BAYERISCHES ZENTRUM
FÜR ANGEWANDTE
ENERGIEFORSCHUNG

ZAE BAYERN

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA task preparation: Solar Cooling, Paris, March 28, 2011

Is there a chance for real solar cooling systems ?

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Status of Solar Cooling

Technical feasibility: proven

Energy saving: critical (low COPs, high parasitic power demand)

Limited economic competitiveness

→ **Prospect for wide-spread application unclear**

Status of Solar Heating

Domestic hot water preparation: established, limited economic attractiveness

Space heating: surplus heat in summer, seasonal storage required; cost: not affordable for individual installations

Market growth: dependent on introduction in heating sector

→ **Prospect for wide-spread application unclear**

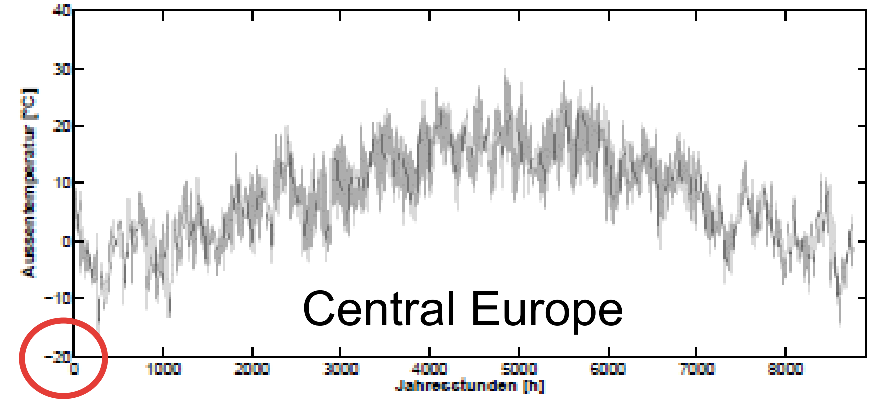
Chance: Synergies of Solar Heating & Cooling

Required:
- Low system complexity
- adaptation to climatic situation
- adaptation to building requirements (thermal parameters)
- energy saving …. at affordable cost !

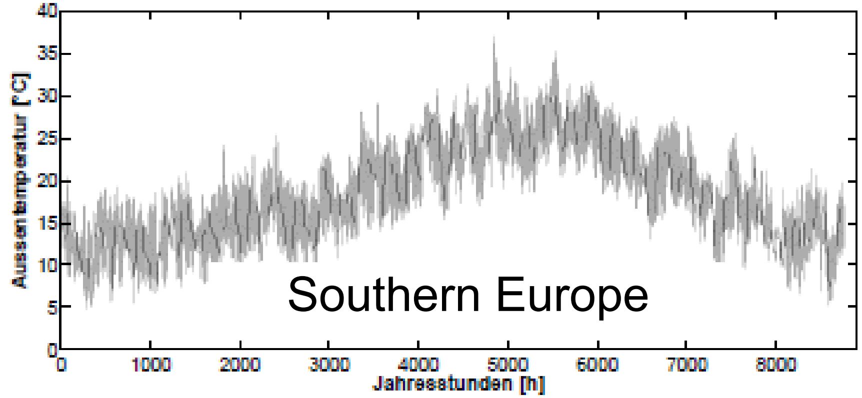
Supporting aspects

- Thermal energy provides alternative to electric supply
- Gas-infrastructure available as backup
- Thermal heat pumps are entering the heating market. Next step: heating and cooling

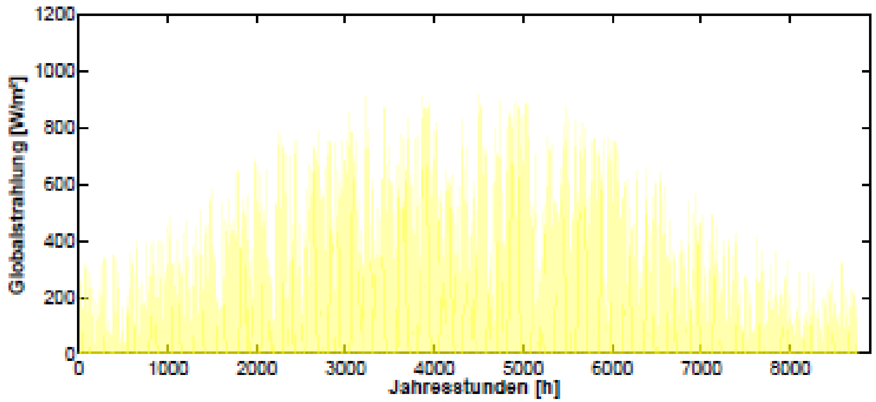
Climate, Location
→ System selection



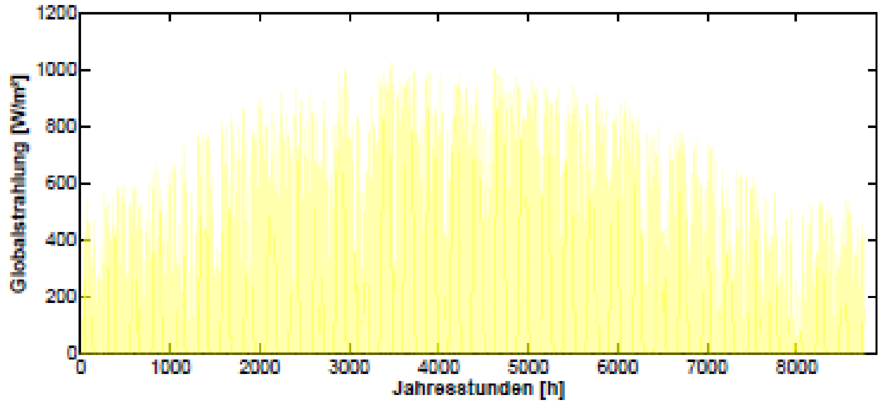
Aussentemperatur Arnstorf



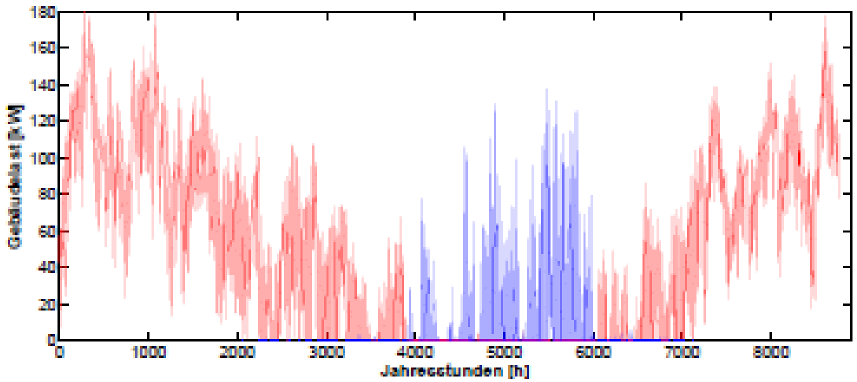
Aussentemperatur Almeria



Globalstrahlung Arnstorf

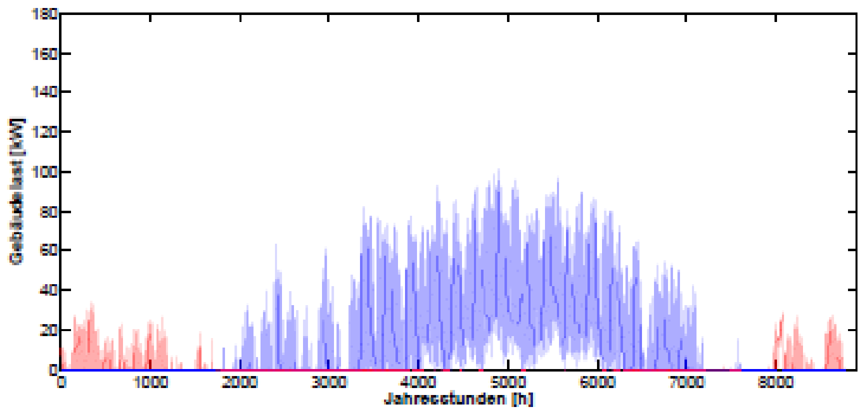


Globalstrahlung Almeria



Gebäudelast Arnstorf

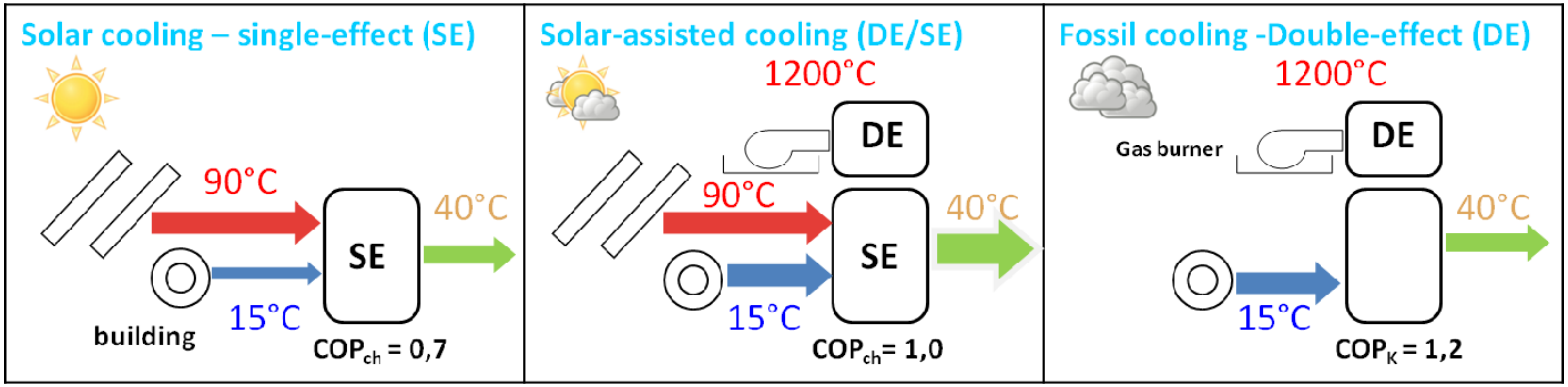
Zentrum für .



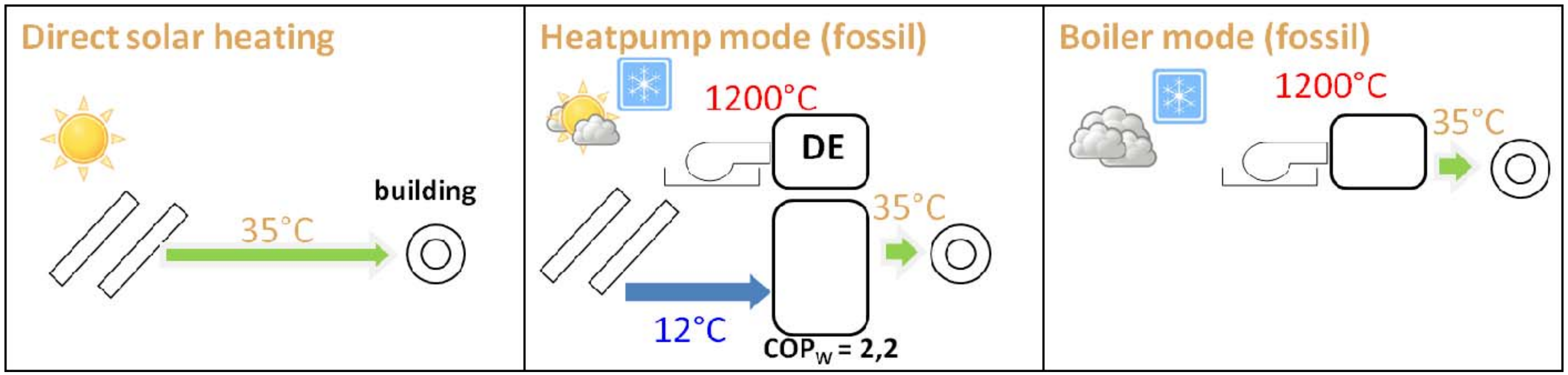
Gebäudelast Almeria

System concept for Solar Cooling & Heat Pump
→ select appropriate applications !

Summer



Spring / autumn / winter



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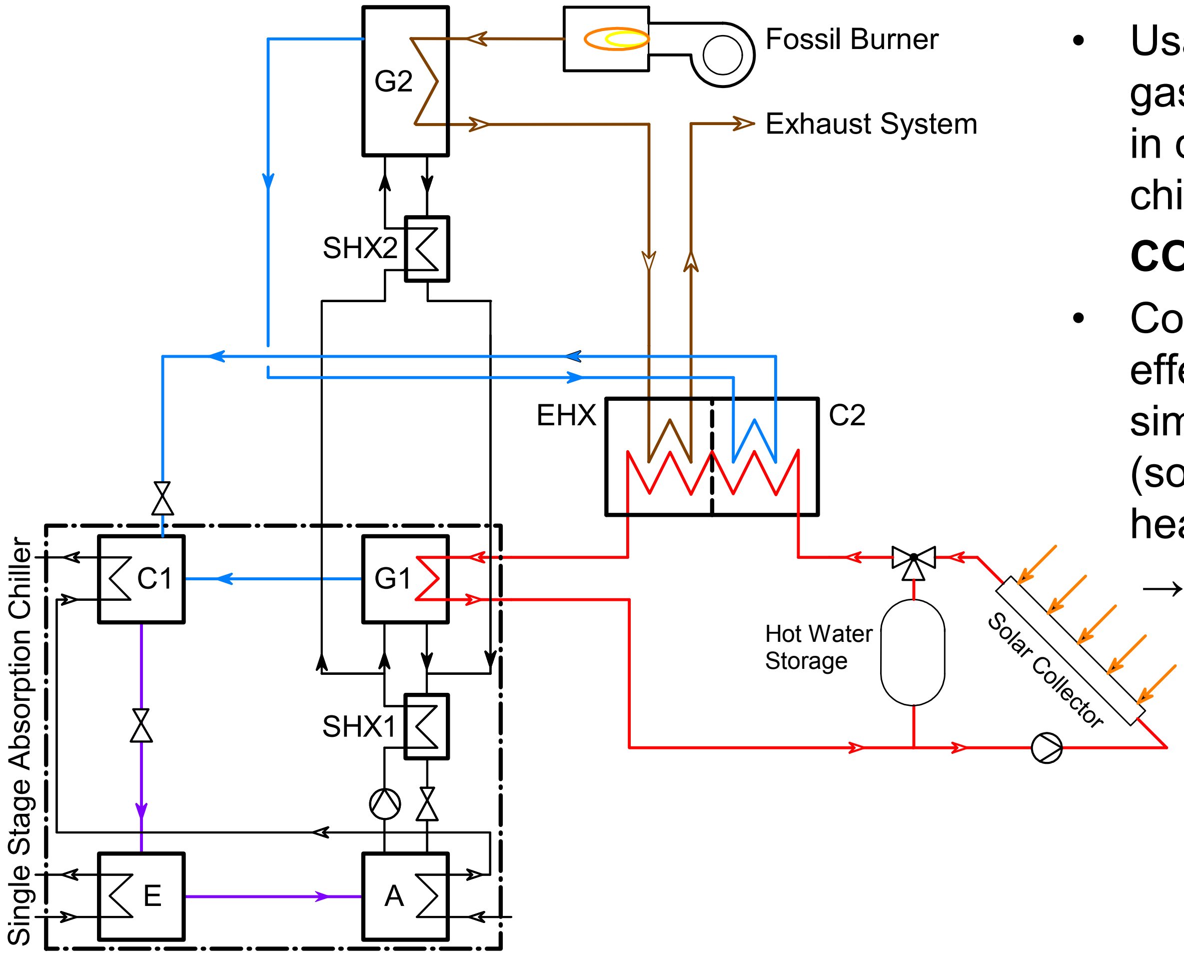
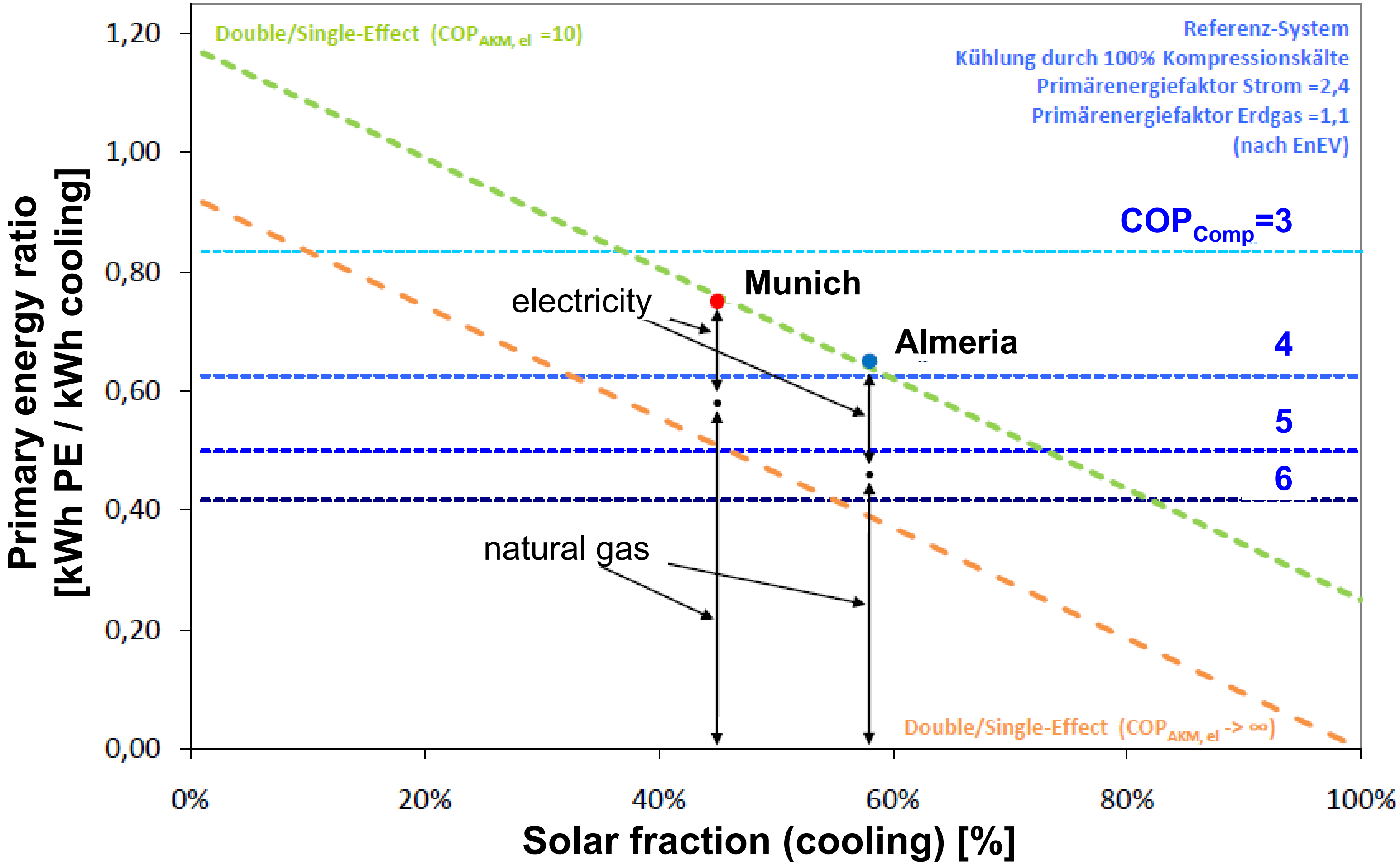
Chiller with direct-fired high temperature stage (generator G2)



- Usage of fossil driving heat (flue gas from a natural gas burner) in double effect (DE) absorption chiller offers higher efficiency

  COP_{DE} ~ 1,3
- Coupling of single- and double-effect chiller (DE/SE) allows for simultaneous usage of hot water (solar collectors) and fossil driving heat **($COP_{DE/SE}$ ~ 1,0)**

  → improvement of primary energy ratio as compared to a fossil boiler driving a single-effect chiller


Double/Single-Effect (COP$_{AKM, el}$ =10)
Referenz-System
Kühlung durch 100% Kompressionskälte
Primärenergiefaktor Strom =2,4
Primärenergiefaktor Erdgas =1,1
(nach EnEV)
COP$_{Comp}$=3
4
5
6
Munich
Almeria
electricity
natural gas
Double/Single-Effect (COP$_{AKM, el}$ -> ∞)
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0%
20%
40%
60%
80%
100%
Solar fraction (cooling) [%]
Primary energy ratio
[kWh PE / kWh cooling]

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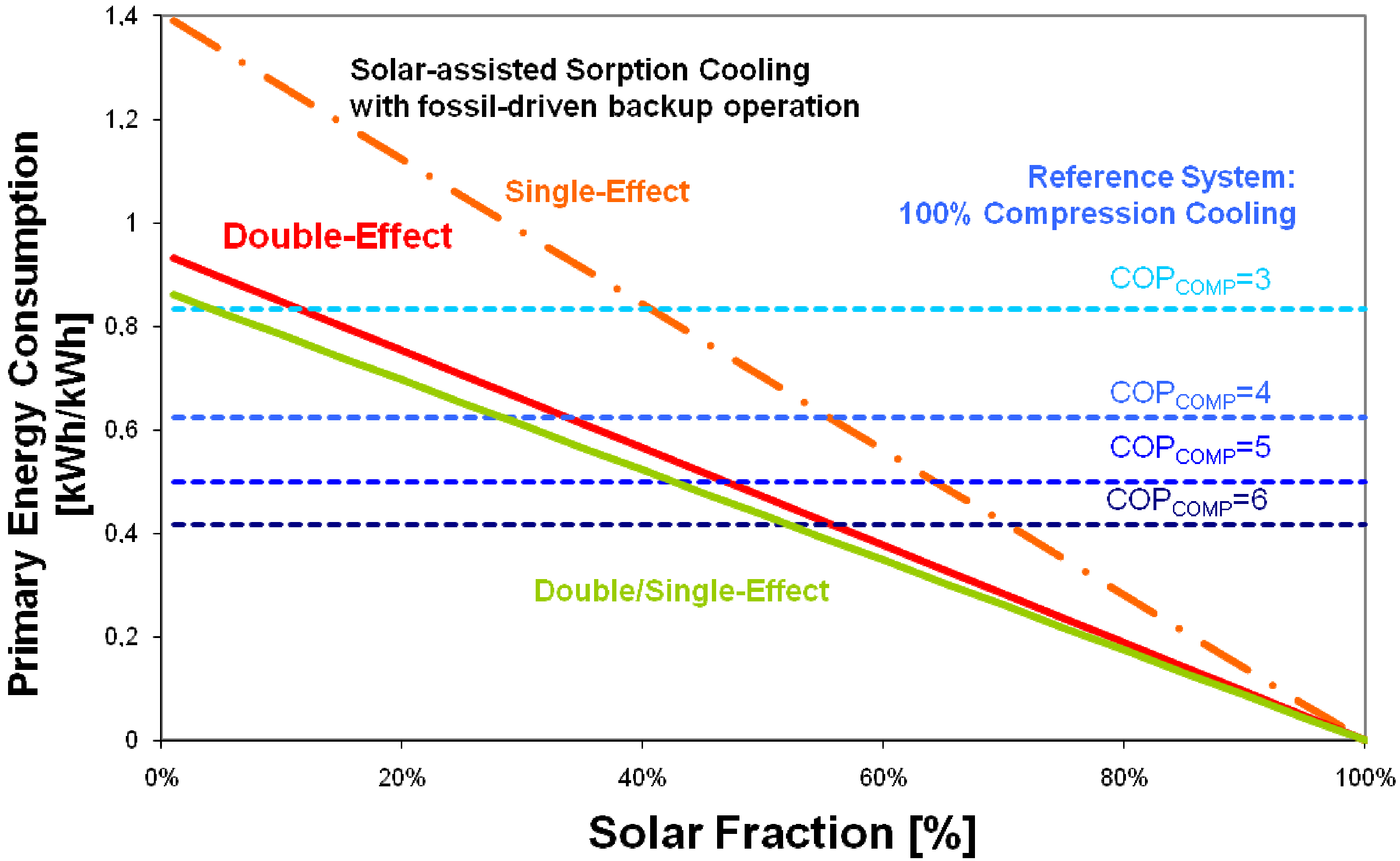
For Double-Effect: System COP ≈ 4
….Single-Effect systems perform worse !



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Optimum sizing
→ solar fraction
→ first cost

Conclusion:

Cooling

- COP acceptable

Heating

- High energy saving (heat pump)
- ground heat source requried

Location	Arnstorf		Almeria	
Solar Collector size [m²]	**280**	**560**	**280**	**560**
Storage volume [m³]	**17**	**34**	**17**	**34**
Heat rejection temp. [°C]	**30**	**30**	**30**	**30**
Solar fraction	0,50	0,67	0,62	0,71
PER (nat. gas only)	0,52	0,34	0,41	0,30
PER (incl. electr.)	0,69	0,52	0,61	0,51
COP_{el}	14,49	14	12,22	12,15
Natural gas [MWh]	14,63	9,54	38,68	29
Solar heat [MWh]	23,58	31,45	100,36	116
Chilled water [MWh]	31	31	105	105
Comparison to compression cooling				
System COP	3,6	4,8	4,1	4,9
improvement	25		16	

Quelle:
Richard Gurtner, Solarthermisch unterstütztes Energiesystem…, Diplomarbeit, ZAE Bayern, 2011

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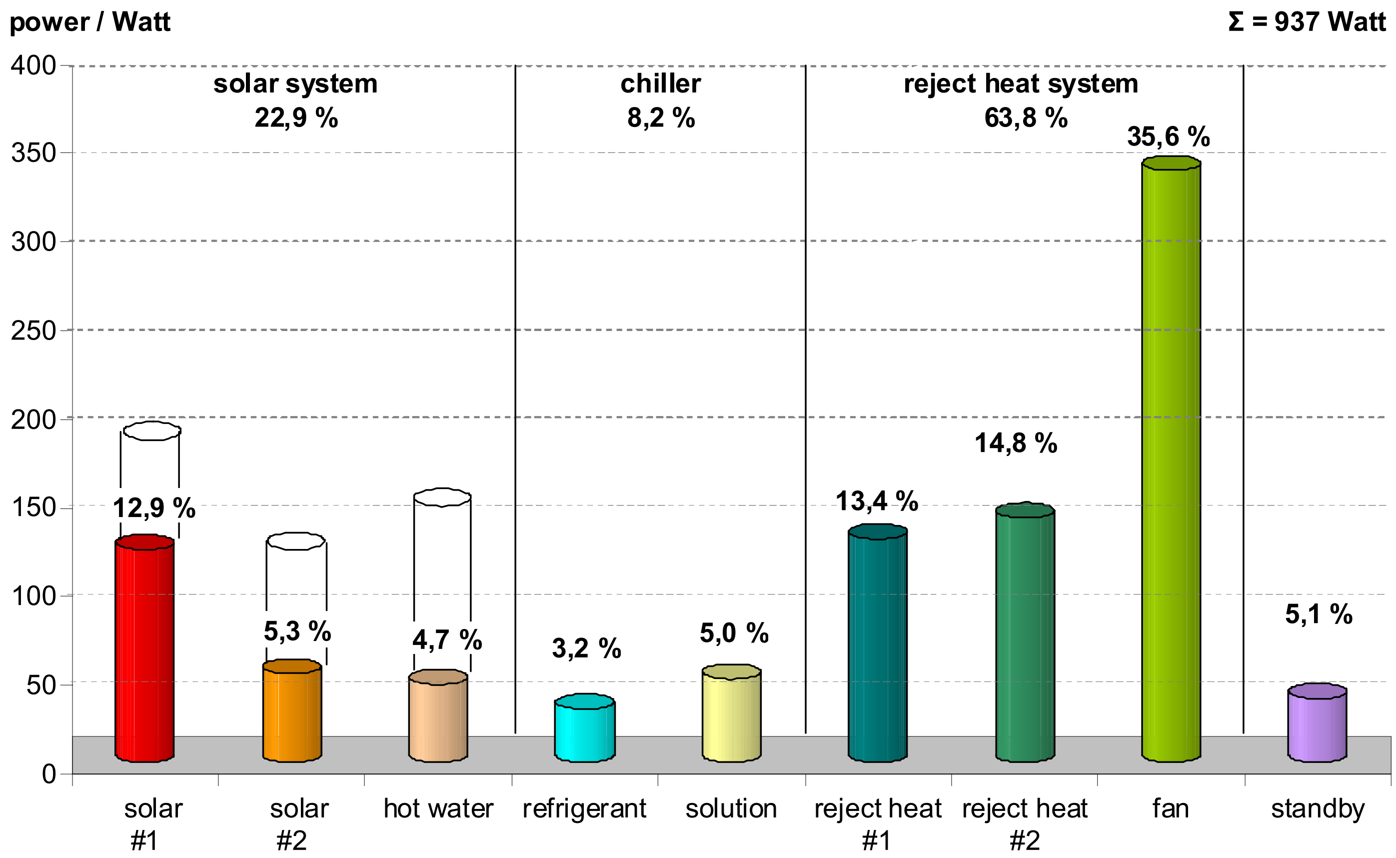
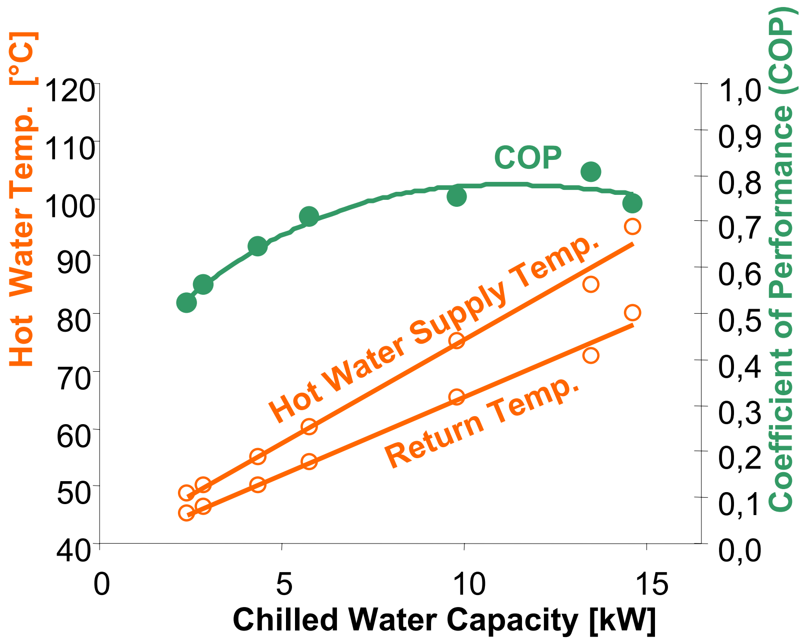
Parasitic power demand
→ System design

Parasitic power demand of a 10 kW solar sorption cooling system → looks fine !



Part load behavior

→ Impact of electric drives increases



Load	**[-]**	100%	75%	50%	25%
COP	**[-]**	0,75	0,72	0,70	0,60
Pumps	[W]	591	591	591	591
Cooling tower	[W]	334	151	47	8
Parasitic power, total	**[W]**	925	742	638	599
COP_{el}	**[-]**	10,8	10,1	7,8	4,2

⇒ System concept, Dimensioning: Base load / Peak load, Backup,

⇒ Component selection, System Control: speed control,…

Focus for future work:

- Design systems with clear distinction of location, climate, and building characteristics (load)
- Not only nominal performance, but part load is essential !
  If part load dominates: Adjust system design!
- System integration:
  - Heating & Cooling
  - Backup
  - Heat rejection

  Multiple use of components (boreholes, room installation,…)
  → reduced complexity ?
  → reduced cost

Target → complete heating and cooling system, no „add-on for cooling“
→ not maximised energy saving, but realistic and affordable

ZAE input

Ongoing and new projects related to the task

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EvaSolK (FhG-ISE, ILK Dresden, ZAE Bayern):

→ Comparison of solar thermal and PV-electric cooling

Solar Heating and Cooling with Latent Heat Storage

→ Product and System development of Latent heat storage

Double/Single-Effect Chiller / Heat pump (Project Lindner)

→ System development and experience for Solar Heating and Cooling with integrated Backup

Development and design of sorption chillers

→ compact plate heat exchangers (R&D)

→ plant development for tri-generation (district heat, co-gen)

Concrete inputs to the work plan

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Subtask A: Best market and systems (market analysis leading to specific best buildings, selected efficient systems leading to cost reduction)

- Select “Generic systems” for relevant boundary conditions
  → Include **information about control, efficiency, and cost**.
- Characterisation of load situations and future building requirements (European Building Directive, EnEV, DIN 18599)
  → **Identification of applications for solar heating and cooling**
- Integrated Systems for **solar cooling and heat pumping**
  → Exchange with IEA activities: Solar Thermal & (Compression) Heat Pumps
- **Comparison to PV-electric-Cooling** (German EvaSolK-Project)

Concrete inputs to the work plan

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Subtask B: Quality procedure (simplified design tool, design and commissioning procedure, packaging support, monitoring/O&M procedures)

- Experience in **implementation of sorption cooling systems**:
  System concept, Planning, Commissioning, Analysis of plant performance, Control strategy, Operational issues (vaccum, corrosion)
  → Quality procedure
- Knowledge about detailed system modeling
  → Input for **simplified design tool** (climate, load profiles, technical equipment)

  The design tool shall support the entire project life cycle (from design to operation)

Subtask C: Certification and Contracting (standard elaboration: Solar Cooling Keymark, contracting protocol, guarantees and results)

- Definition of **test cycles and criteria for performance evaluation** (full / part load, load changes, …), interaction with solar system
- **Additional quality criteria**: maintenance effort, plant safeties (vacuum, cristallisation), plant control and data communication,.