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.

Daylight strategies and systems have not always lived up to their promise as energy-efficiency strategies that enhance occupant comfort and performance. One reason is the lack of appropriate, low-cost, high-performance daylighting systems, simple tools to predict the performance of these advanced daylight strategies, and techniques to integrate daylight planning into the building design process.

Common barriers that have hindered the integration of daylight in buildings in the past are:

- Lack of knowledge regarding the performance of advanced daylighting systems and lighting control strategies,
- Lack of appropriate, user-friendly daylighting design tools, and
- Lack of evidence of the advantages of daylighting in buildings.

The barriers, identified at the beginning of the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Task 21: Daylighting of Buildings, were resolved by coordinated tasks that covered three broad areas: 1) assessment of the performance of systems and lighting control strategies, 2) development of integrated design tools, and 3) case studies to provide evidence of daylight performance in actual buildings.

To remedy the lack of information about the performance of advanced daylighting systems, specified systems were assessed using standard monitoring procedures in test rooms in actual buildings, and using scale models under artificial skies. Parameters to measure both quantity (e.g., illuminance and luminance) and quality (e.g., visual comfort and acceptability) of daylight were determined prior to testing. This source book describes the systems tested, the results of the assessments, and the appropriate application of the results. On the whole, the study's results indicate that, when appropriately located, the majority of systems tested improved daylighting performance in perimeter building zones relative to the performance of conventional windows.

The daylighting of buildings is essentially a systems integration challenge for a multidisciplinary design team, involving building siting and orientation and the design optimization of fenestration, lighting and control systems. A survey of existing architectural solutions is included in this source book as a CD-ROM, which shows the integration of systems in building design and includes conventional as well as advanced systems with some indication of the problems that may result from wrong design decisions.

This source book is aimed at building design practitioners, lighting engineers, and product manufacturers. It should be used in the earliest stages of the design process because the initial conception of the building envelope, the location of openings and their size and shape, and the systems for solar and daylighting control are all crucial to daylighting design.

Objective and Scope of This Source Book 1.2.

The objective of this source book is to promote daylighting-conscious building design. Selected advanced daylighting systems are described in detail, as well as ways in which these daylighting systems can be integrated in the overall building design process. The reader is also introduced to shading and electric lighting control systems and design tools.

Daylighting planning needs to be considered from a building's conceptual design phase through the selection of systems and their application. **Chapter 2** outlines initial-stage planning parameters, such as basic decisions on shape and window size, as well as specific functional objectives of the daylighting strategies. Application of daylight strategies for windows and rooms is also discussed, along with advice on how to choose systems for specific sky types.

Innovative daylighting systems work by redirecting incoming sunlight and/or skylight to areas where it is required, and, at the same time, controlling glare. These systems are particularly appropriate where an interior space is too deep for conventional windows to provide adequately uniform lighting or where there are external obstructions. Systems that control glare as well as the quantity of daylight entering a space may also be a good solution for shallow rooms; thus these systems also merit consideration as innovative.

A daylighting strategy can be characterized by its performance parameters. These parameters include quantity of light, distribution of light and glare, cost, and energy use. **Chapter 3** defines these parameters and discusses each in a worldwide context. Because daylight offsets the need for electric lighting energy, issues that influence energy savings, such as design and commissioning of lighting control systems, are also addressed.

Chapter 4 focuses on selected innovative daylighting systems that can be applied in new and existing buildings that have a high aggregate electricity savings potential (such as offices, schools, and other commercial and institutional buildings). The systems are classified according to whether they have been designed as shading or non-shading systems. An overview is given in Chapter 4.2 of all the described systems using a matrix format. The detailed systems descriptions include light shelves, louvers and blinds, prismatic panels and films, laser-cut panels, light-guiding materials, holographic optical elements, and anidolic systems, which are systems with reflectors based on non-imaging optics. Detailed information on each system follows the matrix. This information includes, for each system, a technical description, factors related to its application, methods of control, cost and potential energy savings, examples of use, and, in most cases, measured results. Potential energy savings are expressed in terms of daylight enhancement. Chapter 4 does not include glazing systems that selectively attenuate light without redirecting it, e.g., electrochromic or angular selective glazings.

Proper integration of daylight with electric light ensures that energy is efficiently used and that glare is controlled. This integration can only be achieved through a carefully coordinated design of the daylighting and electric lighting systems. An introduction and adjunct to IEA SHC Task 21's Application Guide on lighting controls is provided in **Chapter 5**. This chapter includes general information on the nature of daylight and electric light and their integration, the application of shading and electric lighting control systems with daylighting systems, and the benefits from controlling daylight and electric light input.

Chapter 6 summarises state-of-the-art of daylighting design tools with emphasis on tools that address the advanced daylighting systems that are the focus of this source book. Daylighting design is a creative process. Because it aims to generate appropriate architectural and/or technical solutions while reducing energy consumption of buildings, it is both an art and a science. Qualitative information and visual feedback on a given daylighting concept are as important for a building designer as quantitative figures. Because there are so many parameters to consider in daylighting design, design tools play a significant role in the decision-making process and must therefore fit the most significant phases of architectural projects. These tools provide support for designers as they make a sequence of decisions that leads from the formulation of daylighting concepts to the final implementation of daylighting strategies in real buildings.

Chapter 7 summarises the results of this work and indicates future work required to ensure that daylighting becomes the preferred option for building design in the 21st century. **Appendices** to this book include a glossary, chapter references, an overview of the monitoring procedures used in our daylighting system evaluations, the measurement methods used to determine each system's physical characteristics for formulating computer software algorithms, a description of the test room facilities used, and a list of product manufacturers.

This is the only book currently available that provides this essential information about advanced daylighting systems. Much still remains to be done in the areas of human response and acceptance of daylighting systems, which is a critical element in any daylighting design, and in the integration of these new advanced daylighting systems with the hardware and software elements in a design. More research on these issues is currently being proposed within the IEA SHC framework.

Other IEA SHC Task 21 Publications 1.3.

In addition to this source book, other publications resulting from IEA SHC Task 21's work include:

- **The Application Guide for Daylight Responsive Lighting Control Systems** is in two parts. The first part addresses general design considerations involving electric lighting and shading controls, installation procedures, and the prediction of energy savings and costs. The second part consists of the monitoring procedures used and the results of performance evaluations of lighting controls installed in test rooms.
- **Survey: Simple Design Tools** lists various types of design tools, including simple computer tools, with different fields of application.
- **ADELINE 3.0** is a software package that brings together several programme modules required for an integrated lighting design.
- **LESO-DIAL**, a programme that gives architects relevant information regarding the use of daylight during the very first stage of the design process. (This software includes about 100 terms in a daylighting and lighting vocabulary.)
- **Daylight in Buildings: 15 Case Studies from Around the World**, contains 15 case studies representing a range of building types worldwide. All were constructed or refurbished after 1990. The case studies were monitored according to standard procedures and give evidence that daylighting strategies save energy. Post-occupancy evaluations were performed for a small set of selected buildings in this group to determine occupant reactions.

How to Use This Source Book 1.4.

This book is not intended to be read page by page from beginning to end. Readers are invited to go directly to the sections that address their interests. For example, readers seeking general knowledge about the daylighting of buildings should go to Chapter 2. Specific knowledge about advanced daylighting systems can be found in Chapter 4.