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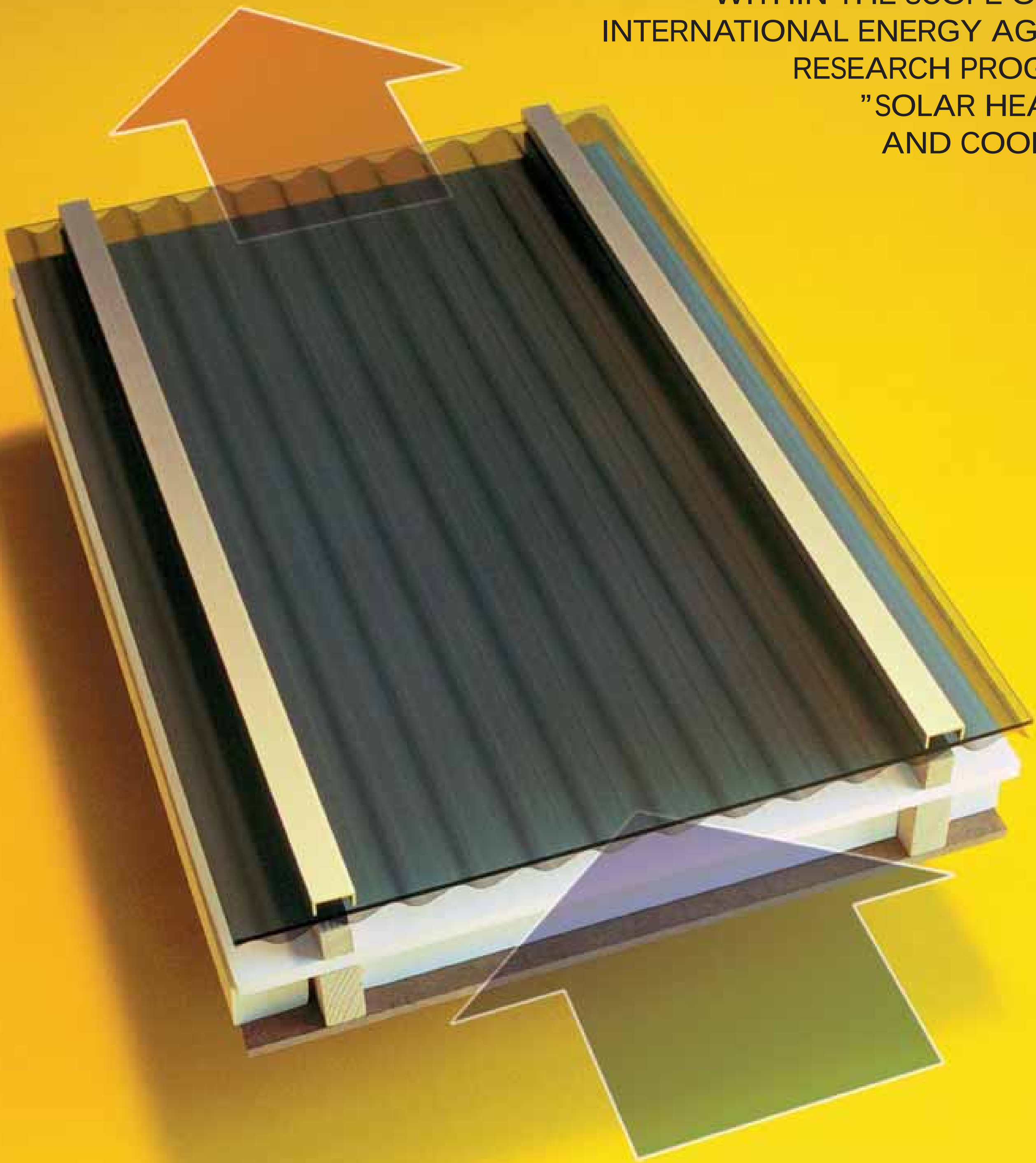
ENERGY

SOLAR AIR SYSTEMS

AUSTRIAN RESEARCH
WITHIN THE SCOPE OF THE
INTERNATIONAL ENERGY AGENCY
RESEARCH PROGRAM
"SOLAR HEATING
AND COOLING"



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IEA TASK 19 "SOLAR AIR SYSTEMS"

Modern building technology increasingly aims at reducing the space heating loads and tries to supply the required residual heating by means of renewable sources of energy as far as possible.

Task 19 forms part of a comprehensive international research project with Austrian cooperation on solar heating and cooling initiated by the International Energy Agency (IEA). The project is to bring together the most recent findings concerning the utilization of solar energy in modern building construction, to test technologies in practice, and to promote the diffusion of these technologies on an international scale. Task 19 is concerned with the use of ***solar air systems*** in buildings.

Since first attempts undertaken in the U.S.A. at the end of the 19th century, different solar air technologies have been developed on a global scale. While these innovative technologies seem to be very promising their practical use is not widespread as yet.
In order to canalize the knowledge of solar air systems on a global scale, the IEA initiated a five-year program, in 1994, dealing with the planning and the construction of such systems.
Austrian activities within the scope of this international framework program were financed by the Austrian Ministry of Science and Transport (BMWV).

Solar air systems are capable of supplying a great part of heat demand in a building, with the roof and, above all, the facades serving as air collectors, thus fulfilling an additional function.
In buildings with good heat insulation and sealing, however, ventilation is an important factor, too. Therefore, solar assisted ventilation systems with heat recovery are becoming more and more important. The design and installation of solar air systems has to take into account architectural and technological factors of the building. Active utilization of solar energy in such systems offers greater efficiency, better heat distribution and, thus, greater comfort than passive systems.

Within the scope of the IEA Task 19 program, existing buildings have been evaluated, documented, and analyzed in detail for at least one heating period. The findings obtained from this analysis served as a basis for working over and fine-tuning the planning instruments. The Austrian research project "Solar Air Systems" has been implemented by Dr. Manfred Bruck, consulting engineer in Vienna; activities in the province of Vorarlberg have been coordinated by the Energy Institute Vorarlberg. This research was to document the results of 18 measuring projects and to present a systematic survey of different hot-air heating systems. The Austrian research center "arsenal research" (DI Hubert Fechner) tested different air collectors within the scope of this international research project.

The final reports on the two Austrian sub-projects ("Solar Air Systems", Dr. Bruck, and "Investigations on Series Produced Solar Air Collectors, DI Fechner) have now been published. Dr. Bruck's engineering office has also completed the research project "Double Facade", commissioned by the Austrian Ministry of Science and Transport.

Additional **results of the program** include:

- The paper "Built Examples" describing 33 buildings fitted with different types of hot-air heating systems.
- The paper "Product Catalogue" presenting components of solar air systems.
- The updated computer simulation program TRANSYS, which takes into account the most recent research results.
- A design and planning manual for solar air systems is in preparation.

Results of the international Task 19 program have shown that virtually all types of buildings could be equipped with solar air systems. In all cases, the avoidance of fossil fuel would contribute to relieving the environment. Simple air-preheating systems are economically viable in spite of low energy costs.

Solar Air Systems

convert solar energy to heat, which is transported by the medium air to a storage or directly to a heat dissipation system. The collector used is comparable to a conventional water collector, the difference being that air instead of water is circulating behind, through or above the absorber.

SOLAR AIR SYSTEMS

The final report on the project "Solar Air Systems" describes the various applications for solar air heating systems and presents a survey of the different types of such systems.
The report sums up the advantages and limitations of these designs as compared to merely passive solar energy systems as well as solar hot-water heating systems. The project analyzed and documented 18 already existing buildings including a wide range of design, thus, presenting different framework conditions and requirements (architecture, technology, heat demand, and user behavior): single-family houses, multiple-family buildings, office buildings, schools, kindergardens, a garage, and a sports hall.
The results of these measuring projects have been summed up in brief reports. The Austrian projects "Garage Maetzler", "Hauptschule Koblach", "Kindergarten Baeumle", and "Haus Frei" have been documented in greater detail in the final report.

SOLAR AIR HEATING SYSTEMS – HOW DO THEY WORK?

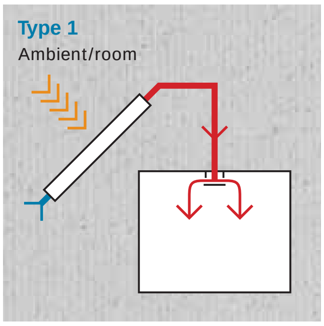
The following elements may serve as collector integrated in a building:

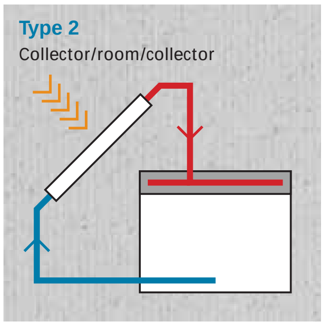
- Facade or roof-integrated panels (glazed or unglazed), which also provide a weather skin and noise protection
- Double windows with internal adjustable blinds serving as absorber
- Transparent second facade in front of the primary facade
- Glazed spaces, such as atriums, winter gardens, and attics

Heat storage is implemented by hypocausts (concrete floor with built-in channels through which solar heated air is passing), murocausts (hollow core walling) or rock-bed storage in the basement or in the core of the building. Of course, solar heated air may also be circulated directly into the space without intermediate storage, thus supplying not only heat but also fresh air and, at the same time, regulating air humidity.

Air circulation is brought about automatically as heated air is rising (natural convection); however, most solar air heating systems use fans. In well designed systems the ratio of energy demand for fan operation to total energy output (heat) should be from 1:15 to 1:25. In ideal cases, the energy needed for fan operation is generated by photovoltaic (PV) panels, the advantage being that this system is self-regulating as PV-induced fan performance increases in proportion to solar thermal output.

Heat distribution is implemented by means of conventional ventilation systems, hypo- or murocaust or directly from space to space.





APPLICATIONS

Usually, direct air supply is used only for halls, storehouses, and for drying of agricultural products. Indirect heat supply (e.g. by hypocausts), in contrast, is preferred for space heating in residential buildings because the warm surfaces provide agreeable radiant heat to the space. Another possible application consists in ventilation air preheating combined with heat recovery. Practice has shown that multi-function systems usually are more economical.

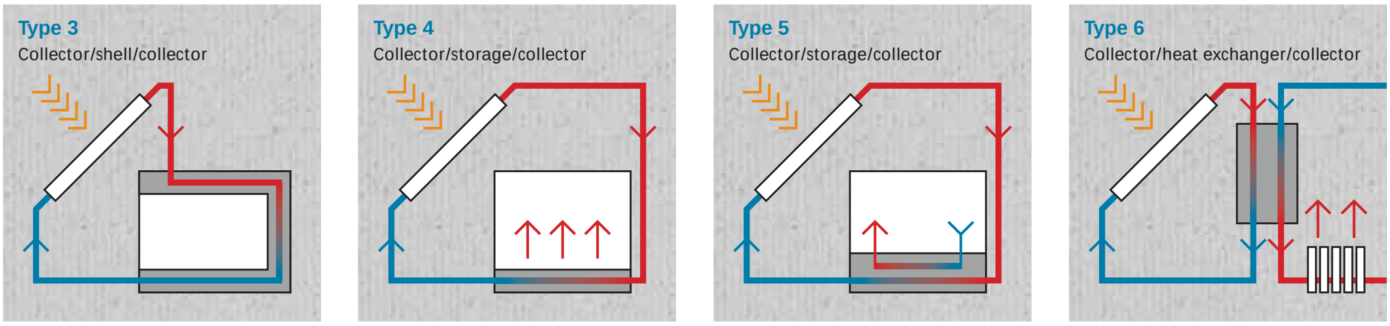
Typical applications include:

- solar space heating
- fresh air preheating
- water heating systems
- induced cooling (e.g. solar "chimneys")
- power generation (hybrid PV-systems)
- shading (e.g. window collectors)

ADVANTAGES AND LIMITATIONS

Solar air heating systems feature a number of advantages as compared to merely passive solar systems or solar heating systems using water. In comparison to passive solar systems they show the following positive characteristics:

- more efficient use of solar energy without comfort restrictions (overheating)
- better timing and adaptation to demand through heat supply from buffer storage in the evening and at night



Source: Kanzlei Dr. Bruck

- better heat distribution (solar heat may also be supplied to rooms facing north)

Compared to solar heating systems using water as fluid solar air heating systems feature advantages as far as safety (leakage in the system does not cause damage to the building) and environmental protection (no anti-freeze) are concerned.

Other positive aspects of such systems consist in their additional functions. Solar air systems integrated in the building often serve as weather skin and as a barrier against street noise or as load bearing elements (snow load). The individual components of the system form an integral part of the conventional building shell and can easily be combined with mechanical ventilation, which is constantly gaining ground not only in office buildings but also in low-energy houses.

Nevertheless, solar air heating systems also have a disadvantage:

- Air has a very low heat-storing capacity as compared to water (0.0003 kWh/m^{3}K versus 1.16 kWh/m^{3}K for water).
- A relatively large volume of air is necessary to transport a relatively small amount of heat.
- Consequently, large cross-sections are necessary for the transport of the air volume involved.

SYSTEM TYPES

The final report on IEA Task 19 "Solar Air Systems" presents and analyzes various types of solar air systems drawing on data derived from the individual measuring projects.

Type 1 is a very simple construction: ambient air passes from a glazed or unglazed collector directly into the room to provide ventilation and heating. Applications include vacation cottages (dehumidification) and large industrial buildings requiring adequate ventilation.

Type 2 circulates room air to the collector. The heated air rises to a thermal storage ceiling from which it is conveyed back into the room. This system uses natural convection and is well suited for apartment buildings.

Type 3 is particularly suited for retrofitting poorly insulated buildings. Collector heated air passes through a cavity between an outer, insulated wall and an inner facade. This creates a buffer which considerably reduces heat loss via the facade of the building.

Type 4 is the classical solar air heating system and is commonly used. Collector heated air is circulated through channels in the floor or in the wall. Heat is radiated into the room with a time delay of four to six hours. The advantage of this system consists in the large radiating surfaces, which provide for a comfortable climate. Systems with forced ventilation (fans) provide the best efficiency and thermal output. They may be used in buildings with large surfaces, which serve as radiation sources.

Type 5 is an advanced version of type 4; room air is circulated through separate channels of the storage. Thus, heat can be stored for a longer period of time and released when it is needed. However, this type is rarely used as investment costs are rather high.

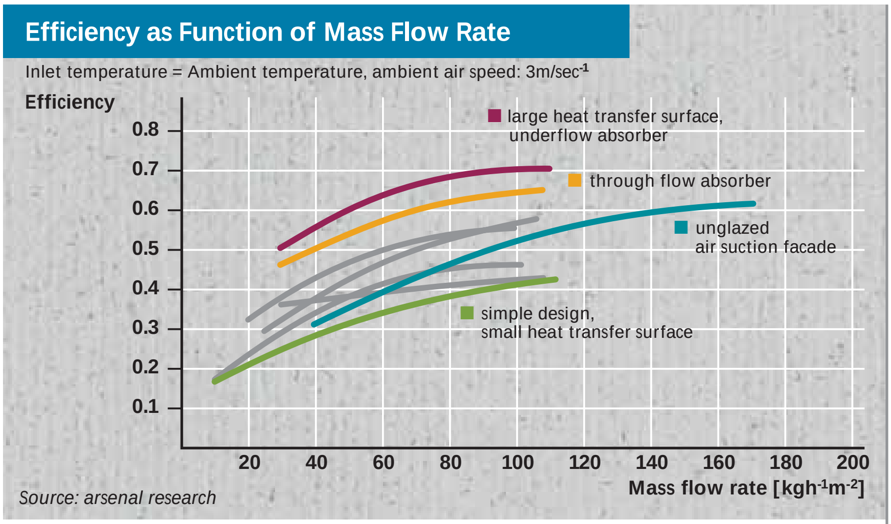
Type 6 combines a solar air collector and, via a heat exchanger, a conventional heating system. Thus, common radiators and floor or wall heating components may be used. This system can also provide domestic hot water and is particularly suited for retrofitting and for buildings in which heat has to be transported over long distances.

INVESTIGATIONS ON SOLAR AIR COLLECTORS AT THE AUSTRIAN "ARSENAL-RESEARCH" CENTER

The central part of any active solar system consists of the collector, which absorbs radiation energy from the sun and converts it into heat. At present, solar air collectors are not yet very widespread: On a global scale, there are only a dozen manufacturers engaging in the series production of air collector systems. While there are international and national testing standards for hot-water solar collectors, as well as uniform standards on a European level, there are no testing standards for air collectors, as yet.

Contributing to IEA Task 19 "Solar Air Systems", the Austrian Ministry of Science and Transport commissioned "arsenal research" with a project inviting manufacturers of air collectors to submit their products for comprehensive testing. Seven manufacturers from different parts of the World (Europe, Canada, Australia) responded to the offer and had their series produced collectors, as well as some prototypes of different design tested in Austria.

The objective of the project consisted in the development of adequate framework conditions and testing procedures, a meaningful presentation of efficiency in dependence on temperature and mass flow as well as in a comparison of the efficiency of different collector designs. Testing technology used at the "arsenal research" included the existing sun simulator and a test stand for water collectors as well as a sophisticated air conditioning system with a 150 m^3 climatic chamber.



Source: arsenal research

The project investigated the following items:

- Efficiency in dependence on the difference between ambient temperature and outlet temperature
- ***efficiency in dependence on mass flow rate***
- air leakage rate
- pressure drop in dependence on mass flow rate
- influence of exterior convection
- behavior at stand-still
- absorber efficiency

In some cases, the results of these investigations have been integrated by manufacturers in the further development of their products.

As is the case with hot-water solar collectors, a good collector alone does not guarantee optimal solar gain; the following factors may have a decisive influence on the overall performance of a system:

- the actual flow pattern in the collector
- design of collector array
- collector control design
- required temperature level
- ambient air speed (especially with uncovered above flow collectors)
- air leakage rate
- storage

The planning instruments developed within the scope of the IEA Task 19 program constitute a well-founded technological basis for the design of solar air systems. The results of this investigation may benefit innovative building owners, planners and architects in designing buildings relying predominantly on renewable energy for space heating.

"DOUBLE FACADE" QUANTITATIVE THERMAL PERFORMANCE AND DESIGN RECOMMENDATIONS

■ Within the scope of IEA Task 19, an additional study dealing with the thermal performance and the advantages and disadvantages of a second facade in buildings has been commissioned by the Ministry of Science and Transport and carried out by the engineering office Dr. Bruck, Vienna.
A "double facade" consists of an exterior wall assembly, in which an additional transparent facade is attached to the outside of the main facade. Since ventilation of the building is effected through the buffer space between outer and inner facade, planning of this building component involves architectural and climatic considerations, which are closely interrelated.

From a functional and esthetic point of view the "double facade" is a hybrid between an air heating collector, which uses the opaque outer wall components as absorber and a sun space, however without offering the usual habitable space. The construction affords a reduction of heat losses due to transmission and ventilation, on the one hand, and, on the other, maximum utilization of solar gains by means of preheating air used for ventilation.

These advantages and other positive aspects (such as the potential for esthetic design or natural ventilation) have led to increased popularity of this construction with architects and building owners. The study analyzes the particular characteristics of the "double facade" for individual applications like new construction or retrofitting of office or residential buildings. The objective of the study was to identify the quantitative influence of key parameters in order to create a basis for concrete guidelines and design recommendations.

ZAHLEN / DATEN / FAKTEN

PROJECT SPONSORS

The studies mentioned below were commissioned by the Austrian Ministry of Science and Transport (BMWV):

"Solar Air Systems", and *"Double Facade"*, T. Zelger, M. Bruck, C. Muss, Vienna, 1999
Engineering Office Dr. Bruck
Prinz Eugenstrasse 66, A- 1040 Vienna
e-mail: bruck@magnet.at

"Investigations on Series Produced Solar Air Collectors",
DI Hubert Fechner, Vienna, 1999,
arsenal research
Faradaygasse 3, A-1030 Vienna
Internet: www.arsenal.ac.at

PUBLICATIONS

The final reports on these studies have been published in English in the series ***"Berichte aus Energie- und Umweltforschung"*** (Reports on Energy and Environment Research) by the Austrian Ministry of Science and Transport (BMWV) and are available from:
PROJEKTFABRIK,
Nedergasse 23, A-1190 Vienna, Austria.
A complete list of the series "Reports on Energy and Environment Research" can be found on the FORSCHUNGSFORUM HOMEPAGE.

International publications
by James & James Ltd., 35-37 William Road, London NW1 3ER, UK:

Solar Air Systems – Built Examples,
S. Robert Hastings (ed.), IEA Solar Heating and Cooling Programme,
ISBN 1-873936-85-0

Solar Air Systems Product Catalogue,
S. Robert Hastings (ed.), IEA Solar Heating and Cooling Programme,
ISBN 1-873936-84-2

Solar Air Systems: A Design Handbook,
ISBN 1-873936-86-9

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