R&D for solar thermal + PV coupled with heat pumps

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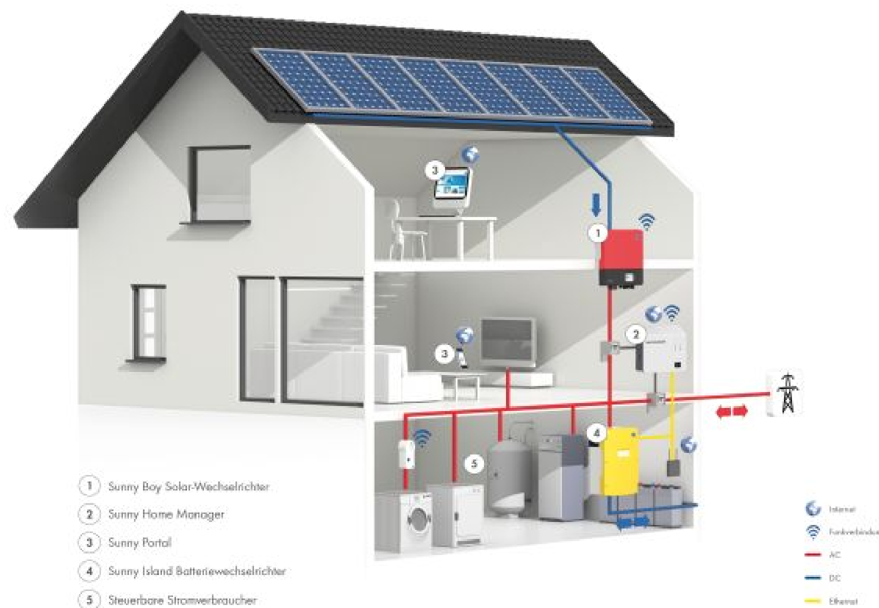
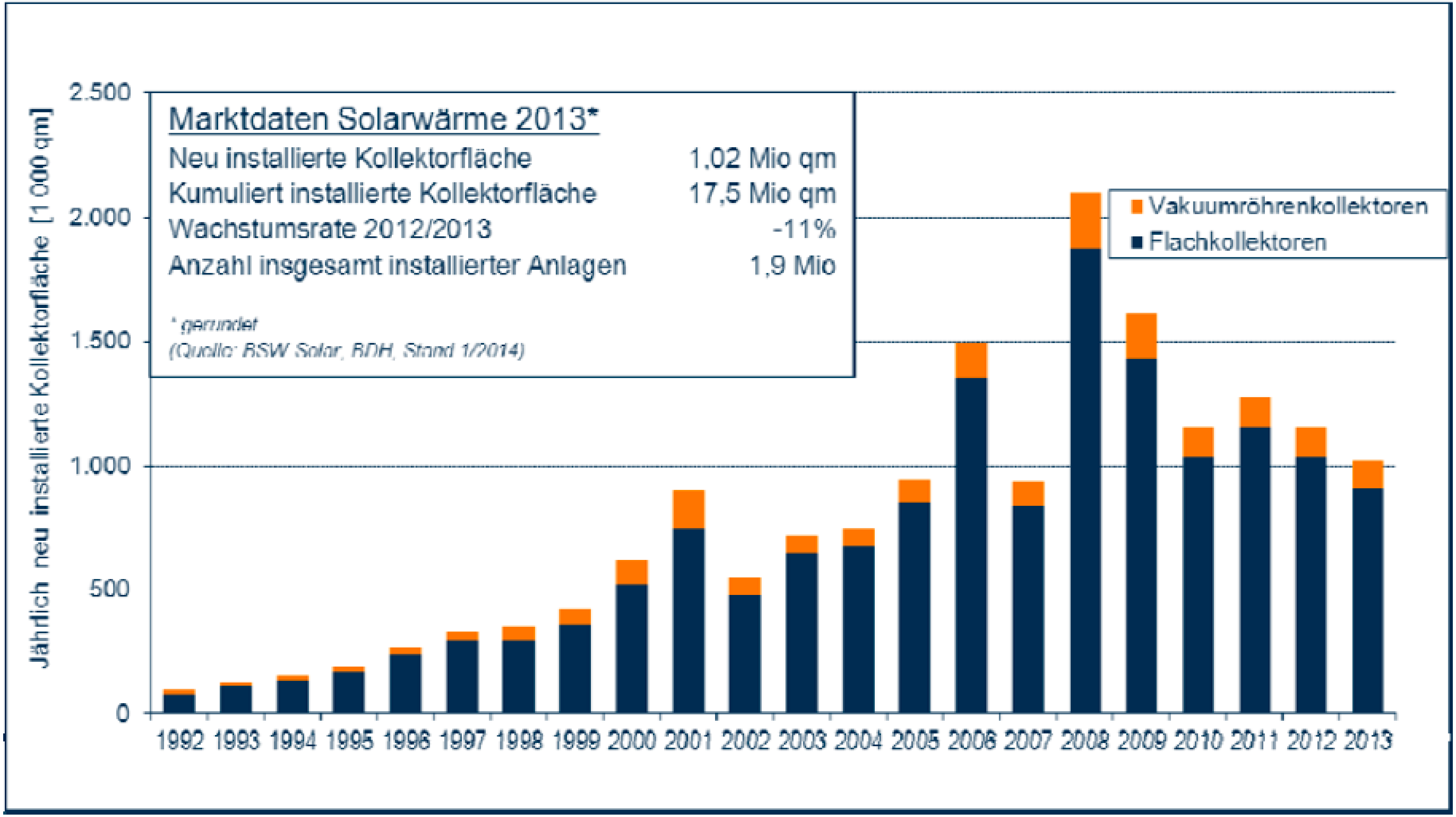
Source: Tisun

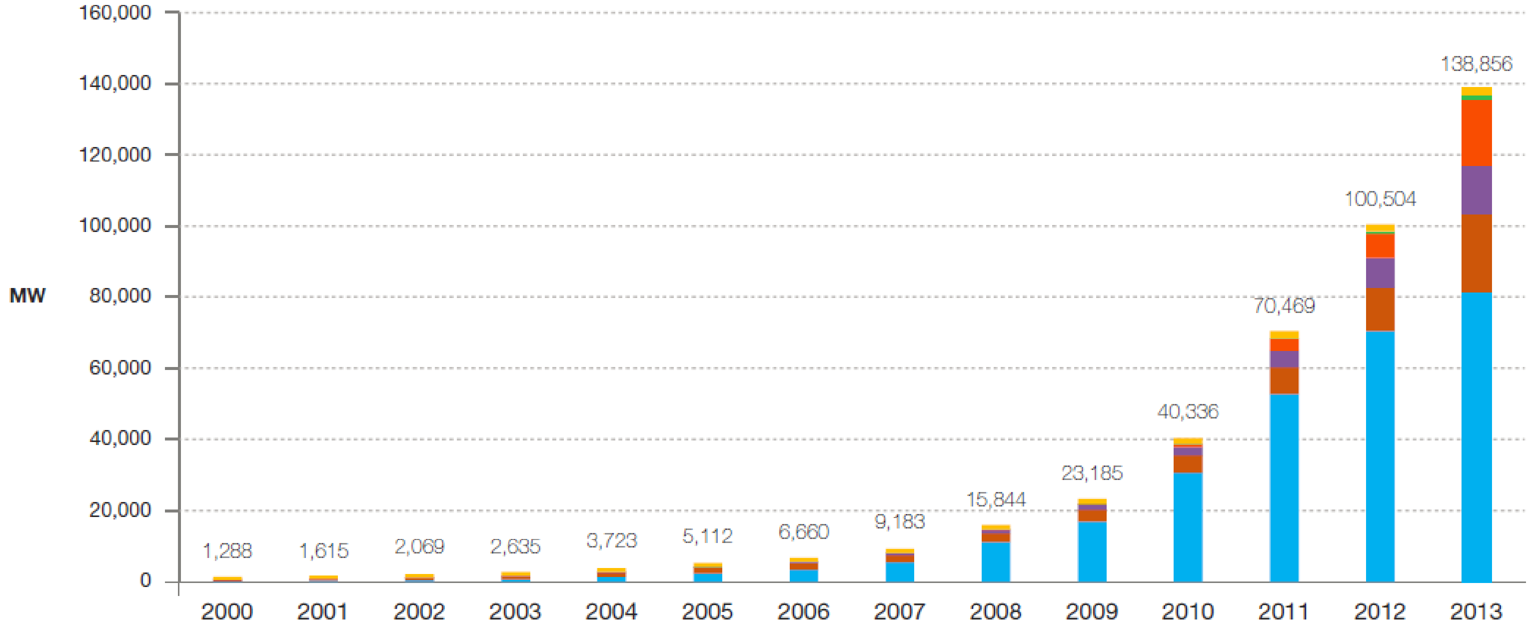


Source: ep-photovoltaik.de

Solar Thermal Market in Germany



Worldwide cumulative installed PV-Power 2000 – 2013

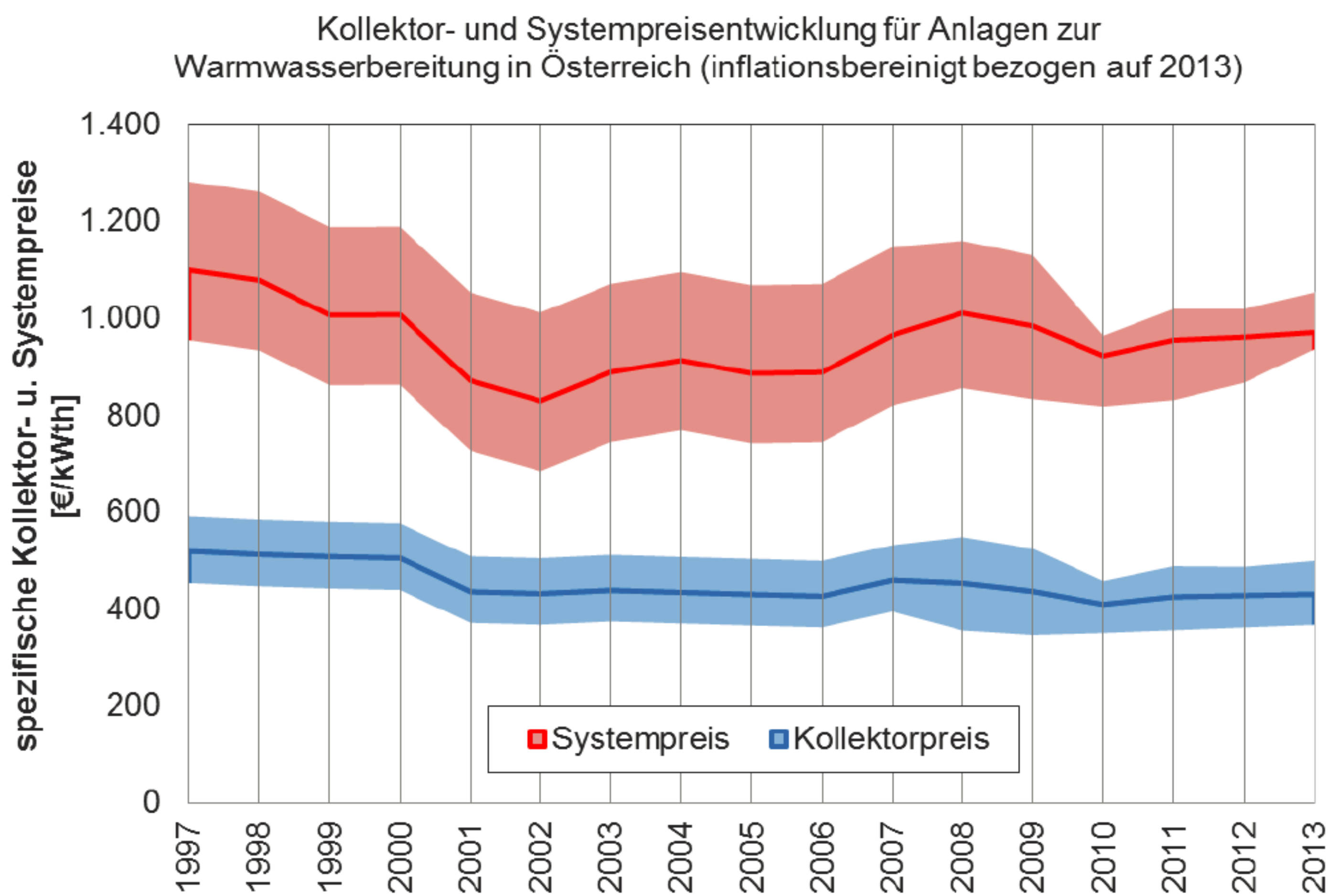


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
RoW	751	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,590	2,098	2,098	2,098
MEA	n/a	n/a	n/a	n/a	1	1	1	2	3	25	80	205	570	953
China	19	24	42	52	62	70	80	100	140	300	800	3,300	6,800	18,600
Americas	21	24	54	102	163	246	355	522	828	1,328	2,410	4,590	8,365	13,727
APAC	368	496	686	916	1,198	1,502	1,827	2,098	2,628	3,373	4,951	7,513	12,159	21,992
Europe	129	265	399	601	1,306	2,291	3,289	5,312	11,020	16,854	30,505	52,764	70,513	81,488
Total	**1,288**	**1,615**	**2,069**	**2,635**	**3,723**	**5,112**	**6,660**	**9,183**	**15,844**	**23,185**	**40,336**	**70,469**	**100,504**	**138,856**

RoW: Rest of the World. MEA: Middle East and Africa. APAC: Asia Pacific.
Methodology used for RoW data collection has changed in 2012.

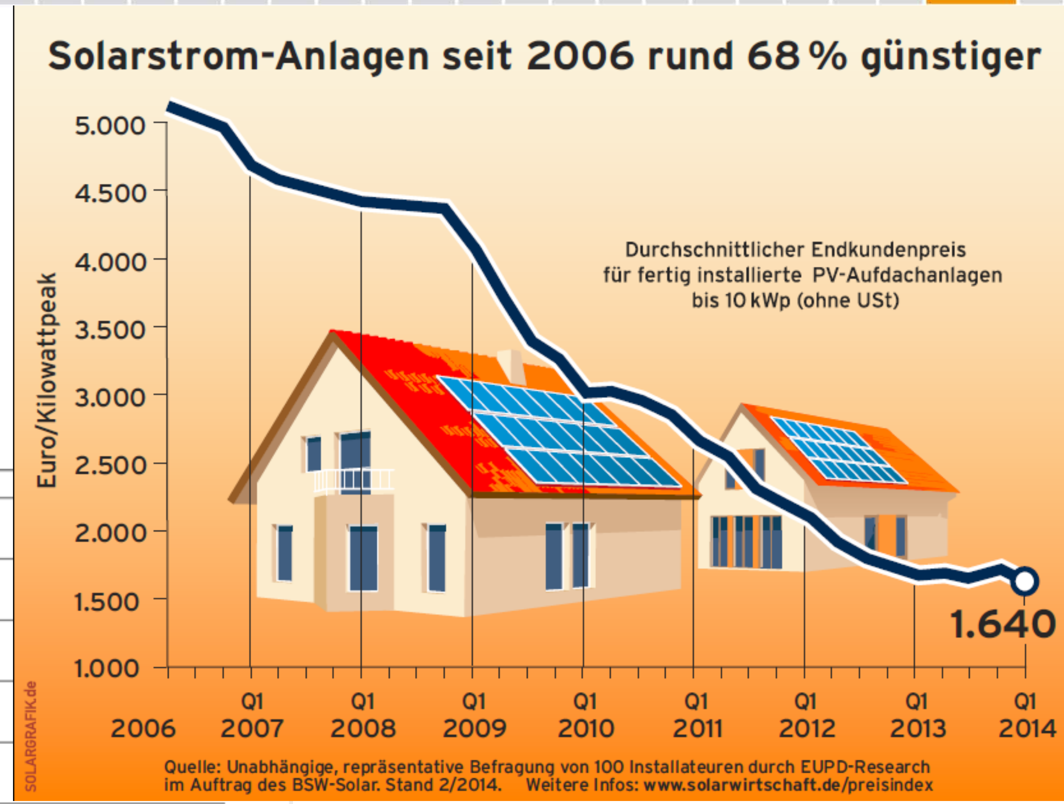
Source: PV Global Market Outlook, EPIA, 2014

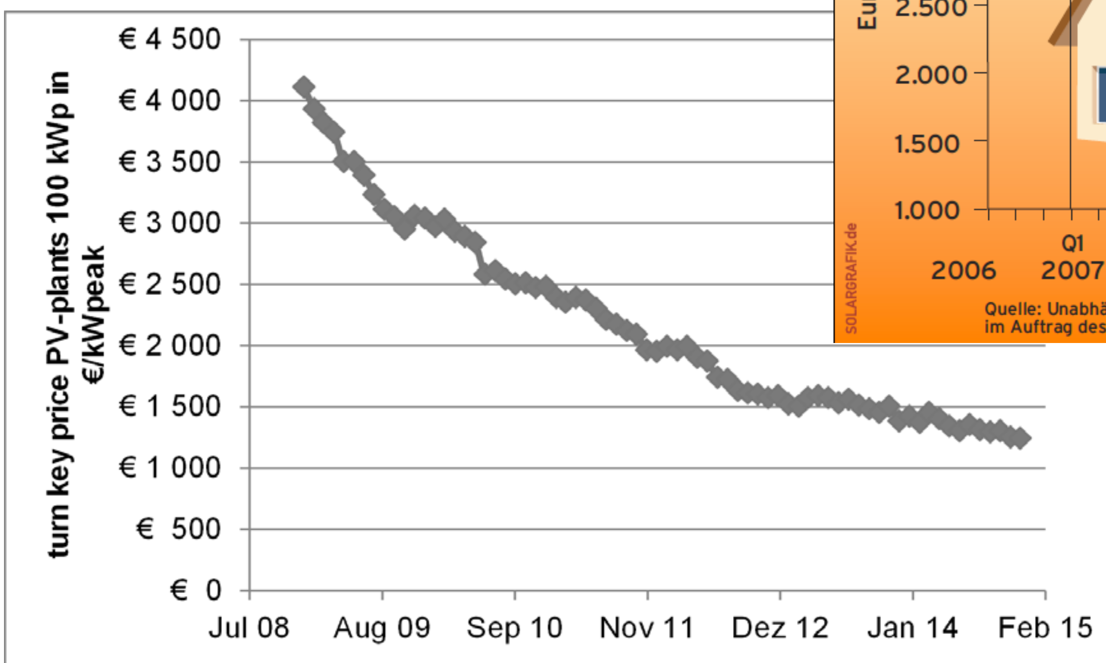
Price Development Solarthermal in Austria (no price reduction)



Source: AEE-INTEC

End-User Price development of PV plants





End-User Price development of 100 kW_{peak} turnkey photovoltaic plants in Germany in €/W_{peak}, values from http://www.photovoltaik-guide.de/pv-preisindex, downloaded 02/2015.

Source: Werner Weiss

The final Goal:

100% solar heating and cooling of new buildings

1: reduce consumption

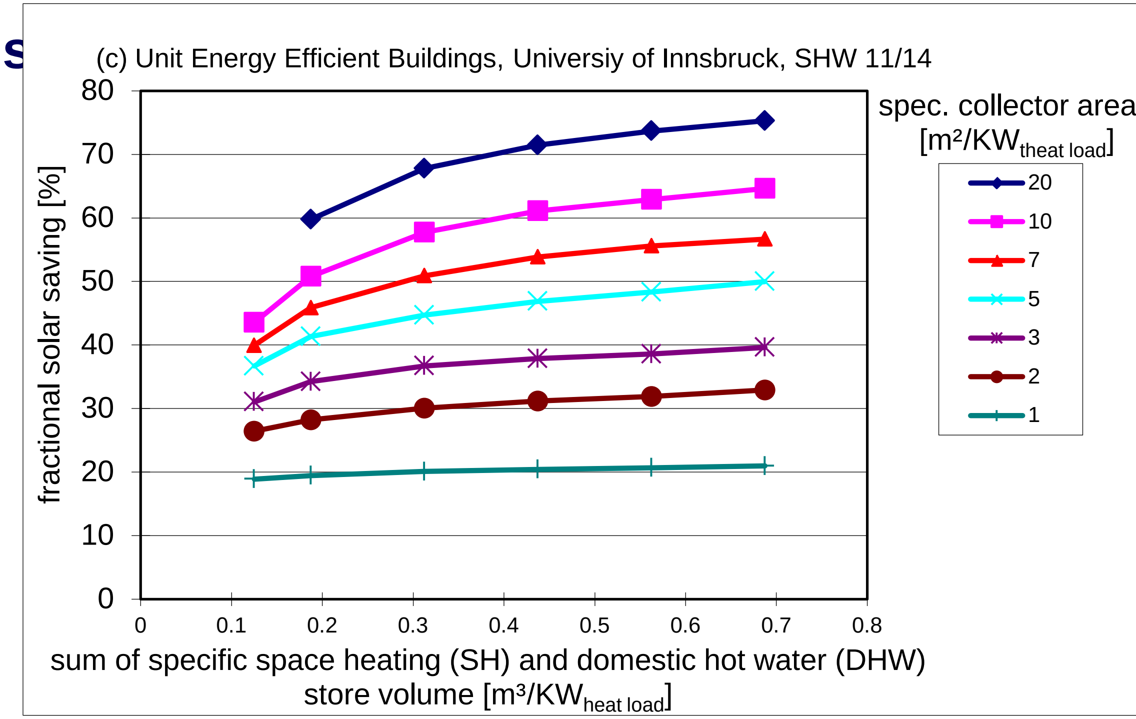
2. Include renewables

Competition: Solar ⇔ Thermal-PV

- The same areas on the building (free parts of roof and southern facade)
- DHW: Solar Thermal + backup – PV (heat pump or direct?) + el.
- DHW+SH: the same, PV currently already an option
- DHW+SH+Cooling: the same with reversible heat pump, PV mostly cheaper
- Excess energy (Energy that can not be stored on site)
  - Solar thermal: Excess energy lost, collector in stagantion
  - PV: Excess energy is fed into the grid – feed in tariff?
- PV + heat pump is most often less complex to build as solar thermal
- PV + heat pump has about the same efficiency as solar thermal

Debate currently: How High should be the Solar Fraction

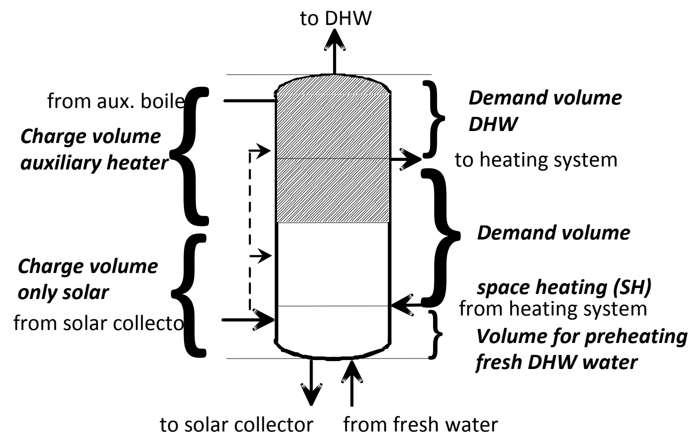
- **High solar fractions are desirable to reduce the us of other fuels**



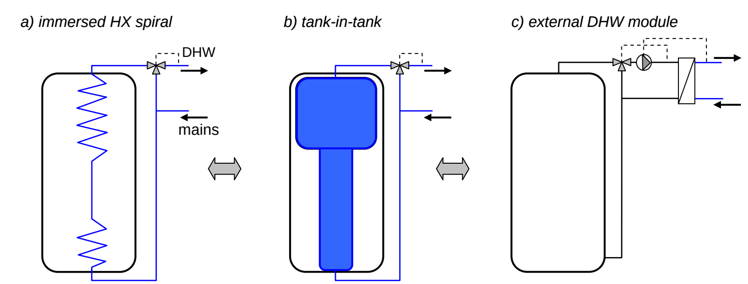
- **The higher the solar fraction, the more oversized is the plant in summer:**
  - **The specific collector yield drops and specific costs per kWh increase**
  - **More stagnation problems**

Current Technical knowledge: Example Combistores

- **Important geometry**
  - Heights of inlets/outlets
  - Heights of sensors
  - Insulation
  - Embedded thermosyphon connections

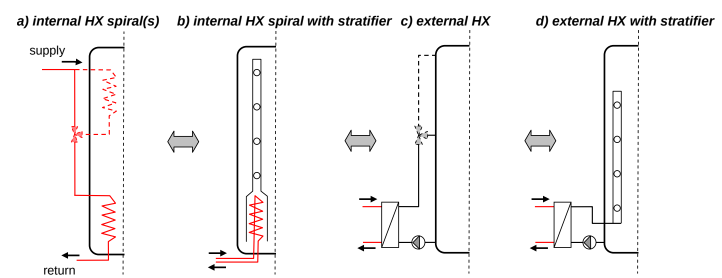


- **DHW production**



Source: Haller, 2010

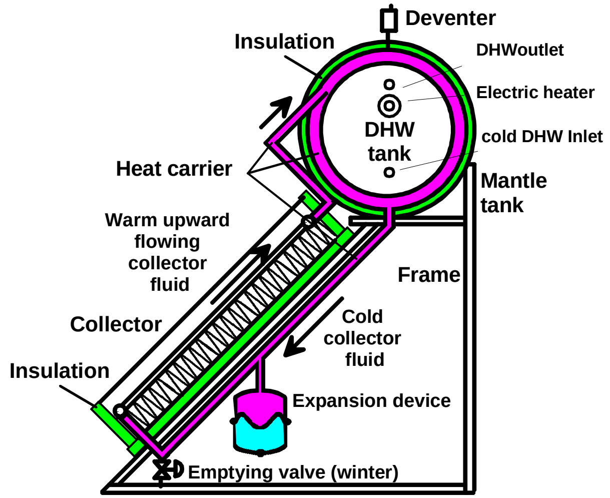
- **Solar Input stratified**
  - Low heat losses (1st law thermo)
  - Low temperature losses (2nd law th.)

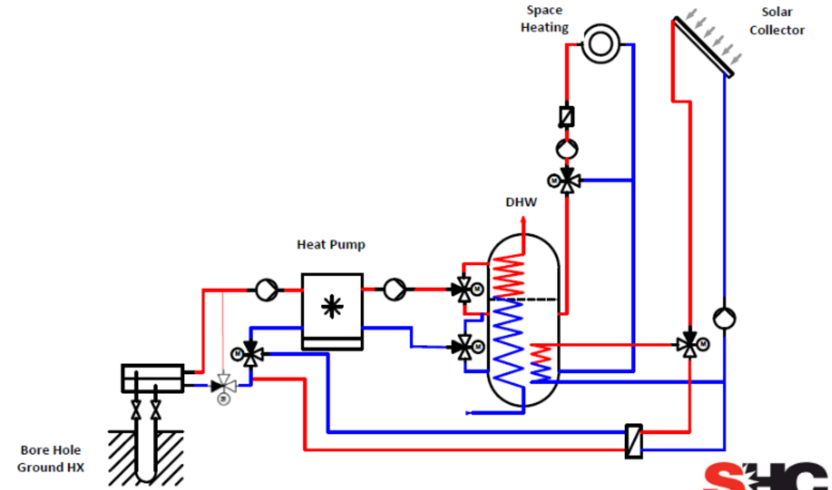


Two Technological Options for R&D

- „Low Tech“ approach
  - Cheap
  - Simple
  - Small number of components
  - Efficiency good but not optimal

- „HighTech“
  - More expensive
  - Complex
  - High number of components
  - Efficiency „theoretical optimal“

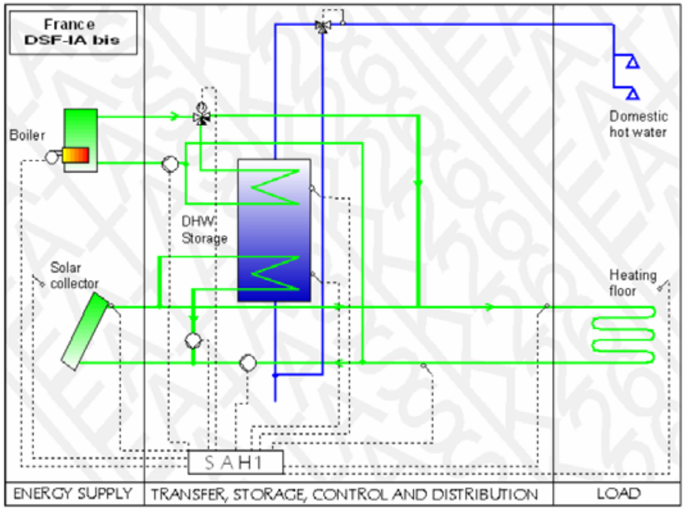


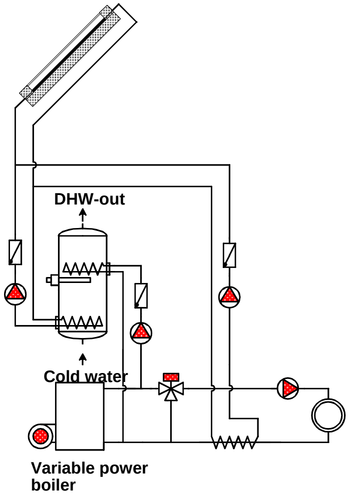


Source: IEA SHC Task 44

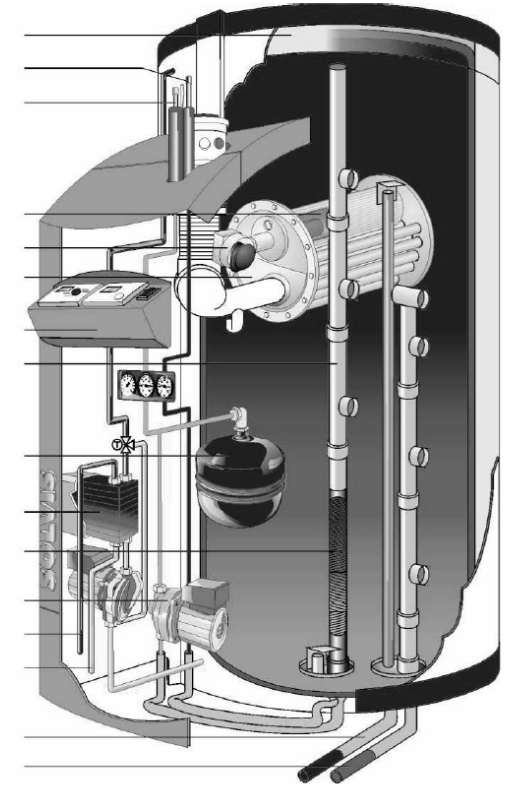
Example Simple System: Direct Solar Floor (Philippe Papillon, 1998) – Smart Thermal Grid

- + SH storage is concrete floor „activated thermal mass“
- + No heat losses of SH store
- +- Would be nice to have predicitve control for weather situation
- - More heat store – danger of room overheating and therefore additional heat demand
- System is now again in the focus: PV-Heat Pump and/or solar thermal. Far cheaper than e.g. batteries



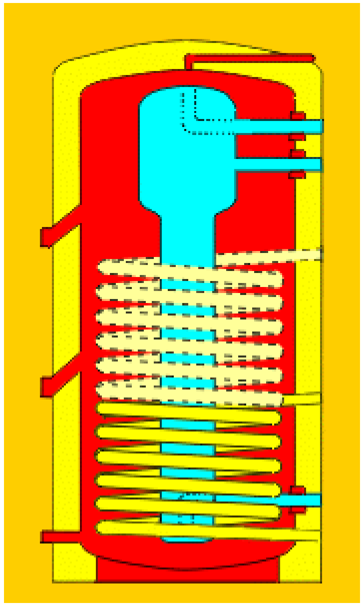


Example Compact Systems
Solvis and Jenni: old but good

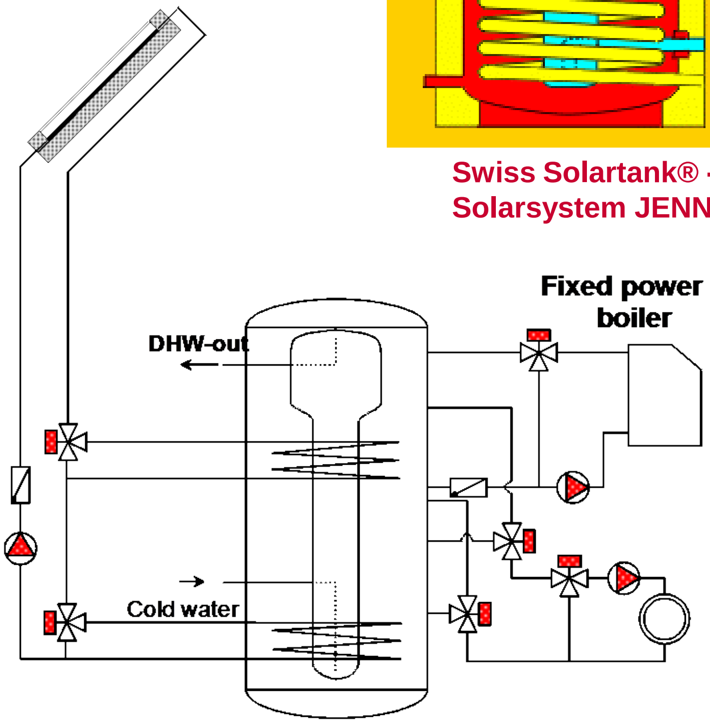


Source: Solvis

Source: Vaillant



Swiss Solartank® - Solarsystem JENNI



Adding Solar Thermal Cooling …

- Idea is nice: load and energy at the same time
- Complexity is rising: Higher number of apparatus and measurement points
- Temperature lifts in the collector: small for cooling and SH, high for DHW
- Auxiliary electricity demand can be high => matter of optimization
- PV with compression cooling is often cheaper
- Plants with high DHW share and no cooling backup can be economic compared to compression colling

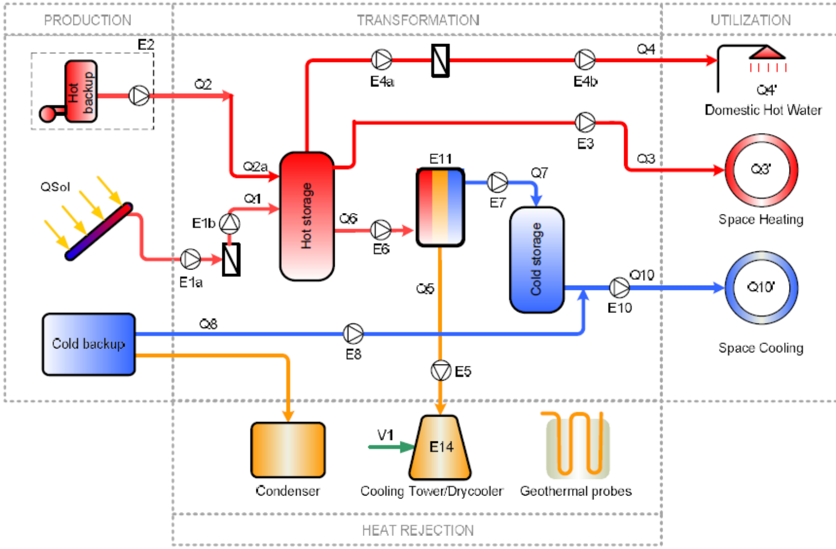


FIGURE 4 - SCHEMATIC DIAGRAM OF A SMALL PRODUCTIZED SOLAR AIR-CONDITIONING/HEATING/DOMESTIC HOT WATER SYSTEM

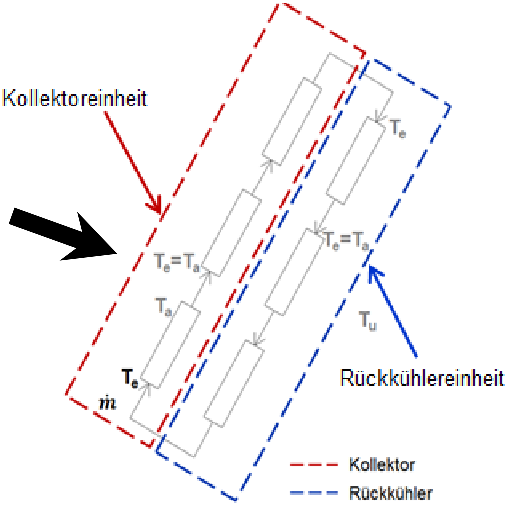
IEA SHC Task 48, report C 4.3, Boudehenn et. Al, 2013

Example R&D Work in Cost Reduction: Polymers

e.g. IEA SHC Task39, SolarNor-Norway, Sol-Pol-Austria, Magen-Israel

- **Technical problems:**
  - Low cost = max. temperature < 100°C
  - High performance under working conditions
  - Low thermal conductivity

- **Several solutions under R&D**
  - „Not too good“ collectors with stagnation temperature < 130°C and permanent heat sink
  - Collectors with internal overheat protection with recooler at the back. But: increase of costs by additional cooler.
  - Future: Maybe collectors made of plastic foils



R&D needs Solar Thermal

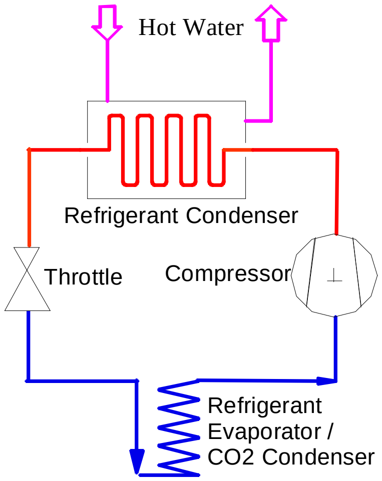
- **Integrate solar collectors in building surfaces => to reduce cost**
- **Use alternative materials, technologies and manufacturing techniques for system cost reduction and performance improvement.**
- **Address challenges in system design by development of standardised kits and plug-and-function systems.**

IEA 2012, Technology Roadmap Solar Heating and Cooling, International Energy Agency, Paris, France, www.iea.org

Heat Pumps general R&D

Research items

- **Reduce costs of system:**
  - Trend to Air-Water heat pupms
- **Improved thermodynamics**
  - Desuperheater
  - New refrigerants
  - Two stage compressor
- **Mikro heat pump for air heat and moisture recovery, heating and cooling for decentralized use or passive houses**
- **Boreholes without pump (CO2 probe)**
- **...**

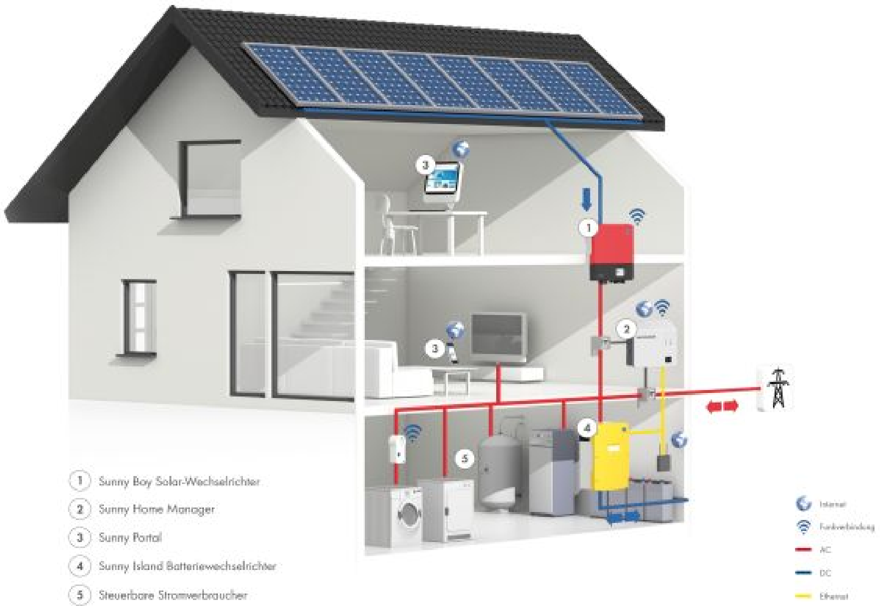


Naturally circulating CO_2-Probe(s)

Heat Pumps coupled to PV

Reserch items

- DC drives for speed controlled compressors directly coupled to PV
- Use of thermal mass (floor heating or activated layer) with model predicitve control
  - weather next day bad: overheating of thermal masses
  - weather next day good: no overheating; feed into the DHW store or into the grid
- Use of space heat store
- Optimization is also dependent on varying feed in tarrifs

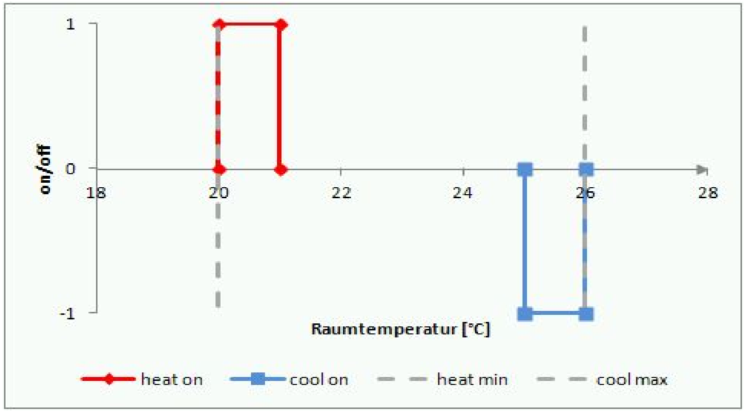


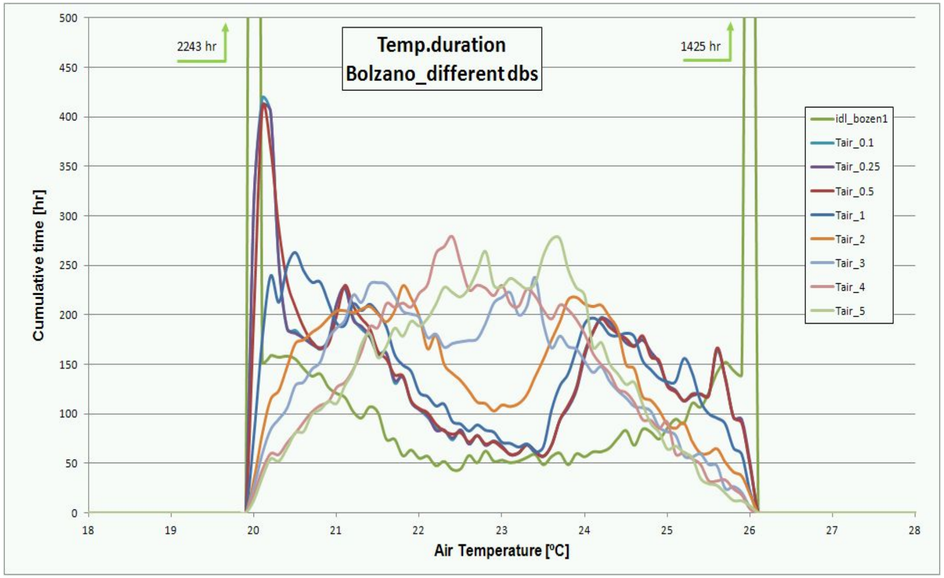
ep-photovoltaik.de

Building as Heat Storage

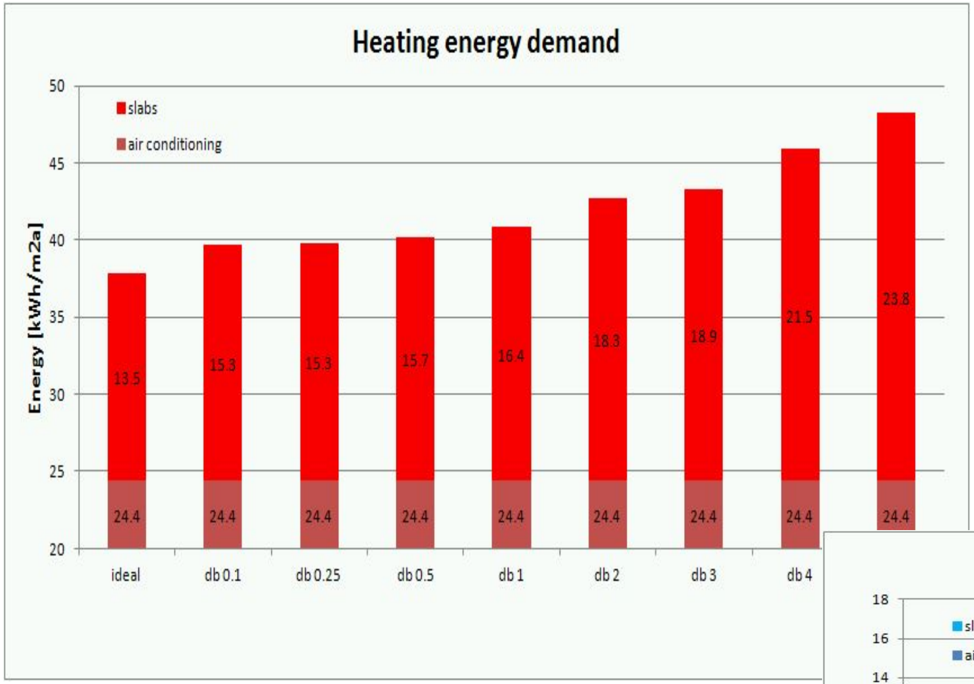
Reserch items

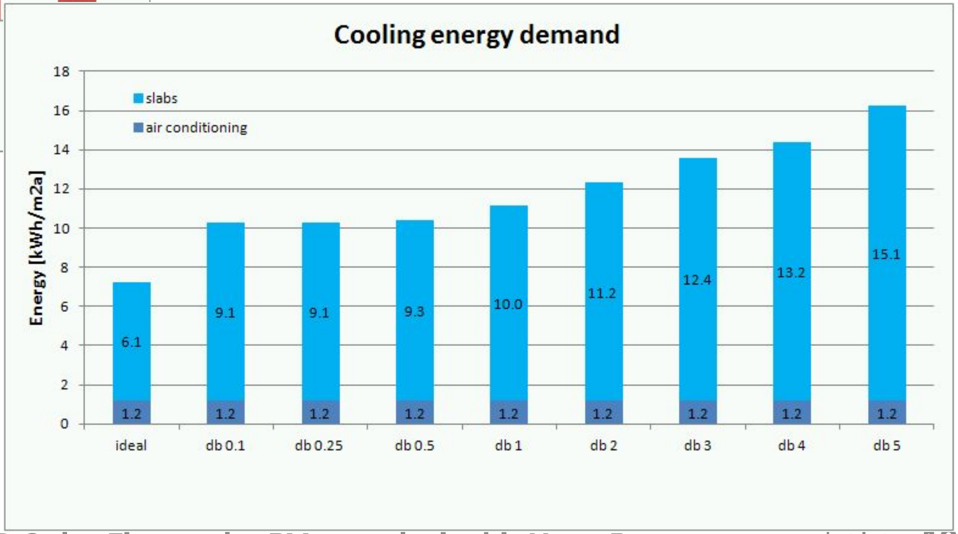
- **Combined heat and cooling delivery system (e.g. acivated ceiling)**
- **Interaction of activated thermal mass and building**
  - – Overheating increases the room temperature and therfore heat demand in winter
  - – Overcooling in Summer increases cooling demand
  - + Both increase thermal comfort
  - + Both increase the possibility to used PV directly and reduce cycling
  - – Both increase circulation pump running time





Building as Heat Storage

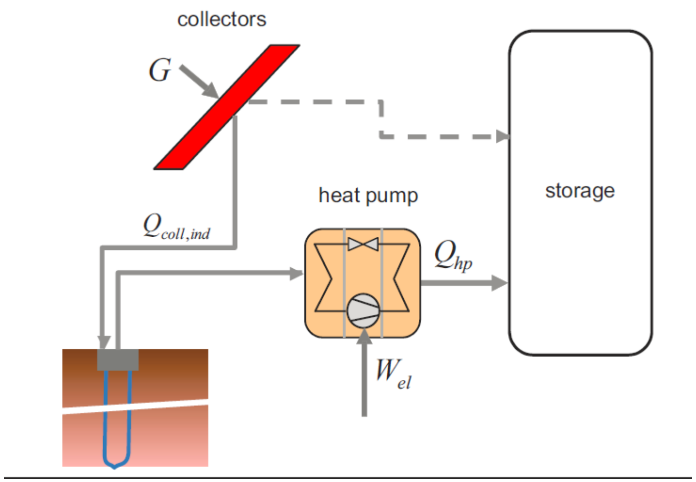


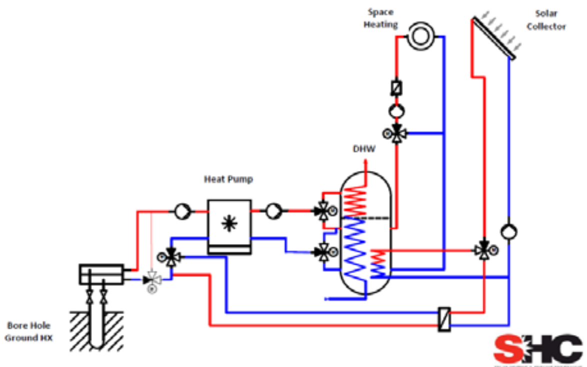


Heat Pumps coupled to Solar Thermal

Results of research so far (IEA SHC Task44)

- Small benefit to couple in series (collector as heat source for heat pump)
- Little benefit also for parallel (solar thermal has high yield when also heat has high COP)
- Complete decoupling (e.g. heat pump for space heating and solar thermal for domestic hot water) is interesting
- Thermal regeneration of ground by solar thermal may allow smaller ground area
- Heat pump with PV is a direct competitor and cheaper + simpler for many applications

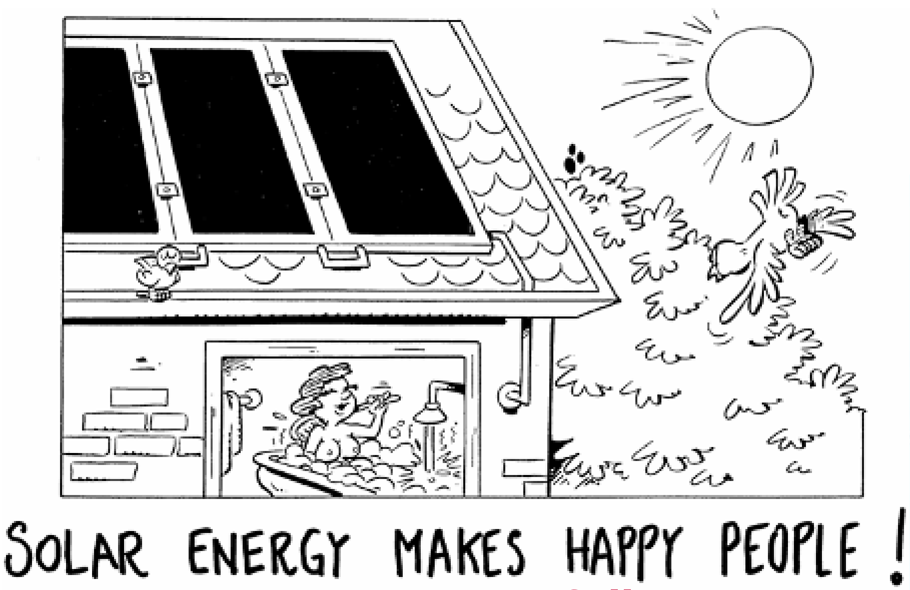




Conclusion

- There is Plenty of Room for Solar Thermal and PV in Sustainable Energy Systems.
- Energy Efficient Buildings help to Reduce the Efforts of Solar Thermal and PV for the Same Solar Fraction
- Solar Thermal has Similar Markets as PV (when coupled with Heat Pump),
- PV has far bigger market than Solar Thermal
- Solar Thermal has to Reduce Costs and Complexity to be Competitive
- Heat Pumps (espec. In combination with „green electr. Or PV directly) will play a major role in future
- A Common Strategy for the Renewables in a Changing Energy System is needed.

Thank you very much



Hopefully