FORSCHUNGSFORUM
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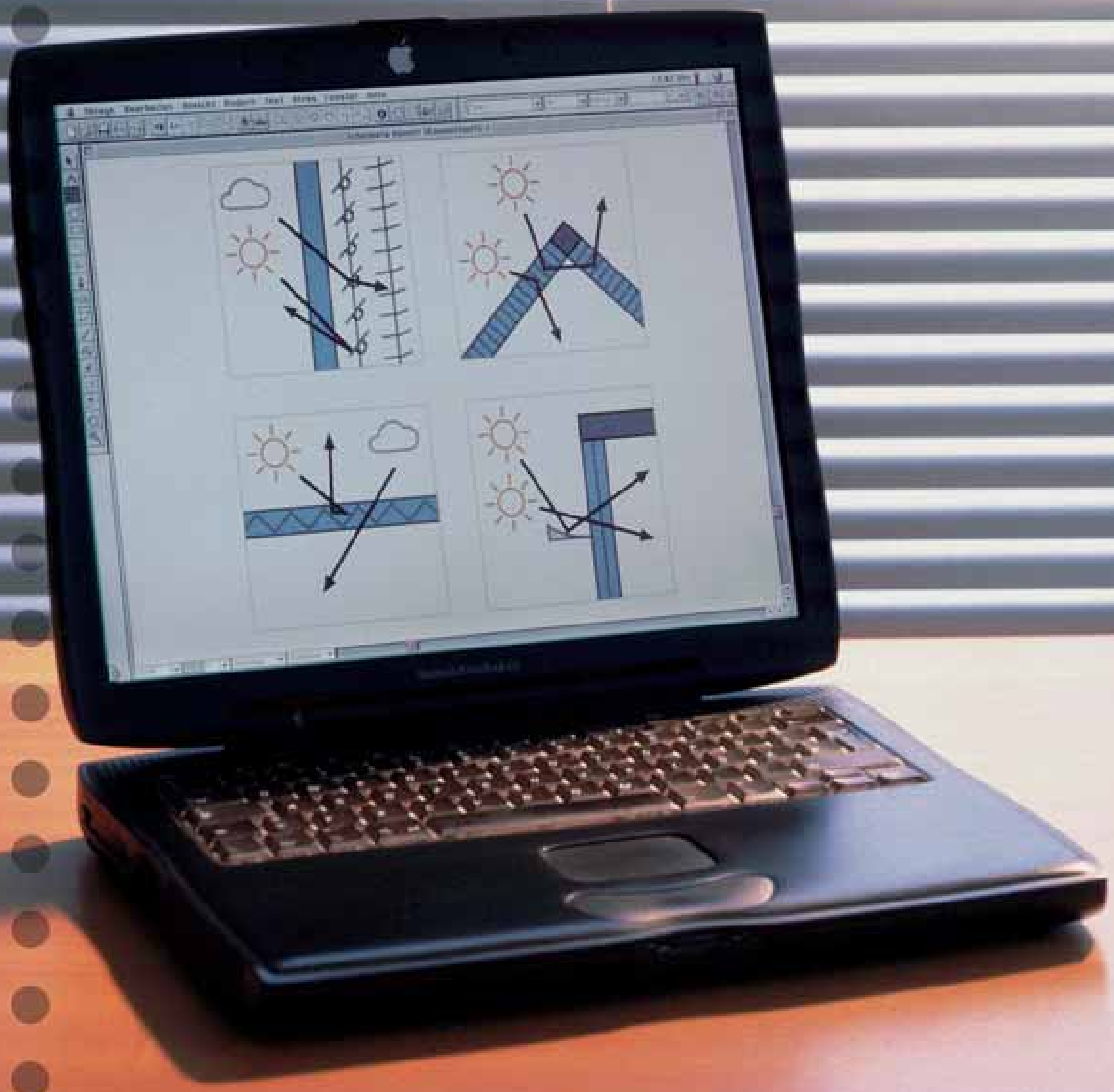
ENERGY

DAYLIGHT IN BUILDINGS

AUSTRIA'S CONTRIBUTION TO TASK 21 OF THE IEA "SOLAR HEATING AND COOLING" PROGRAM



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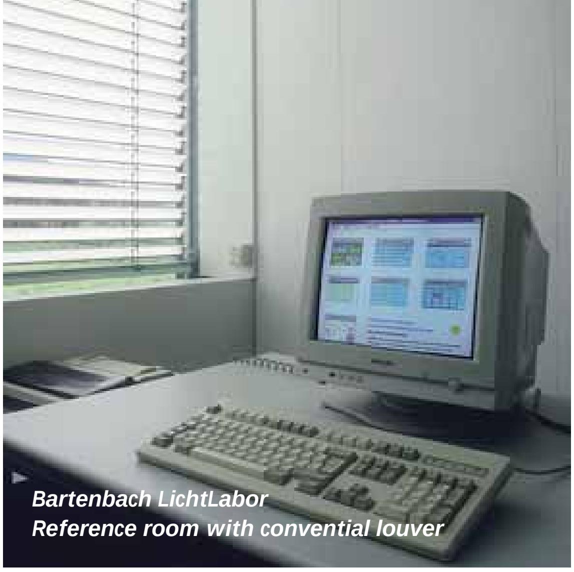
PROJECT

IEA TASK 21: DAYLIGHT IN BUILDINGS



Innovative daylighting technologies can contribute to the reduction of energy consumption in office and commercial buildings.

Today, the use of artificial light in office and public buildings (schools, kindergartens, multiple use halls etc.) accounts for a considerable proportion of total energy consumption. Architectural solutions that provide for better use of daylight, innovative daylighting systems, and efficient methods of lighting control may considerably reduce consumption of electrical energy by using natural resources.

An international research cooperation organized within the ***IEA "Solar Heating and Cooling" Program*** dealt with the subject "Daylight in Buildings" on a broad basis. The Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) commissioned experts of the "Bartenbach LichtLabor" to participate in this research program.

Today, many planners of buildings do realize that window and shading systems are of great importance. Daylighting as part of the building design plays an essential role with regard to energy consumption for heating and cooling as well as with a view to visual quality in buildings. In spite of numerous activities towards the development of innovative daylighting systems there are still considerable barriers causing planners to ignore daylighting as an essential factor in building design.

The deficits mentioned below have prevented the implementation of innovative approaches on a larger scale:

- Lack of information on the characteristics of daylighting systems and lighting control strategies
- Lack of user-friendly design tools for daylight planning
- Insufficient documentation on existing applications demonstrating the advantages of daylighting systems

The main objective of the international research program was to counteract these deficits by gathering and documenting state-of-the-art information and to support the development and improvement of existing daylighting technologies. In order to promote the implementation of the research results and to put them into practice in the design of buildings the findings of the project will be made available to the target group of architects, planners, and civil engineers.

For reasons of clarity the Task was divided into four parts (subtasks):

Subtask A **Performance of Systems** dealt with the presentation of existing daylighting systems and describes their specific characteristics and possible applications. Energy savings by using daylight can usually be ensured only if electric lighting output is controlled by a daylight responsive system.
The objective of *subtask B* **Control Systems** was to present effective control systems and to develop monitoring procedures for such systems.
Subtask C **Design Tools** offers a compilation of easily applicable design tools and a survey of available methods and algorithms for daylight simulation.
Subtask D **Case Studies** focused on the documentation of 15 buildings equipped with a daylighting system. In order to be able to compare the performance of the buildings the experts developed a uniform monitoring protocol and applied it to all 15 buildings under study.

The Austrian experts (engineering office Martin Klingler in cooperation with "Bartenbach LichtLabor") worked predominantly within the scope of subtask A. As the Austrian participants' activities concentrate on components and systems using prismatic panels the project focused on prismatic systems, and the results have been documented in the Source Book. In 1998, a meeting of experts was organized in Austria.

IEA (International Energy Agency) "Solar Heating and Cooling Program"
In 1991, the IEA's "Renewable Energy" working group developed the research program "Solar Heating and Cooling" involving 20 IEA member states, which dealt with research, development, and marketing of solar heating, cooling and lighting installations and their integration in buildings and energy systems. Task 21 deals with the subject "Daylight in Buildings". 16 countries and a total of 67 experts participated in this comprehensive program.
Further information on the whole program is available at: ***www.iea-shc.org***

INNOVATIVE SYSTEMS AND MONITORING PROCEDURES

The **"Source Book"** prepared within the scope of subtask A (Performance of Systems) focuses on the presentation of available innovative daylighting systems and the development of fundamental tools such as testing and monitoring procedures for the comparison and evaluation of different systems.
It became apparent, though, that the performance and, thus, the benefit of daylighting systems can not be described by mere data and figures. An evaluation requires testing in practice and "experiencing" the systems under real life conditions. For this purpose, a number of real size testing and reference rooms have been installed in several parts of the world, which permitted long-term monitoring and measuring of the performance parameters of different daylighting systems.

SYSTEMS

Eight different daylighting systems are described in the "Source Book". The descriptions of the various systems follow a uniform structure and provide information on the different concepts: Light shelf, louvers and blind systems, prismatic panel, laser cut panel, angular selective skylights, sun directing glass, holographic panels, and anidolic systems. The annex of the final report drawn up by the Austrian participants presents two selected examples of such systems.

Louvers and blinds

Louvers and blinds are composed of multiple horizontal, vertical or sloping slats placed on the exterior, interior or between two panes of glass. The slats can be either fixed or adjustable to act as a shading device controlling direct solar radiation, reduces glare and, in addition, redirects sunlight and skylight to the ceiling for deeper penetration of light into the space. Louvers and blind systems reduce undesirable solar gain and, thus, contribute decisively to the reduction of energy demand for cooling.

Depending on solar position, exterior or interior position, slat surface reflectance characteristics, solar radiation (diffuse and direct) is obstructed, absorbed, reflected and/or transmitted to the interior. Thus, the window's optical and thermal properties are highly variable. There are translucent blinds and different types of light directing or reflecting systems, which are usually fitted between two window panes. These light directing louvers often feature an upper surface of highly specular material, sometimes with a concave curvature and perforations and redirect a major part of the incident daylight to the ceiling.

The "Fish-system" is an innovative louver system consisting of fixed horizontal slats with a triangular cross-section that are precisely aligned by means of special connecting pieces. The system can redirect diffuse light, afford better light distribution, and reduce glare. The louvers are designed in such a way that they transmit the outer upper quart of the sky to the inner upper quart of the room (ceiling). Theoretically, the system transmits 60% of diffuse light for an aluminum surface with a reflectance of 85%.

Prismatic Panels

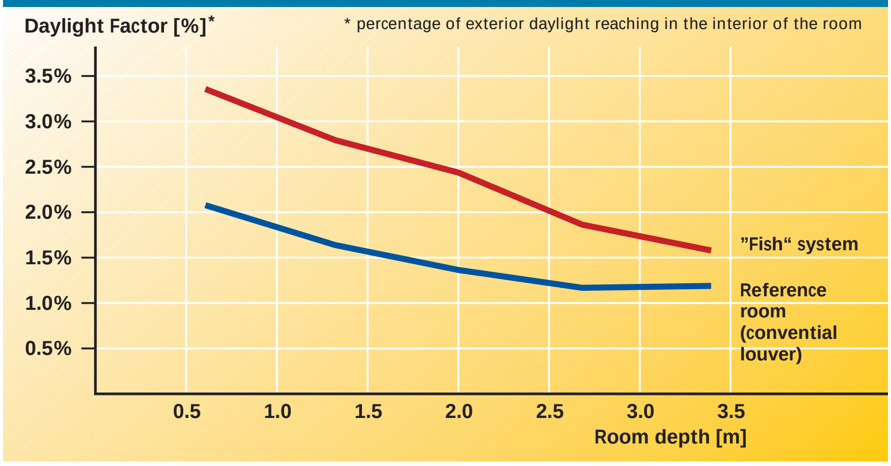
A prismatic panel consists of an array of acrylic prisms with one surface of each prism forming a plane surface (the prism backing). There are two refracting angles. Prismatic systems are often integrated in a double glazed unit for low maintenance.

Prismatic panels are used in fixed and moveable arrangements. They cover two different functions: They provide for sun shading and, at the same time, are a light directing device. The prismatic panel uses the principles of both reflection and refraction to guide diffuse daylight or sunlight into the desired direction. The main function is deeper penetration of natural light into the room. The system can be designed to reflect light coming from a certain range of angles and to transmit light coming from other angles.
In order to ensure light distribution into greater depths of the room the prismatic element must accommodate a wide range of solar altitudes.
The refracted light should emerge at an angle less than 15° above the horizontal to obtain optimal penetration of light into the room. In order to avoid glare, descending radiation has to be minimized. The overall performance of a prismatic system depends largely on an appropriate configuration of refracting angles. The different geographic situations require prismatic profiles adapted to the prevailing conditions in order to achieve optimal light distribution in the room. In addition, an adequate texture of the ceiling surface is necessary to achieve high reflectivity.

MONITORING

Until recently, no standard monitoring procedures have been available to assess and compare performances of daylighting systems and daylight responsive lighting control systems. Within the scope of IEA-Task 21 the performance assessment of selected systems using standard monitoring methods in test rooms and in actual buildings under various types of skies has been documented.
The **"Case Study Book"** documents 15 buildings, which have been monitored for at least one year. The emphasis in the monitoring procedures for test rooms was on effective daylight utilization, electrical energy savings and user acceptability. The procedure developed within the scope of the

Distribution of the Daylight Factor over the Depth of the Room



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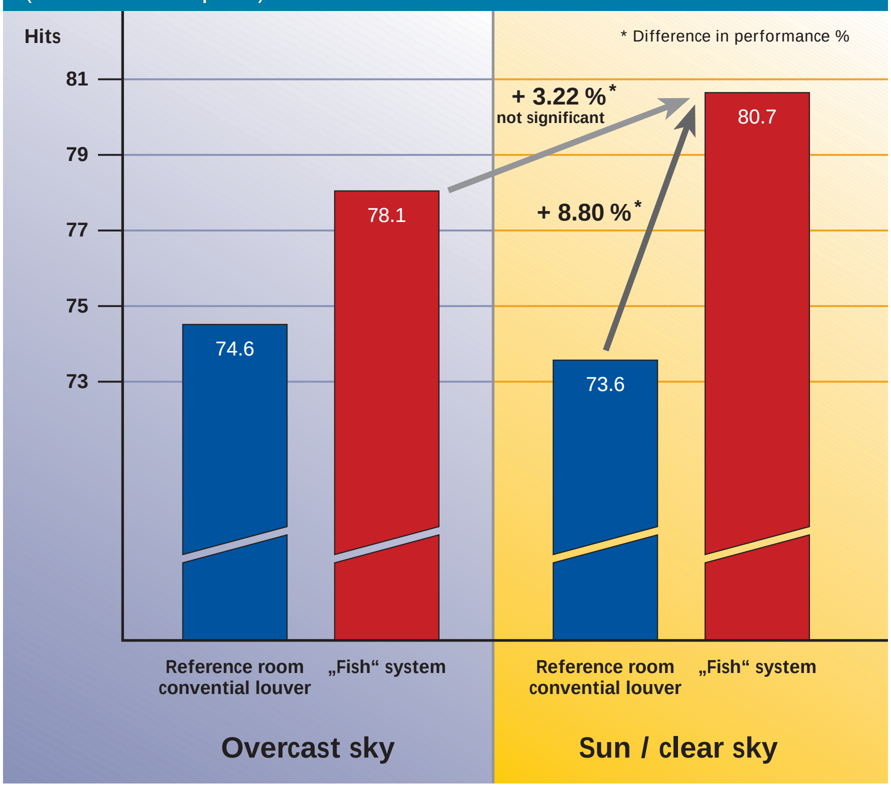

Source: Bartenbach LichtLabor

program describes the necessary parameters to be considered, defines measuring procedures and accuracy of the measurements as well as methods for the description of user behavior.
A uniform monitoring protocol for the evaluation of conventional office buildings with horizontal work planes has been developed. The performance of a daylighting system or control system was assessed by comparing a room equipped with the system with an identical room (reference room) without the system under the same sky conditions. Additional questionnaires were used for a more detailed evaluation of visual comfort and user acceptance.

"Bartenbach LichtLabor" installed two identical model rooms and equipped them with different daylighting systems. In the reference room conventional but high-quality louvers were installed in front of the glazing. The second room was equipped with the reflecting light directing "Fish" system. In a comprehensive test series differences in visual quality were measured and test persons participated in performance tests. The two graphs below show some interesting results of this monitoring process.

Fig. 1 shows a comparison of the distribution of the daylight factor in the two rooms. Measurements in the room equipped with the "Fish" system yielded a considerably higher amount of daylight.

Fig. 2 represents the performance of test persons engaging in activities comparable to text processing by means of a computer. Again, both rooms were compared under clear and overcast sky conditions. There was a considerable difference in the performance of test persons in the two rooms. One of the remarkable results was that the performance in the room with the louvers decreased in clear sky situations (more glare from sunlit louvers), while it improved in the room equipped with the "Fish" system.

Photos: Peter Bartenbach

OBJECTIVES

DESIGN OBJECTIVES AND PERFORMANCE OF DAYLIGHTING SYSTEMS

The primary design objective of daylighting systems is to provide usable daylight for a particular climate or building type for a significant part of the year, so that part of the energy needed for artificial lighting can be saved. When planning a daylighting system as integral part of the building design different parameters of the system have to be taken into consideration: visual performance, comfort, device characteristics, building energy use, economy, and building integration.

Innovative daylighting systems are developed and used to fulfill various different **functions**: They

- provide usable daylight at greater depths from the window wall
- increase usable daylight for climates with predominantly overcast skies
- increase usable daylight for very sunny climates where control of direct sun is required
- increase usable daylight for windows that are blocked by exterior obstructions and therefore have a small view of the sky
- transport usable daylight to windowless spaces

In order to achieve an objective evaluation of the systems performance parameters and a range of acceptable values have been defined within the scope of the IEA project. The following variables have to be taken into account for an evaluation: weather (solar position, cloud cover), site building conditions (latitude, window orientation, size and placement), and room and task condition (distance from the window, task surface orientation etc). Laboratory and field tests were used to test and analyze different systems. The experts agreed, however, that a merely quantitative evaluation of a system does not suffice as basis for decision-making. The evaluation must include all system characteristics and will also depend on the building application. User acceptance and subjective assessment of visual comfort are crucial factors for successful operation of an innovative daylighting system.

In order to safeguard high quality and substantial energy savings the **control of daylight** and daylight responsive control of artificial lighting are of great importance. Here, too, user behavior plays an important role. Any kind of annoyance through the system causing glare, a temporary reduction or sudden changes in 'lightness' or through noisy mechanical systems will reduce a system's acceptance and its effectiveness. While automatic control systems are very effective from a technical point of view they are often rejected by users for psychological reasons (not having control of the louvers).

In order to use daylighting systems successfully it is imperative to harmonize light design with other planning criteria such as energy consumption (lighting, heating, cooling), heat loss and heat gain, sound transmission and economy at an early planning state.

The experts participating in the IEA Task 21 program developed a **Design Guide** that presents a survey of currently available control devices for electrical lighting systems, their installation and maintenance as well as methods for the prediction of potential energy savings. The Guide also describes the systems tested within the scope of the program and the methods used for their evaluation.

IEA-TASK 21 DOCUMENTATION

The following papers are being prepared or have already been published (in English) within the scope of the four subtasks:

Subtask A: Performance of Systems

Source Book
Documentation of the characteristics of innovative daylighting systems and measuring methods for their evaluation

Survey of Architectural Solutions
Documentation of projects using remarkable daylighting solutions, without innovative system technologies

Subtask B: Control Systems

Design Guide
Handbook on the use of automatic systems reducing artificial lighting through utilization of daylight

Subtask C: Design Tools

Survey of Simple Design Tools
Compilation of design tools for daylighting design

Subtask D: Case Studies

Case Study Book
Documentation of 15 buildings, which have been monitored for at least one year

A list of publications with relevant sources of supply, including recent publications and authors, addresses can be found on the IEA homepage:
www.iea-shc.org

Photo: Croci & du Fresne

Schweizer Bankverein Biel:
System using prismatic panels for light directing and sun shading.

FIGURES/DATA/FACTS

PROJECT SPONSORS

The study below was commissioned by the Federal Ministry of Transport, Innovation and Technology (BMVIT):
"Endbericht zur Teilnahme am IEA Solar Heating and Cooling Program, Task 21: Daylight in Buildings"
Project management:
Bartenbach LichtLabor GmbH, Rinnerstraße 14, 6071 Aldrans;
Study author: Ingenieurbüro Martin Klingler, Kaplanstraße 2, 6063 Rum/Innsbruck.

PUBLICATIONS

The final report on the above-mentioned study has been published in the series ***"Berichte aus Energie- und Umweltforschung"*** (Reports on Energy and Environment Research) by the Federal Ministry of Transport, Innovation, and Technology (BMVIT) and is available from:
PROJEKTFABRIK,
Nedergasse 23, A-1190 Vienna, Austria.
A complete list of the series can be found on the FORSCHUNGSFORUM HOMEPAGE:
http://www.forschungsforum.at

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