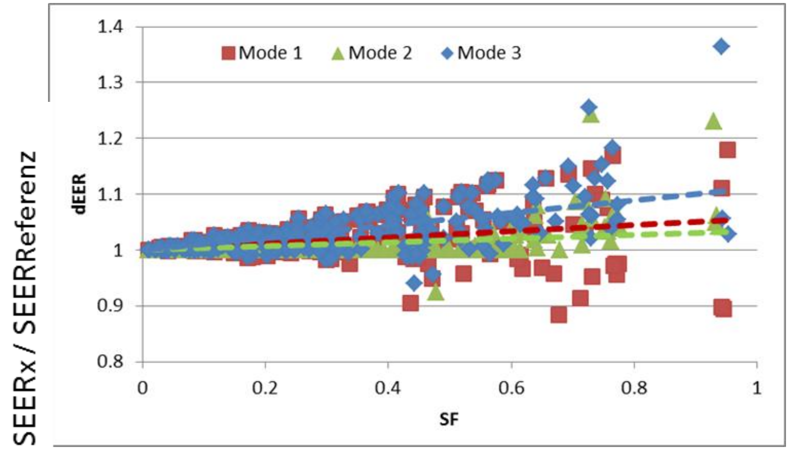


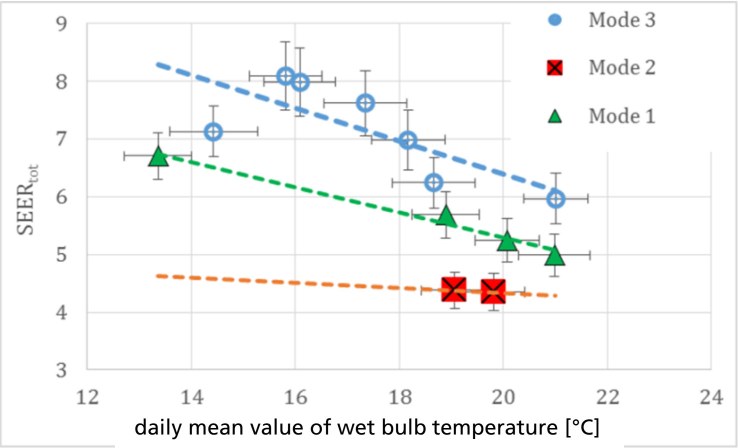
Optimisation potential of solar thermal cooling systems (II)

- Optimization approaches
  - Mode 1: Control of MT temperature by control of fan
  - Mode 2: Control of MT flow rate
  - Mode 3: Control of MT temperature and flow rate
- Simulations and tests on real systems

Optimisation potential of solar thermal cooling systems (III)

- Simulation results
  - Highest efficiency increase in part load operation
  - Control of fan more significant compared to flow rate control
- Results of real tests
  - Highest increase of SEER in Mode 3 (control of MT temperature and flow rate)





B. Nienborg, A. Dalibard, L. Schnabel und U. Eicker, „Approaches for the optimized control of (solar) thermally driven cooling system," Applied Energy 2016.

Results and outlook (I)

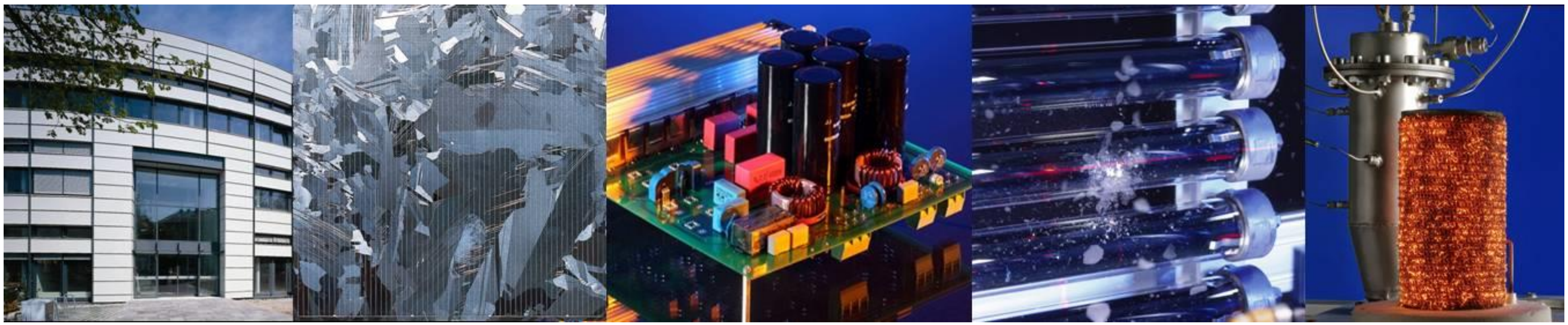
- Solar thermal and PV systems
  - Successful operation of pilot cooling systems with solar thermal and PV supply
  - Increasing demand on solar driven cooling in storage and transport (solar autonomous / off-grid systems)
  - Optimisation potential in market available components (e.g. compressors)
- Optimisation potential of solar thermal systems
  - Electricity savings up to 40 % in real tests, depending on dimension, boundary conditions and reference
  - Biggest potential from combination of MT temperature (fan speed) and flow rate
  - Parameter optimisation over entire operating range is required (also for part load operation)
  - Optimisation measures also applicable to other technologies (e.g. compression chillers)

Results and outlook (II)

- Still a demand for solar cooling systems in the context of a greener grid?
  - Arguments for solar cooling systems help for overloaded or weak grids
  - Do we see a breakthrough of PV driven systems with grid connection?

- Chances for solar stand-alone systems on different scales
  - Simple split units or decentralised systems for food, drug cooling …
- → Questions of system reliability:
  - High requirements for e.g. food cooling result in higher complexity
  - Lower requirements for off-grid air conditioning (some hours out of the comfort zone are mostly accepted)

Thank you very much for your attention!



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