FORSCHUNGSFORUM
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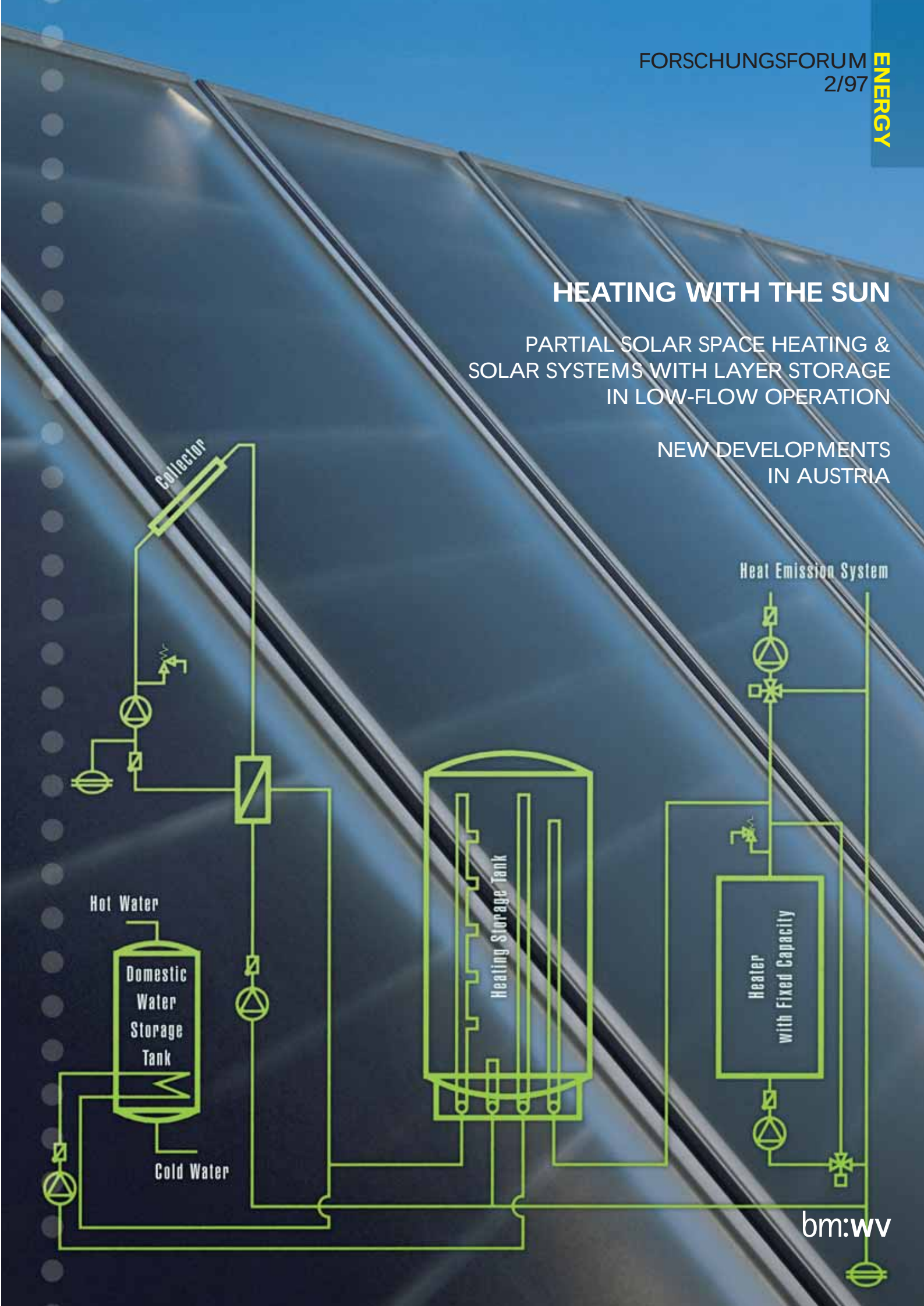
ENERGY

HEATING WITH THE SUN

PARTIAL SOLAR SPACE HEATING & SOLAR SYSTEMS WITH LAYER STORAGE IN LOW-FLOW OPERATION

NEW DEVELOPMENTS IN AUSTRIA



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P R O J E C T

PARTIAL SOLAR SPACE HEATING - OBJECTIVES OF THE PROJECT

As regards the utilization of solar energy by means of thermal collectors, Austria is in the top league of EU Member states.

In 1995, the total surface of solar collectors installed in Austria for energy production was 1.2 square kilometers. Approximately one-fourth of the total collector surface consists of plastic absorbers used for pool heating. The remaining 75% of collector surface are mainly needed for water heating in single and multi-family homes. These thermal solar systems for domestic water heating have today reached a level of maturity and technical reliability. As a result of the high standard of these systems, the option of using solar power for heating purposes is becoming more and more attractive. In Austria, a large number of family homes have been equipped with systems for partial solar heating.

As the planning of such systems requires considerably more know-how than a simple water heating system, a research project on "partial solar space heating" was commissioned by the Federal Ministry of Science and Transport within the context of a federal/regional cooperation agreement. The aims of the project managed by ARGE Erneuerbare Energie (Society for Renewable Energy) were to examine the framework conditions and prerequisites for solar space heating and to document and evaluate various system alternatives.

As a first step, a comprehensive survey of existing systems was conducted. Nine systems equipped with thermal solar heating systems were selected and upgraded with an appropriate measuring technology in 1994. In the 1994/95 and 1995/96 heating seasons, data from all nine systems were compiled and evaluated. Already after the first heating period the operators were able to implement the findings of the study. After some of the systems underwent certain adjustments, improvements were achieved in the second heating period.

The measuring results document that it is possible to support heating systems efficiently with thermal solar systems. They also show that the overall solar proportion depends significantly on the quality of the hydraulic system, the insulation of the storage tanks and the tubing. With insufficient storage tank insulation and poor hydraulic performance, solar proportions may be considerably below expectations.

After measurements were performed, all data were evaluated and relevant parameters were established as the basis for general statements and evaluations. These evaluations formed the basis for the planning and sizing of such systems. The results, basic technical concepts and practical implementation details were compiled in a planning handbook.

Another sizing aid is ***SHW, a computer simulation program,*** which was developed using the measuring data obtained within the context of this project.

With the help of this program, yearly simulations of solar power systems for hot water preparation and space heating as a function of meteorologic data of a given location and the other system parameters. Another important part of the job was to review and improve the program on the basis of the new findings. The majority of systems are highly consistent with the simulations. The handbook "Heating with the Sun" and the simulations program SHW constitutes a reliable tool for predicting the yield of solar systems for partial solar heating.

SHW - Simulation Program for Solar Water Heating and Space Heating Systems

The program was initiated between 1993 and 1995 at the Institute of Heat Technology of the Graz University of Technology in order to support several research projects. The program was written in FORTRAN and is able to calculate solar heating systems for the supply of hot water, for combined hot water supply and (partial solar) heating, as well as for long distance heating systems. Input and output data were formatted in ASCII. These data sets can be prepared and interpreted by means of different editors, word processing and spread sheet programs. The program was validated in three different partial solar heating systems of one family dwellings and showed good congruence of the measurements (hourly mean values of relevant temperatures and energy flows measured over a period of three weeks in each case).

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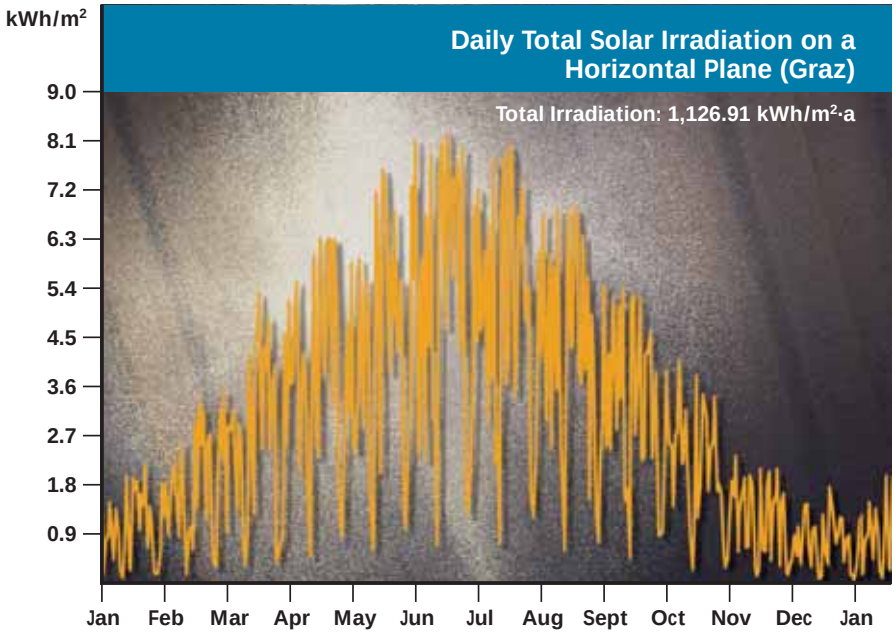


FRAMEWORK CONDITIONS FOR SOLAR SPACE HEATING

PREREQUISITES

The heating season in Austria lasts from September until May for a total of approx. 5000 heating hours.
The figure shows the daily aggregate amounts of global horizontal plane solar irradiance in Graz for a regular meteorological year. At the onset and at the end of the heating period, solar irradiance is relatively strong although there are weather-related fluctuations in irradiance over days, weeks and the course of the year. When a new building is planned, attention regarding the selection of the construction site should be paid to the shape and zoning status of the house. Plots with southbound exposure at the same site get 10-30% more overall irradiance than slopes with a northern inclination. Other important prerequisites for solar heating systems include a good building insulation system and the passive use of solar energy. As a first step in already existing buildings, sanitation will therefore almost always be appropriate.

Ideal conditions for solar heating are found in low-energy houses with an annual heating energy demand of less than 70 kWh/m^2 useful floor area. The heating demand of low energy buildings currently under construction is 30-50%. Numerous examples and studies show that these buildings, when properly planned, require no or only minor extra expenditures.

Combinations of low-temperature wall and floor heating systems are particularly well-suited for solar heating due to their low supply temperatures. The mean supply temperature of low-temperature under-plaster wall-heating systems during the heating season is below 30°C. This temperature level can be achieved by a solar system even with poor winter irradiation. The heating elements for these systems are manufactured from copper and plastic tubings and are usually installed inside the exterior building walls. In buildings with adequate insulation, these surfaces are generally sufficient to meet the demand in heating.

SYSTEM CONCEPTS

To offset seasonal and meteorological fluctuations in irradiance and outside temperature, an energy storage medium must be available. A general decision must be taken as to whether the building should rely exclusively on solar heating or whether the solar system is only intended to support the conventional heating system (”partial solar space heating“).

Some previously completed systems show that it is essentially possible to store summer heat in large-scale water storage tanks for use in the winter season and thus to rely on solar energy alone. As far as costs are concerned, solar systems with seasonal storage devices are only interesting on a large scale and in combination with local heating grids as there is a marked decrease of storage costs with the size of the system.

From an economic point of view, ”partial solar heating“ with collector surfaces of 20 to 40 m^2 in combination with short-term storage facilities is a more efficient approach. With such heat storage tanks between 1 and 5 m^3, fluctuations in energy supply and demand lasting for several days may be equalized and bridged. Determination of the size of the system is subject both to the required solar capacity and to the back-up heating system used.

PROJECT RESULTS

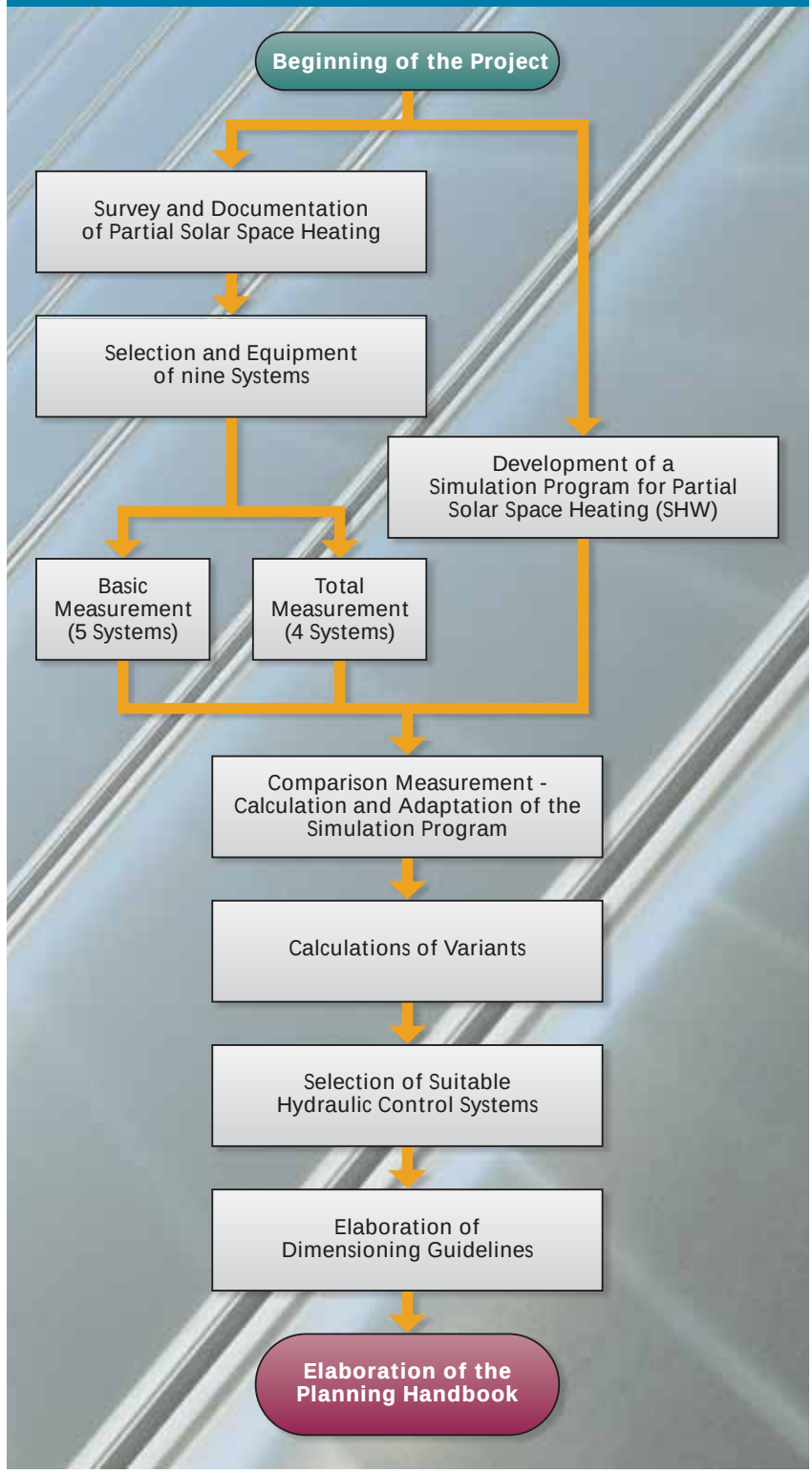
Due to the contracting agencies, the survey area of the project was restricted to the federal provinces (Länder) of Lower Austria, Upper Austria, Salzburg and Styria.

In January 1994, all operators and suppliers of partial solar heating systems were contacted and asked to fill out a questionnaire containing questions on the most important system data with a view to obtaining an overview of all systems installed by solar engineering firms or private builder-operator groups. Responses were received from 48 system operators and manufacturers. From these systems, nine were selected and equipped with the necessary measuring technology.

When selecting the systems, attention was above all paid to the need for a variety of system concepts. Thus the survey covered both systems with double and multi-storage tank concepts and single-tank systems with external water heating via a plate heat exchanger or layer storage in combination with low flow systems. The models chosen were also quite variable as regards the thermal quality of the building shell. Systems with less than 16 m^2 collector area were excluded on account of their insufficient contribution to the total amount of space heating energy.

In most systems, there was a strong correlation between measuring results and simulations. The expected results were confirmed for all nine systems under examination. It was demonstrated that relevant amounts of heating energy can be achieved if the house heating load is below 10 kW and if a low-temperature heating system is installed. The better the house is equipped in terms of heat insulation, the larger is the solar proportion. As a general rule, it can be said that, depending on the size of the collector surface (20-40 m^2) and the storage capacity (1-3 m^3), solar proportions (heating and hot water) of 20 to 45% can be achieved. To measure solar space heating integration levels, various parameters including electrical work equivalents, specific collector yields and solar proportions were introduced according to various definitions and computed. As regards electrical equivalents, values of around 40 were measured while the mean specific collector yield for all nine systems was 260 kWh/m^2a.

Overview



SOLAR SYSTEMS WITH LAYER STORAGE IN LOW-FLOW OPERATION

"In view of the rising growth rates in thermal solar collector area already installed and the potential for upgrading of solar systems, a large market share can be expected for low flow systems."

■ Since 1990, substantial annual increases in installed thermal solar collector area have been achieved; while around 80,000 m^2 had still been installed annually in the early 1990s, the area newly installed every year reached 200,000 m^2 in 1995. Growth rates were not only realized for water heating in single family homes but also in systems with partial solar space heating.
A similar tendency can be observed in the sector of large-scale thermal solar systems for domestic water preparation in communal housing projects, hospitals, retirement homes and hotels.
As the market develops, there is a constant improvement in the quality of available systems which aims to increase the yield of solar heating systems and to reduce investment costs.

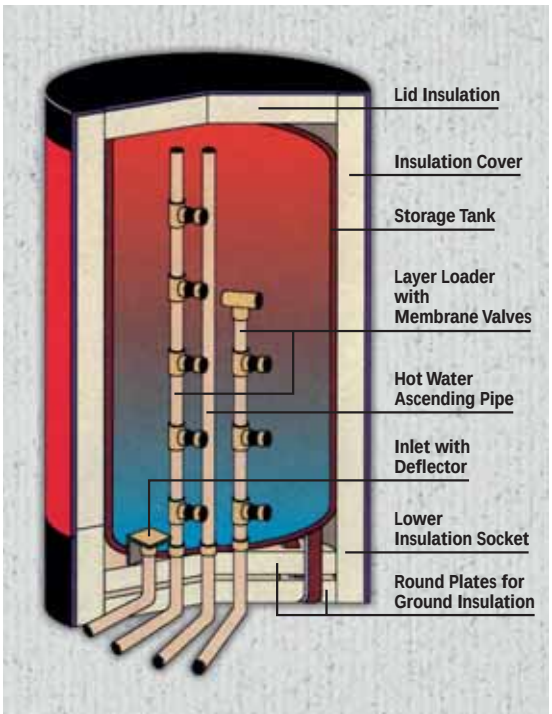
A special type of solar collector is based on the principle of low-flow operation. This novel concept has been under investigation since the early 1990s.
In a project commissioned by the Federal Ministry of Science and Transport, a study entitled "Solar Systems with Layer Storage in Low Flow Operation" was conducted by the Working Group on Renewable Energy (ARGE Erneuerbare Energie). The study explains the physical premises underlying the principle of low flow operation and gives an overview of systems currently available on the market.

Conventional systems (high-flow operation) are being operated with specific collector mass currents of 35-70 kg/m^2 h. The temperature gradient between collector supply and return main are within a range of 15 K. On the premise of constant irradiation, the storage volume will slowly be heated up in every collector passage until the required temperature is reached at a relative slow rate. In low-flow systems, considerably lower specific collector mass currents of only 8-18 kg/m^2h are flowing through the collectors. The ensuing temperature gradient between collector supply and return main is substantially higher, with the supply main temperature already ideally reaching useful temperature. In order to preserve this instant energy availability rate for the consumer, low-flow systems have tanks loaded via so-called layer loading systems in a temperature-based manner. The range of relevant products available on the market includes electrically controlled valve systems and gravity-operated membrane valves.

Both the new study and the experiences gained in the realization of solar systems show that a great potential may be expected from the low flow technology owing to the following advantages:

- Reduction of investment costs because of smaller tube diameters and smaller-scale circulating pumps
- Savings of pump energy because of smaller circulating pump
- Reduction of thermal loss because of minimized tubing surface
- Depending on type of usage and system dimension, an increase in solar proportion of up to 10% may be achieved
- Owing to the temperature-based layer loading device, the system technology can be kept at a very low level.

However, the low flow mode of operation offers new challenges for individual system components such as storage tanks, circulating pump, heat exchanger or collector circuitry. Suitable dimensioning tools for components must also be found. In these areas, there is great demand for new developments.



Cross-section of "Stratos" buffer storage system (Solvis, 1995)

The "Stratos" energy storage device is equipped with a special storage loading device, the Solvis layer loader, which conducts the solar-heated medium directly into the layer of the same temperature. The self-regulating loading device permits the stratification of various water temperatures at different storage levels. The layer loader consists of a polypropylene pipe which is open on the top and which may be closed by several outlets with soft silicone membrane valves to prevent storage tank water from flowing back into the pipe.

HEATING WITH THE SUN - PLANNING HANDBOOK FOR SOLAR HEATING SYSTEMS

Solar energy will only be able to play a major role in Austria's energy market if it is also used for building heating. The proportion of space heating in Austria is approx. 380 PJ, i.e. some 40% of the country's total useful energy demand, which is currently mainly met by fossil sources of energy (oil, gas and coal). Owing to the initiative of private builders, the first systems for solar space heating in Austrian single-family homes have been realized by various solar engineering firms and the Society for Renewable Energy. With a view to further aiding such projects, a planning handbook was produced within the framework of this research project which lists all the findings of the project in the form of planning recommendations. The handbook "Heating with the Sun", describes the most important technical and constructional reqirements for solar heating systems and gives practical suggestions for the implementation of such systems. The handbook further contains examples of previously installed systems to illustrate the technical explanations. Together with the simulation program SHW described above, the handbook is ultimately also an important user-friendly tool to estimate the annual solar energy proportion to be achieved with solar-assisted space heating systems.

PROJECT SPONSOR

The project *"Partial Solar Space Heating"* was launched as a scientific assignment within the framework of a cooperation between the federal and regional governments in the field of resource, energy and environmental research. The project was commissioned by the Federal Ministry of Science and Transport, the Federal Ministry of the Environment and the Regional Governments of Styria, Salzburg, Lower Austria and Upper Austria, and was carried out by the Society for Renewable Energy.

Project managers: Werner Weiß, Michael Eder, Christian Fink;
Other participants included the Working Group on Heating Technology at the Graz Technical University (Dr. Wolfgang Streicher)

The study *"Solar systems with layer storage systems in low-flow operation"* was conducted by the Society for Renewable Energy on commission from the Federal Ministry of Science and Transport.

Project managers:
Michael Eder, Christian Fink

PUBLICATIONS

Final project report
TEILSOLARE RAUMHEIZUNG
Society for Renewable Energy, Gleisdorf 1996

Final project report
SOLARANLAGEN MIT SCHICHT-SPEICHER IM LOW-FLOW BETRIEB
Society for Renewable Energy, Gleisdorf 1996

Both project reports are available at:
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HEIZEN MIT DER SONNE
Planungshandbuch für solare Heizungssysteme
Society for Renewable Energy, Gleisdorf 1997

TEILSOLARE RAUMHEIZUNG
Auslegung und hydraulische Integration
Post-doctoral thesis by Dr. Wolfgang Streicher, Institut for Heating Technology, Graz Technical University

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