FVEE ForschungsVerbund Erneuerbare Energien
Renewable Energy Research Association

Fraunhofer ISE

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

Solar Polygeneration with Concentrating Collectors

Initial Position

Concentrating collectors for process heat and cooling applications can provide heat at temperatures well above those typically required by industrial processes.

Orders for diesel generators indicate, there is a huge market for decentralized electricity generation in the power range up to 5MW.

Polygeneration may exploit the exergy potential of concentrating collectors. Our study should investigate whether this can lead to economic benefits for solar electricity, heat and cold production.

Parabolic trough test facility for process heat applications at DLR, Cologne

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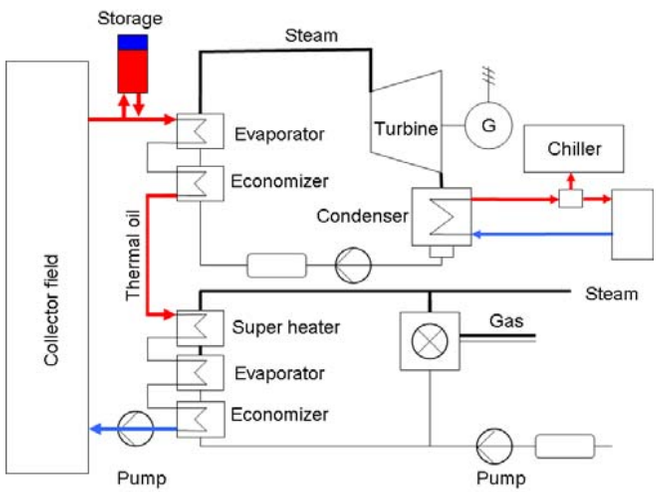
Solar Polygeneration with Concentrating Collectors

Research

For solar co/polygeneration different cycle layouts which have been investigated by Fraunhofer ISE in a research study, are feasible. Depending on the temperature levels needed, different positions of the heat exchangers in the cycle can be assessed with the simulation model developed in this study. The Figure shows a schematic layout of one possible system. Various layouts have been calculated within the project. Parameter variation and optimization have been performed to understand the impact of certain parameters and to maximize the economic results



Possible cycle layout for solar polygeneration
Products: Electricity, Process Steam, Cold
(© Fraunhofer ISE)

Solar Polygeneration with Concentrating Collectors

Results

Result of the study is that solar thermal power plants in the range of 50 kWel to 1 MWel can be economically viable in countries with high irradiation potential. For small plants producing electricity only, feed-in tariffs of about 27 Eurocent like in Spain are only sufficient, if investment costs drop appreciably. For off-grid applications even plants producing only electricity can pay off. Solar polygeneration however can lead to an economically viable system in both grid connected and off-grid applications if heat and cold demand match with solar generation.
More Information: www.mss-csp.info

Contact:
Fraunhofer ISE: Werner Platzer (werner.platzer@ise.fraunhofer.de)
Anton Neuhäuser (anton.neuhaeuser@ise.fraunhofer.de)
DLR: Klaus Hennecke (Klaus.Hennecke@dlr.de)
Institut für Technische Thermodynamik/Köln

Acknowledgements
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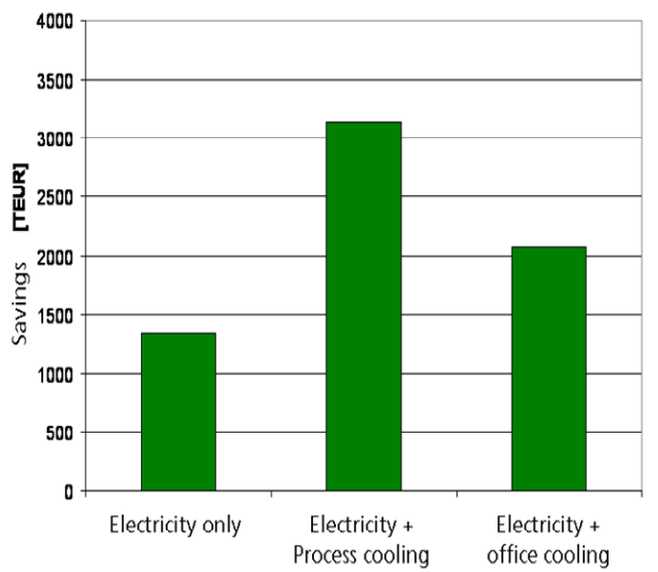


Savings of different cases compared to a conventional Diesel generator system

(© Fraunhofer ISE)

High efficiency flat plate collector based on a selective double-glazing

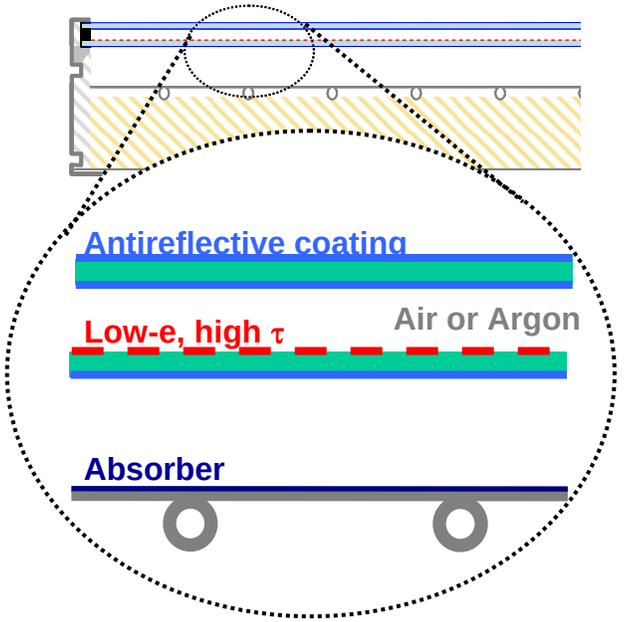
Initial Position

In the past years, flat plate solar collectors have been developed to cost effective and highly reliable products. However, at a temperature level of more than 80°C (typical for process heat) or at a low irradiance level (space heating) they still have to be improved, especially if compared to evacuated tubular collectors.

To obtain a highly efficient flat plate collector, the thermal insulation of the transparent aperture has to be improved.

ISFH is investigating, if the principle of low-e coated insulated double-pane window glazings, which have become a standard in architecture, may be applied to solar collectors. From this new requirements arise:

- highly transparent and stable low-e coatings
- higher temperature level in collectors to be regarded
- the optimization of the geometry for minimized heat losses



Scheme of highly efficient flat plate collector

High efficiency flat plate collector based on a selective double-glazing

Research

The research is focused on the following research topics

- Development of highly transparent low-emission coatings based on TCO, accompanied by a durability optimization against temperature and moisture
- Collector and glazing reliabilty, investigations with regard to
  - – internal and external mechanical load,
  - – temperature load, especially on the edge bond of the glazing
  - – combined UV-temperature-moisture load with artificial irradiance source
  - – Longterm-outdoor exposure
- Investigation of internal collector heat transfer, especially heat transfer coefficients in the gap between absorber and glazing and between the glass panes
  Experimental work is accompanied by simulation and model development.

Test rig for high temperature load and temperature difference measurements

High efficiency flat plate collectors based on a selective double-glazing

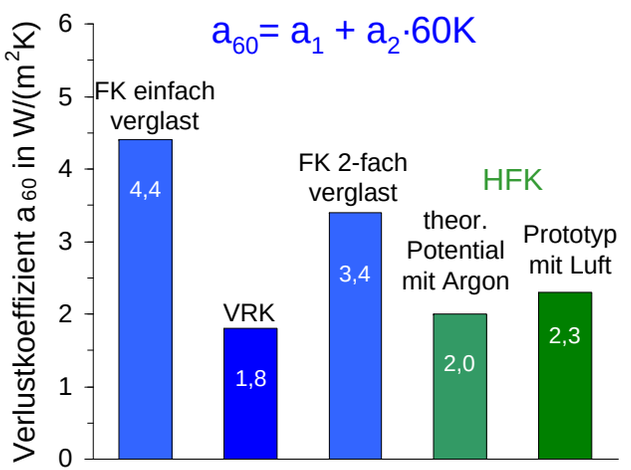
Results

The following results have been achieved:

- The collector heat losses could be significantly reduced, approaching nearly the level of vacuum collectors
- An improvement of the solar transmission of the low-e coating from 72% (commercial) to 85% (laboratory prototype) has been realized, the durability against temperature and moisture is given.
- The thermal and mechanical load may be described, a long-term reliability is achievable.

The project is carried out with partners from collector industry (Viessmann, Vailant, Solvis) and glazing industry (Kömmerling, Centrosolar).

The project is funded by the German Ministry for Environment, Nature Conservation and Nuclear Safety (FKZ 0329280D), due to a decision of the German Bundestag.



Heat loss coefficient of different collector types at a temperature difference of 60 K (FPC = flat plate collector)

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Solar District Heating „Ackermannbogen Munich“

ZAE BAYERN

Initial Position

The renewable energy heat law (EEWärmeG), has the aim to increase the part of renewable energies in the heat sector of today 6.5 % to 14 % in 2020. Solar thermal heat plays a key role in this renewable energy scenario. New and older houses as well as housing areas, with a high fraction of solar energy are in focus.

Within the research funding programme “Solarthermie 2000plus” of the BMU two solar local heating projects were monitored and evaluated by ZAE Bayern. Key aspects of research are heat supply by efficient collectors, seasonal storage of solar heat and local heating, which are adjusted to the fluctuating supply of solar energy.

Solar collector field with 2761 m² distributed over 3 buildings.

Solar District Heating „Ackermannbogen Munich“

ZAE BAYERN

Research

In a development area near the “Olympia Park” in Munich a solar district heating project was implemented. The net living area of the 13 buildings is 30,400 m². The insulation standard undercuts the minimum requirement of the EnEV 2002 by 30 %.
Three collector fields with a total area of 2,877 m² in combination with 6,000 m³ stratified warm water storage provide energy for the local district heating. The coverage of the remaining heat demand results from a hot water absorption heat pump (550 kW heating power), which is driven by the district heating system of Munich.
In order to reach the target of 50 % solar fraction for the accounted heat demand of 2,300 MWh/a for heating, domestic hot water and network losses, in 2000 a feasibility study was prepared, in context of which system simulations were carried out by ZAE Bayern.

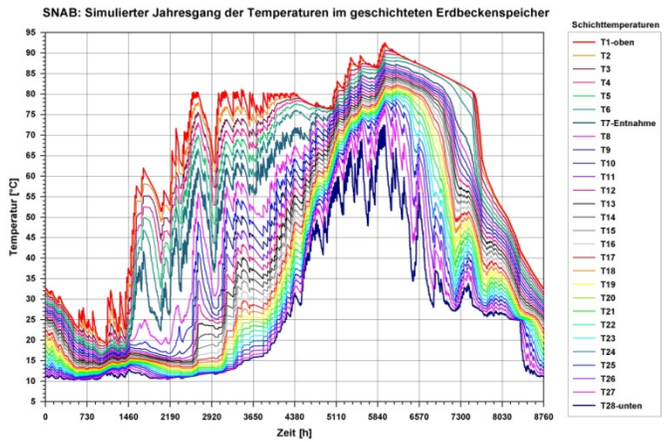
6000 m³ long term heat storage with stratified storage system.

Solar District Heating „Ackermannbogen Munich“

ZAE BAYERN

Results

The solar district heating complex “Am Ackermannbogen” meets mostly the requirements.
Through an intensive mentoring of the builder in the conceptional phase, the aspired low heat demand could be achieved. Notably successful was the effort for low net return temperatures of 30 °C. These were achieved through an innovative concept with a hydraulic coupling of the local heat network and heating system, local heat transfer stations with fresh domestic water heating and serial coupled radiators and floor heatings.
Essential specifications, like solar fraction and specific solar energy gain, are momentarily considerably undercut and make rectification within the system necessary.



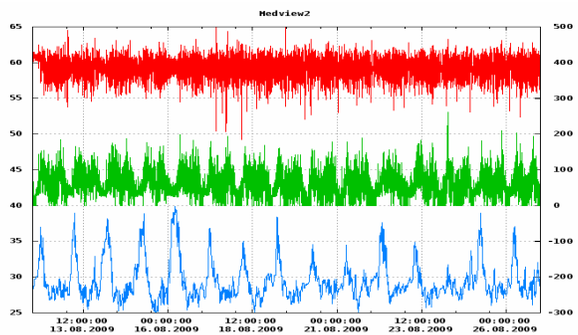
Simulated seasonal cycle of temperature distribution inside the stratified water storage.

district heating system

temperature of feed line

thermal power kW

temperature of return line



Underground Thermal Energy Storages at the German Parliament Buildings, Berlin

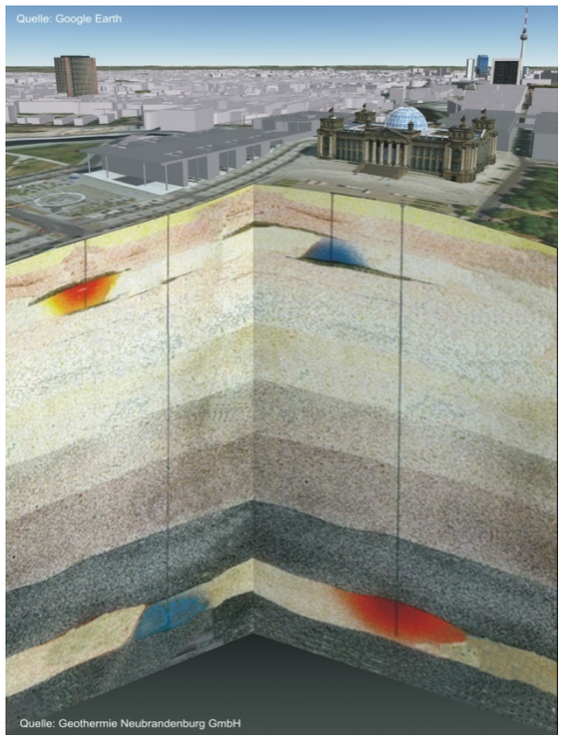
Initial Position

About 70% of the subsurface in Germany offers the potential to use water bearing rock formations, also called aquifers, as thermal energy storage.

Aquifer Thermal Energy Systems (ATES) are characterised by a large storage capacity of up to 10,000 MWh_{th} and are mainly used as seasonal storages.

For the efficient and optimal integration of ATES in energy supply systems further investigations are necessary.

The energy supply system of the German Parliament Buildings, consisting of a so far unique combination of different components and subsystems, offers an excellent possibility for scientific monitoring and applied research on the integration of ATES.



Sketch of the two ATES in the energy supply system of the Reichstag, the German Parliament Builidings in Berlin

Underground Thermal Energy Storages at the German Parliament Buildings, Berlin

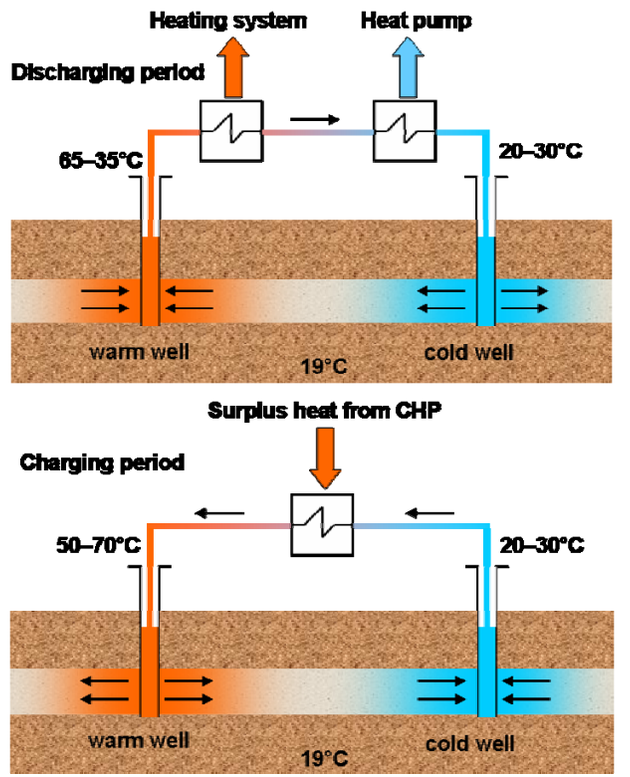
GFZ Helmholtz Centre POTSDAM

Research

The GFZ is coordinating since 2005 an interdisciplinary project group[1] which monitors, analyses and evaluates the ATES and the energy supply system of the German Parliament Buildings.

The main research topics within this project are:

- Hydraulic and thermal simulation of ATES behaviour for the evaluation of different operation strategies (GTN)
- Development of a well sensor for continuous geochemical monitoring (Uni Lüneburg)
- Monitoring, analysis and modelling of surface technology (TU Berlin)
- Modelling and simulation of the total energy system: control strategies, case scenarios, concepts for future energy systems including ATES (GFZ)



Principle of operation for the heat storage system showing discharging (winter period) and charging (summer period)

[1] project partners: Institut für Energietechnik (TU Berlin); Geothermie Neubrandenburg GmbH (GTN); Institut für Umweltchemie (Universität Lüneburg)

Underground Thermal Energy Storages at the German Parliament Buildings, Berlin

GFZ Helmholtz Centre POTSDAM

Results

Continuous scientific monitoring has shown :

•The integration of underground thermal energy storages into the energy system of the German Parliament Buildings significantly contributes to the efficient supply of power, heat and chill.

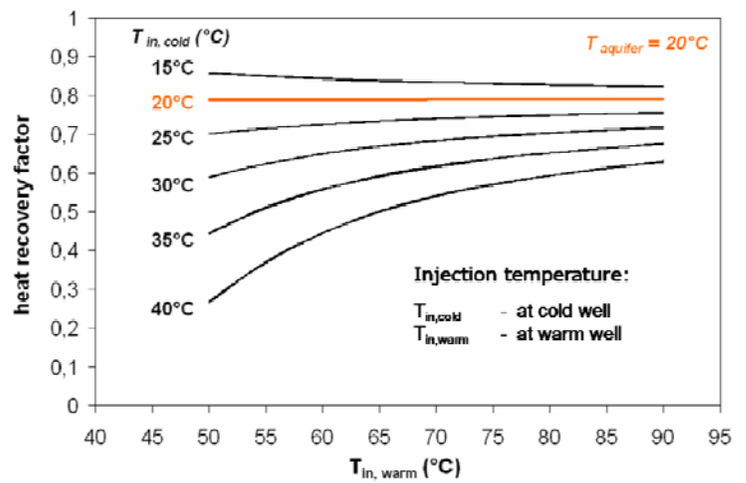
•The cold storage, for example, meets 40-50% of the total chill demand

Further project results can be summarized as:

• Recommendations for an improved ATES operation at the German Parliament Buildings

• Development of geochemical monitoring and maintenance concepts for reliable ATES operation

• Development of general best practice recommendations for the integration of ATES considering the plant design and operation



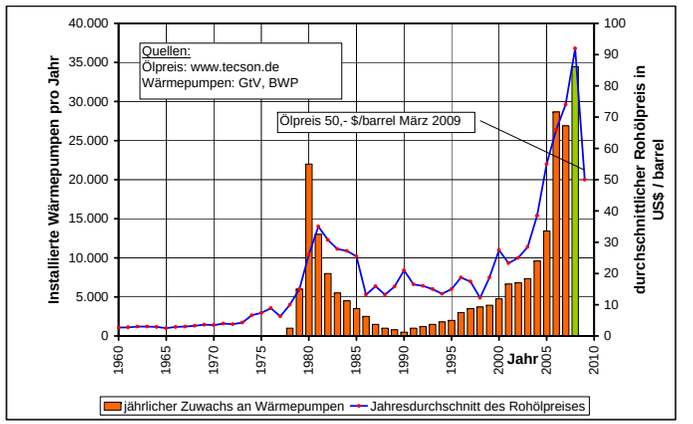
Heat recovery factor as a function of cold and warm well injection temperatures

Shallow Geothermal - Quality Management of Borehole Heat Exchanger and Ground Collector Systems

ZAE BAYERN

Initial Position

The continuous growth of the market for shallow geothermal systems like ground source heat pumps and underground storages for heating and cooling in the last 5 years requires quality assurance in design and construction of these systems to guaranty a sustainable and ecologically beneficial development of this technology.
A major focus is put on further development of the Thermal Response Test (TRT) as a useful instrument for site investigation to gain reliable data for a proper system design from the technical and economic point of view. Intensive research combined with exchange of experiences on an international level within the IEA ECES Annex 21 should improve the technology but also promote the application worldwide.
In the construction phase borehole grouting is an important issue from a technical and environmental point of view. Connecting aquifers and pollution of aquifers by leaking borehole heat exchangers operated with antifreeze and corrosion inhibitors are major concerns of the water authorities.
This research project deals in several subprojects with different problems which affect the system quality.



Increase of the annually installed ground source heat pumps.

(source: statistics from GtV and BWP)

Shallow Geothermal - Quality Management of Borehole Heat Exchanger and Ground Collector Systems

Research

The project is divided into six sub-projects, three of them are described briefly:
The TRT is a procedure to investigate thermal properties like underground thermal conductivity and borehole thermal resistance for a proper design of BHE's. Three major subjects which were identified from practical experiences with the mobile test equipment of ZAE :

- Development of improved evaluation models
- Evaluation of the TRT with respect to geological layers
- Investigation of the influence of ground water

IEA ECES Annex 21 „Thermal Response Test", coordinated within this project, provides an excellent international platform of experts for exchange and collaboration
The principal task of the grouting, the sealing of the borehole and the provision of good thermal contact, is investigated in a large experimental setup which allows to measure the coefficient of permeability at a model 'borehole' with 150 mm diameter and a length of at least 2.5 m under real operating conditions.

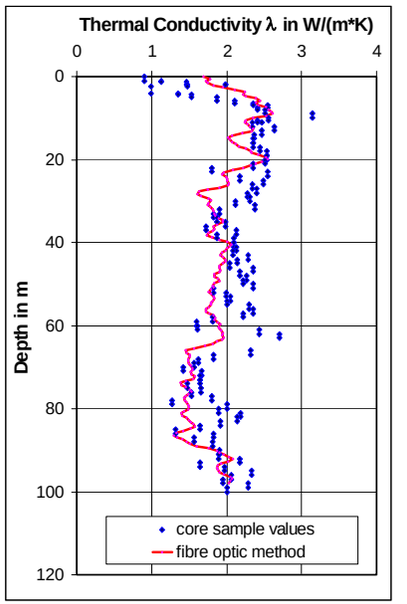
Mobile TRT equipment for site investigation

Shallow Geothermal - Quality Management of Borehole Heat Exchanger and Ground Collector Systems

ZAE BAYERN

Results

The classic TRT, the single step pulse test with constant heat flux, was modified by using a 'dynamic' heat flux which was varied in several steps. Vertical temperature profiles taken in the BHE during the TRT (enhanced TRT) allows a layer related evaluation of data and thus gives more detailed information on the underground. The results are compared to laboratory measurements of core samples from the same drilling.
IEA ECES Annex 21 brings together more than 20 experts from allover the for exchange of information. Among others a standard test procedure will be developed to improve the quality of testing.
Reference samples of a number of borehole grouting materials selected from a market survey were characterized regarding the coefficient of permeability. These materials will be tested in larger scale in the new developed experimental setup.
The results of this project will also be considered in the new edition of German VDI 4640 Guidelines – Thermal Use of the Underground planned for 2010.
This project is funded by the German Ministry of Economy and Technology (FKZ: 0327453A).



Enhanced TRT results compared to λ-values from core samples

Solar Air-Coditioning in Solarthermie 2000plus

Contact:
Dr.-Ing. Peter Schossig
Fraunhofer Institute for
Solar Energy Systems ISE
Freiburg, Germany
Phone: +49 (0) 7 61/ 45 88-5130
peter.schossig@ise.fraunhofer.de
www.ise.fraunhofer.de

Initial Position

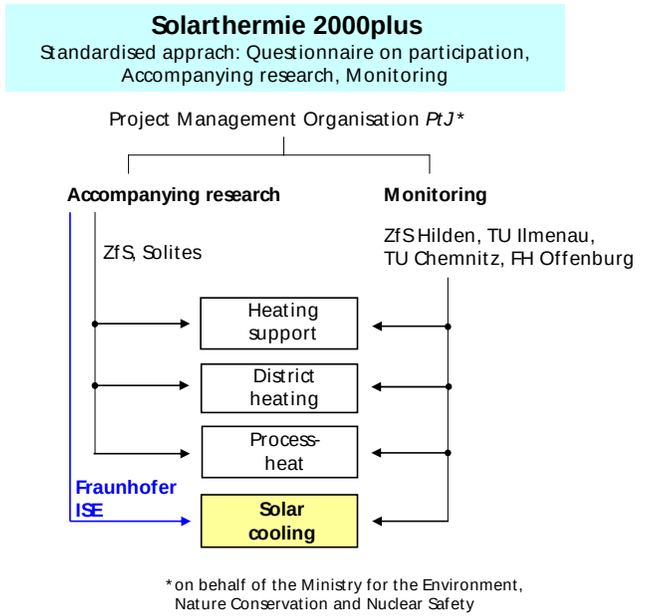
The funding scheme SOLARTHERMIE 2000plus, launched by the German Ministry for the Environment, Nature Conservation and Nuclear Safety, has provided funds for large solar thermal pilot and demonstration applications.

One of the main objectives within this programme was to demonstrate the applicability of solar thermal techniques in new and extended application fields, of which solar thermally driven air-conditioning is one.

In each application field, accompanying research was organised. Fraunhofer ISE is responsible for the accompanying research in solar cooling and air-conditioning applications.

Although the programme SOLARTHERMIE 2000plus is closed for new projects since the end of 2008, the accompanying research is still continued in order to evaluate the installed plants.

The funding programme was executed by the Project Manage-ment Organisation (PtJ), Jülich.



Application fields in the SOLARTHERMIE 2000plus programme and organisations, responsible for accompanying research and monitoring

Solar Air-Coditioning in Solarthermie 2000plus

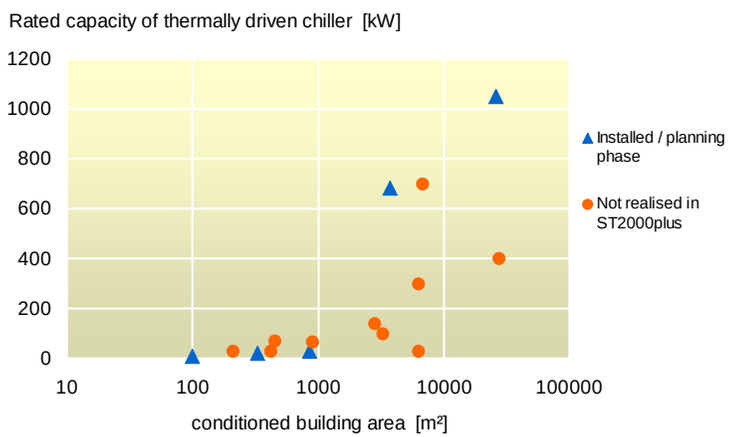
Research

Main objectives in the accompanying research of solar cooling and air-conditioning in SOLARTHERMIE 2000plus:

- Decision support to the project management organisation in the selection phase of the proposals
  (evaluation of project concepts with respect to environmental impact and technical feasibility)
- Support in the pre-planning phase of the projects
- Elaboration of the monitoring concept in close collaboration with the monitoring partners
- Analysis of monitoring data and evaluation of the system operation
- Supporting activities to the IEA Task 38 ‘Solar air-conditioning & refrigeration‘

17 proposed concepts were evaluated; 4 plants were realised, another plant is currently in the planning phase

Furthermore, a field test containing 10 small solar cooling applications has being started



Nominal capacity of the thermally driven chilling equipment versus conditioned area in the concept proposals

Solar Air-Coditioning in Solarthermie 2000plus

Results

Example:

- Solar assisted air-conditioning at the Technology Center of FESTO AG & Co. KG, Esslingen-Berkheim
- 1.05 MW chilling capacity with adsorption technology for air-conditioning of 26.000 m² office area
- Heat sources: waste heat and gas boilers
- Since end of 2007: additionally solar heat from 1218 m² aperture area of evacuated tube collectors in order to decrease use of heat from gas boilers (funded within ST2000+)
- Low driving temperatures of the adsorption process: 70°C
- Only water as collector fluid used
- Free cooling option through cooling tower in winter
- Since 2009, strong increase in the share of solar and waste heat on the total heat input through modified operation stragtegy
- In general reliable system operation

monthly review	Net solar system efficiency [%]	Solar fraction of total heat input [%]	Share of solar and waste heat on total heat input [%]	COP of chiller 1-3 [-]
2008				
June	41.4	9.5	20.3	0.48
July	40.4	9.1	29.5	0.52
August	32.9	6.2	34.8	0.53
September	32.5	3.5	36.1	0.52
October	26.1	3.0	29.4	0.49
November	11.6	0.5	24.8	0.44
December	6.6	0.0	33.3	0.46
2009				
January	9.6	0.6	30.4	-
February	11.2	1.2	57.8	-
March	22.4	5.4	78.1	-
April	33.8	16.0	79.2	0.44
May	41.5	15.6	67.2	0.48
12 Month	29.5	5.4	37.9	0.50

Performance of the solar thermally assisted air-conditioning plant at FESTO AG & Co. KG.

Keep Cool II – From cooling to sustainable summer comfort

Initial Position

The project aims to contribute reducing the increasing cooling needs for public and office buildings in the European Community. Two international studies from 1999 and 2003 forcast a quadruplication of cooling need in Europe. For the International Energy Agency (IEA) cooling and climatisation is even one of the fastest growing fields of new energy need.
The project is focussing on the idea of „sustainable summer comfort“. This means to install comfortable ambient conditions in office rooms during summer with no or small needs in fossil energies. Especially buildings to be refurbished should then be equipped with sun shading devices, efficient lighting systems, good buildings shell insulation or other passive matters to avoid overheating in the offices. So often the subsequent installation of mechanical cooling systems could be unnecessary, and comfortable interior room conditions with low energy consumption would be met.

www.keep-cool.eu

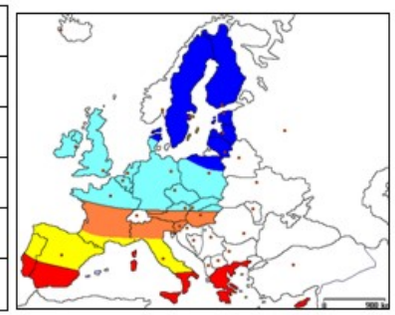
Funded by the European Programme Intelligent Energy for Europe

Keep Cool II – From cooling to sustainable summer comfort

Research

The main focus of the project were the simulations of energy efficiency improvement actions (EIA) or package solutions for refurbishment measures in the building stock. These simulations were effected for five climate zones and different building types such as public, office and residential buildings with both natural ventilation and air condition. The aim was to meet comfortable summer conditions without or with low fossil energy consumption.

Representative cities
Stockholm
Paris
Milan
Lisbon
Palerme



The selected climate zones

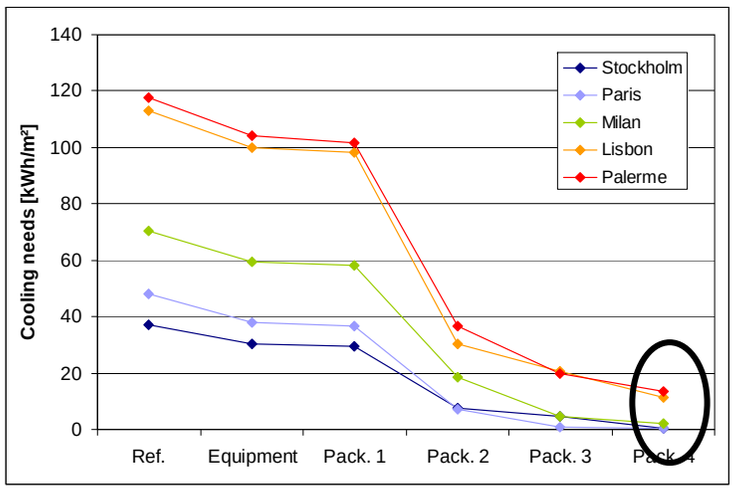
Keep Cool II – From cooling to sustainable summer comfort

Results

The results for one of the simulated office buildings show that the most effective way to reduce the cooling need considerably was a package (Pack. 4) of actions such as reduction of internal loads, installation of outer venetian blinds with radiation control, increased air change rate during day and night, efficient windows and insulation of the roof.

The most efficient single action was the installation of outer venitian blinds with radiation control. With such actions comfort conditions following the En 15251 could be observed in almost all selected climate zones.

Contact person: Barbara Dröschel, droeschel@izes.de



Evolution of cooling needs for the different packages studied in Office 1

Monitoring and Exergetic Evaluation of Heating and Cooling Concepts with Geothermal Energy

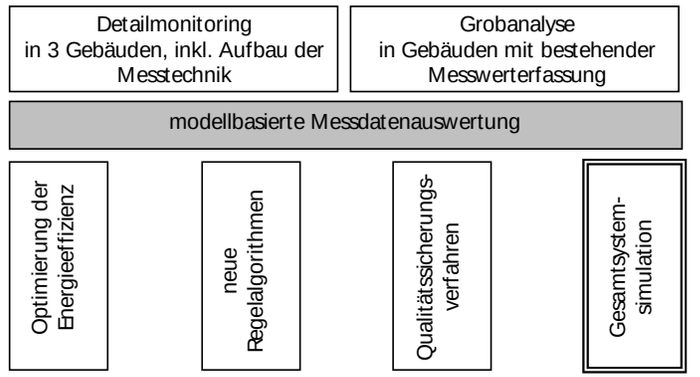
Contact:
Dipl.-Ing. Doreen Kalz
Fraunhofer Institute for
Solar Energy Systems ISE
Freiburg, Germany
Phone: +49 (0) 761/ 4588-5403
doreen.kalz@ise.fraunhofer.de
www.ise.fraunhofer.de

Initial Position

The project LowEx:Monitor focuses on the analysis of heating and cooling concepts for non-residential buildings that use primarily surface-near geothermal energy as environmental heat source/sink and thermo-active building systems (TABS) as heating/cooling delivery system. Achieved results in terms of supplied heating/cooling energy, energy efficient of the plant and thermal comfort are based on long-term monitoring campaigns.

The comparative evaluation of the subsystems in all buildings identifies weak points and success factors of the plant systems. Therefore, the project contributes to the identification of optimization measures that emerge from the interaction of single plant components and subsystems considering.

Adopting an overall system approach, important measures are the characterization and optimization of single plant components within the hydraulic circuits, the sound integration of technologies, the continuous optimization of the operation, and the development of novel control algorithms.



Structure of the project: the four working packages focus on the analysis and evaluation of long-term monitoring campaigns in non-residential buildings.

Monitoring and Exergetic Evaluation of Heating and Cooling Concepts with Geothermal Energy

Research

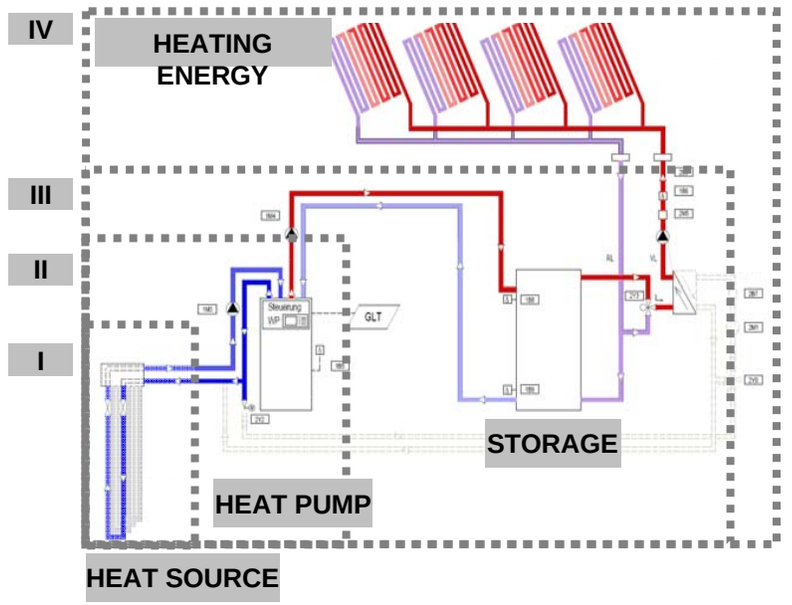
The entire heating and cooling system and the corresponding subsystems are evaluated according to four balance boundaries: (I) environmental heat source/sink, (II) heat pump system, (III) thermal storage and energy distribution, and (IV) delivery of heating/cooling energy to the room.

Taking a small non-residential building (floor area 2.100 m²) as an example (Figure at the right), it follows for the heating mode that:

Boundary I: The ground provides 19 kWh/(m²a) of heating energy harvested by borehole heat exchanger with an energy efficiency factor of **SPF-I10.9**.

Boundary II: The heat pump system increases the given ground temperature to the necessary low heating temperature of 30 to 35 °C resulting in a total heating energy of 26.0 kWh/(m²a) and an energy efficiency factor of **SPF-II 3.7**.

Boundary III+IV: The distribution of heating energy through the building and delivery to the rooms requires additional auxiliary energy for the hydraulic systems. Therefore, the resultant efficiency performance of the entire heating system is in the order of **SPF-IV 2.3**.



Adopted methodology for the energy and efficiency evaluation according to four defined balance boundaries I to IV. System schematic for a small non-residential building.

Monitoring and Exergetic Evaluation of Heating and Cooling Concepts with Geothermal Energy

Fraunhofer ISE

Results

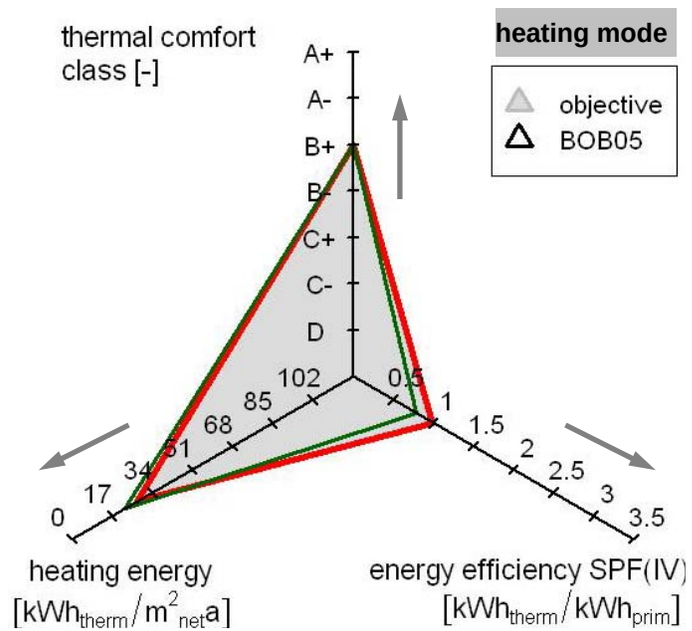
A holistic approach to the evaluation of heating and cooling concepts seeks to achieve a global optimum of

- occupant thermal comfort
- heating and cooling energy demand
- energy efficiency
- primary energy use

Therefore, the approach allows to compare different concepts, verifies the achieved aims in correspondence with the target objectives, identifies success factors and further optimization potential, and determine the environmental impact.

Results are derived separately for the heating and cooling mode and are presented in form of a triangle.

Results for are residential building (figure) show that good thermal comfort compliant with class B is achieved with a significantly reduced heating demand (26 kWh/m²a) which is supplied with an overall system efficiency of 2.3 (related to end energy) and 0.8 (related to primary energy, figure).



Objective (red triangle) vs. monitoring results (green triangle): thermal comfort, useful heating, and energy efficiency. Arrow indicate direction of optimum.