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SPF INSTITUT FÜR SOLARTECHNIK

Trends and Challenges of Solar Thermal Energy

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University of Applied Sciences HSR
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Institute for Solar Techology SPF (www.spf.ch)

Competence Center for Solar Thermal Energy in Switzerland

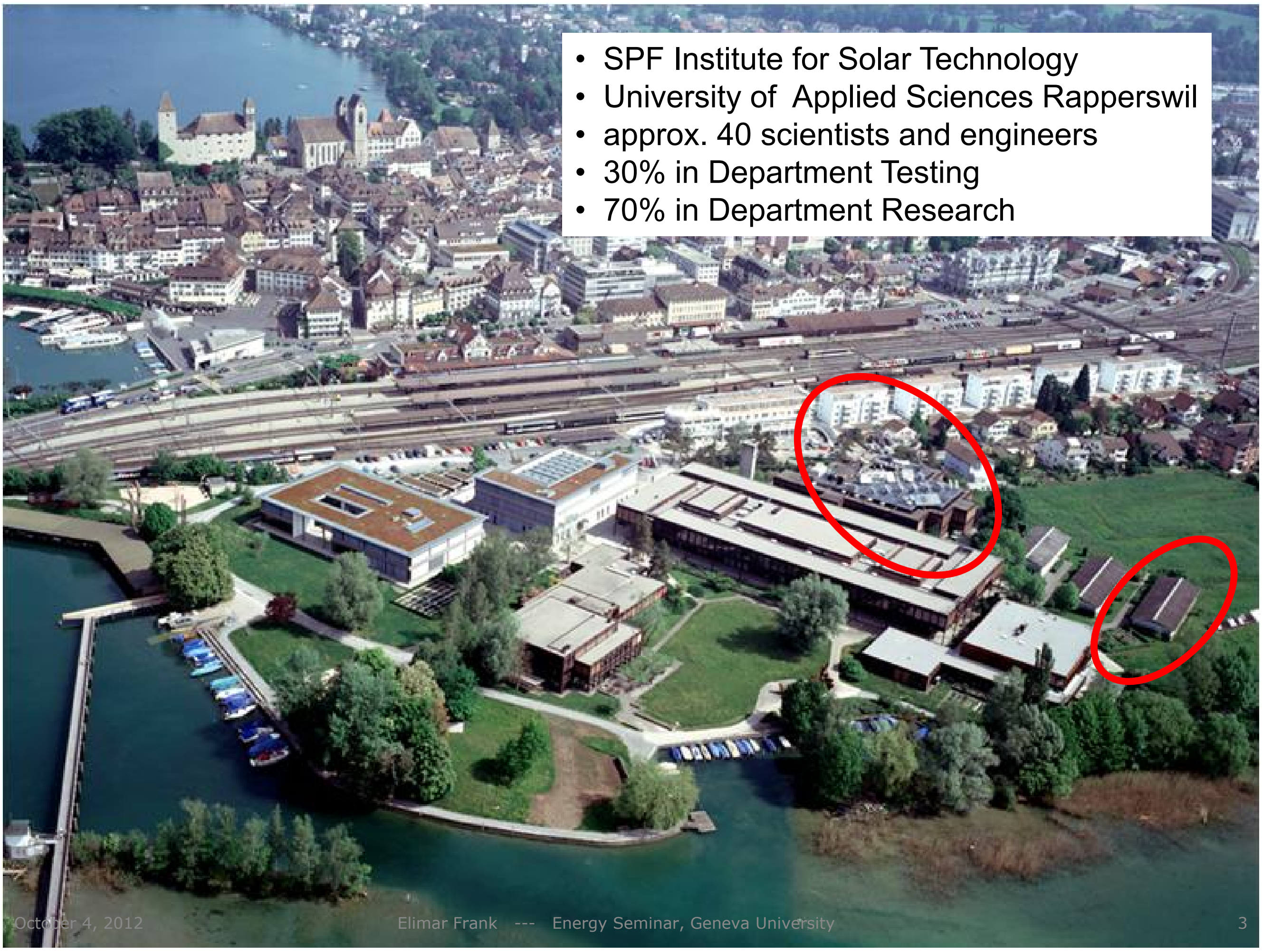
Development and testing of components, collectors and systems in collaboration with the industry

Swiss national and EU projects

Contribution to IEA-Tasks, e.g.

- IEA-SHC-Task 49 on Solar Heat for Industrial Processes
- IEA-SHC-Task 44 on Combination of Solar Thermal and Heat Pump Systems

Challenge for the next years: Combination of renewable energy technologies!

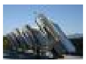


- SPF Institute for Solar Technology
- University of Applied Sciences Rapperswil
- approx. 40 scientists and engineers
- 30% in Department Testing
- 70% in Department Research

All testing facilities for collector and system testing

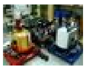
Research Infrastructure (selection) – www.spf.ch

Solar simulator
Our modern solar simulator is an ideal tool for collector optimization when indoor measurements are desirable.

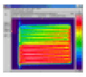


Tracker
Our two-axis tracking systems guarantee collector performance measurements of utmost precision.

Test rigs
We rely on a wide range of special test rigs for the development of components such as pumps, compensators, fresh-water modules, etc.; all of which can be adjusted at will.

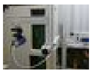


Spectroscopy
A wide range of spectrometer systems are available for the measurement of spectral radiation distribution (radiometrics) and to ascertain the absorption, emission, reflection and transmission of materials.



Thermography
Thermography gives us an insight into the world of heat radiation. Our high-precision liquid-nitrogen cooled thermal imaging camera makes weak spots immediately visible.

Research Infrastructure (selection) – www.spf.ch



PIV and LIF
Particle **I**mage **V**elocimetry enables a non-intrusive quantitative visualization of flows in fluids and gases (eg. free convection in storages). Temperature fields can be deduced using a similar visualization relation from **L**aser **I**nduced **F**luorescence (LIF).

Test rig for combi systems
The unique test rig for combi-systems makes it possible to evaluate realistically the interaction between collector, tank, auxiliary heating unit and the controller. The integration of auxiliary heating can be achieved by means of gas, oil, biomass boilers and eventually heat pumps. The test stand resulted from work on the Concise Cycle Test method.

Environment simulation
In our climatic exposure test cabinets and high-temperature ovens materials and components can be tested for their resistance to environmental influences such as temperature, humidity, condensation and irradiation.

Research Tools (selection) – www.spf.ch

Polysun
Polysun is a versatile simulation program originally developed at SPF. Working in close cooperation with the spin-off company Vela Solaris we make advantage of programme features in the software development field that are concealed to "regular" users.

TRNSYS
TRNSYS is a modular, dynamic building and system simulation program boasting excellent flexibility; if needed the program can be integrated with custom-developed components.

EES
EES is a program for the solution of differential and algebraic equation systems. Its programmable user-interface can be programmed with customer specific applications. (TubeCalc was programmed in EES).

Raytracing
Non-sequential Raytracing enables the enhanment in optical performance of collectors with mirror systems.

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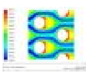
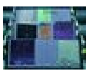
Research Tools (selection) – www.spf.ch

FEM
The **F**inite **E**lement **M**ethod can be used wherever complex heat conduction processes may no longer be solved analytically.



CFD
As opposed to FEM, **C**omputational **F**luid **D**ynamics allows material transport processes to be modelled where fluid heat transfer processes are concerned. It is suitable for all flow processes inferred through the simulation fluids and gases.



ALT
Accelerated **L**ifetime **T**ests allows prediction on the expected lifetime of new materials to be made, such as with solar absorber layers under preset operating conditions.

Concise Cycle Test
The **C**oncise **C**ycle **T**est method is a dynamic method developed at SPF to test solar combined systems. The method draws on previous and parallel works of experience from other research institutes [more…].

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Publications: www.spf.ch

- → Sort by year, author, keyword, …
- → Short description of each publication
- → link for download
- → **2be updated soon ;)**

Publications

2011

Experimental Investigations on Charging and Discharging Strategies of Thermal Energy Stores and Their Effect on System Efficiency

R. Haberl, E. Frank / 2011 / en

A combisystem with four different storage and storage integration concepts was tested under realistic load conditions, using the Concise Cycle Test (CCT) method. The common features of all tested systems are the auxiliary heater and the solar collectors as well as the storage volume. The experiments revealed a considerable range of annual fuel consumption to cover an identical load.

ISES SWC Paper

On the Potential of using Heat from Solar Thermal Collectors for Heat Pump Evaporators

M. Haller, E. Frank / 2011 / en

In this paper a general mathematical relationship is derived for determining whether using heat from solar collectors for the evaporator of the heat pump instead of using it directly is beneficial for the energetic performance of these systems. It is shown that there is a limit for the solar irradiation on the collector field above which using collector heat for the evaporator of the heat pump instead of using it directly is not advantageous.

ISES SWC Paper

A Computational Fluid Dynamics Study on the Accuracy of Heat Transfer from a Horizontal Cylinder into Quiescent Water

W. Logie, E. Frank / 2011 / en

The discipline of prototyping and designing parts or components via direct numerical simulation offers engineers today a powerful tool in the understanding of physical problems. The manipulation and operation of numerical fields representing the conditions we wish to consider (for example by way of Newtonian fluid physics) provides insight and comparative confidence in decisions otherwise grounded on experience or experimental data. To gain this confidence however - that the model parameters and numerical solver are realistic - we must be stringent in their validation for any given problem. Illustrated in this paper is such a validation for free convective heat transfer (Nusselt number) from a horizontal cylinder into quiescent water. The fluid properties and free convective range of application reflect those occurring within Solar Domestic Hot Water (SDHW) storages with helically coiled Immersed Heat Exchangers (IHX).

ISES SWC Paper

Investigations on Solar Thermal Process Heat Integration with Parabolic Trough Collectors

H. Marty, E. Frank / 2011 / en

The calculations presented in this paper may serve as a first indicator for planning decisions regarding the orientation of parabolic trough collector fields for latitudes in central Europe. For supplying solar process heat, not only the yearly specific or total energy yields but also the course of direct irradiance and peak power over a day and the

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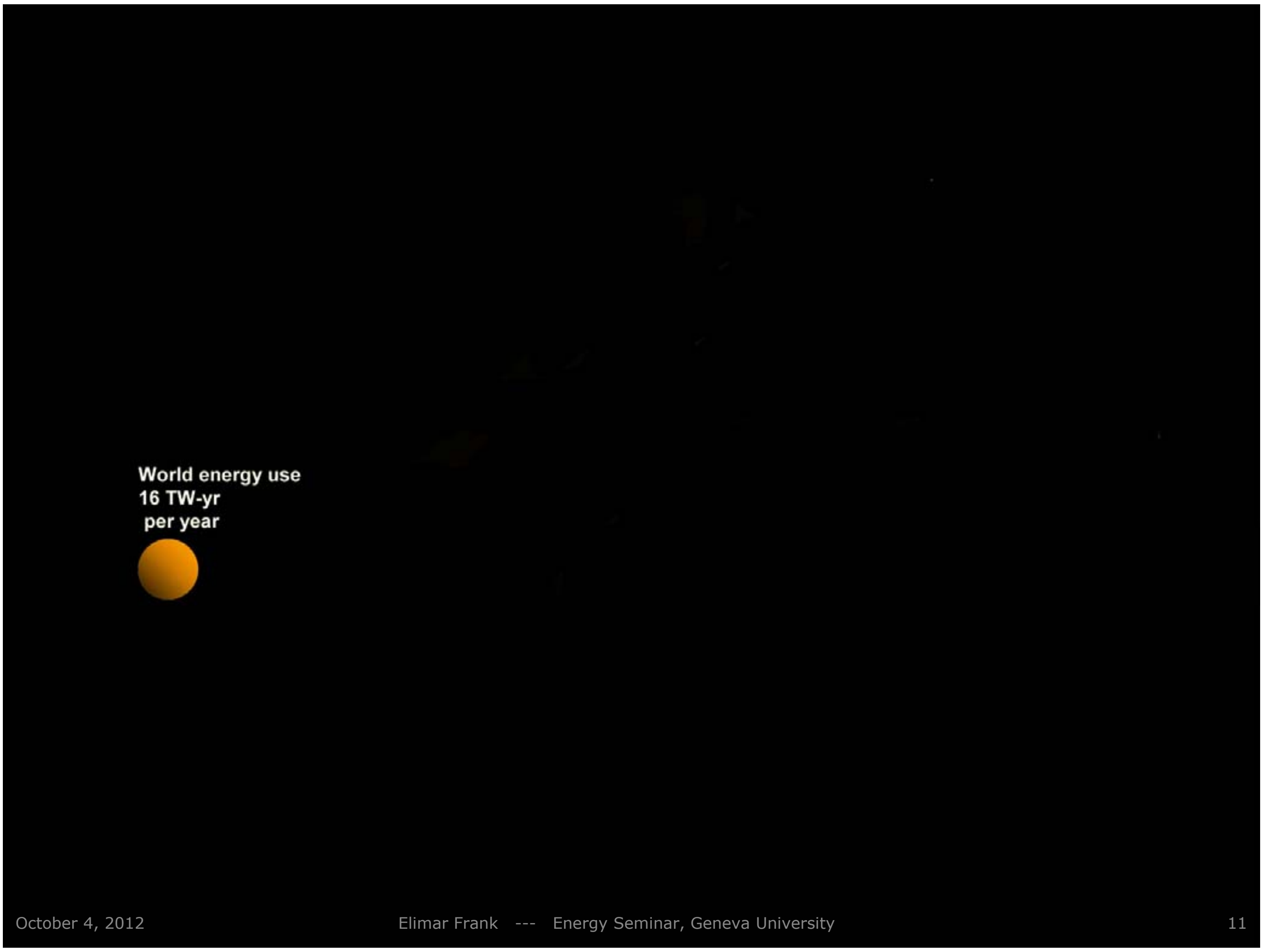
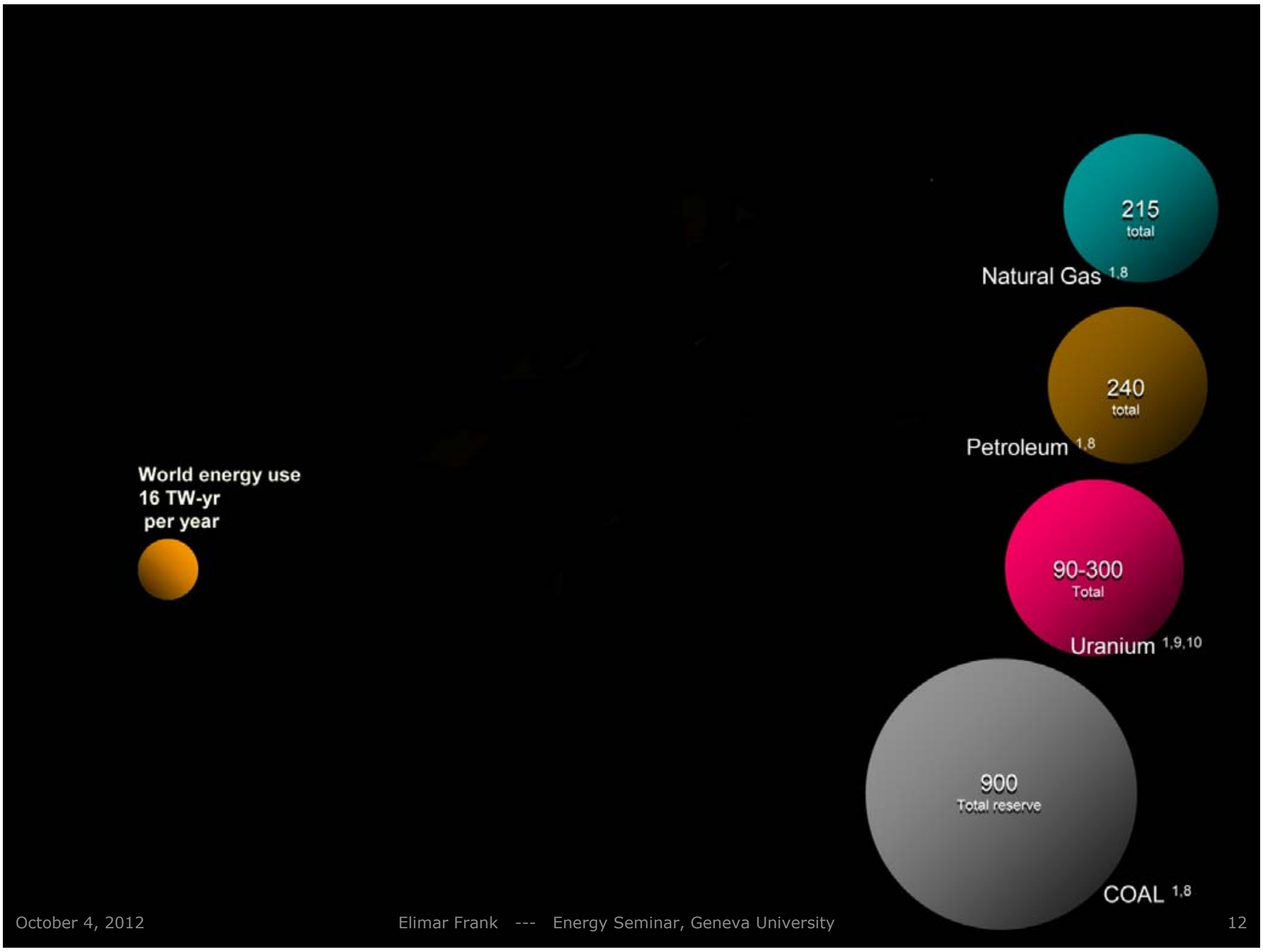
Trends and Challenges of Solar Thermal Energy

- Why use solar energy?
- Why use solar thermal energy?
- Market figures
- Trends and Challenges…

  … with a focus on …
  - The combination of Solar Thermal with Heat Pumps
  - PVT collectors and systems
  - Solar Process Heat Applications
  - Solar Thermal Water Disinfection


World energy use
16 TW-yr
per year
October 4, 2012
Elimar Frank --- Energy Seminar, Geneva University
11


World energy use
16 TW-yr
per year
215
total
Natural Gas [1,8]
240
total
Petroleum [1,8]
90-300
Total
Uranium [1,9,10]
900
Total reserve
COAL [1,8]
October 4, 2012
Elimar Frank --- Energy Seminar, Geneva University
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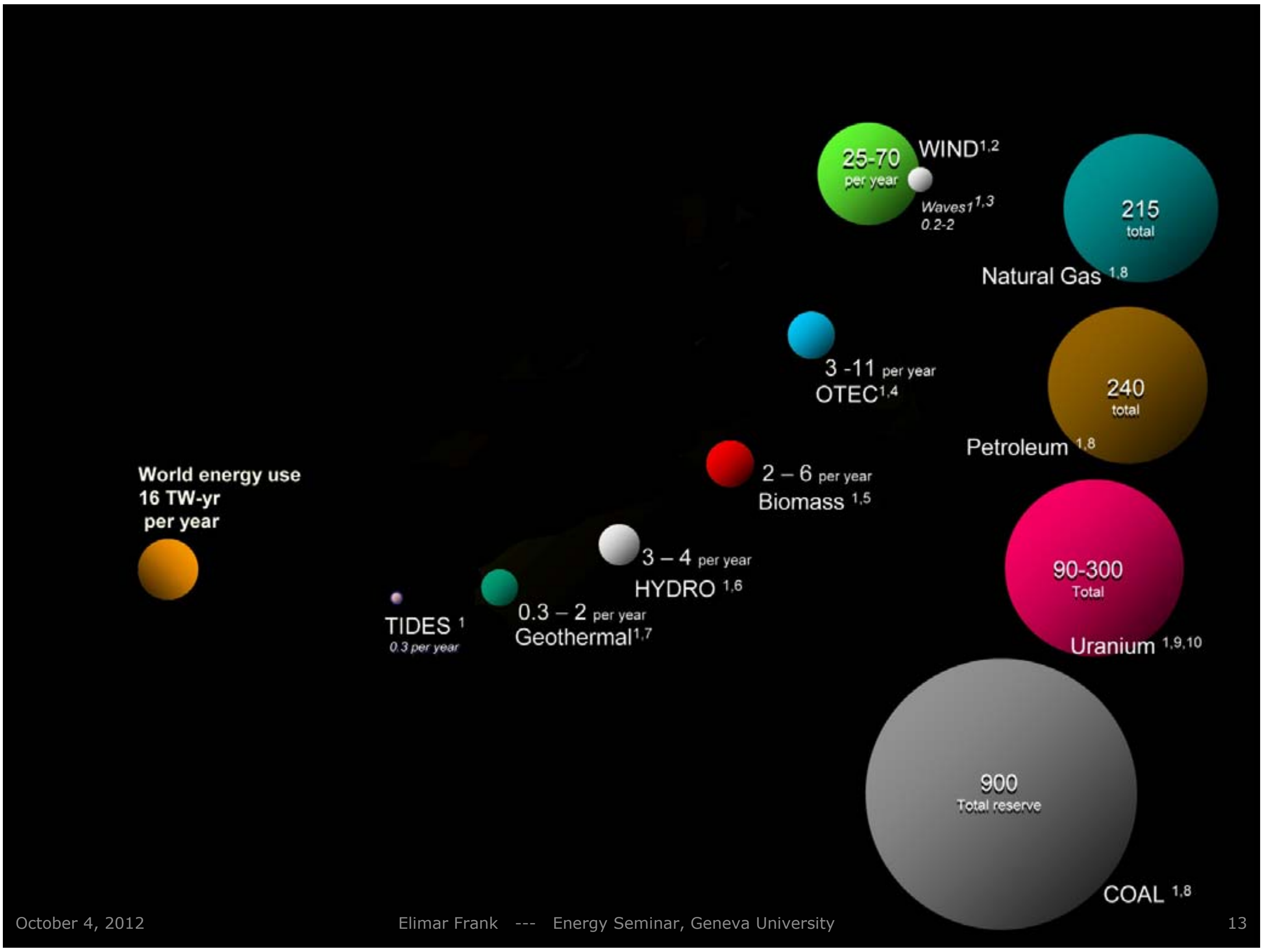

WIND1,2
25-70
per year
Waves1 1,3
0.2-2
215
total
Natural Gas 1,8
3 -11 per year
OTEC1,4
240
total
Petroleum 1,8
World energy use
16 TW-yr
per year
2 – 6 per year
Biomass 1,5
3 – 4 per year
HYDRO 1,6
90-300
Total
Uranium 1,9,10
TIDES 1
0.3 per year
0.3 – 2 per year
Geothermal1,7
900
Total reserve
COAL 1,8
October 4, 2012
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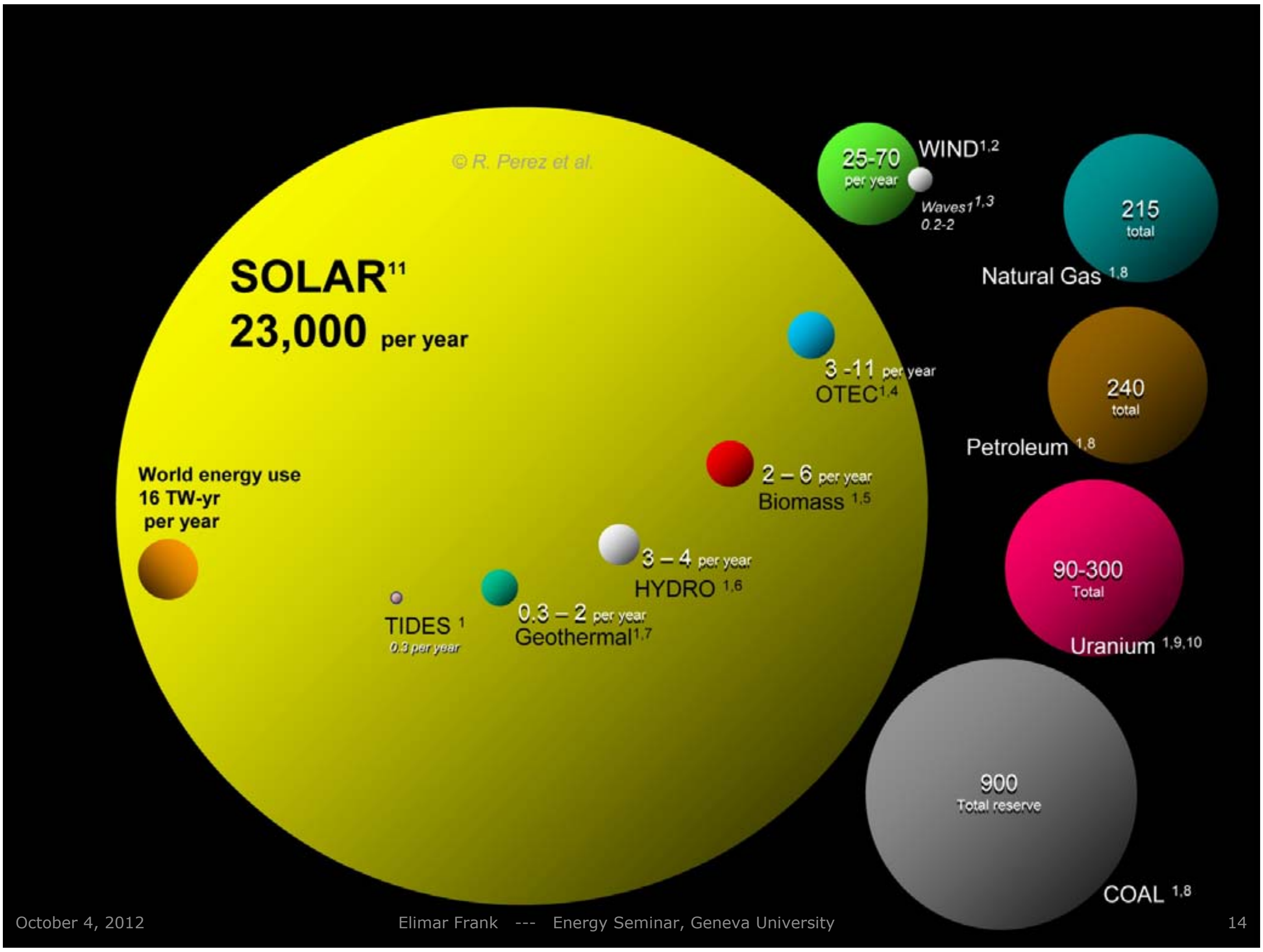

© R. Perez et al.
SOLAR11
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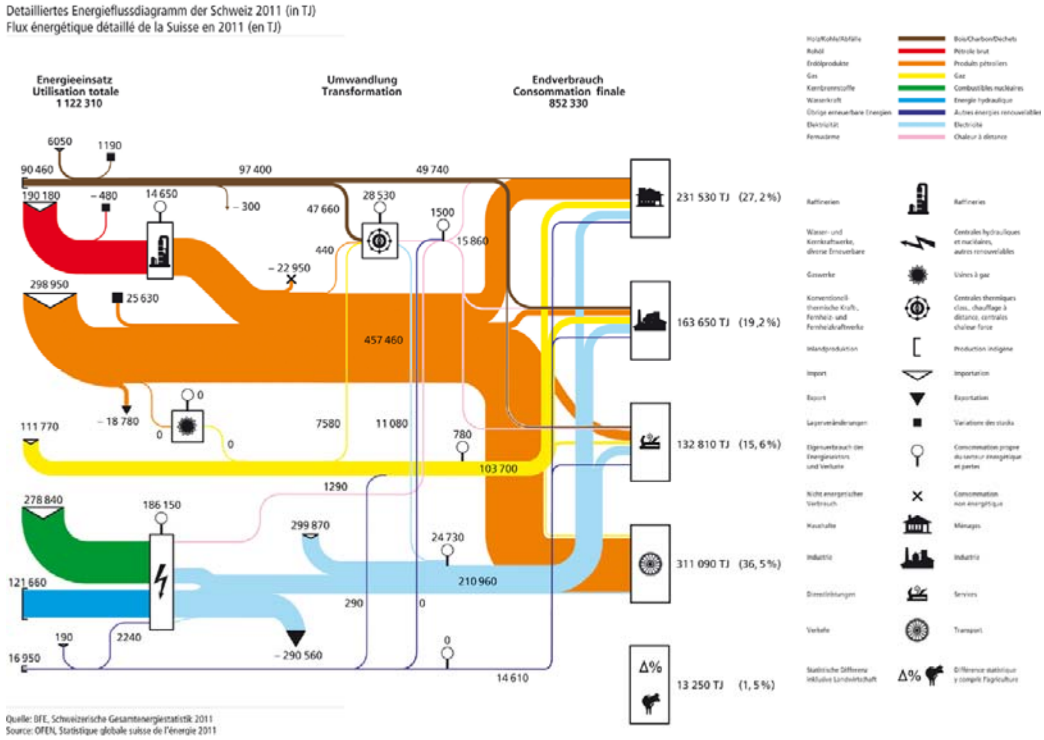
Why use solar thermal energy?



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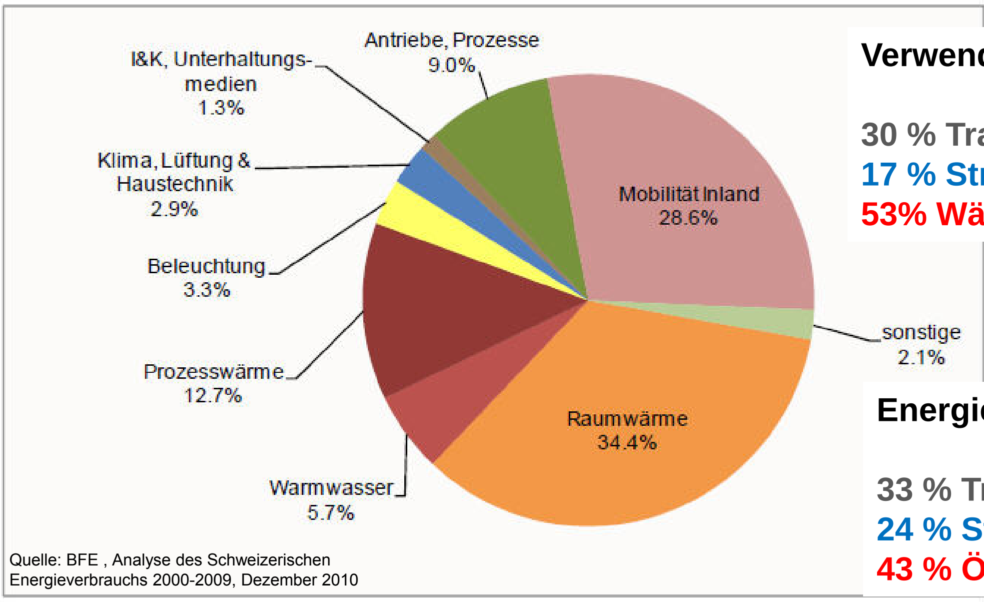
Why use solar thermal energy?

Energy use in Switzerland (2009)



Verwendungszweck:

30 % Transport
17 % Strom
53% Wärme

Energieträger:

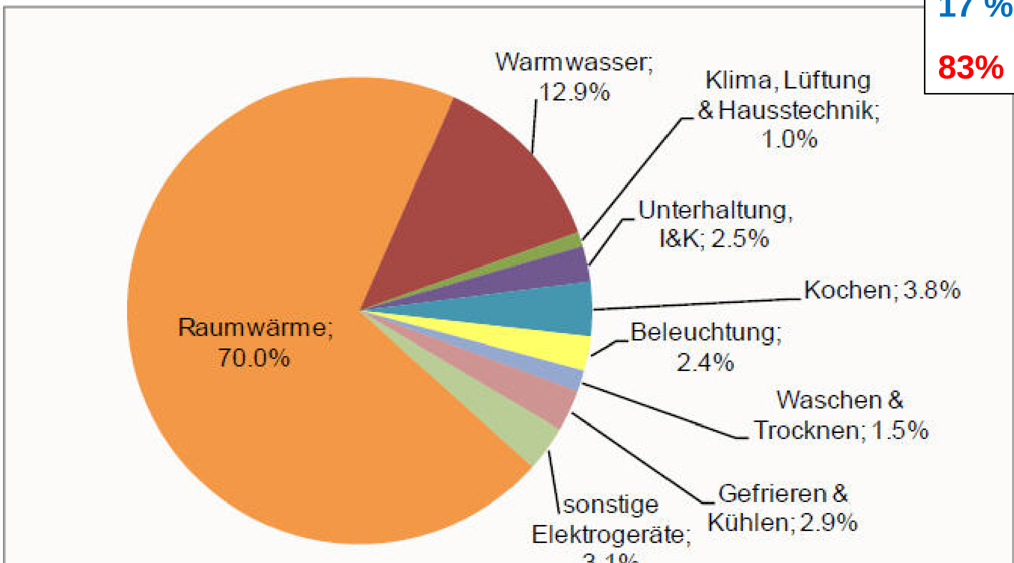
33 % Treibstoffe
24 % Strom
43 % Öl, Gas, Rest

Why use solar thermal energy?

Energy use in households in Switzerland (2009)

17 % Electricity

83% Heat



Quelle: BFE , Analyse des Schweizerischen Energieverbrauchs 2000-2009, Dezember 2010

Solar Thermal Worldwide

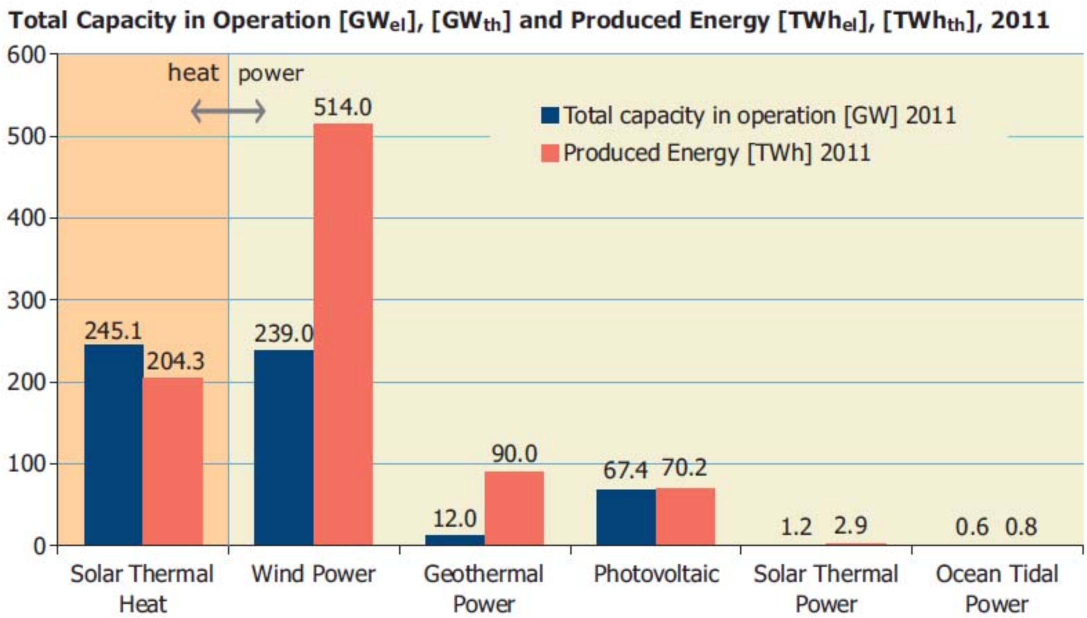


Figure 2: Total capacity in operation [GW_{el}], [GW_{th}] 2011 and annual energy generated [TWh_{el}], [TWh_{th}].

Sources: EPIA, EGEC, Earth Policy Institute, IEA SHC 2011, WWEA

Solar Thermal Worldwide

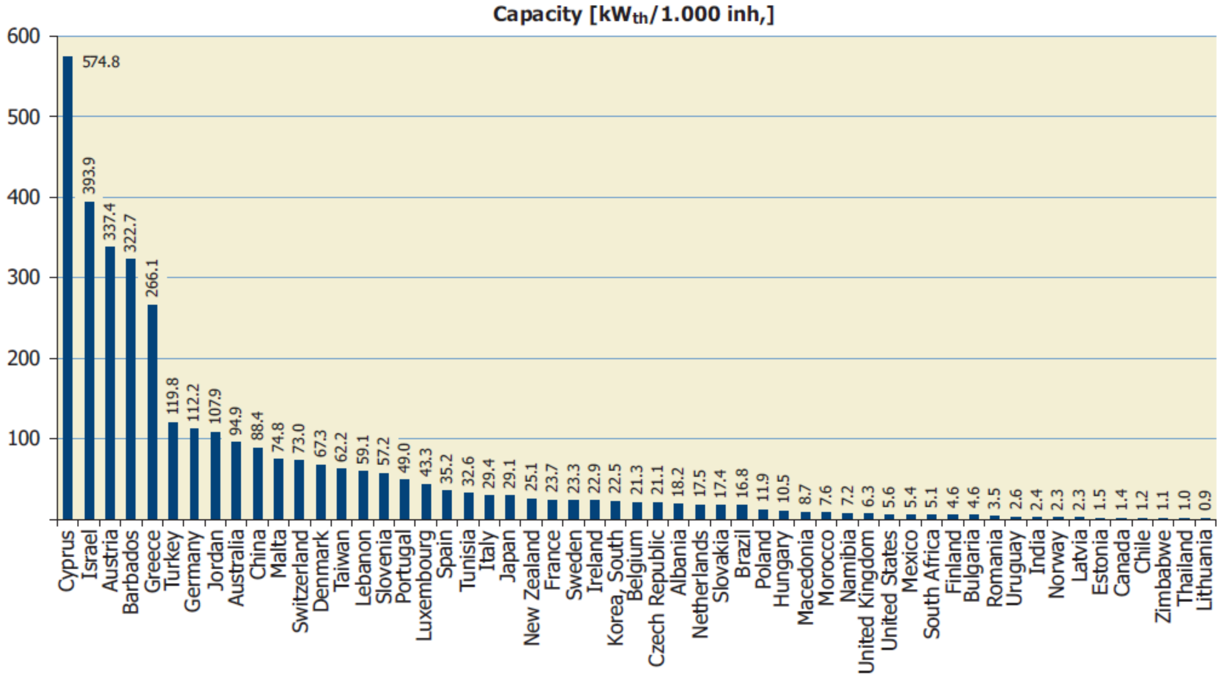
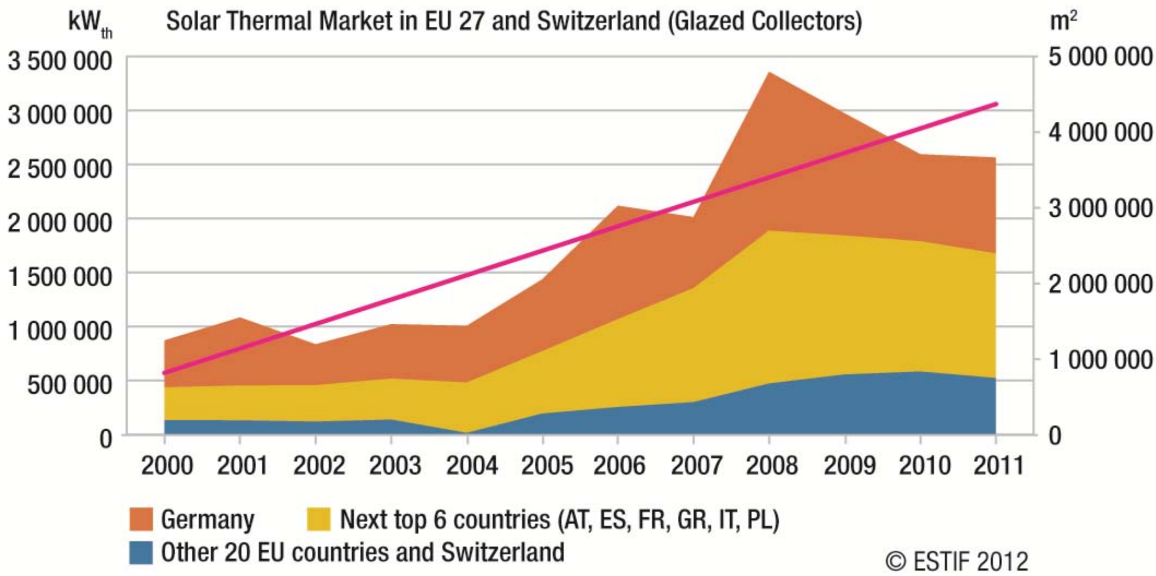
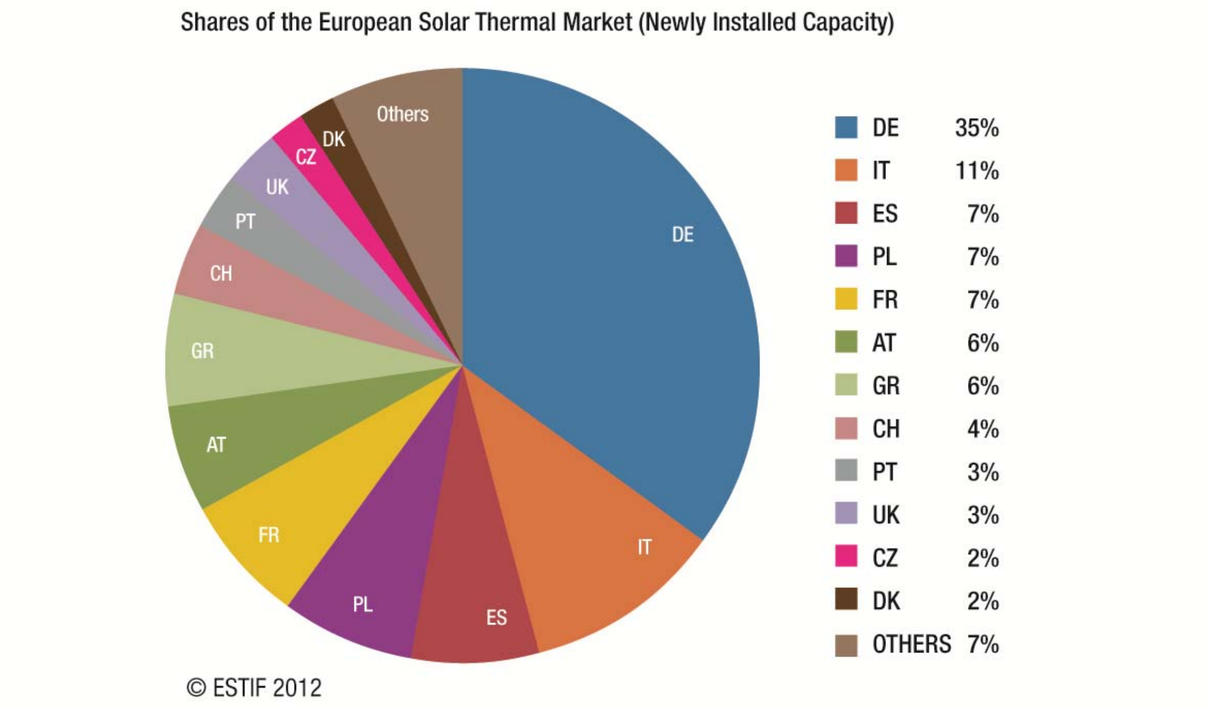


Figure 7: Total capacity of glazed flat plate and evacuated tube collectors in operation in kW_{th}

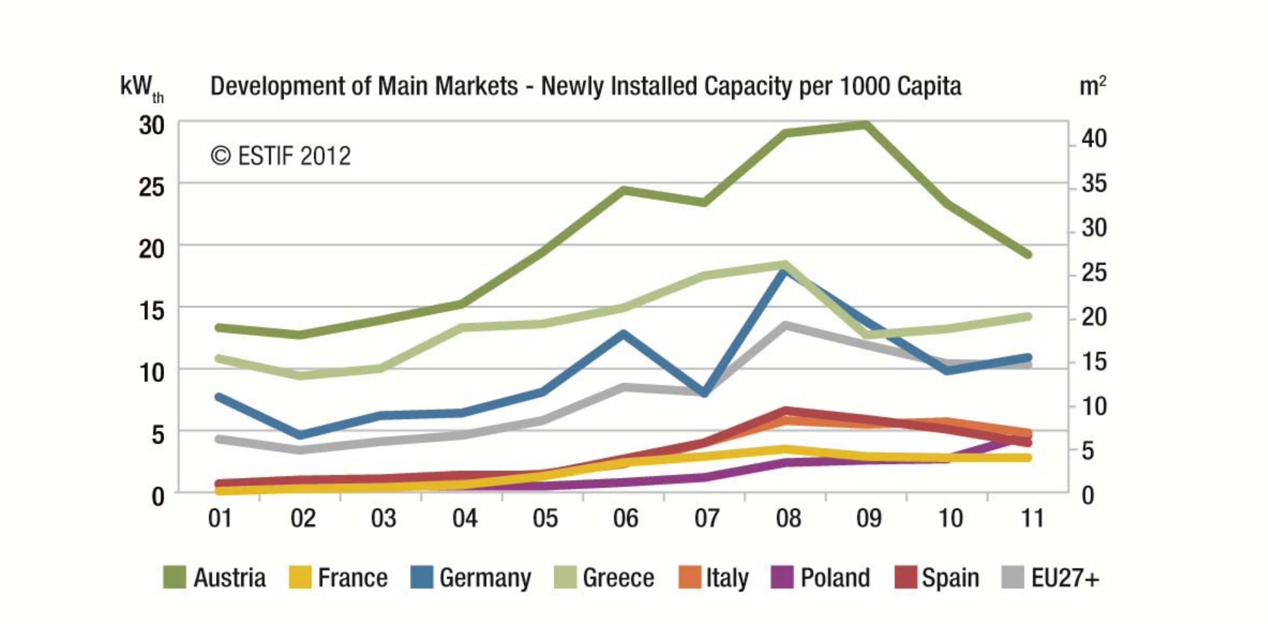
Solar Thermal EU 27+CH



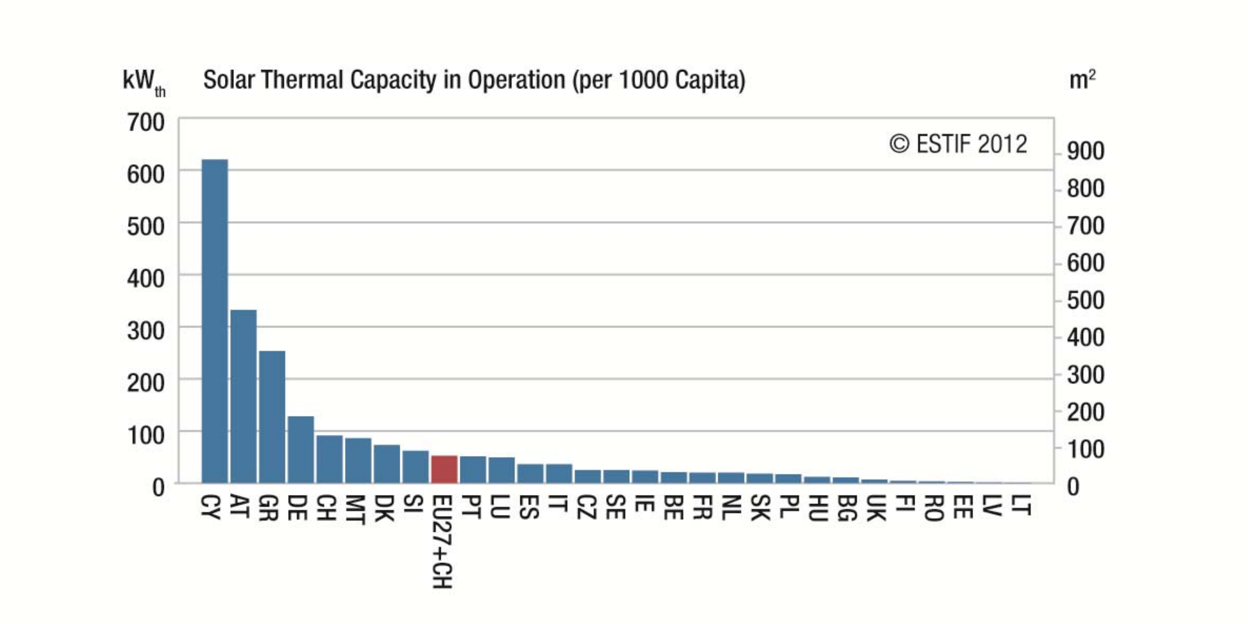
Solar Thermal EU 27+CH



Solar Thermal EU 27+CH

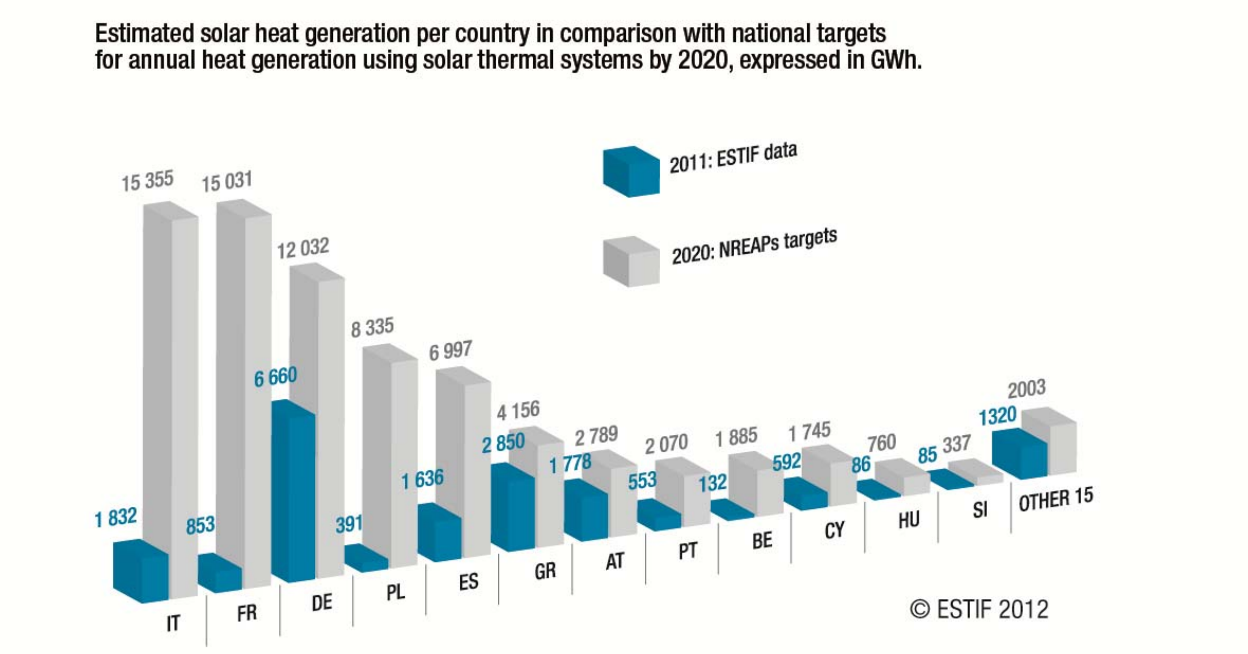


Solar Thermal EU 27+CH



Switzerland: about 1 Mio m2 installed (2012), currently about 200'000 m2/a

Solar Thermal EU 27+CH



Why use solar thermal energy?

The European solar thermal market remained static in 2011, close to the 2.6 GWth installed in 2010

Some important markets continued to grow such as the biggest European market, Germany, and also Poland. Others went through a very difficult time, especially in Southern European countries, such as Italy, Spain and Portugal; however, Greece bucked this trend with a slight market growth. There were some positive developments for both large and very systems, but these alone cannot offset the downturn experienced in more traditional market segments.

With almost 2.6 GWth installed in 2011, the total installed capacity in Europe is now 26.3 GWth, generating 18.8 TWh of solar thermal energy while contributing to savings of 13 MMt CO2. Despite the impact of the economic and financial crisis, the solar thermal sector still shows an average growth of 3.9% and 9.0% over the last five and ten years, respectively

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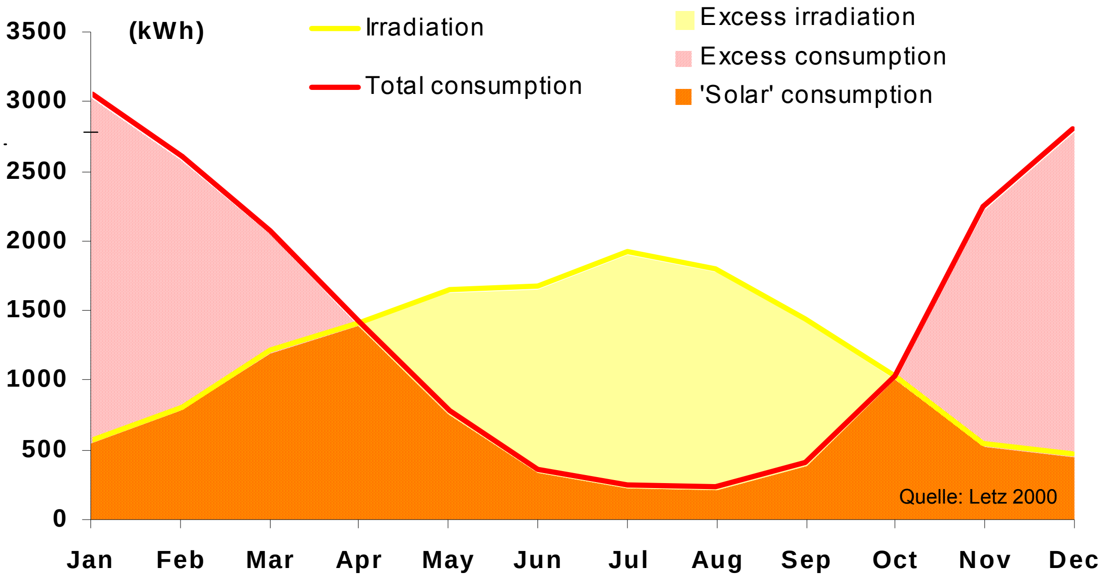
Applications of solar thermal energy

- Drying
- Cooking
- Drinking Water Supply (Desalination, Disinfection)
- DHW supply
- Space Heating
- Cooling
- Process Heat
- Solar Thermal Electricity (e.g. CSP)
- (Very) High Temperature Applications, e.g. material research
- …

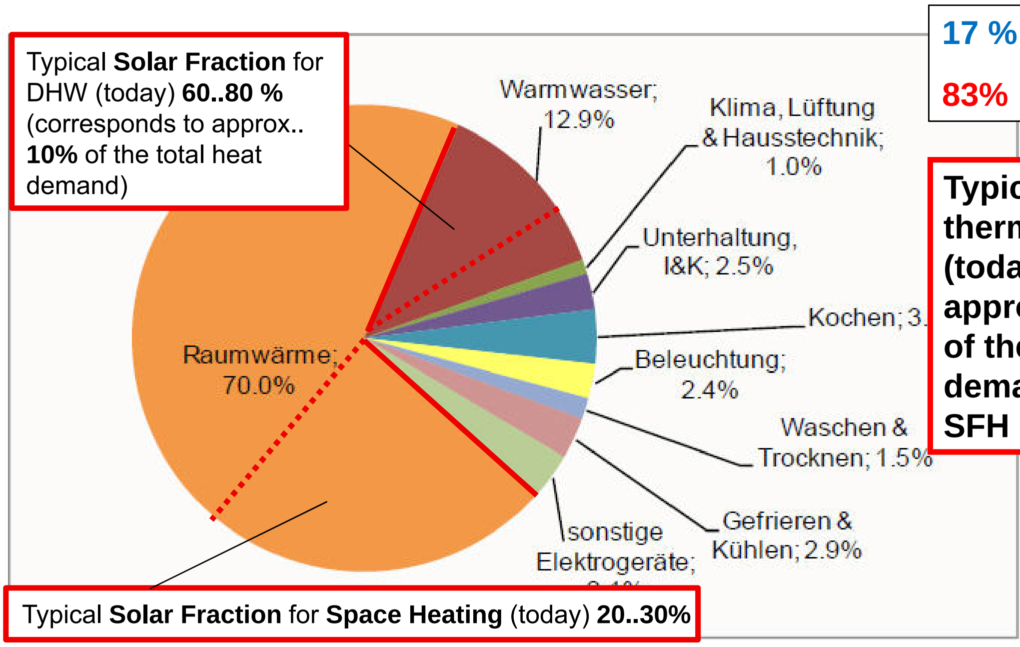
Availability and Use of Solar Thermal Energy

Example: Single Family House in Central Europe



Availability and Use of Solar Thermal Energy

Energy use in households in Switzerland (2009)



17 % Electricity

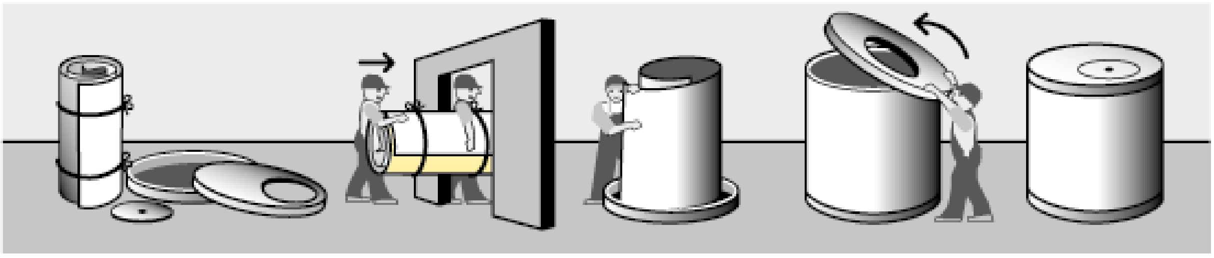
83% Heat

Typical solar thermal system (today) covers approx. 25..35% of the HEAT demand in a SFH

High Solar Fractions with large(r) Water Storages

New Storage Concepts for larger volumes

- For retrofitting (e.g. Fsave, Haase)



High Solar Fractions with large(r) Water Storages

New Storage Concepts for larger volumes

- To put outside or in the ground

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High Solar Fractions with large(r) Water Storages

«Jennihaus» 100% Solarwärme (267m² Kollektor, 205m³ Speicher)

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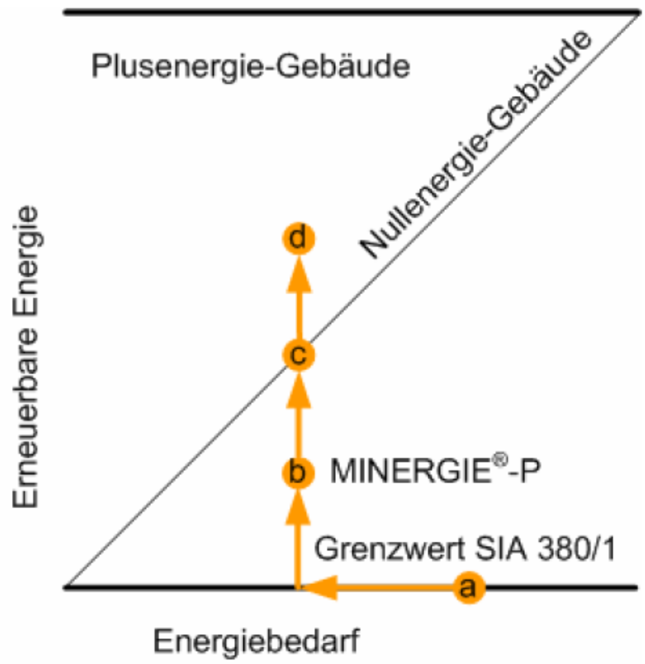
Energetische Gebäudekonzepte



Quelle: M. Hall, Nullenergie-Gebäude – die nächste Generation energieeffizienter Bauten. Brenet-Statusseminar, 2010.

Konzept „Aktiv-Solarhaus": Definitionen

Z.B. „Sonnenhaus"

Sonnenhaus-Kriterien:

Dämmstandard (Transmissionswärmeverlust):
Neubau: H_T' max. 0,28 W/m²K (entspricht Grenzwert EnEV 2009 minus 30%)
Gebäudebestand: H_T' max. 0,40 W/m²K (entspricht EnEV-Neubaustandard)

Primärenergiebedarf max. **15 kWh/m²a**

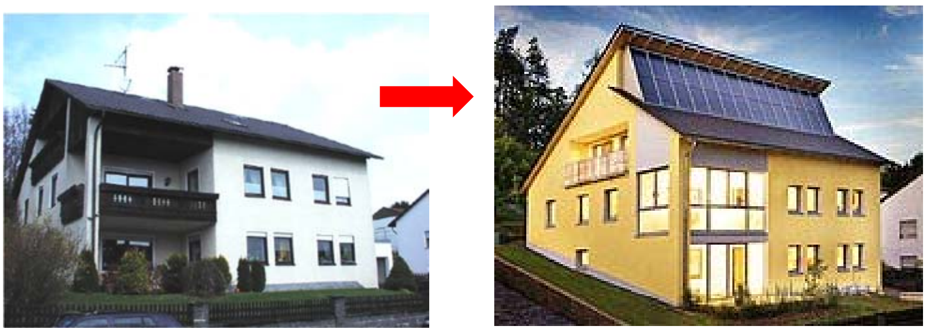
Solarer Deckungsgrad mindestens **50%**

Nachheizung möglichst **regenerativ** (Holz)

Ein steil nach Süden geneigtes Solardach und ein großer, im Wohnbereich integrierter Wassertank sind die prägenden Merkmale der Sonnenhaus-Architektur und Symbole für eine weitgehend unabhängige Energieversorgung.

Quelle: www.sonnenhaus-institut.de

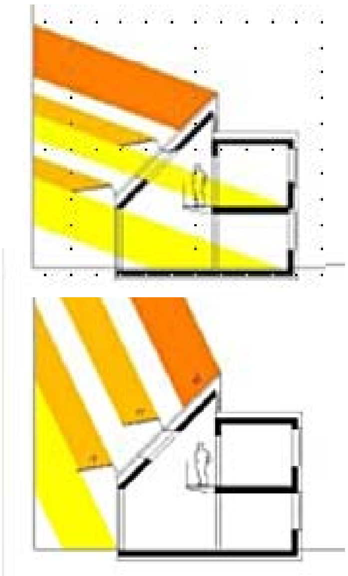
Beispiele „Sonnenhäuser"

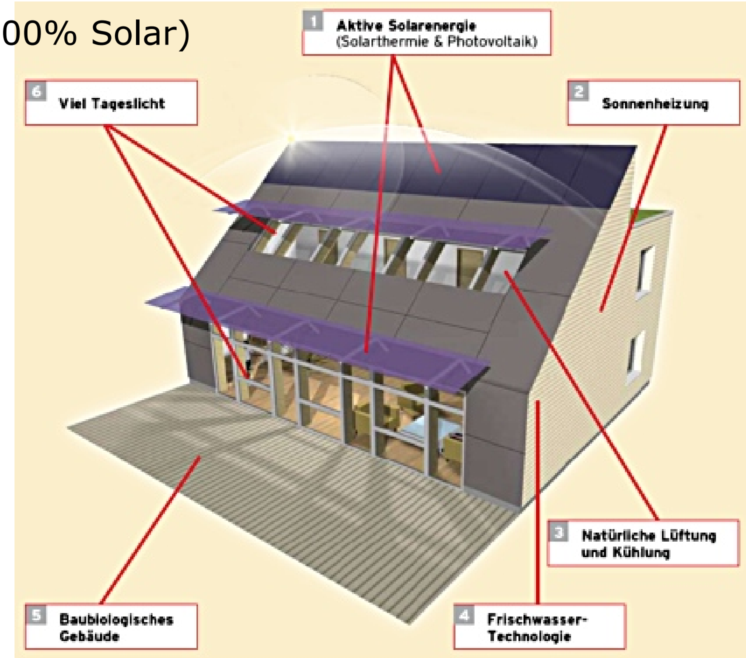


Quelle: www.sonnenhaus-institut.de

Konzept „Aktiv-Solarhaus"

Z.B. „Solar-Aktivhaus" (100% Solar)





Quelle: www.solar-aktivhaus.com

Konzept „Aktiv-Solarhaus": Aspekte

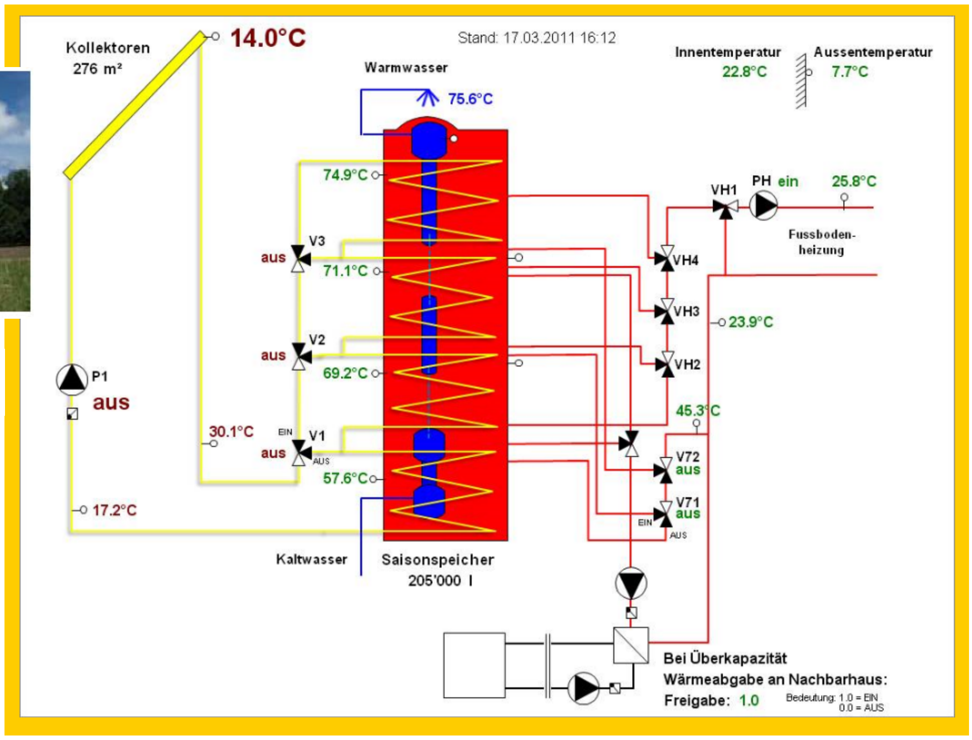
- Aktive und passive Solarenergienutzung:
  >50 und bis zu 100 % Sonne
- Gut gedämmtes Gebäude
- Aktives Heizverteilsystem
- Reduktion der Haustechnik
- Optimierung der Investitions- und Betriebskosten
- Reduktion des Primärenergie-einsatzes für Bau und Betrieb

Quelle: Sonnenhaus-Institut

Quelle: Soli fer

Konzept „Aktiv-Solarhaus": Beispiele

Quelle: www.jenni.ch
17.03.2011, 16:20 Uhr



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Konzept „Aktiv-Solarhaus": Beispiele

24. Februar 2011 • 346 Solarthemen

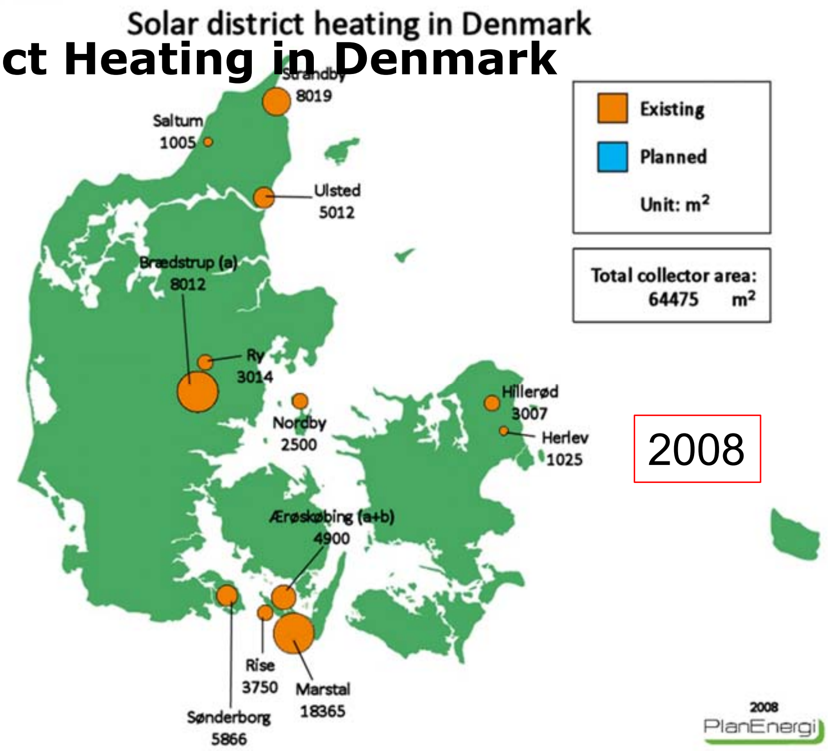
...mietern empfohlen

...haberstückes für engagierte Ökos an. Zunehmend mehr Mehrfamilienhäu-

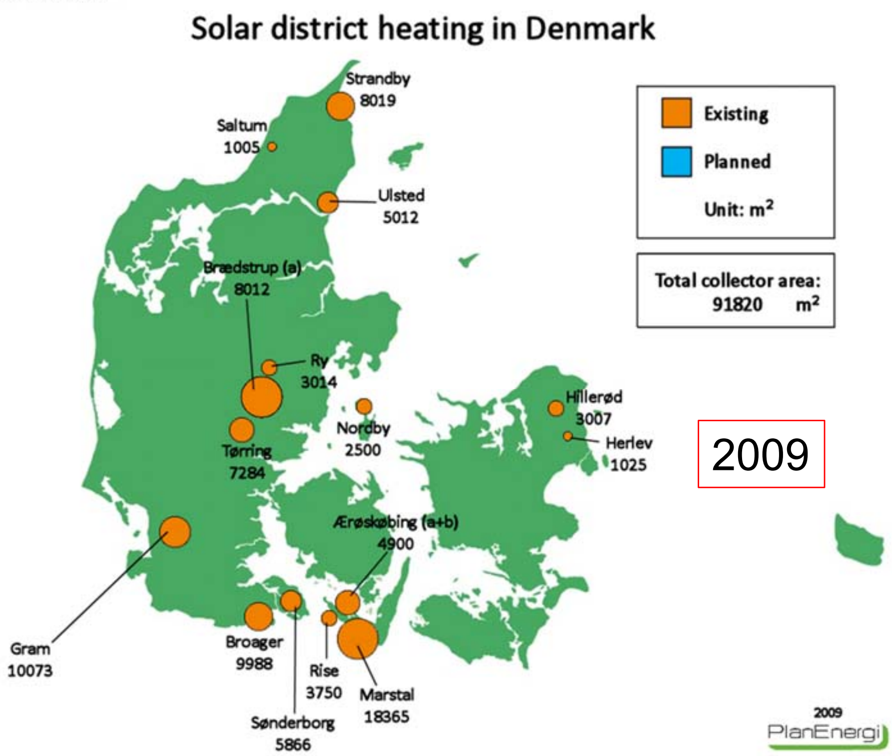
...hraufwand bedeu- ...anderen Sonnen- ...ntuell an wenigen Tagen im Jahr erforderliche Nicht-Solarenergie etwa über einen Pellets-

gibt es kaum Beispiele. Nur der Solar-pionier Josef Jenni wagte sich zuvor – im Jahr 2007 – an den Bau eines Mehrfamilienhauses heran, das zu 100 Prozent allein durch solarther-

District Heating in Denmark

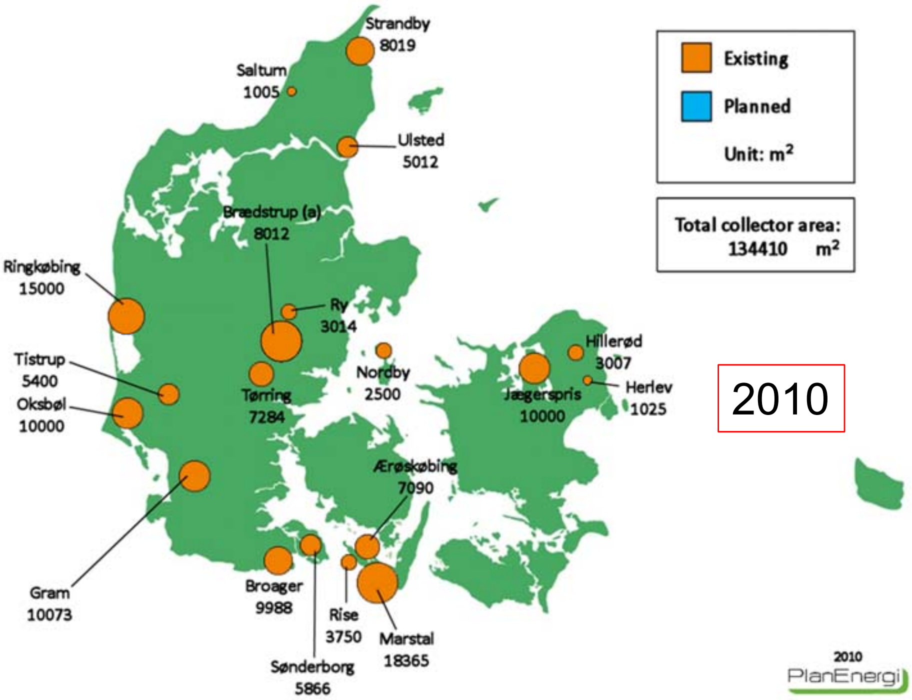


2008



2009

Solar district heating in Denmark



2010

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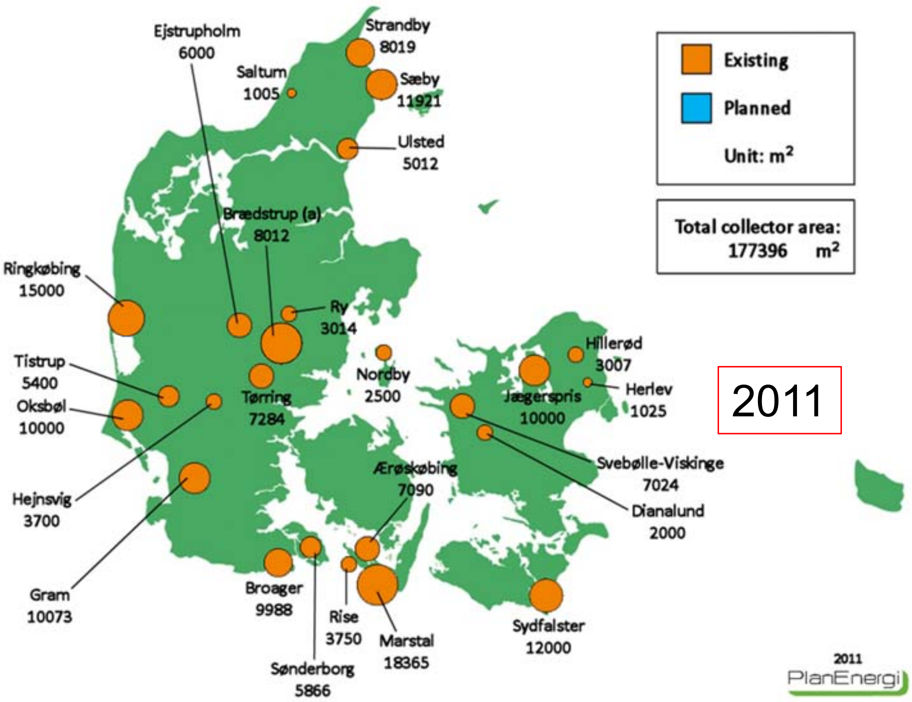
Solar district heating in Denmark



2011

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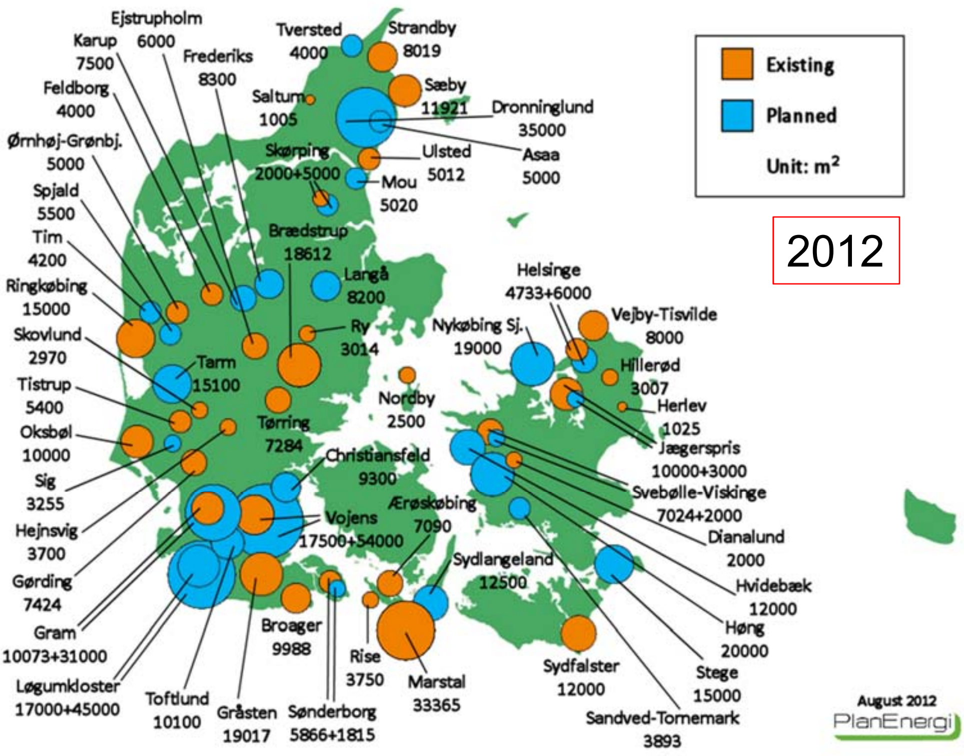
Solar district heating in Denmark



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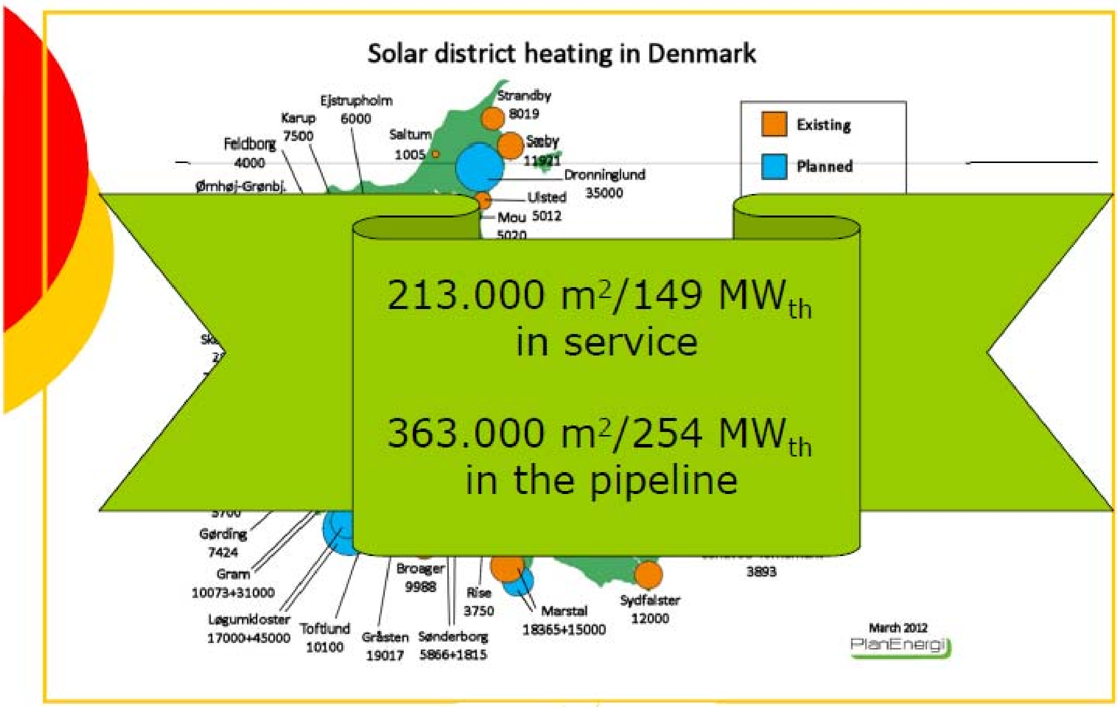
District Heating in Denmark



District Heating in Denmark

Why does the large scale solar technology explode in Denmark??

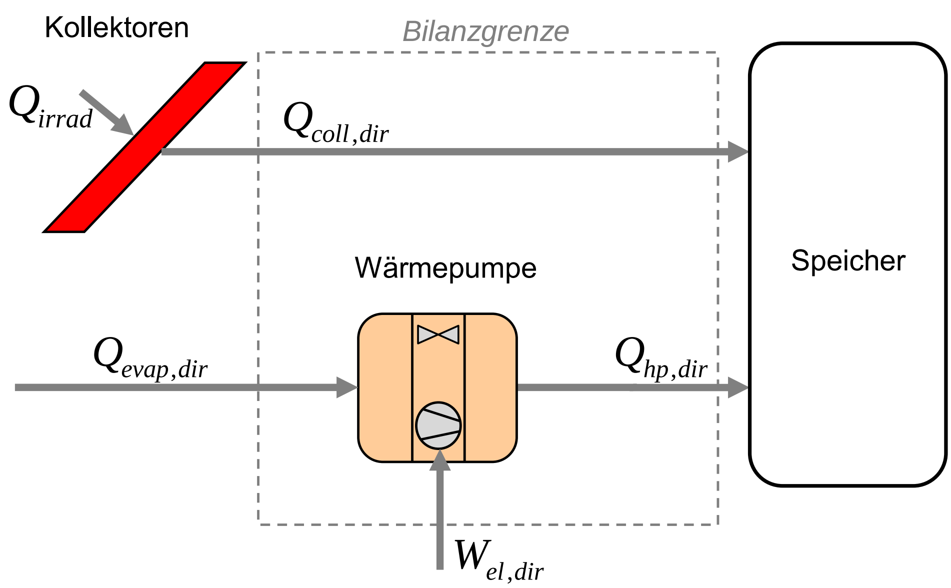
1. The experiences of large scale solar in combination with district heating CHP very are good
2. The maintenance work is minimal
3. The maintenance costs are low:
   approx. 1 EUR/MWh heat
   (3 – 4 kWh electricity pr. produced MWh heat)
4. Costs - all-Inclusive (included capital costs - 20-year loan of 3% real rate):
   30 – 40 EUR/MWh heat

Production in Denmark: 450 kWh/m2

Combining Solar Thermal with Heat Pumps

Direct Use of Heat from the Collectors

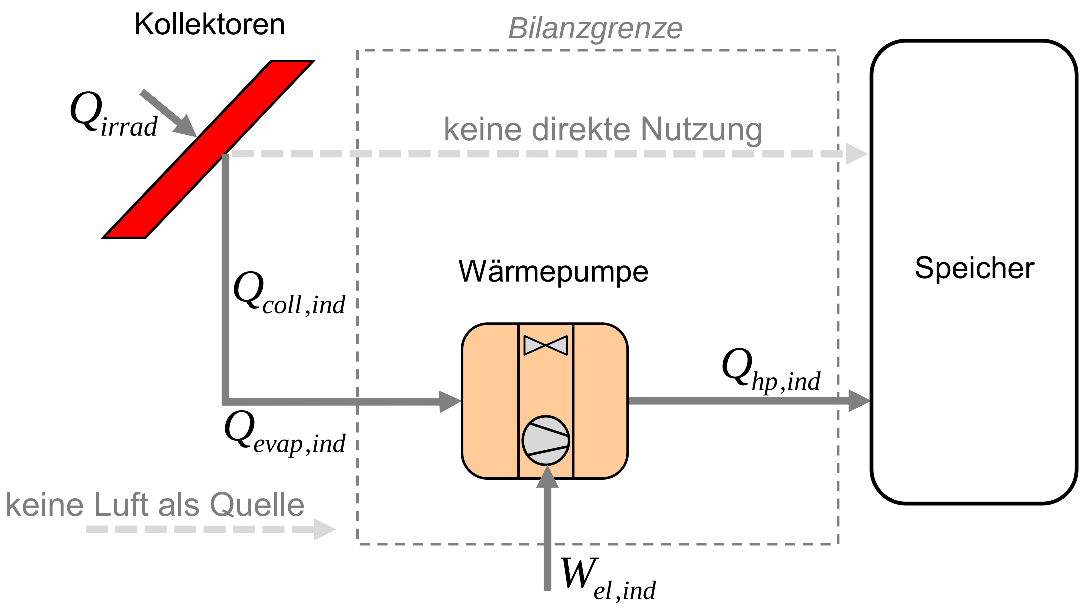
(parallel to the operation of a Heat Pump)



Combining Solar Thermal with Heat Pumps

Direct Use of Heat from the Collectors

(Solar Heat for the Evaporator of the Heat Pump)



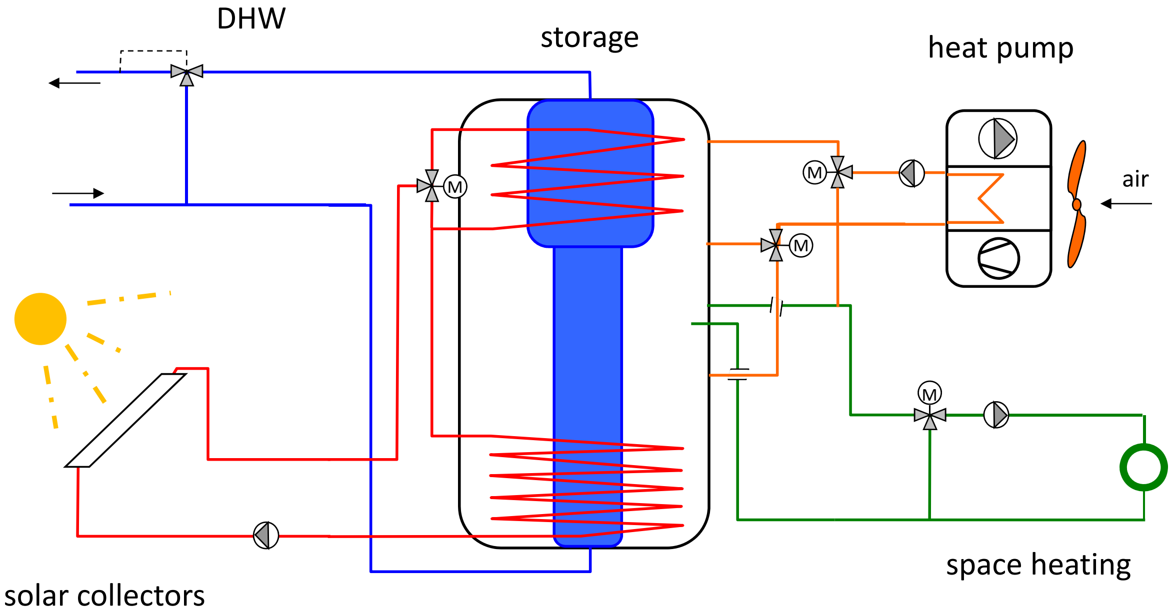
Combining Solar Thermal with Heat Pumps

What is different for a parallel integration?

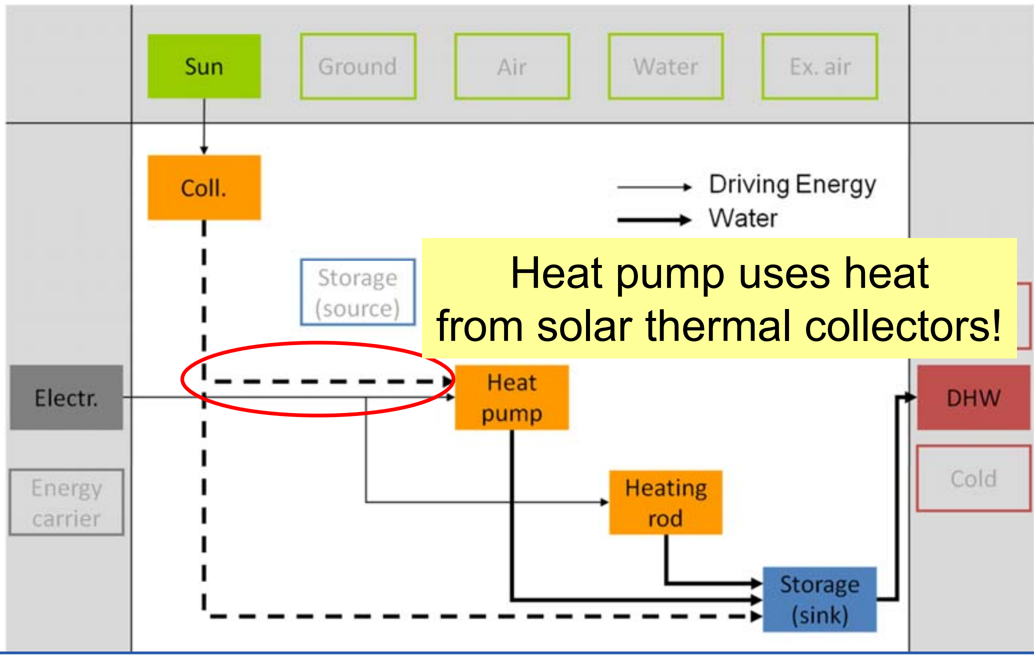
- ***Hohe Volumenströme*** des Heizmediums (3-5 x grösser als bei Öl-, Gas- oder Pelletskesseln)
  - (z. Bsp. ***1500 lt/h anstatt 400 lt/h***)
  - ***Speicheranschlüsse*** / ***Wärmetauscher*** müssen dafür ausgelegt sein (***keine Durchmischung im Speicher***)
- ***20 K erhöhte Betriebstemperatur*** führt zu ***40-60% mehr Strombedarf*** (bei kondensierenden Öl- oder Gaskesseln: nur ca. 5-8% mehr Brennstoffbedarf)
- Zumindest bei kleinen Wärmepumpen meistens keine Modulation* der Heizleistung / ***Ein-Aus-Betrieb?***

Combining Solar Thermal with Heat Pumps

Well-functioning parallel system concept

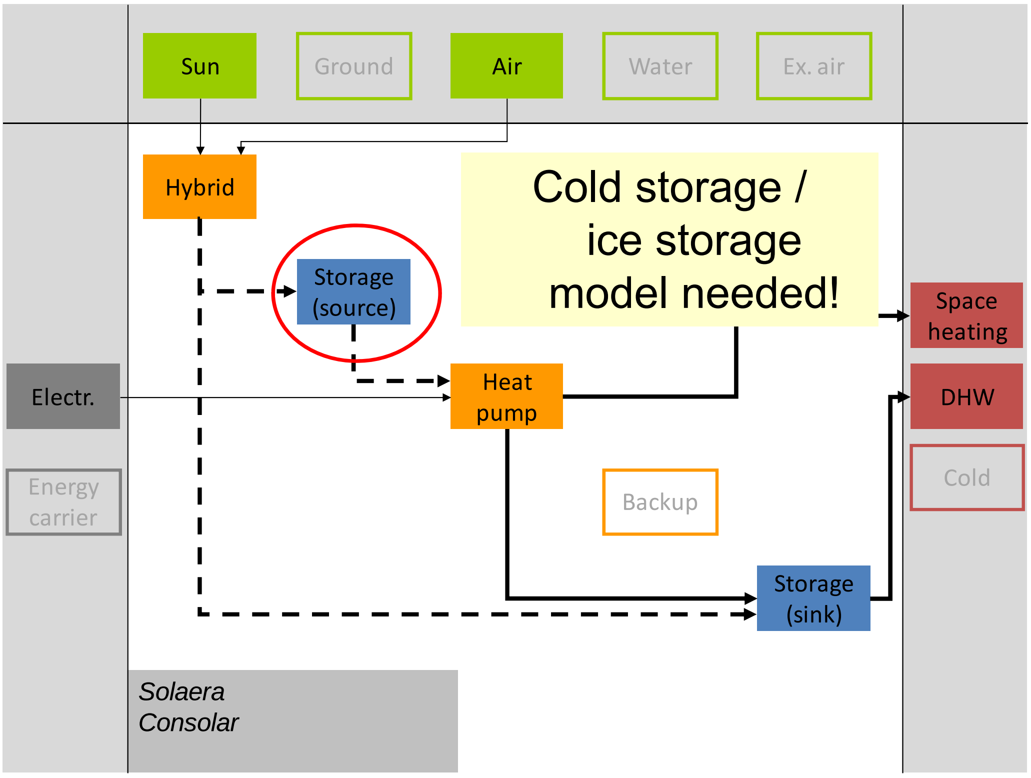


Special system concepts: Collector heat use



For further explanation of the System Square View download publication from www.spf.ch:
E. Frank, M. Haller, S. Herkel, J. Ruschenburg: Systematic Classification of Combined Solar Thermal and Heat Pump Systems. In: Proceedings of ISES EuroSun Conference, Graz/Austria, 2010

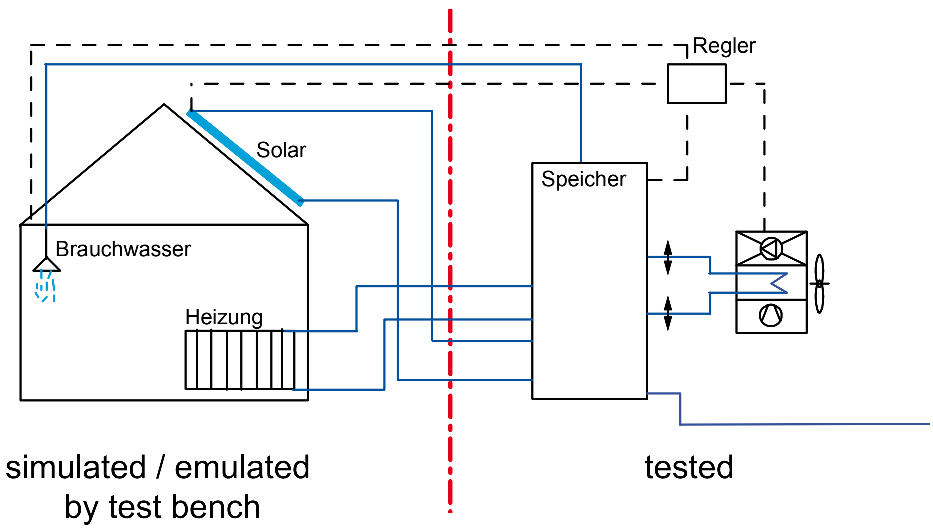
Special system concepts: Ice storage



How to test whole systems?

Install a complete heating system on the test rig.

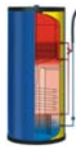
Emulate realistic boundary conditions of climate and a typical load.



Concise Cycle Test (CCT) ersetzt Feldmessungen!

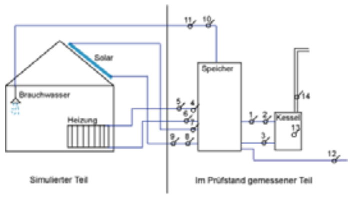
1. Kurzer Test an Komponenten

Wärme-pumpe

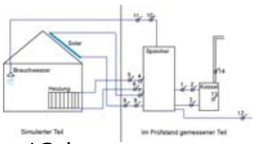


Speicher

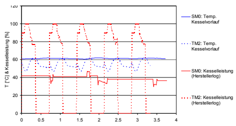
2. 12-Tages System-Test



3. Modellbildung und Validierung (optional)

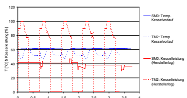


12d

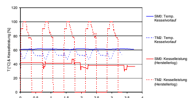


12d

4. Jahressimulation (TRNSYS, optional)



12d validiert



365d

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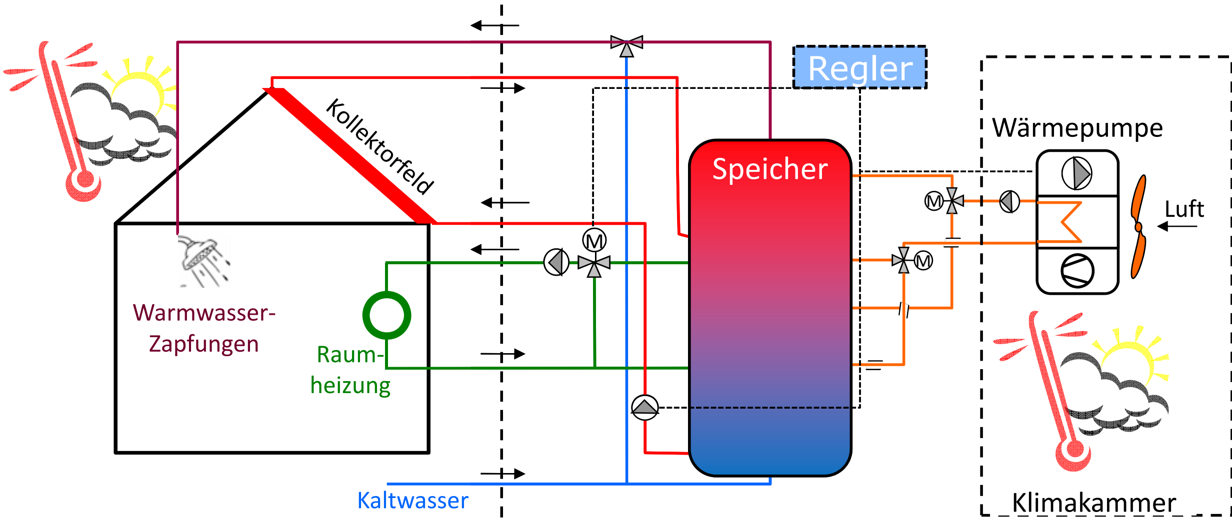
Was wird geprüft im 12-Tages-Test

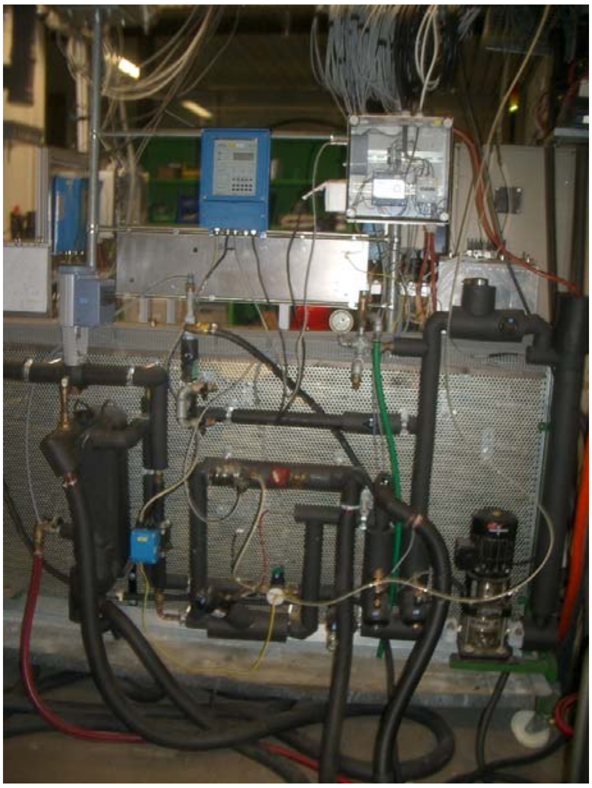
Voraussetzung: Kollektoren müssen EN12975 geprüft sein (Leistungsdaten werden verwendet)



Simulation und Emulation durch Teststand SPF

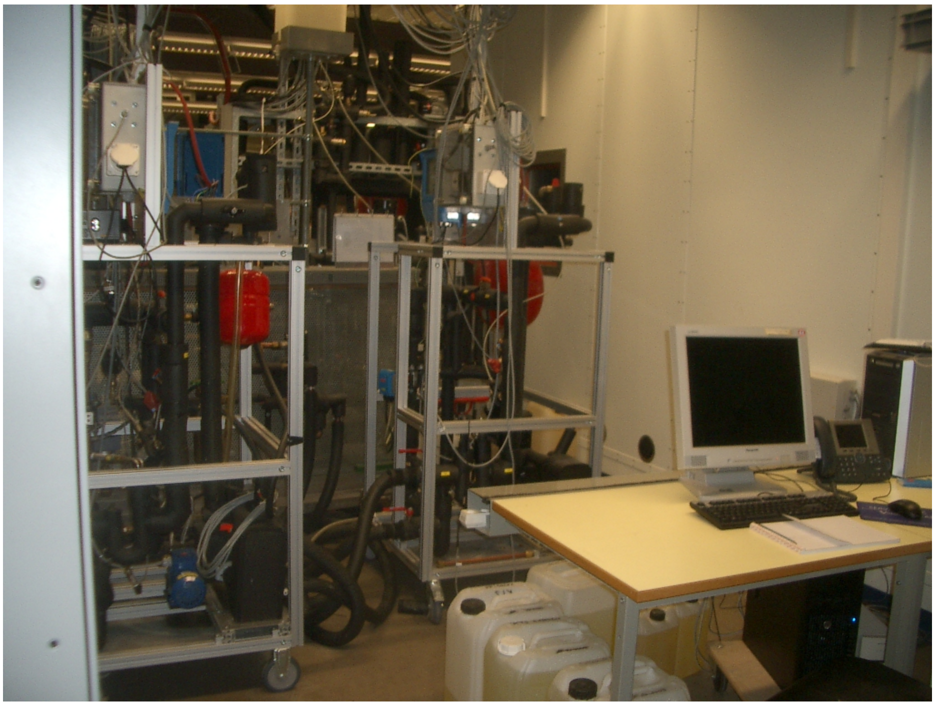
Installation durch Hersteller im Test-Kellerraum

Climatic chamber for system testing ST+HP



Testing facilities for Concise Cycle Tests

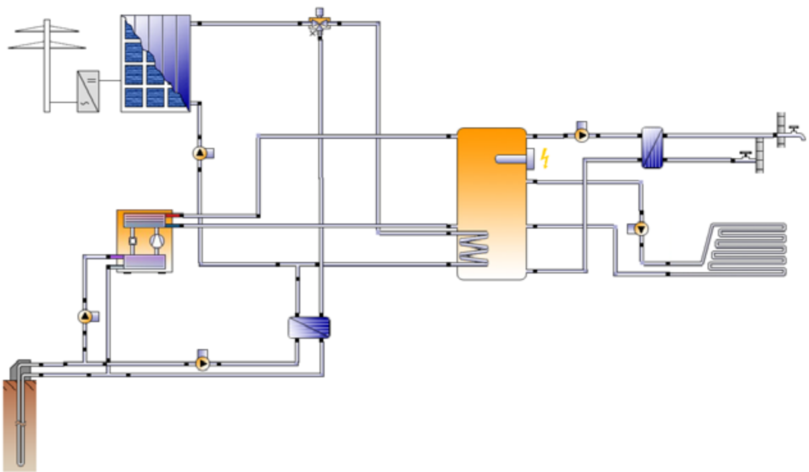
CCT-Testing facility



PV/T Kollektoren

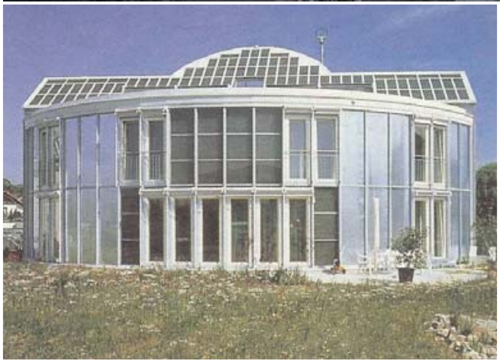
Strom und Wärme aus einem Kollektor

(abgedeckt, nicht abgedeckt)



Quelle: 3s Photovoltaics

Why PVT?



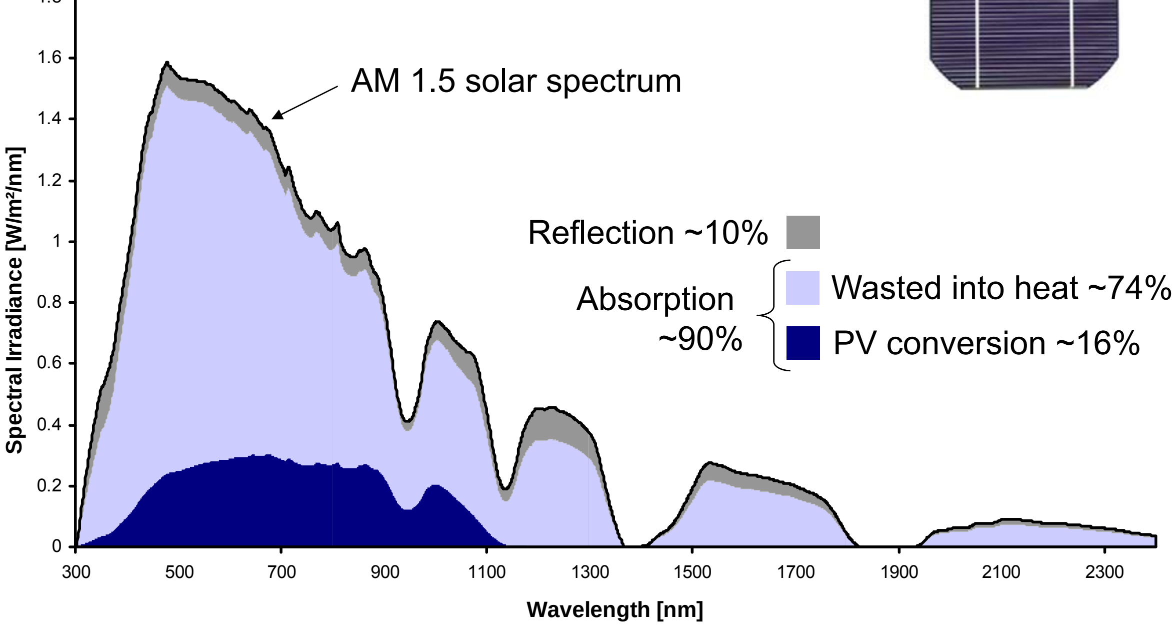
All buildings need electricity and heat.

PV-modules convert only about 15% of the solar radiation into electricity and about 75% into waste heat.

Solar radiation is used most efficiently with PVT-collectors.

In the future, the solar radiation which is available on the envelope of a building must be used as efficient as possible for:
- electricity
- heat
- daylighting

Spectral properties of a sc-Si cell



Graphical representation based on actual measurements (reflection, EQE and I-V)

Source:
Dupeyrat, Fraunhofer ISE

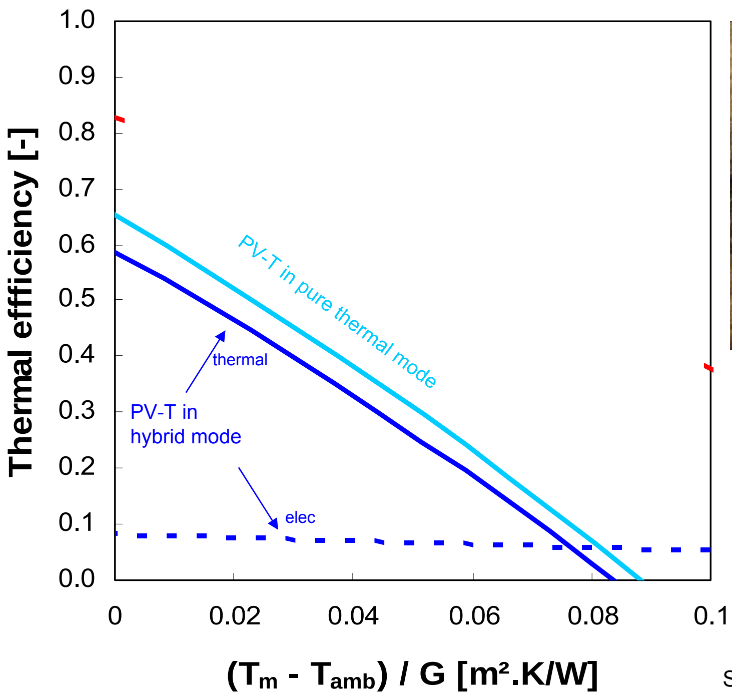
Overview on Development of PV-T collectors

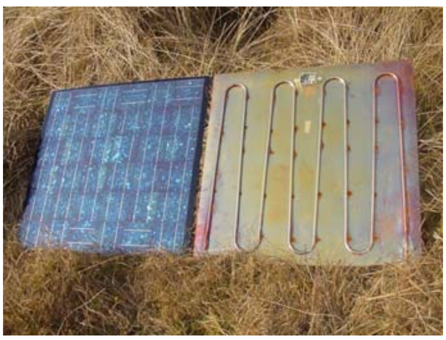
1. Glazed PVT flat-plate collectors for domestic hot water applications

2. Unglazed PVT-collectors for application in combined solar thermal and heat pump systems

3. (Concentrated PVT)

Efficiency curves of a single glazed PVT flat-plate collector

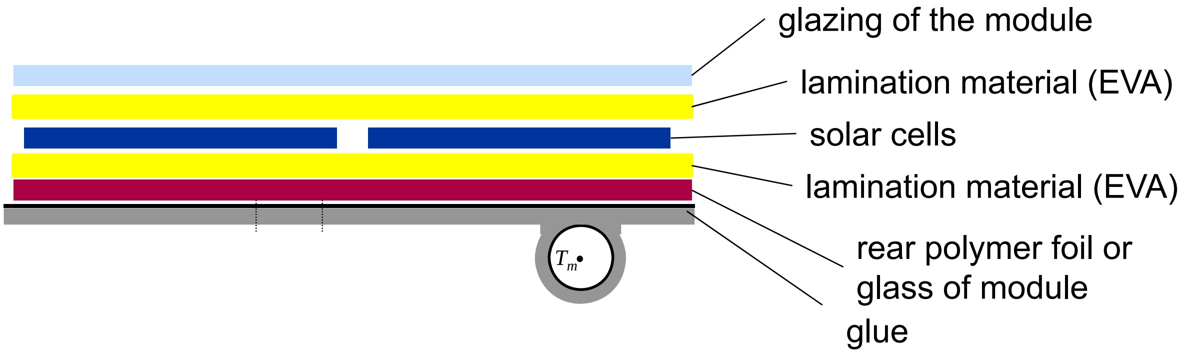




Source: ECN

Source: Dupeyrat, Fraunhofer ISE

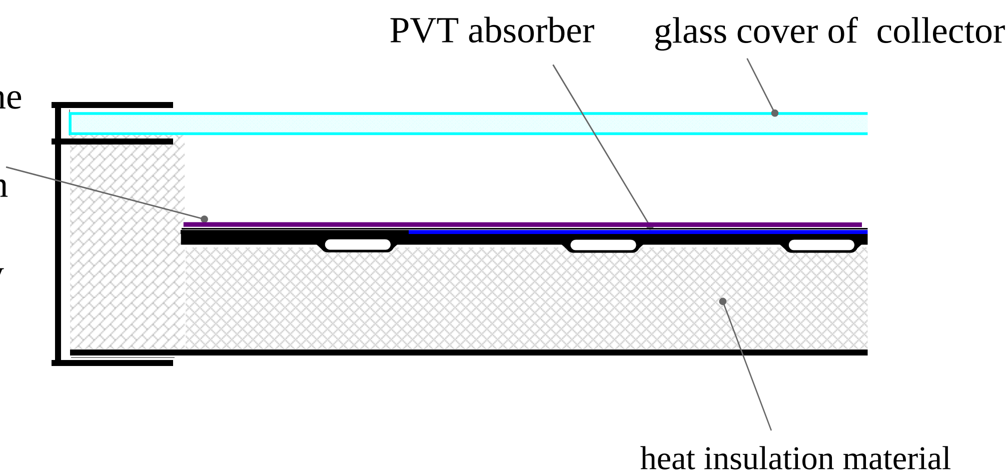
Technical challenges for improved η_0-values



- Low heat resistance between solar cells and collector fluid
- Direct lamination of cells on metallic heat transfer sheet
- absorber constructions with high F' values
  (not fin-and tube absorbers but fully wetted absorbers
  or aluminium roll bond absorbers)

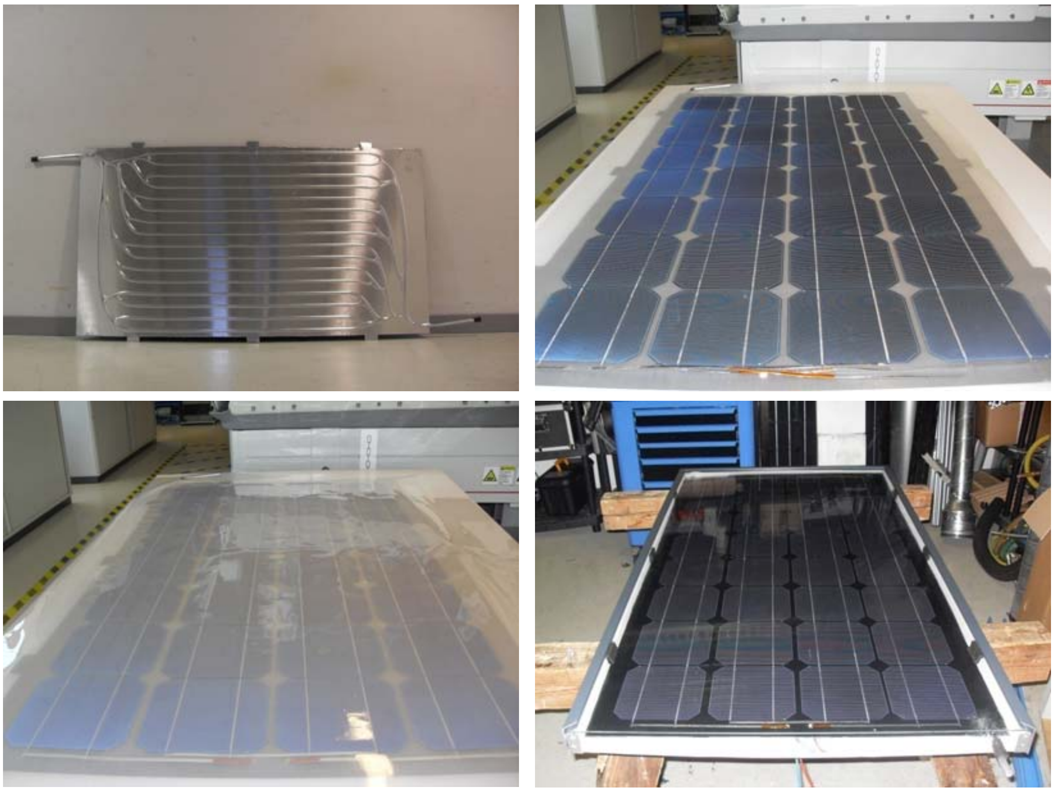
Possibilities for optical improvements because glass is not necessary to protect the PVT absorber

FEP-foil improves the absorbed radiation on the PVT absorber by 3% .



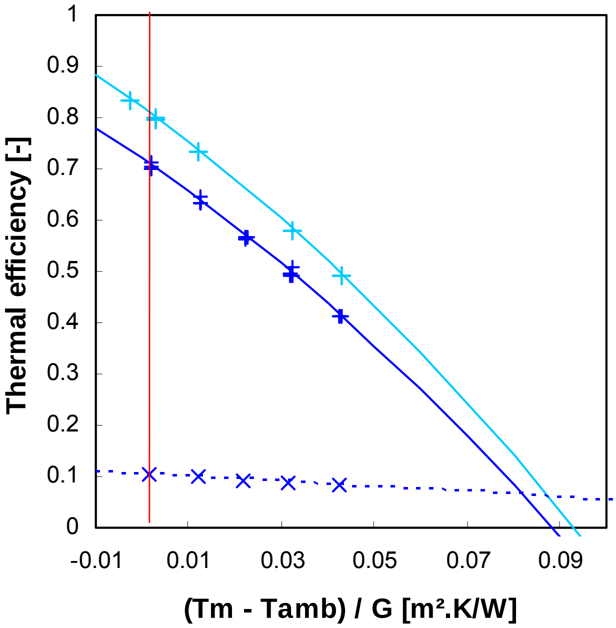
The glass cover on the PVT absorber is not necessary because:

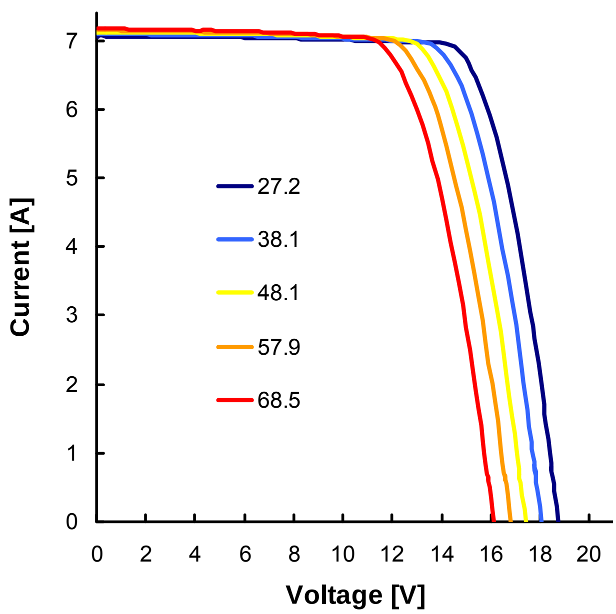
1. the mechanical stability ist provided by the metallic heat transfer sheet
2. Protection against hail and mechanical loads such as snow is provided by the glass cover of the collector.



Source:
Dupeyrat, Fraunhofer ISE

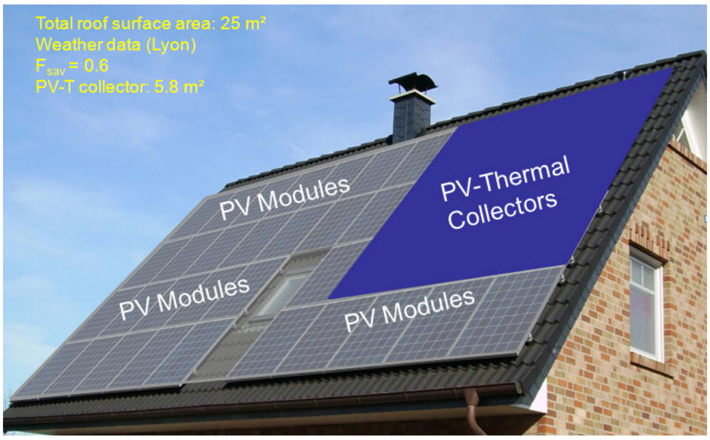
Measurement results of protptype PVT collector





Source:
Dupeyrat, Fraunhofer ISE

Simulation results for the prototype PVT collector in a specific DHW application



Result:
The roof produces 13% more electricity with PVT-collector and the same heat gain

	$Q_{elec(total)}$ [kWh]	F_{sav} [-]	PES [kWh]	Exergy [kWh/m²]	Avoided CO_2 [t(CO2)/year]
PV-T Collectors and PV modules	2958	0.60	11248	4006	1.21
Thermal Collectors and PV modules	2626	0.60	10083	3650	1.12

Source: Dupeyrat, Fraunhofer ISE

Glazed PVT-collectors for large multi-family houses

Favorable conditions for applications of glazed PVT collectors are systems with low solar fractions, that means low operating temperatures as in large multi-family houses.

Domestic hot water pre-heating systems

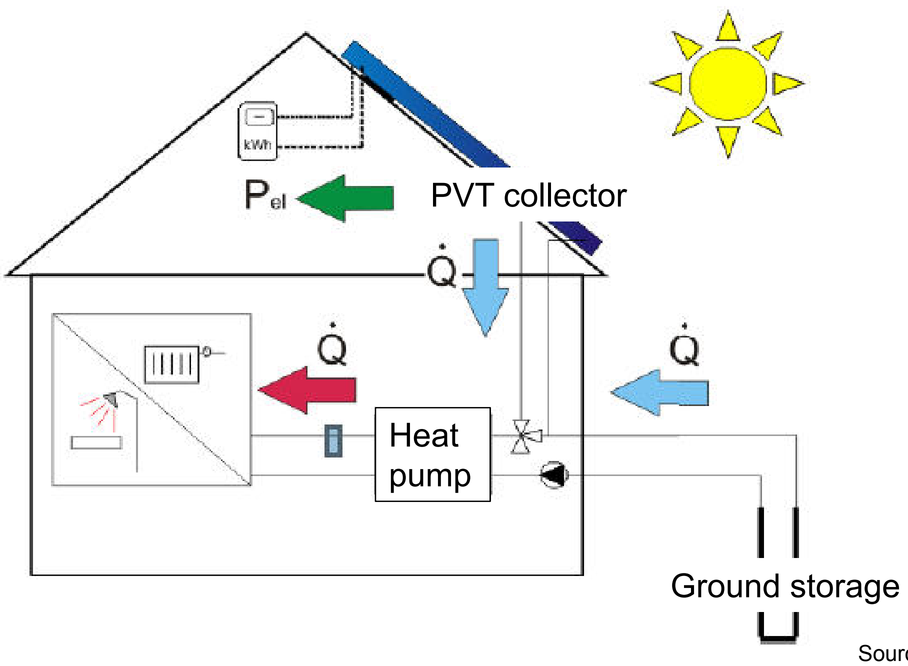
Not PVT collectors but selective flat plate collectors installed in Zurich

Source: Schweizer

Development of glazed PVT-collectors

- η_0-values in the range of 80% may be reached:
  - fully wetted absorbers with high values of F'
  - direct lamination of the cells on the absorber
  - FEP-foils (n=1.3) instead of glass (n=1.5)
  - anti-reflevtively coated glasss as collector glazing
- The thermal performance of non-selective flat-plate collectors are reached.
- low-e coatings on glass may further improve the glazed PVT collectors
- thermally improved collectors may lead to higher stagnation temperatures -> higher stress on PVT-absorber construction and the materials used.
- market: There is a certain highly interested group of end-users and potential buyers but still (not yet?) a fully developed marketable product.

Unglazed PVT-collectors in combination with heat pump and ground storage



Source:
Bertram, ISFH, OTTI 2010

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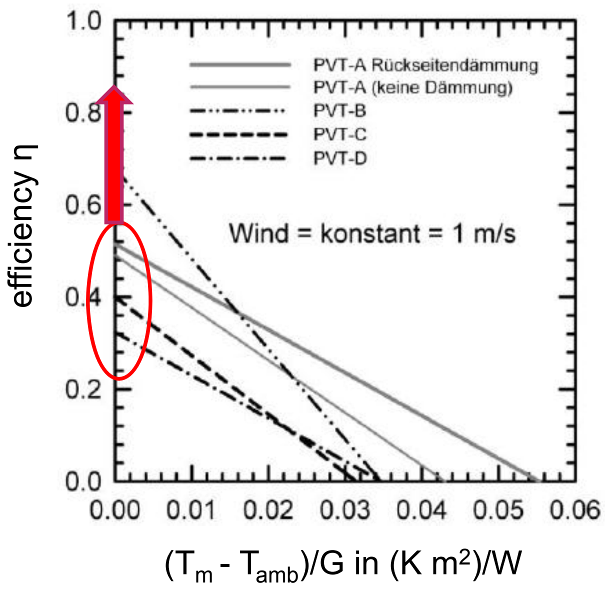
Measured efficiency curves of different unglazed PVT-collectors



Source:
Bertram, ISFH, OTTI 2010

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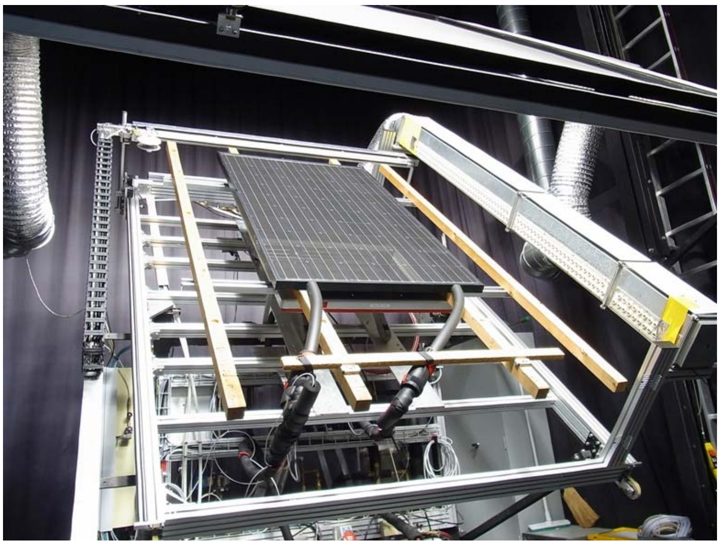
Development of uncovered PVT-collectors at SPF



Measurements on unglazed PVT-collectors at solar simulator laboratory of SPF

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New technical challenges for uncovered PVT collectors because of condensation and ice formation

Uncovered stainless steel absorber from Energie Solaire SA, Sierre, CH

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Development of uncovered PVT-collectors

- The improvement of the heat transfer from the cell to the flluid is decisive:
  - for the solar thermal efficinecy
  - for the cooling of the PV-cell and thus for an improved electrical efficiency
  - for the efficiency of the PVT-collector as air to water heat exchanger
- New challenges for the materials and the module constructions come up due to possible condensation and ice formation when uncovered PVT-collectors are operated in systems with heat pumps.
- Innovative cost-effective hydraulic conectors have to be developed for uncovered PVT-collector systems:
  - maximum temperatures are below 100°C
  - no stagnation conditions with evaporation of the fluid.

Development of uncovered PVT-collectors

- **Systems Heat pumps plus PVT:**
  many concepts are possible which have to be investigated in more detail (ground storage, Ice storage, control strategies…)

- **Market:**
  Good marketing chances exist **for well developed systems** with uncovered PVT collectors and high regenerative energy fractions on the total energy demand of buildings

  ⇒ Solar collectors
  + PV
  + heat pump
  + innovative storages !!!

Applications and Technologies…

… e.g. Solar Heat for Industrial Processes…

… and again: Looking at the whole system is decisive!!

What is «Process Heat»?

Heat that is used for industrial processes:

< 100° C ("low temperature")

- washing, rinsing, drying, food preparation, …
- also: space heating and hot water preparation

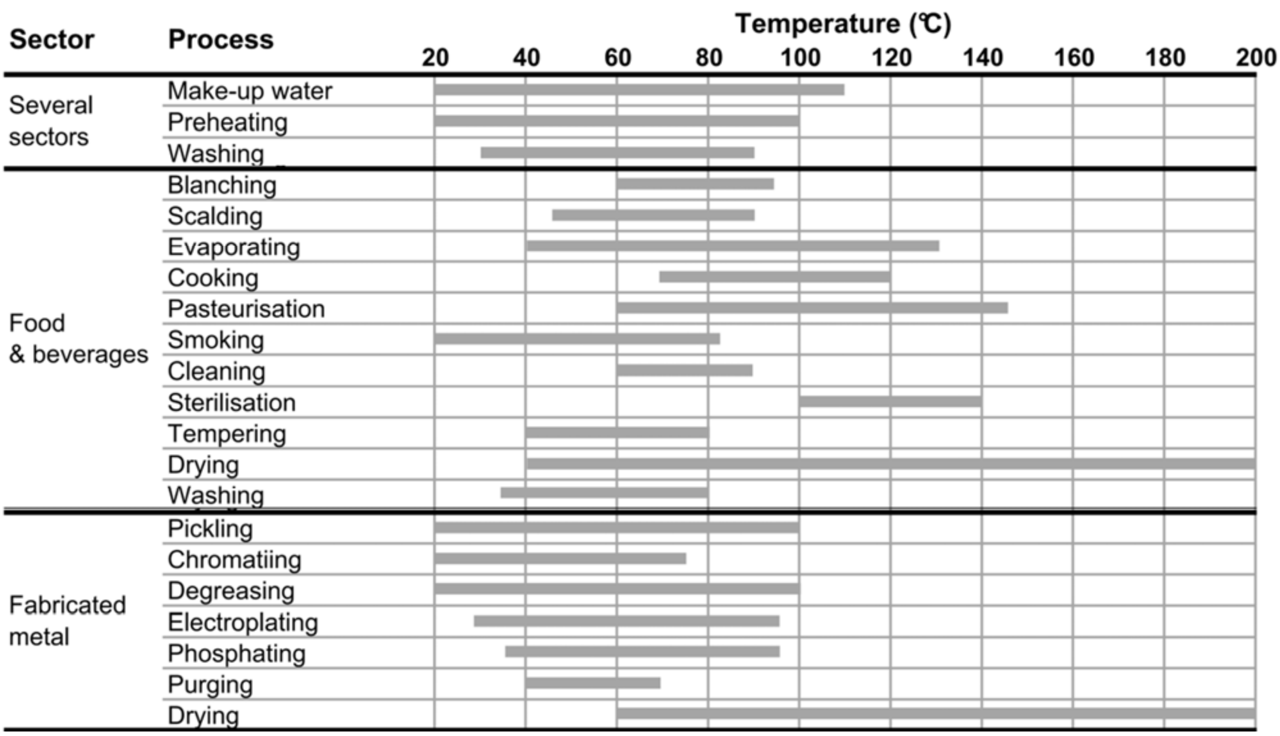
100° C .. 250° C (.. 400° C) ("medium" temperature)

- evaporation, drying, …
- often supplied through steam as a local heat carrier

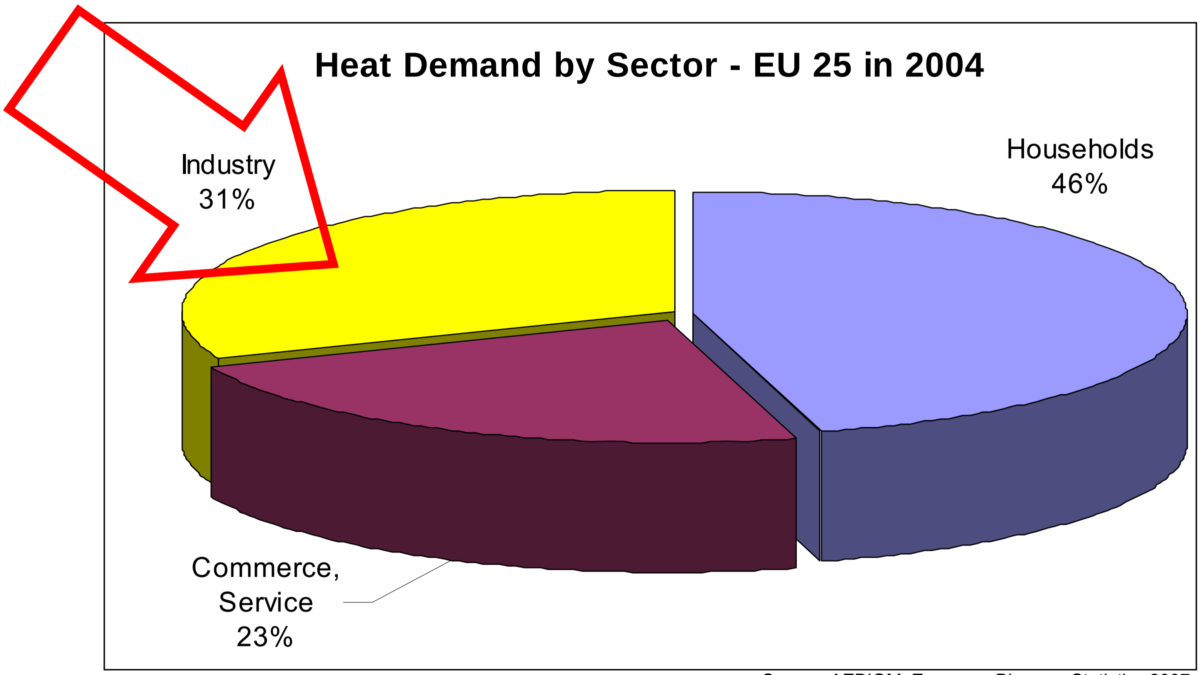
> 400° C ("high" temperature)

- manufacture of metals, ceramics, glass etc.

Sector, Process and Temperature

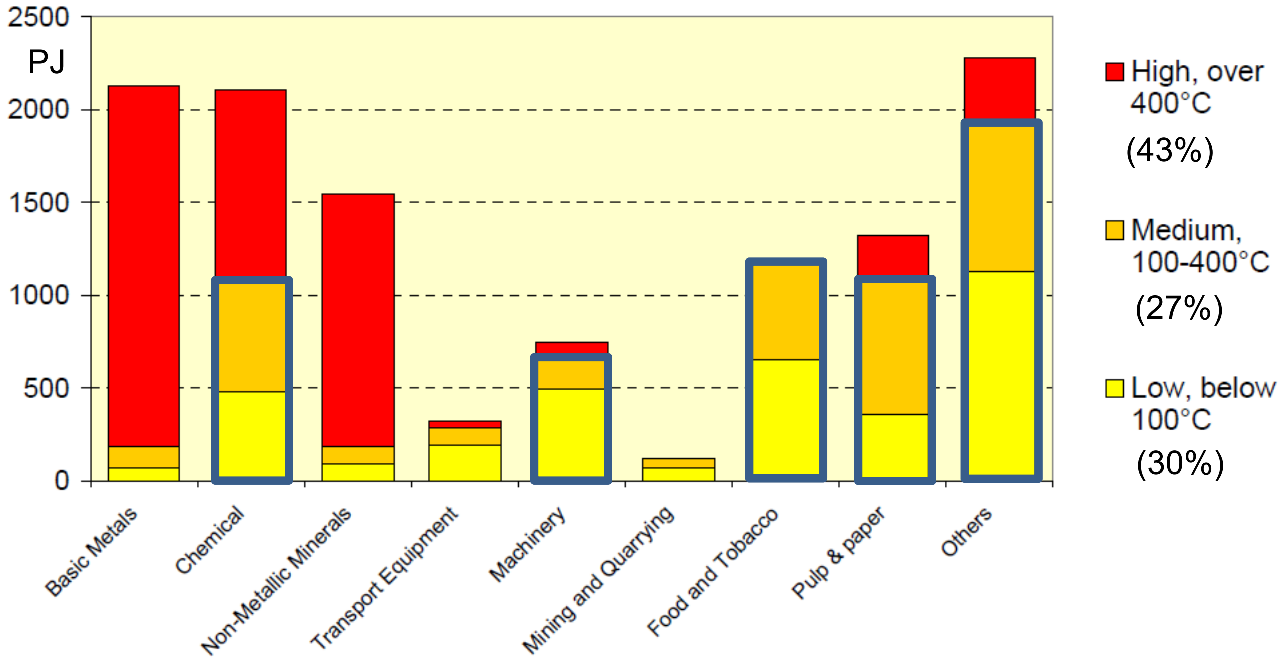


Industrial Heat Demand in Europe



Source: AEBIOM, European Biomass Statistics 2007

Industrial Heat Demand in Europe



Source: Ecoheatcool and Euroheat & Power 2005-2006

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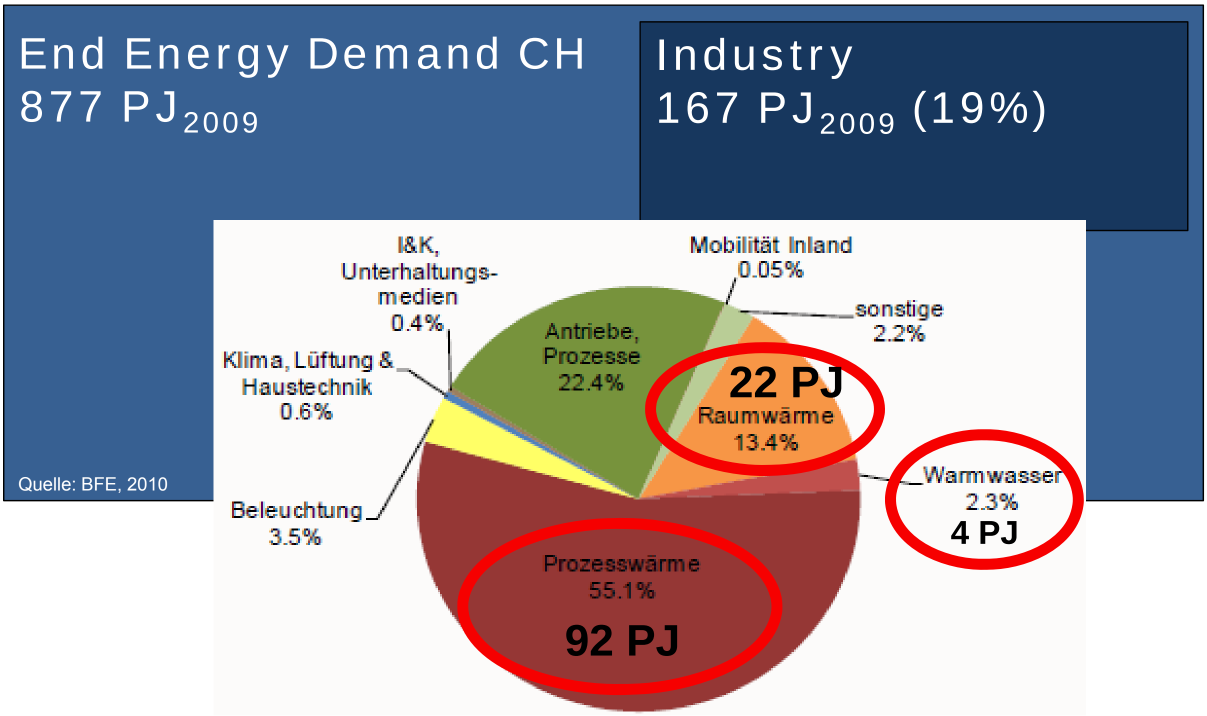
Industrial Heat Demand in Switzerland



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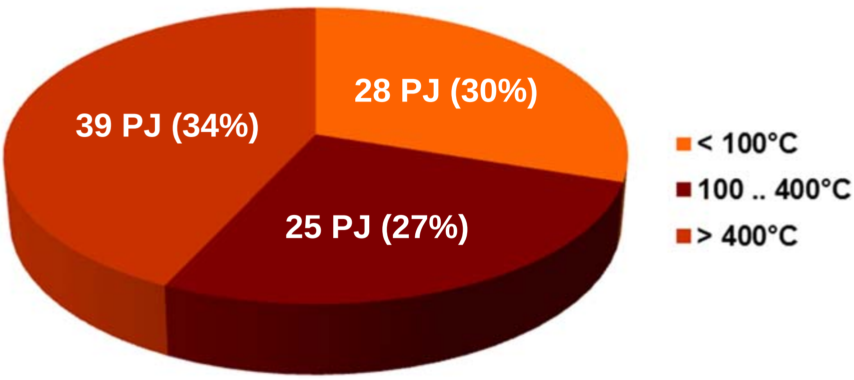
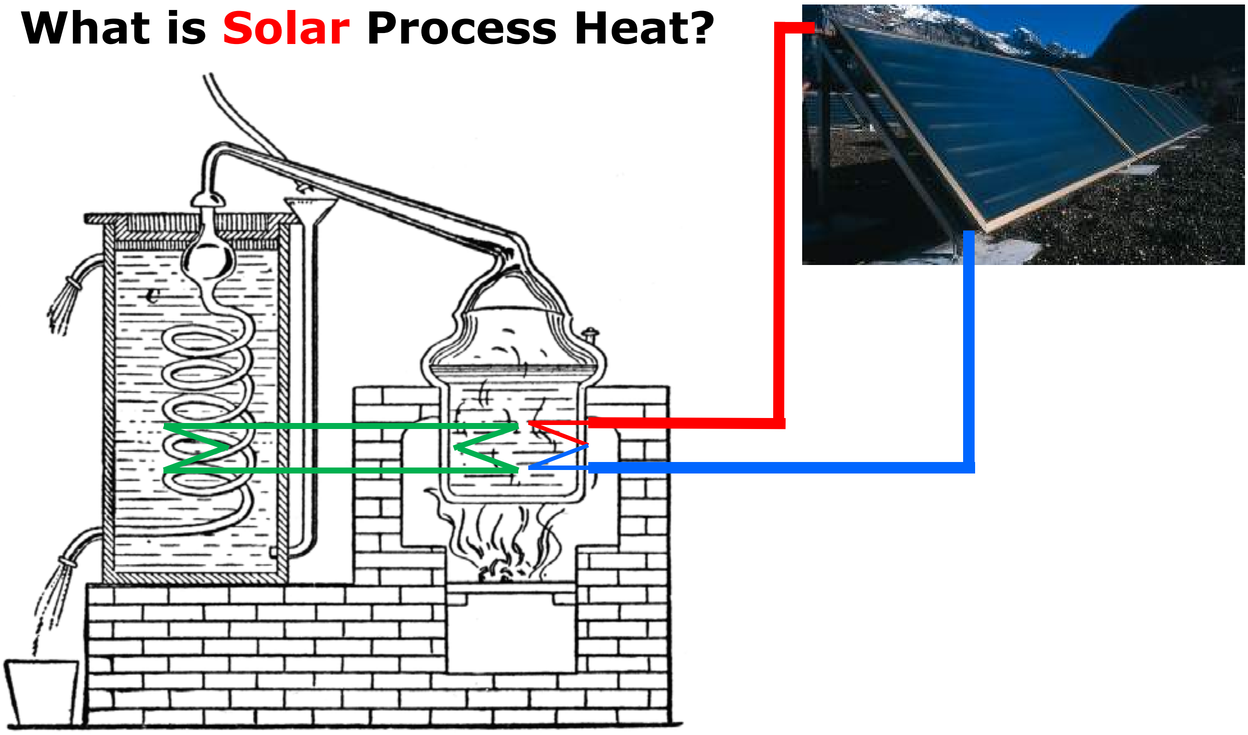
Temperatures of Process Heat Demand in CH

(using statistical values according to IEA SHC Task 33, 2008)



But: Theoretical Potential $\neq$ Technical Potential !!

What is Solar Process Heat?



Why Solar Process Heat?

Keep Production Costs low (with increasing Energy Prices)

Fullfill obligations (based on Energy Policy)

Clean Production as competitive advantage (Image)

High potential for GHG emission reduction

High specific solar gains achievable

IEA SHC Task 49 / Solar Paces Annex IV

Subtask A
Process heat collectors

INTEGRATION

OPTIMIZATION

PROCESS

Subtask C
Case studies,
Integration tools
Design guidelines

Subtask B
Process optimization
Process integration
Process intensification

IEA SHC Task 49 / Solar Paces Annex IV

- 15 countries participating
- 80 different research institutions and companies (appr. 40+40)
- Up to now >50 projects identified which are linked to the topic
- Next Meeting 5/6th March 2013 at SPF in Rapperswil/Switzerland
  - See www.iea-shc.org/task49 or
  - contact the Operating Agent: c.brunner@aee.at

Principles of system integration

Source: B. Schmitt, Uni Kassel

Supply level

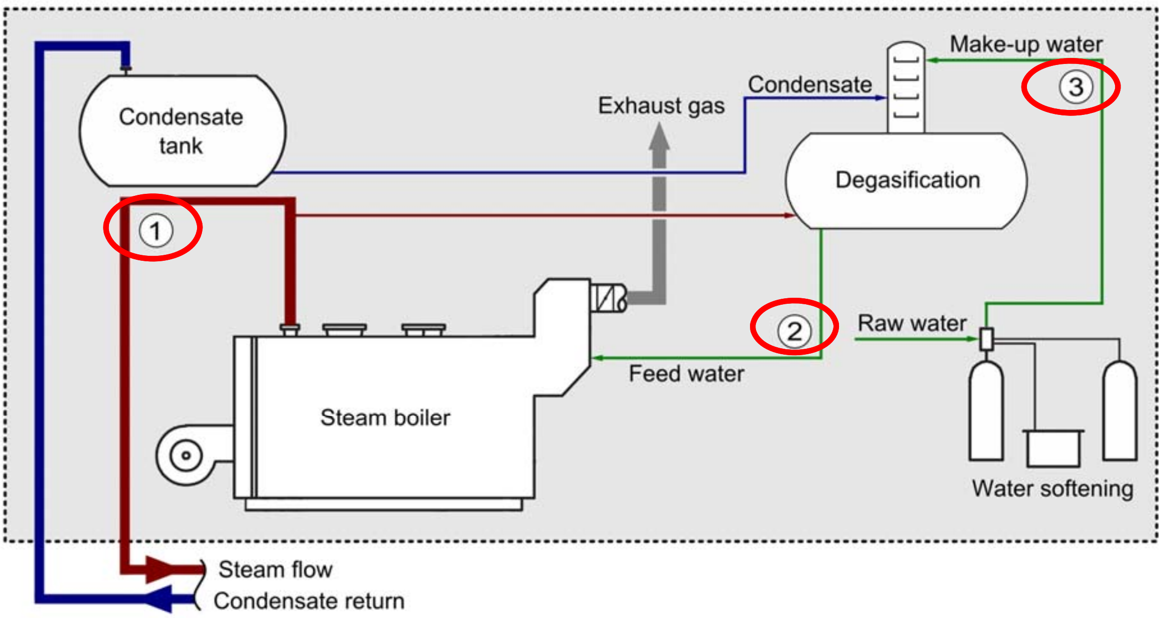
Process level

Integration on Supply level (steam)

Source: B. Schmitt, Uni Kassel

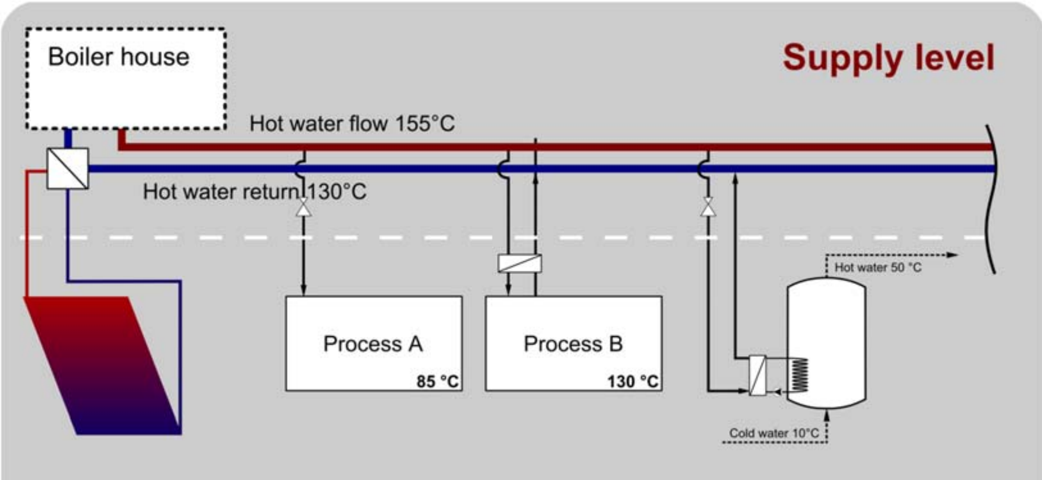
(1) Parallel integration: Direct steam supply

(2,3) Serial integration: Preheating of make-up or boiler feed water



Supply level - Hot water systems

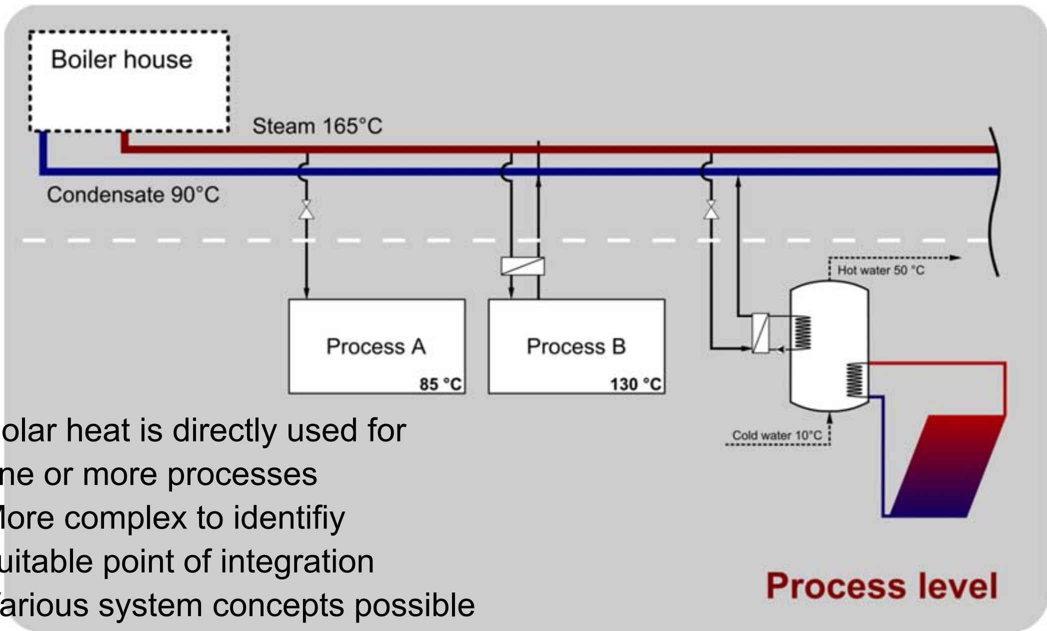
Source: B. Schmitt, Uni Kassel



- Solar heat directly used for heating circuit
- Usually less complex to identify suitable system concept
- Higher temperatures
- Special requirements for collectors and collector loop

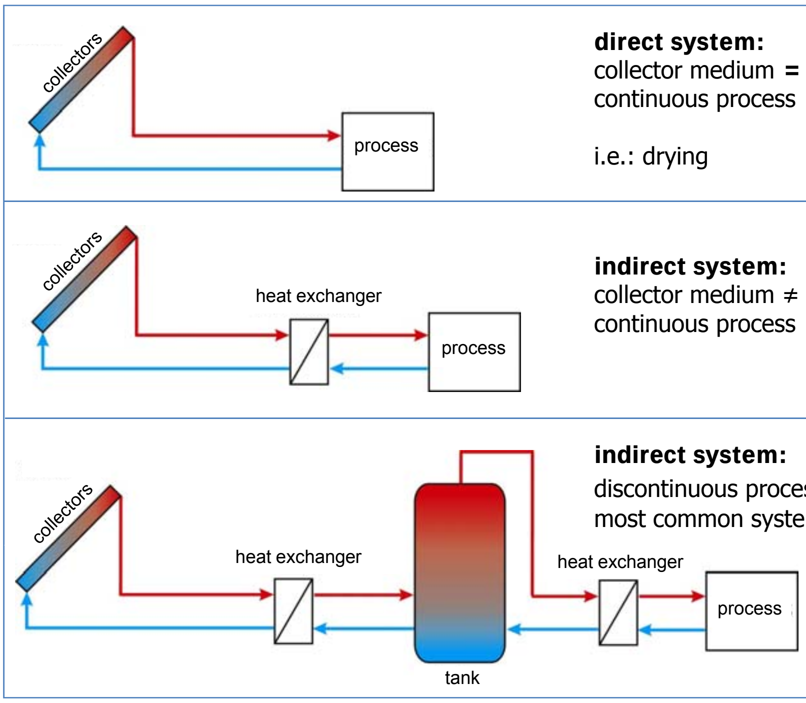
Integration on Process level

Source: B. Schmitt, Uni Kassel



- Solar heat is directly used for one or more processes
- More complex to identifiy suitable point of integration
- Various system concepts possible
- Variable set temperatures, higher specific solar yields possible

Integration on Process level



direct system:
collector medium = processing medium
continuous process

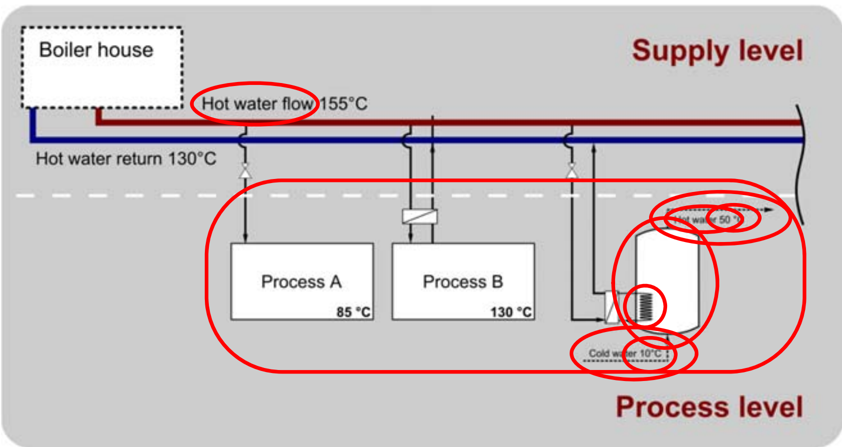
i.e.: drying

indirect system:
collector medium ≠ processing medium
continuous process

indirect system:
discontinuous processes → storage
most common system

System Integration in general

Source: B. Schmitt, Uni Kassel



- Heat Transfer Fluid
- Heat Demand
- Load Profile

- Open/closed loop
- Temperature
- Heat Demand
- Load Profiles
- Process Medium
- Existing Storages
- Heat recovery

Process Boundary Conditions ←→ Integration Concept ←→ Collector

Design Guidelines (processes)

Source: S. Hess, FhISE

- SO-PRO project: Design principles for four selected applications:
  - Heating of hot water for washing or cleaning
  - Heating of make-up water for open steam networks
  - Heating of baths or vessels
  - Convective drying with hot air
- Holistic planning approach with consecutive steps

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Design Guidelines (processes)

5.3 Heating of industrial baths or vessels

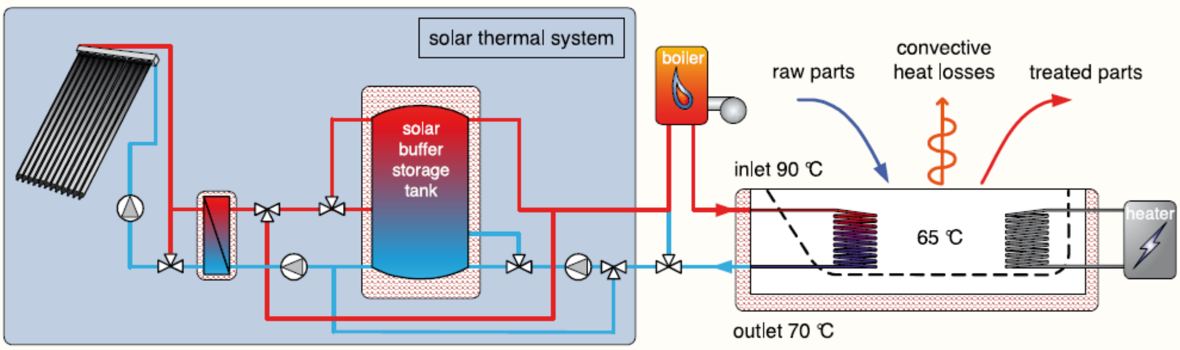

Fig. 15: Example of a system concept for the solar heating of an industrial bath. The backup heating is done serially by a boiler. A bypass of the solar buffer storage tank allows direct solar heating of the bath. The electrical heater is only used for temperature adjustment control of the bath.

- More aspects and design nomograms in the guidelines
- Download: www.solar-process-heat.eu/guide

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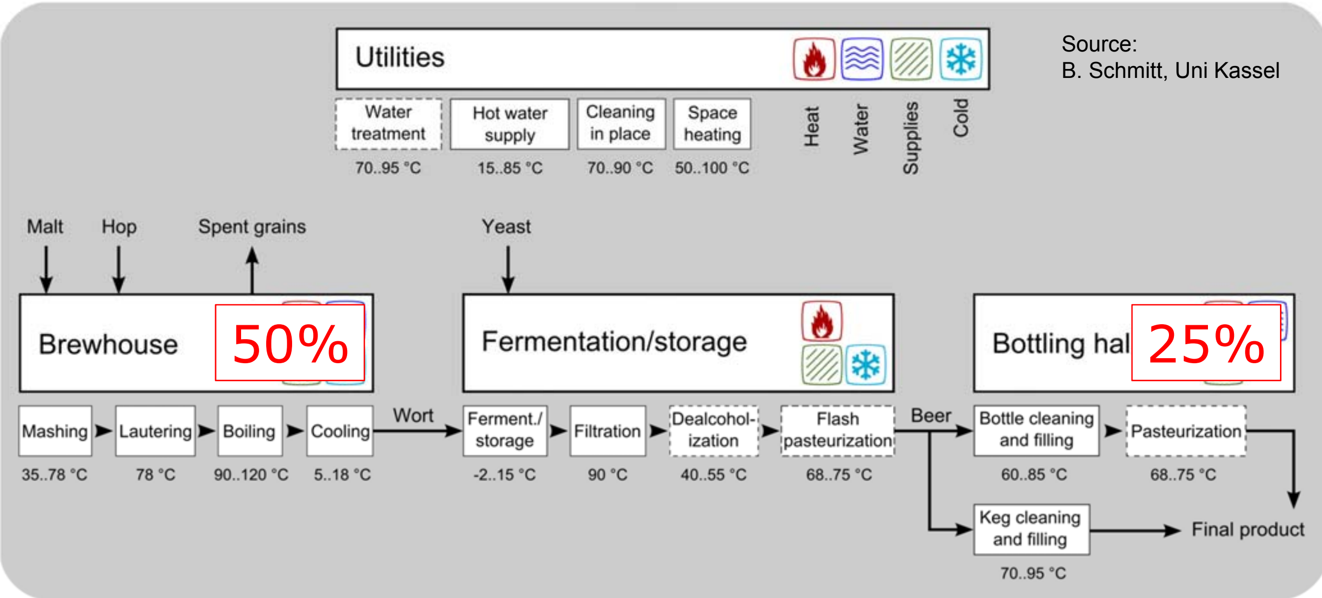
Design Guidelines (sub-sector: Breweries)



- For specific integration: further analysis necessary
- Approach and guideline: www.uni-kassel.de/downloads

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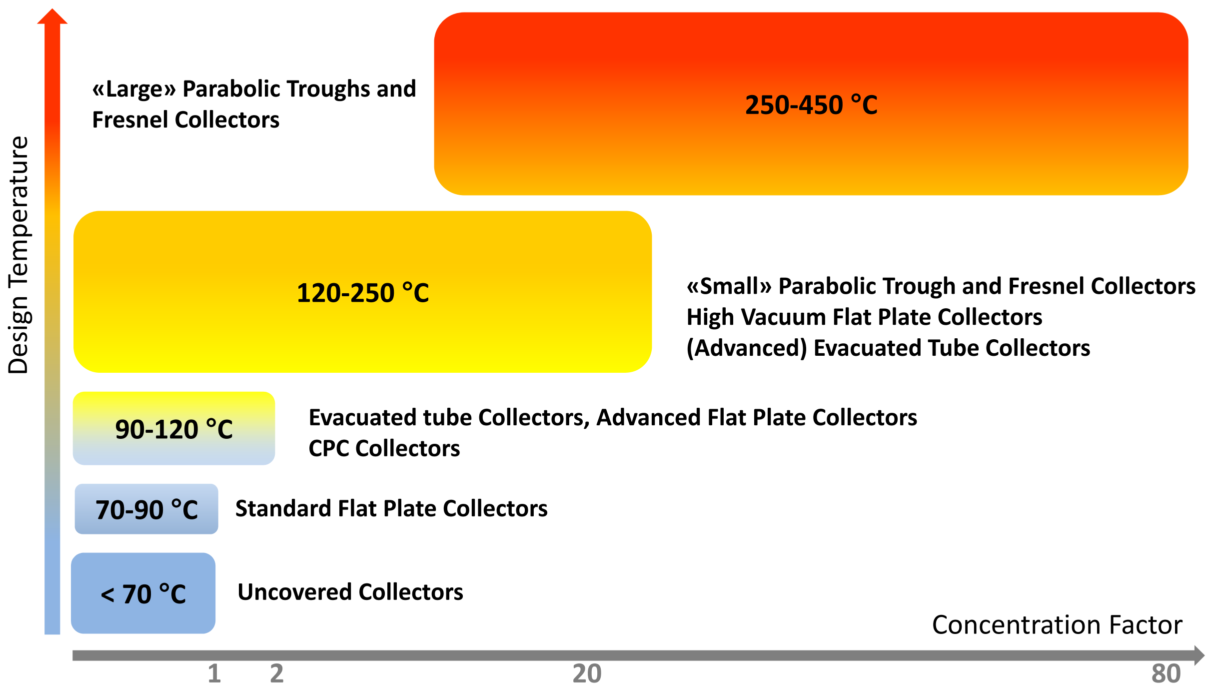
Collectors and Operating Temperatures



Collector Development

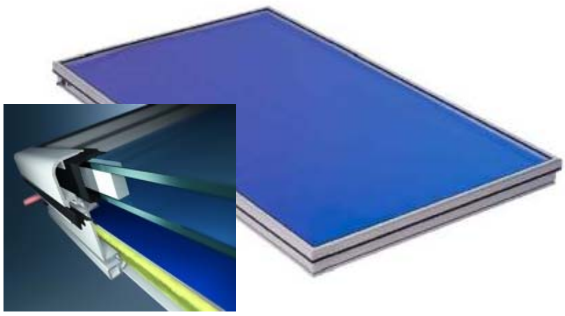
Technical aspects

- Thermal Performance (temperature and power)
- Durability and reliability (e.g. mechanical loads)
- Versatility (modularity, HTF options, range of boundary conditions, …)
- …

Economic aspects

- Collector costs
- Transport costs
- Field Installation costs (collector mounting and installation , piping and hydraulics, …)
- Maintenance
- …

Collectors



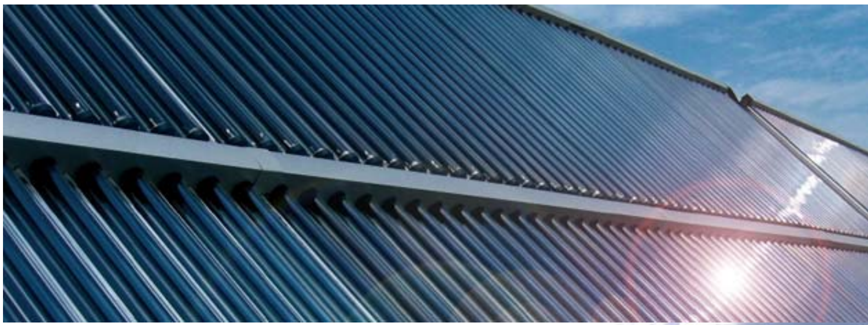
www.schueco.com

SCHÜCO

www.solid.at

SOLID solarinstallation+design

Collectors

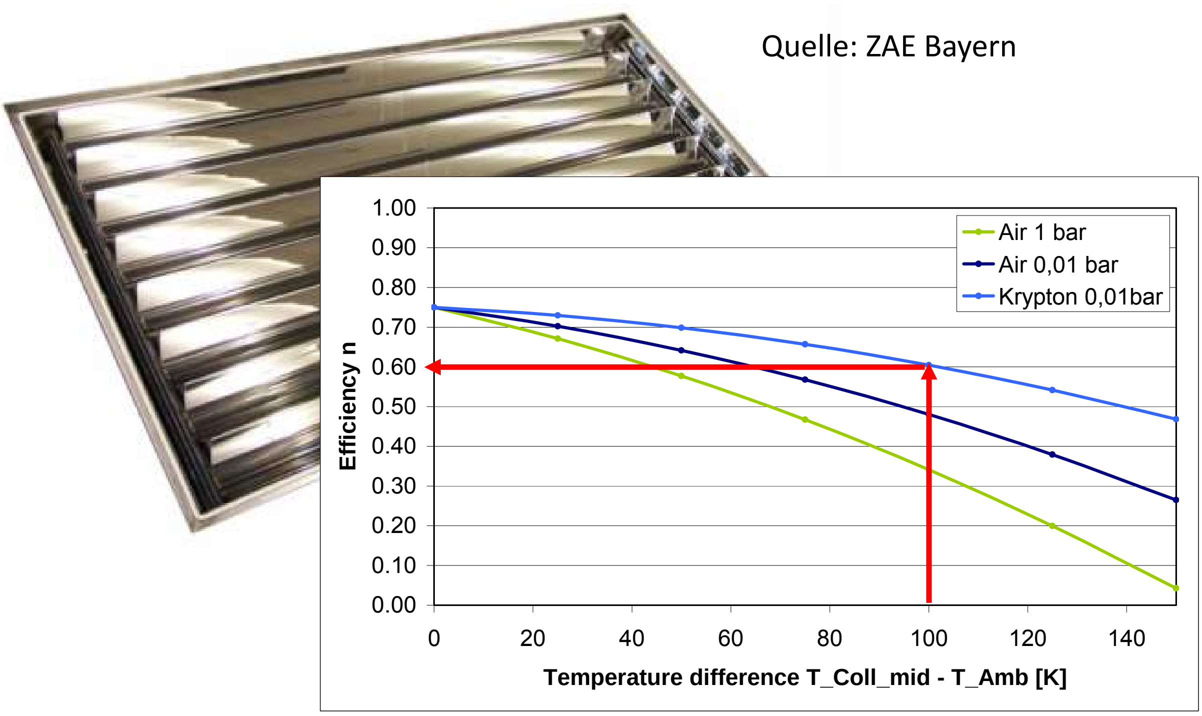


www.ritter-gruppe.com

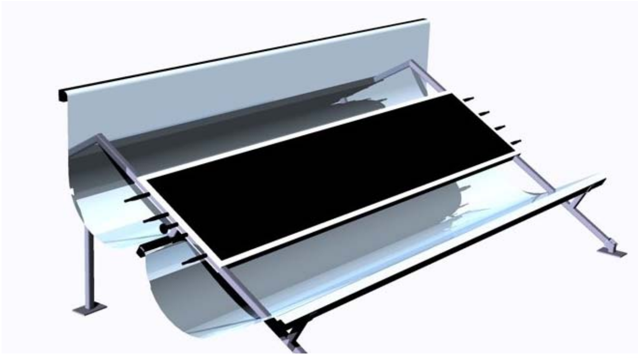
www.kollektorfabrik.de

Collectors

Quelle: ZAE Bayern



Collectors



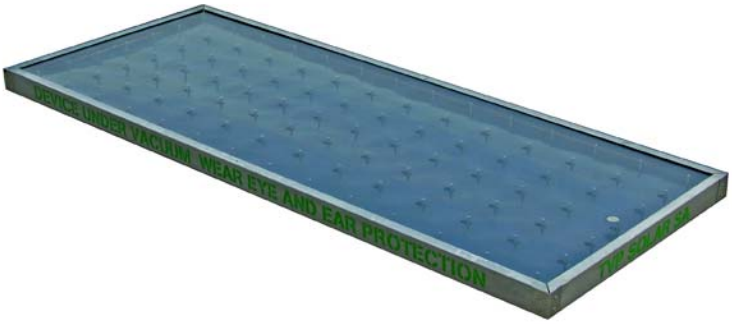
www.srbenergy.com

SRB ENERGY

CERN SWISS TECHNOLOGY

www.tvpsolar.com

TVP SOLAR



Collectors

www.nep-solar.com

www.itcollect.de

IT-COLLECT
der intelligente Kollektor

Collectors

www.smirro.de

www.solitem.com

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Collectors

www.soltigua.com

soltigua concentratori solari

www.absolicon.com

ABSOLICON SOLAR CONCENTRATOR

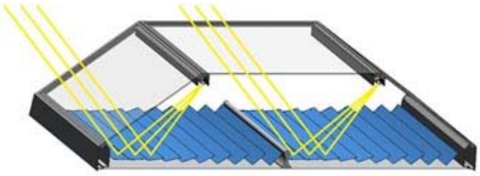
Collectors

www.industrial-solar.de

INDUSTRIAL SOLAR
thermal solutions

www.chromasun.com

CHROMASUN

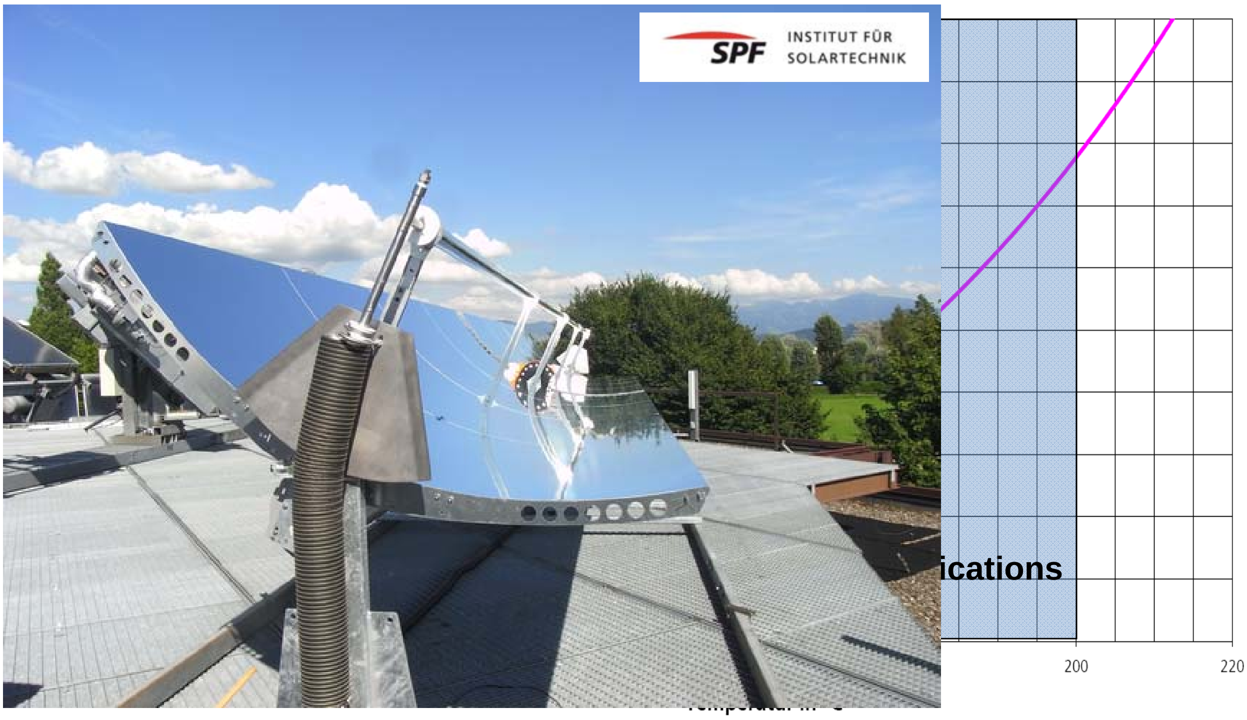


Collectors

www.tsc-concentra.com

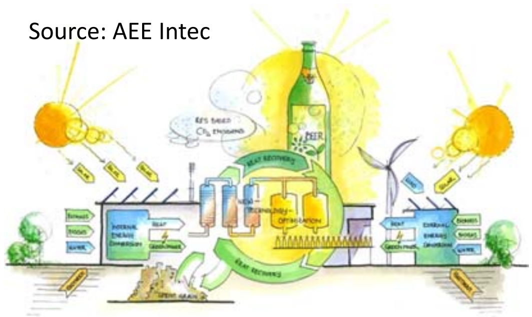
tsc
TECNOLOGIA SOLAR CONCENTRADORA

Testing…



Project example: SolarBrew

Source: AEE Intec



Solar Brew: Solar Brewing the Future

EU FP7 (2012 – 2015)

Heineken

SUNMARK SUSTAINABLE SOLAR SOLUTIONS

SEVENTH FRAMEWORK PROGRAMME

klima+ energie fonds

GEA

Solar process integration in breweries and malting plant

- Holistic approach: process optimization and solar integration
- Realization of three demonstration plants in Austria / Spain / Portugal with Flat Plate Collectors (∑ > 7.200m² resp. 5 MWth)
- Further development of “Green brewery sector concept”

Project example: P3 (Pilot Plant for Process Heat Generation in Parabolic Trough Collectors)

108 m² Solitem Parabolic Trough collectors on the roof of the Alanod production facility in Ennepetal / Germany

Direct Steam Generation

Consumer: Steam line (4 bar, 143°C)

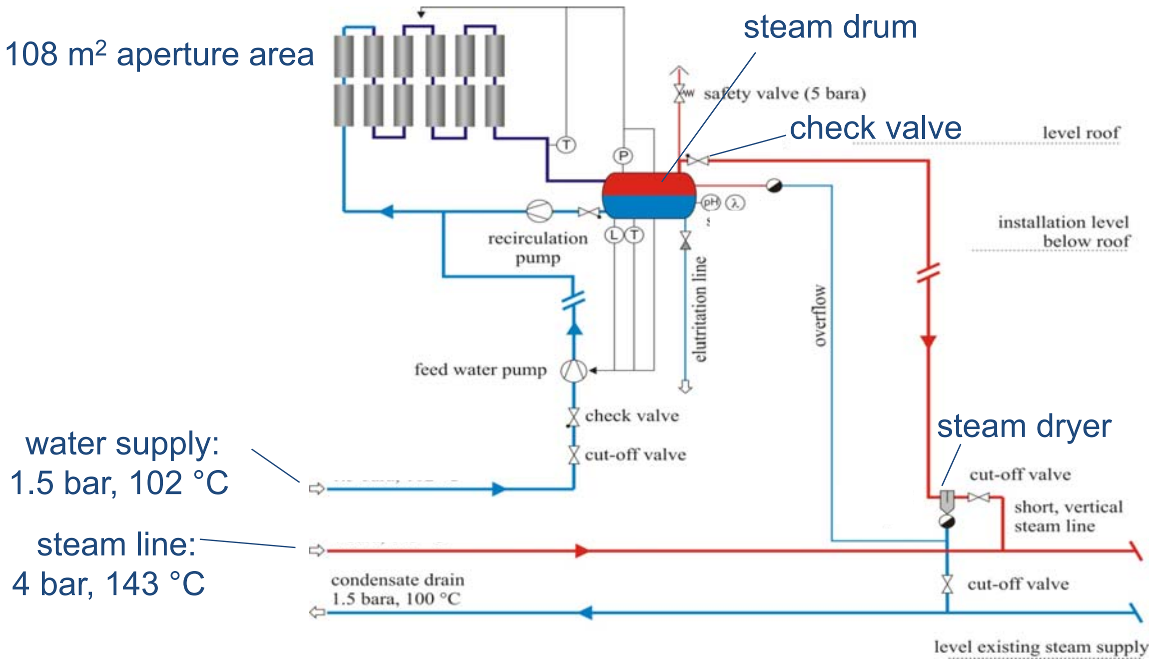
Project Partners: Alanod, Solitem, DLR, ITW, SIJ, ZFS

Project Report available

Source: Solitem

Project example: P3 (Pilot Plant for Process Heat Generation in Parabolic Trough Collectors)

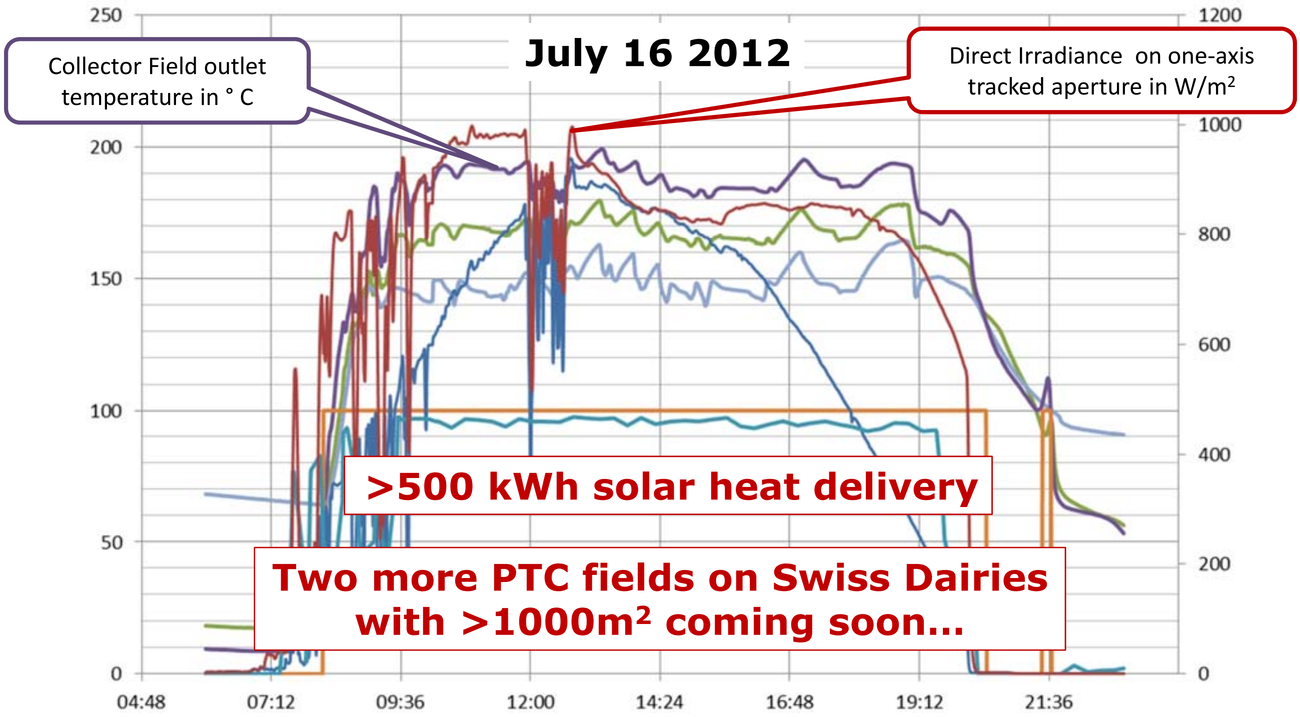
Source: ITW



Project example: Dairy in Switzerland

- Highest-located dairy in Europe (altitude 1800m)
- 115 m² Parabolic Trough Collector (NEP 1200)
- Indirect Steam Generation
- Collector loop operated at approx. 180°C collector outlet temperature
- Thermal oil
- Energy contracting
- Replaces about 70 MWh/a fossile fuels
- CO_2 reduction of 18 t/a

Project example: Dairy in Switzerland



Project example: Swiss Paintshop

Source: www.sunwindenergy.com

→ 400 m² ETC provide hot water @110° C
→ Up to 200 MWh/a solar gain (160 MWh/a guaranteed)
→ Payback approx. 5a (including subsidies)

Equipment supplier also offers solar process heat plant !!

Project example: InSun - Three Solar Process Heat demonstration plants in the meat/dairy/brick industry

Berger Fleischwaren GmbH → Sausage Production in Sieghartskirchen, Austria

Flat plate collector system of SOLID

- Planned maximum flat plate collector area: 1489 m²
- Hot water storage: 80 m³
- Expected total annual solar heating gains: 600 MWh/a

Laterizi Gambettola SRL → Brick drying in Gambettola, Italy

Linear Concentrating Fresnel Collector of Soltigua
Direct steam production at 180°C (12 bar)

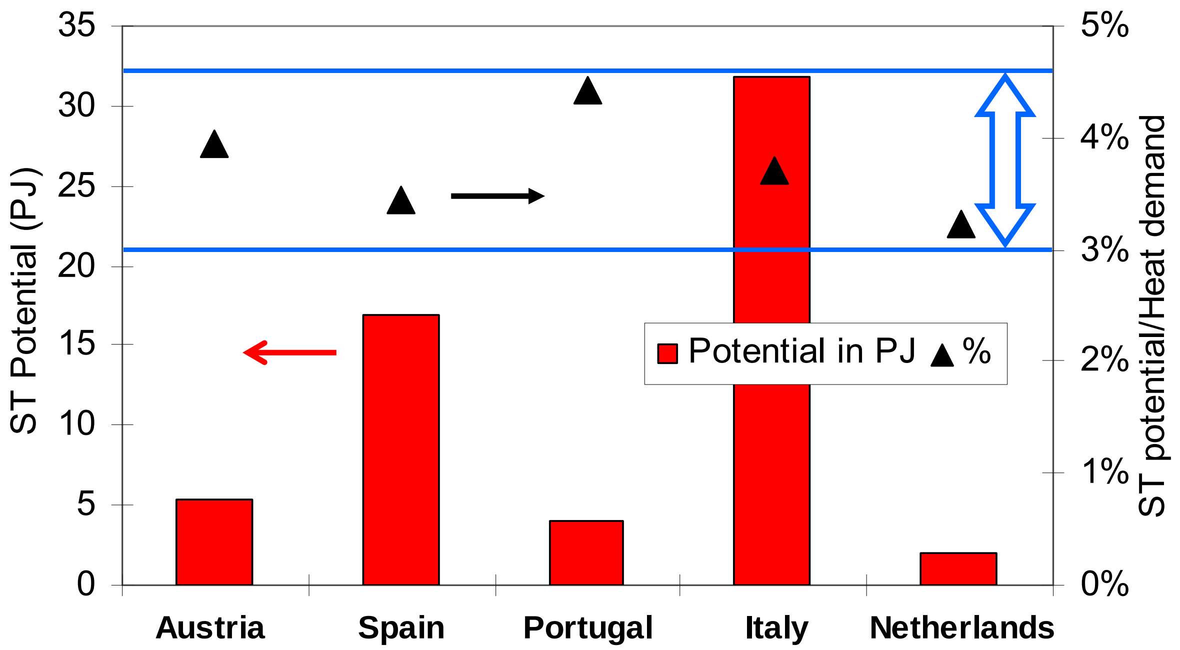
- Fresnel collector model: FTM36 (132 m² /collector)
- Solar field size: 2 640 m²
- Peak solar field net capacity: 1'264 kW

Lácteas Cobreros → Milk powder production in Castrogonzalo-Zamora, Spain

Parabolic trough collectors of Solera Sunpower GmbH
Indirect steam generation 200°C outlet temperature.

- Number of Parabolic trough collectors: 600
- Total collector area: 2040 m²
- Expected heating energy gains: 1 GWh/a

Technical Potential for Solar Process Heat



Source: IEA SHC Task 33, R. Battisti, C. Vannoni

Opportunities, obstacles and outlook

Technical aspects:

- High potential in Europe and worldwide (EU25: approx. 125 GW_{th} – now!)
- High specific solar gains achievable
- Significant solar fractions achievable → planning security
- Collectors, concepts and some best practise available

Economic aspects:

- Comparably high investment costs
- Still high costs for planning and BoS
- Competition with (too?) low fossil energy prices and with other heat sources, especially CHP and waste heat
- Combination with process optimization → solar sometimes «only» an additional feature

Communication aspects:

- Lack of incentives, interest and knowledge (and thus often a drop-out on the first level of decisions)

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Last not Least...

Solar Water Disinfection





SPF Solartechnik Prüfung Forschung

Background

The supply of drinking water is one of the biggest challenges today:

- Worldwide, approximately **2.3 billion people have no or limited access** to safe drinking water
- **Every year more than two million people die** due to the lack of safe drinking water (WHO)
- This equals **4300 people per day (or three in a minute) (or 36 during this presentation)** of which 90% are children less than 5 years old.

waterkiosk

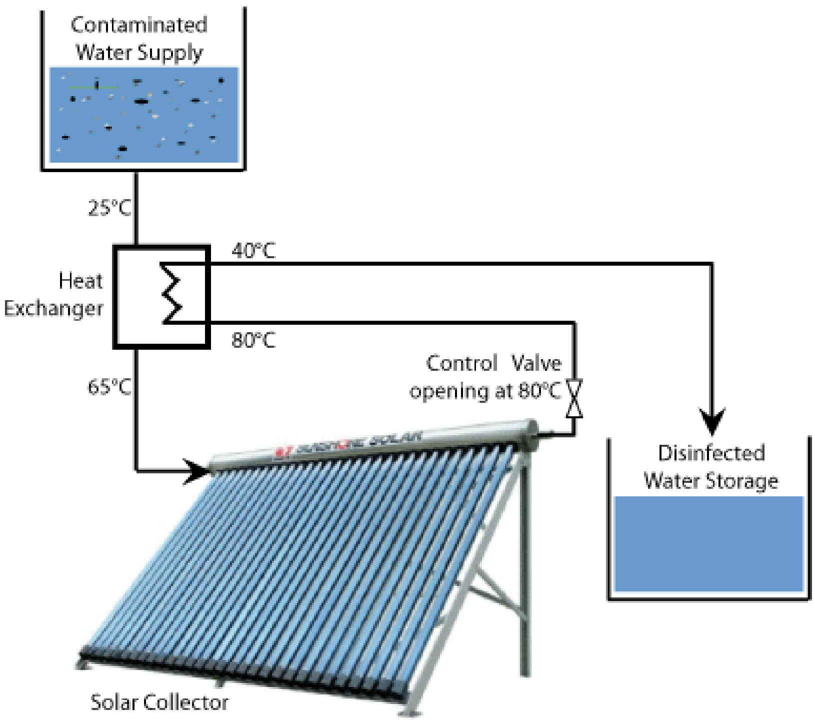
Goals „SoWaDis“

- Simple technology
- Reasonable
- Self-sustaining
- Safe and robust
- Also commercially applicable

Area of Application:

- Small communities in remote areas of developing and emerging countries (200..1000 l/d)
- Water available, but no drinking water, coming from
  - Rivers, lakes etc.
  - Rain water (harvested)
  - Wells with low water quality
  - Local distribution nets (often with low water quality)

Functional Principle



Technical Development: Components

collector

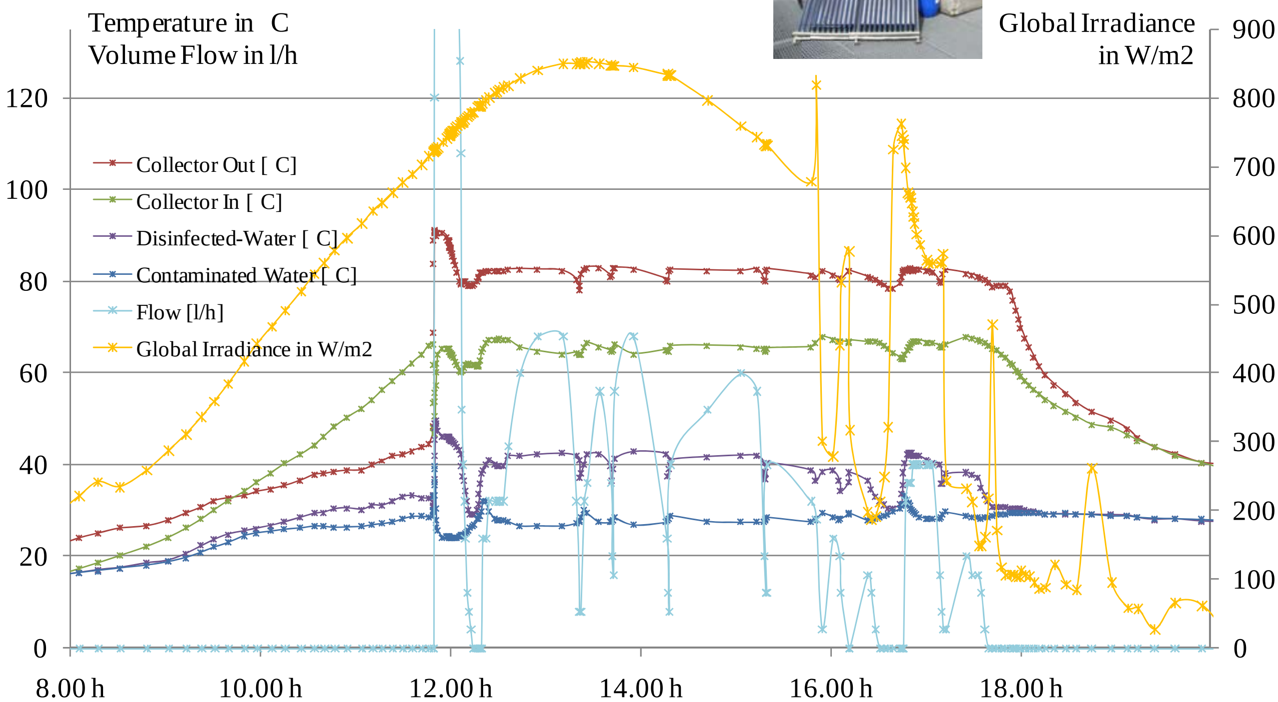
valve

heat exchanger

Integrated system

Technical Development: System

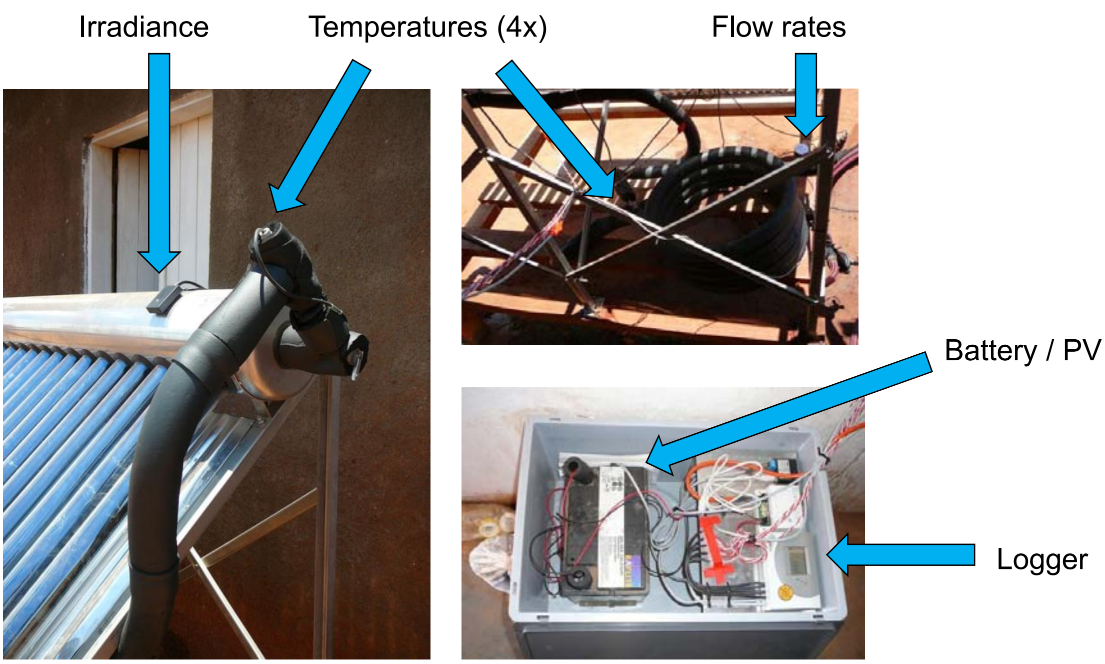
System operation on sunny day (27.07.2009)
in Rapperswil. Collector: 45°, south



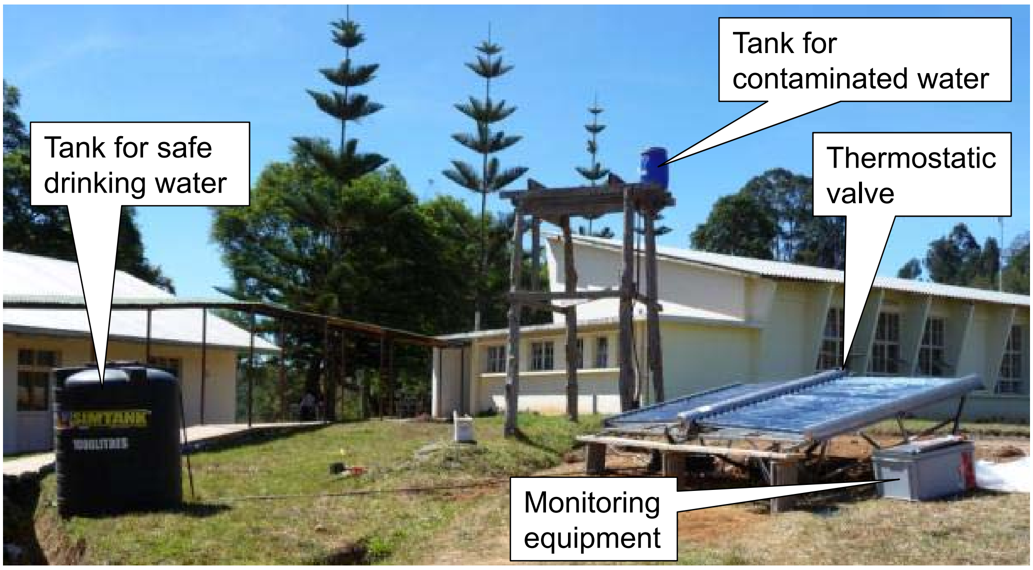
Systems in the field (August 2011)

	Mocambique	Bangladesh	Tanzania
Partner	Helvetas (NGO)	Prism (NGO in Dhaka)	Ev.-Luth. Church of Tanzania
Systems	7	2	2
Environment	Remote Villages	Urban	College Campus, Village
Concept	• Schools (2) • Health Stations (2) • Communally operated (1) • Privat economy (2)	• Privat economy (2)	• Operated by University (1) • Water kiosk (1)
			

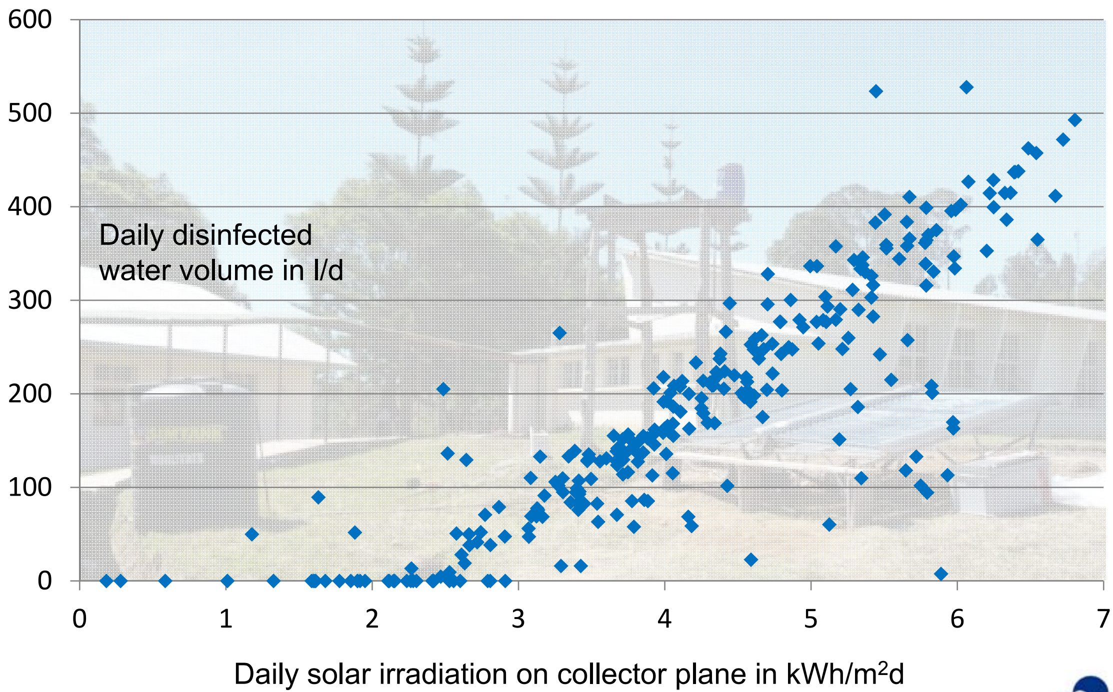
Monitoring Equipment



Field Data Tanzania



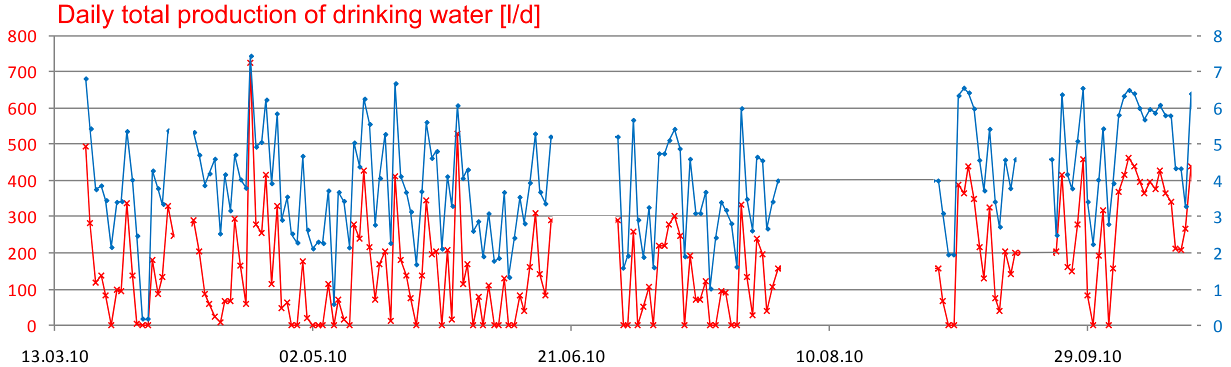
Field Data Tanzania

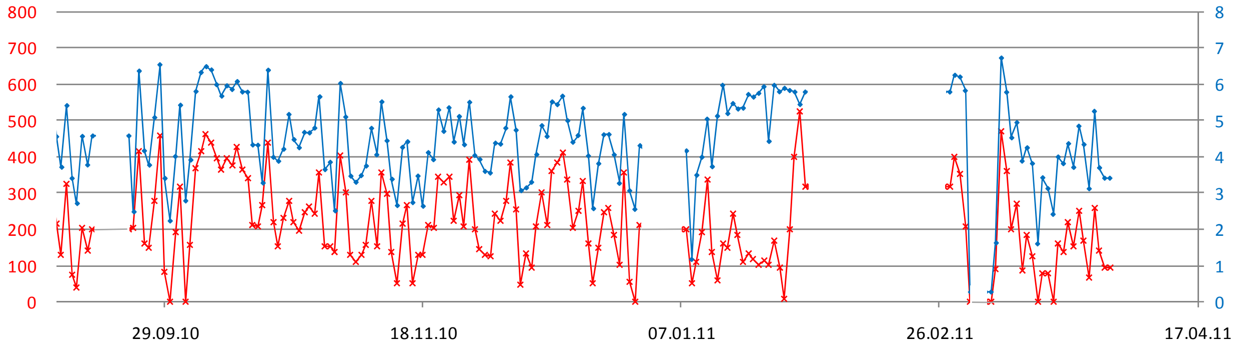


Field Data Tanzania

Daily global irradiation [kWh/m^{2}d]

Daily total production of drinking water [l/d]





SPF Solartechnik Prüfung Forschung

Systems in the field (August 2011)

HELVETAS Together for a better world — PRISM Bangladesh

	Mocambique	Bangladesh	Tanzania
Partner	Helvetas (NGO)	Prism (NGO in Dhaka)	Ev.-Luth. Church of Tanzania
Systems	7	2	2
Environment	Remote Villages	Urban	College Campus, Village
Concept	• Schools (2) • Health Stations (2) • Communally operated (1) • Privat economy (2)	• Privat economy (2)	• Operated by University (1) • **Water kiosk (1)**
			

waterkiosk

Not just another charity...
... through the implementation of Water Kiosks

Not just another charity...
... through the implementation of Water Kiosks

Cash Flow Models

„Classical“ development aid

Note: “one-way street“ for cash flow, no ROI, no market mechanisms

Donations and funding (private, public etc…) → Organisation in Charge (e.g. NGO) → Programme / Projects to improve life standard

Mixture

Note: Also one-way street for initial cash flow, but with the implementation market mechanisms are combined to induce an intrinsic motivation to keep the system running. After initial cash flow financial sustainability shall be achieved for the kiosk.

Donations, CSR and other Social Investment etc. → Implementing Organisation (e.g. SwissWaterKiosk) → Programme / Projects to improve life standard

Classical “Business-Case”

The implemented programs / projects are profitable enough that the operation of the whole chain including overhead can be covered and the investor gets a profit.

Invest → Implementing Organisation (e.g. local company) → Programme / Projects to improve life standard

Outlook

- End of 2013:
  70 systems in operation
- Access to safe water for more than 20‘000 people
- Funding from different sources

Roll-out (focus countries) (2012-2013)

[Antoinette Hunziker-Ebneter]

+GF+ GEORG FISCHER

HELVETAS Together for a better world

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FHO Fachhochschule Ostschweiz

May 2011: Formation of the WaterKiosk Foundation

www.waterkiosk.org

Summarizing a few points…

- Heat Storage and Storage management is always very important…
- … but good components do not neccessarily make a good system…
- Bring down costs…
- Improve system performance (of heating systems in general)…
- Explore new applications…

… and …

- Combine RE technologies in smart and robust systems...
- … thinking not only on a local but regional / national / … level!!

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Thanks for listening and for your questions…

Elimar Frank
elimar.frank@spf.ch