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FACADE-INTEGRATED THERMAL SOLAR INSTALLATIONS

SYSTEM AND BUILDING PHYSICS FUNDAMENTALS AND IMPLEMENTATION OF RESULTS WITHIN THE SUB-PROGRAM "BUILDING OF TOMORROW"

bmvit

"BUILDING OF TOMORROW": SUBPROGRAM OF THE STIMULATION PROGRAM "SUSTAINABLE ECONOMY"

Strategies for sustainability, such as using renewable sources of energy and raw materials and improving resource efficiency as well as user and service oriented approaches constitute important aspects of future-oriented fields of research and development.

Within the scope of its stimulation program "Sustainable Economy" the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) dedicated its sub-program "Building of Tomorrow" to a particularly important issue: future-oriented dwelling and building construction. Sustainable residential and office buildings can be defined as buildings offering a high level of quality of life and user-oriented features and taking into account ecological aspects and which, at the same time, are highly cost-efficient as to construction and operation. The five year research program "Building of Tomorrow" aims at developing sustainable solutions for residential, office, and commercial buildings with a high market potential. The program is to support innovative research, development, and demonstration projects and to demonstrate the feasibility of various technologies by means of concrete projects.

One of the focal points in the category "technology development" consisted in the elaboration of scientific fundamentals and the development of solar collectors. ***The following projects have been selected:***

- *The AEE INTEC – Arbeitsgemeinschaft Erneuerbare Energie, Institut für Nachhaltige Technologien is studying the systemic, building physical and solar technical fundamentals for the construction of facade integrated solar collectors without ventilation.*
- *GREENoneTEC is developing the technology and components for the manufacture of flat collectors without ventilation.*
- *Doma Solartechnik focuses on the technological and esthetic requirements involved in the application in multiple story residential and office buildings.*
- *In still another project SIKO Energiesysteme developed a modular collector "SUN 2000", which can be installed without tools.*

FACADE INTEGRATION OF THERMAL SOLAR COLLECTORS

Utilization of solar energy by means of thermal collectors meets with growing interest in Austria. These usually small-scale installations are used predominantly for hot water supply. Other applications such as solar space heating, large-scale installations in urban residential buildings or solar-based district heating meet with problems as there is not enough roof area with adequate tilt angle and orientation towards the sun. When mounted on existing roofs either directly or by means of supports these installations often have the effect of an alien element.

With a view to a broader market introduction it is therefore necessary to develop sophisticated solutions for the integration of collectors in the envelope of a building. Apart from technical-functional aspects, other factors such as an esthetic design and improved integration into the roof or the facade play an important role in this context. The ***integration in the facade,*** in particular, offers promising marketing opportunities, which have not been covered by conventional roof-integrated or roof-mounted systems.

The companies AEE INTEC, GREENoneTEC, and DOMA Solartechnik **concentrated on the following items:**

- Survey of existing installation and analysis of weak points
- Identification of requirements from the architectural point of view
- Establishment of technical and building physics fundamentals
- Development of systems technology, constructive, hydraulic, and esthetically appealing solutions
- Sizing of facade-integrated collectors
- Setting up test installations and development of measuring programs

The goal consists in developing constructive solutions for the abovementioned items and to provide manufacturers, planners, and architects with the basic knowledge and a database necessary for the sizing, manufacture, and installation of facade-integrated solar collectors. The participants of this project have succeeded in establishing a close cooperation between research and industry thus promoting the process of implementation.

The ***facade-integrated collector*** *serves not only as collector, it also serves as thermal insulation and as a formal element of the facade. This multi-purpose use of building components may result in a reduction of costs. Another advantage of facade-integrated collectors consists in a rather even irradiation of sunlight over the whole year. The fact that inclined collectors can be snow covered in winter, while facade-integrated collectors benefit from increased irradiation through reflection from snow has been largely neglected until recently.*

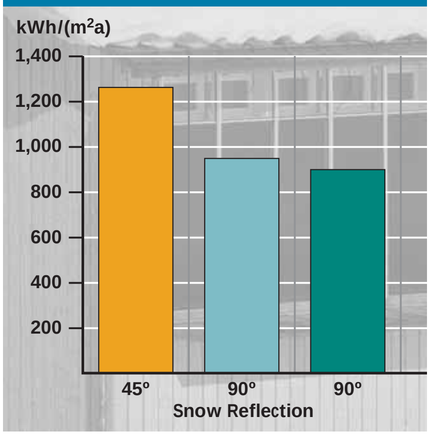
FUNDAMENTALS OF DIRECT FACADE INTEGRATION

The term facade-integrated solar collector refers to collector elements directly mounted on the facade with thermal insulation of the building also serving as insulation for the collector. There is no thermal separation between the two structural elements such as a ventilation on the back of the collector elements. These collector elements without ventilation constitute an essential improvement of the current state of the art of technology with a view to resource and energy efficiency as the collector fulfills several functions in a given building component:

- Function as thermal flat collector
- Improvement of the building's thermal insulation
- Passive solar element at low irradiation (collector fluid not circulating)
- Weatherskin for the facade through collector glazing
- Structural element of the facade

The collector technology is suitable for new construction as well as for the renovation of existing building stock. The aim consists in the development of a facade collector element with a U-value of < 0,20 (W/m^{2}K) for the system wall – collector.

Annual Aggregate Irradiation
on south-facing surfaces



BUILDING PHYSICS FUNDAMENTALS

In order to be able to evaluate the dynamic behavior of the system "wall – collector", the heat flow has been calculated for five selected wall constructions. Other typical wall constructions without collector served as reference systems for comparison.

The purpose of these calculations was to identify problems of overheating in the case of high irradiation and to define minimum insulation requirements to avoid overheating. In addition, the test series examined the influence of the absorber (also in the inactive state) on the heat loss of the wall construction through transmission in winter.

For the summer period, heat transmission (W/m^2) of the wall to the space at the back was measured for wall systems with and without collector. From these data the temperature gain as compared to a room without collector was ascertained. One of the criteria to define minimum insulation requirements for walls with a collector was that the temperature increase in comparison to a room without collector must not exceed 1 K. This prerequisite resulted in the following insulation thicknesses:

- Massive construction:
  5 – 8 cm collector insulation
- Lightweight construction:
  10 cm building insulation and
  5 cm collector insulation

The temperature differences for such wall constructions with the above insulation values range between 0.28 K and 0.98 K as compared to walls without collector. Thus, an impairment of the indoor climate and of comfort on account of overheating need not be expected in rooms behind walls with facade integrated collectors.

The simulations also showed that the facade integrated collector had a positive influence on heat loss by transmission in winter (by reducing the U-value). The winter scenario showed a reduction of U-values for all examples as compared to a wall construction without collector. On cold winter days with intense irradiation effective U-values were reduced by up to 90%, as compared to the static U-value, depending on wall construction. On days with low irradiation, the collector acts as "passive solar element" on account of its direct integration into the facade. On days with low irradiation the reduction of the U-value still reached as much as 45%.

SIZING OF FACADE COLLECTORS

Irradiation profile

In facade-integrated solar collectors the disadvantage of a reduced global annual irradiation as compared to roof mounted collectors is compensated for by a very even energy output profile and improved thermal insulation of the collector as well as of the building. Annual global irradiation on the facade is some 30% less as on 45° tilted surfaces. While inclined roofs show peak levels of the irradiation profile in summer, irradiation on the facade has a rather even profile from March to September.

Until recently, reflection by snow, which increases irradiation on the facade, has largely been neglected, while roof mounted collectors are often snow-covered during that time. Taking into account reflection by snow, annual global irradiation on a vertical surface is only 24% less than on a 45° tilted surface. In the period from November to February irradiation on the facade increases by 20% on account of snow reflection and is thus higher than on a 45° tilted surface where the increase is only 5%.

Simulation and yield forecast

Simulations have been conducted within the project with the goal to establish guidelines for the sizing of facade collectors. The resulting data were compared with roof mounted collectors and formed the basis for calculations of the required collector area to yield the same solar fraction as installations with 45° tilted collectors.

Simulations have shown that for domestic hot water only in a typical single-family home with medium hot water demand the area of a facade-integrated collector must be increased by a factor of 1.5 as compared to a 45° tilted collector in order to achieve a 40% solar fraction. If the solar fraction is to be increased further, the area of vertical collectors has to be increased disproportionately. Calculations for multi-family dwellings yielded similar results.

Simulations including space heating showed quite different results. The larger the collector area (thus, the overall cover ratio), the smaller the difference in required collector area for 90° and 45° tilted surfaces, respectively, for a given solar fraction; in other words, the percentage of additional collector area needed in the facade decreases. The reason for this lies in the fact that the solar fraction for space heating increases threefold with increasing collector area at 90° and doubles at 45° as compared with the cover ratio in the case of hot water preparation only.

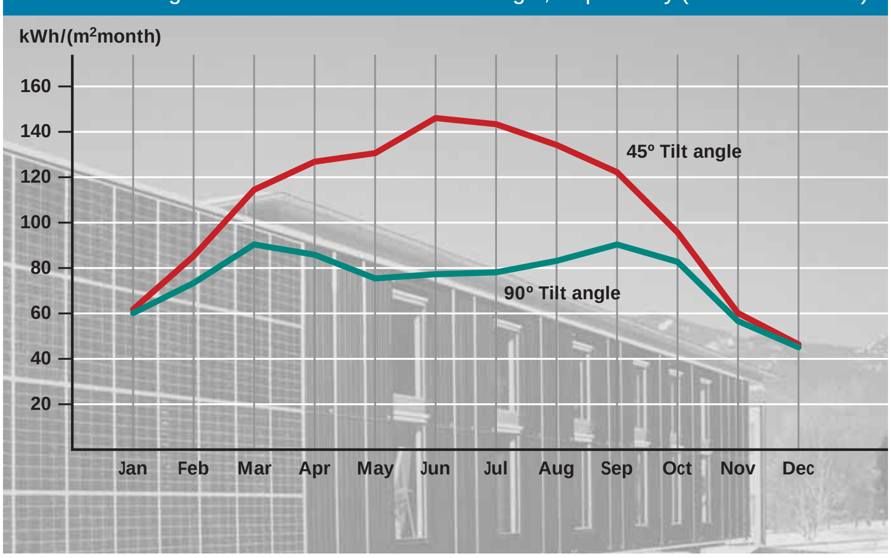
Thus, for combined hot water and space heating systems, the integration of the collector in the facade becomes the more efficient the higher the solar fraction of the installation.

Generally, experience has shown that facade-integrated collectors have advantages when used in large structures such as buildings and halls for trade and industrial applications. In these buildings demand for hot water usually is low, while the consumption of energy for space heating is considerable. The large surfaces of these facades are often intricately designed and glazed anyway, thus, the integration of collectors in the facade causes only minimum additional costs or even reduces overall costs.

Recent studies of vapor diffusion have shown that there were no condensation related problems in the selected wall constructions with facade-integrated collectors that were not ventilated at the back.

In the testing installations used in the project temperature and humidity were measured in all layers of the wall structure. The measurement programs were to illustrate processes under real life conditions and, at the same time, define the scope of further analyses of vapor diffusion in building structures.
In addition the project aimed at developing suitable piping between individual collector elements in the facade as well as a control system with an adapted storage management for facade-integrated collector installations.

Seasonal Profiles of Average Daily Aggregate Irradiation
on south-facing surfaces with 45° and 90° tilt angle, respectively (Klimadaten Graz)



ANALYSIS OF EXISTING INSTALLATIONS AND ARCHITECTURAL ASPECTS

Some existing facade-integrated collectors of various designs have been documented within the scope of fundamental studies and analyzed as to possible weak points from the point of view of building physics, technical and architectural integration, and system technology. A total of fourteen installations have been documented.

The study has shown that most of the installations comply with the state of the art and basically operate without major problems. In some of the installations the following **deficiencies of planning and workmanship** have been identified:

- **Shading of the collectors by other building components**

e.g. by projecting parts of the roof, adjacent buildings or trees

- **Mounting of absorbers**

In some installations there is thermal bridging between the absorber or the piping and timber structures. This causes constant outgassing of the timber elements and eventually charring of the material.

- **Selection of profiled parts used to fasten the glass cover**

Inadequate aluminum profiles and rubber sealings constitute a safety risk and impair the efficiency and the service life of the collector.

- **Appearance**

If plain, clear glass is used for the collector cover, special attention has to be given to the selection of materials for the absorber and to the workmanship of the collector.

- **Mounting of the collector to the wall**

The connection between collector and wall requires special attention from the point of view of structural calculation and building physics.

In order to identify the requirements for the facade collector from the point of view of architects a survey by means of a questionnaire and a workshop have been carried out: As far as dimensions of collector elements are concerned architects wished as much creative leeway as possible. However, given the fact that too great a variety of different sizes would cause a considerable increase of costs, architects considered the development of modular dimensions a feasible approach.

At present, manufacturers can meet the demand for a variety of absorber colors only by means of paint coating.

Architects seem prepared to accept reduced solar yields for the sake of esthetic aspects.

Still another requirement by architects concerns esthetically appealing cover strips for the collector frames. The results gained within the project so far have shown that the dissemination of fundamental information to all actors involved is of great importance for the implementation and broad marketing of this innovative technology.

INTEGRAL ”SUN 2000“ MODULAR COLLECTOR

The Integral ”SUN2000“ modular collector has been developed by SIKO Energiesysteme. One particular feature of the collector consists in the fact that it can be mounted without the use of tools. This solid aluminum collector can be connected to the adjacent module without soldering or the use of screws. The connecting element also provides for stress-free operation of the absorber in any temperature range as the thermal expansion is compensated for in the connecting element itself. Flow and return piping, too, can be snapped on without the use of tools.

The special frame design facilitates an absolutely tight integration of the collector into the roof. A sheet metal edging system is available as optional accessory. Low-iron prismatic solar glass and a vacuum coated absorber are further features of this collector system.

Technical data

Dimensions:

W/L/H: 1070 / 2070 / 130 mm

Weight: 50 kg / collector

Applications:

- Roof integration
- Rooftop mounting
- Detached installation

TEST INSTALLATIONS

Two test installations will be analyzed by means of measuring programs and documented within the scope of the project; they are to serve as a starting point for the further development and broad marketing of facade-integrated solar collectors without ventilation between wall and collector. Construction of the prototypes and development of special technology for the joints between collector and facade are being implemented by the companies ”DOMA Solartechnik“ and ”GREENoneTEC“.

The test facades will be mounted on different wall constructions (massive and lightweight) in order to analyze the potentially different behavior of these two ”wall-collector“ systems.

Test facade 1 (DOMA Solartechnik) has already been completed. It has been installed on the south-facade (lightweight construction) of a two-family dwelling at Graz and uses a collector with a special paint coating. The collector covers a gross area of 55 m^2 and relies on low-flow operation with a speed controlled circulation pump in the collector circuit.

Test facade 1: Two-family home in Graz, Architect: Albert Feldner.

Technical data:

- 3,570 liter layered storage tank
- 500 liter domestic water tank
- 12 kW heating load
- 240 liter/d hot water at 60°C.

The second test facade for an office building at St. Veit is currently being developed by GREENoneTec. This project will use a collector mounted on a massive wall (25 cm wall system using highly porous bricks). The planned gross area will be 25 m^2, the collector will use selective surface coating.

The projects will be active until the end of 2001. The results of the measuring programs are to serve as a database for the sizing, manufacture, and installation of such systems and will be published after completion of the project.

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PROJECT SPONSORS

Fundamentals of System Technology and Building Physics for the Integration of Thermal Solar Collectors in the Facade without Ventilation

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PUBLICATIONS

Information and publications on the BMVIT sub-program ”Building of Tomorrow“ are available on the site www.hausderzukunft.at

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