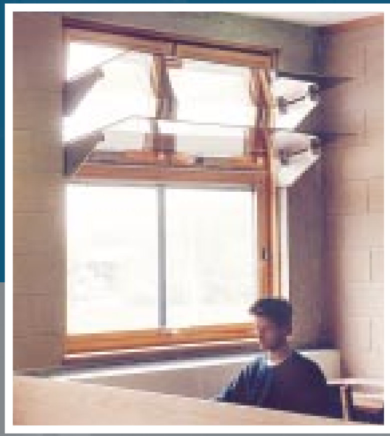
Daylight in Buildings



A SOURCE BOOK ON DAYLIGHTING SYSTEMS AND COMPONENTS

International Energy Agency
Energy Conservation in Buildings
and Community Systems Programme

International Energy Agency
Solar Heating & Cooling Programme

Daylight in Buildings

A SOURCE BOOK ON DAYLIGHTING SYSTEMS AND COMPONENTS

A report of IEA SHC Task 21/ ECBCS Annex 29, July 2000

Daylight in Buildings

A SOURCE BOOK ON DAYLIGHTING SYSTEMS AND COMPONENTS

By Nancy Ruck with Øyvind Aschehoug, Sirri Aydinli, Jens Christoffersen, Gilles Courret, Ian Edmonds, Roman Jakobiak, Martin Kischkoweit-Lopin, Martin Klinger, Eleanor Lee, Laurent Michel, Jean-Louis Scartezzini, and Stephen Selkowitz

Edited by Øyvind Aschehoug, Jens Christoffersen, Roman Jakobiak, Kjeld Johnsen, Eleanor Lee, Nancy Ruck, and Stephen Selkowitz

Participants in the International Energy Agency (IEA) Solar Heating and Cooling Programme Task 21, Energy Conservation in Buildings & Community Systems, Programme Annex 29 Subtask A: Performance Evaluation of Daylighting Systems: Maurice Aizelwood (United Kingdom), Marilyne Andersen (Switzerland), Heidi Arnesen (Norway), Øyvind Aschehoug (Norway), Sirri Aydinli (Germany), Jens Christoffersen (Denmark), Gilles Courret (Switzerland), Ian Edmonds (Australia), Roman Jakobiak (Germany), Kjeld Johnsen (Denmark, IEA Task 21 Operating Agent), Martin Kischkoweit-Lopin (Germany), Martin Klinger (Austria), Eleanor Lee (United States of America), Paul Littlefair (United Kingdom), Laurent Michel (Switzerland), Nancy Ruck (Australia, Subtask A Leader), Jean-Louis Scartezzini (Switzerland), Stephen Selkowitz (United States of America), and Jan Wienold (Germany)

Information on how to obtain additional copies of this book and other products referred to in this book can be obtained from the Internet site at http://www.iea-shc.org or contact the IEA SHC Executive Secretary, Pamela Murphy Kunz, Morse Associates Inc., 1808 Corcoran Street, NW, Washington, DC 20009, USA, Telephone: +1/202/483-2393, Fax: +1/202/265-2248, E-mail: pmurphy@MorseAssociatesInc.com.

Published by the Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Mailstop 90-3111, Berkeley, CA 94720 with support from Energy Design Resources. Energy Design Resources is funded by California utility customers and administered by Pacific Gas and Electric Company, San Diego Gas & Electric, and Southern California Edison, under the auspices of the California Public Utilities Commission. LBNL Report Number: LBNL-47493.

Preface

For some time the building industry has been in need of a comprehensive reference that describes new and innovative technologies for utilizing daylight in buildings and assesses the performance of these systems. This information is of particular benefit to building design practitioners, lighting engineers, product manufacturers, building owners, and property managers. This book is the result of a coordinated international effort to gather the most up-to-date information available about the application and evaluation of advanced daylighting systems to enhance daylighting in non-residential buildings. Although the text emphasizes the performance of daylighting systems, it also includes a survey of architectural solutions, which addresses both conventional and innovative systems as well as their integration in building design. Innovative daylighting systems are assessed according to their energy savings potential, visual characteristics, and control of solar radiation.

This book is based on work carried out by the Solar Heating and Cooling (SHC) Programme of the International Energy Agency (IEA) under IEA's Task 21, Energy Conservation in Buildings & Community Systems, Programme Annex 29, Subtask A: Performance Evaluation of Daylighting Systems. Subtask A's work programme was coordinated with research carried out by the other IEA SHC Task 21 Subtasks. These included Subtask B: Daylight Responsive Controls, Subtask C: Daylighting Design Tools, and Subtask D: Case Studies.

The IEA was established in 1974 as an autonomous agency within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an international energy programme. A fundamental aim of the IEA is to foster cooperation among 25 of the OECD's 29 member countries and the Commission of the European Community in order to increase energy security and reduce greenhouse emissions. The IEA sponsors research and development in a number of areas related to energy. Within the program of Energy Conservation in Buildings and Community Systems (ECBS), the IEA is carrying out various activities to predict more accurately the energy use of buildings. These activities include comparison of existing computer programmes, monitoring of buildings, comparison of calculation methods, and studies of air quality and occupancy.

The IEA Solar Heating and Cooling Programme (IEA SHC) was initiated in 1977 as one of the first collaborative R&D agreements established by the IEA. The participating countries carry out a variety of projects intended to advance active solar, passive solar, and solar photovoltaic technologies for building applications. The main objectives of the IEA SHC Programme Task 21 and ECBS Annex 29: Daylight in Buildings are to advance daylighting technologies and to promote daylight-conscious building design.

Denmark is the Operating Agent for IEA SHC Task 21. The participating countries are:

Australia	France	Norway
Austria	Germany	Sweden
Belgium	Italy	Switzerland
Canada	The Netherlands	United Kingdom
Denmark	New Zealand	United States
Finland		

Executive Summary

This source book gives a comprehensive overview of innovative daylighting systems, the performance parameters by which they are judged, and an evaluation of their energy savings potential and user acceptance. The book has been written to overcome a lack of evidence of the advantages of daylighting in buildings and a lack of knowledge regarding the performance of innovative daylighting systems in buildings in various climatic zones around the world. The information presented here is intended to be used in the earliest stages of the building design process.

Innovative daylighting systems are designed to redirect sunlight or skylight to areas where it is required, without glare. These systems use optical devices that initiate reflection, refraction, and/or use the total internal reflection of sunlight and skylight. Advanced daylighting systems can be designed to actively track the sun or passively control the direction of sunlight and skylight. The systems included in this book have been generally limited to passive devices.

This book describes in detail the wide range of innovative daylighting systems available worldwide today, including information on their components, principles on which they are based, applications for which they are appropriate, production, control, costs and energy savings, maintenance, examples of use, and performance assessments.

The performance assessment results were obtained by monitoring the system using physical models under sky simulators, or full-scale test rooms or actual buildings under real sky conditions. The types of innovative systems selected for testing are currently available in the marketplace or have been recently developed in laboratories. The results summarized here demonstrate that, if selected according to daylight climate and integrated appropriately with electric lighting and shading controls, the majority of these systems can enhance daylight in building interiors and thereby promote energy savings. It should be noted, however, that performance in actual buildings will differ from test room results.

Daylighting strategies are seldom considered in the earliest stages of a building design. This is, in part, a result of the absence of simple tools that can predict the performance of advanced daylighting strategies. This source book provides information on simple design tools that can predict performance and can be used by non-experts. The book also includes an introduction to the appropriate use of shading and electric lighting controls in order to promote energy savings.

Barriers to the use of advanced daylighting systems still exist, particularly in the transition from research to building practice. There is much to do in research and development as well as in practical application. Two key areas that need further research are the human dimension of the daylighting equation and the integration of daylighting systems in buildings to arrive at low energy solutions that meet human needs. New research in these two areas will be carried out under the auspices of Task 31 (see http://www.iea-shc.org). Nonetheless, the information presented in this book demonstrates that the use of advanced daylighting technologies can close the gap between potential benefits and actual achievements in building practice.

Table of Contents

Contents of the CD-ROM

The CD-ROM Contains the Complete Source Book Above and the Following Additional Materials:

Introduction 1.

In a world newly concerned about carbon emissions, global warming, and sustainable design, the planned use of natural light in non-residential buildings has become an important strategy to improve energy efficiency by minimizing lighting, heating, and cooling loads. The introduction of innovative, advanced daylighting strategies and systems can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment.

Importance of Daylight 1.1.

Evidence that daylight is desirable can be found in research as well as in observations of human behaviour and the arrangement of office space. Windows that admit daylight in buildings are important for the view and connection they provide with the outdoors. Daylight is also important for its quality, spectral composition, and variability. A review of peoples' reactions to indoor environments suggests that daylight is desired because it fulfils two very basic human requirements: to be able to see both a task and the space well, and to experience some environmental stimulation [Boyce 1998]. Working long-term in electric lighting is believed to be deleterious to health; working by daylight is believed to result in less stress and discomfort.

Daylight provides high illuminance and permits excellent colour discrimination and colour rendering. These two properties mean that daylight provides the condition for good vision. However, daylight can also produce uncomfortable solar glare and very high-luminance reflections on display screens, both of which interfere with good vision. Thus, the effect of daylight on the performance of tasks depends on how the daylight is delivered. All of these factors need to be considered in daylighting design for buildings.