SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Daylighting of Non–Residential Buildings

IEA SHC Position Paper

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Contents

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The purpose of this document is to provide an inside view for energy policy makers and decision makers in the private sector to understand why and how the targeted use of daylight in the built environment (non-residential buildings) should be supported and promoted.

Executive Summary

Daylight plays a key role in providing a good visual, biologically effective and energy efficient lighting of indoor spaces. Generally, daylight is the light source preferred by humans. Daylight is the major source of regenerative energy for reducing lighting energy consumption. Electric lighting accounts for approximately 15% of the total electrical power consumption and 5% of greenhouse gas worldwide. In non-residential construction, daylighting – based on distinct evaluation procedures and integrated into diverse energy saving ordinances – has meanwhile become an energy-quantifiable and plannable light source that can be directly offset against the energy requirements for electrical lighting.

Good and energy efficient daylighting is an integrative task. Driven by building design practice, it employs technologies mainly from three industry sectors: façade, electric lighting and building automation technology.

In the non-residential building sector, energy saving opportunities are big, as illustrated for two dominant usage types. In an open plan office, i.e., structures without significant daylight access, annual lighting energy demand easily adds up to 30 kWh/m²a end energy. State of the art office design with the majority of workplaces close to the façade, daylight dependent lighting control and appropriate façade design brings demands down into the range of 8 kWh/m²a or lower. Daylight usage here is responsible for about 70% lower consumption. In manufacturing halls without daylight access (i.e., closed roofs) and with typical two shift manufacturing operations, energy demands are in the order of magnitude of 40 kWh/m²a. An appropriate inclusion of daylight with rooflights and lighting controls divides demand in half, to 20 kWh/m²a or less. Here 50% lower electrical lighting consumption can be attributed to daylight use.

A current barrier, among others identified, is a too strong focus on only the investment costs. Instead, total cost of ownership approaches should be used recognizing long term benefits from daylighting. The lack of market integration between the different technology sectors influencing daylighting means that a direct “caretaker” for daylighting issues is often missing in the building design and construction phases.

Different actions at the government, NGO and private (industry) levels to significantly drive up this market are recommended. These actions encompass recognizing daylight as a “renewable energy source,” revising building ordinances, and including

in sustainability certificates, memoranda of understanding and advanced (automated) building design processes.

Introduction and Relevance

Daylight plays a key role in providing a good visual, biologically effective and energetic efficient lighting of indoor spaces. Generally, daylight is the preferred light source. Providing a line of sight from the inside out is psychologically extremely important. In indoor spaces, existing daylight communicates information about the time of day and weather and thus represents a relationship to the outside through the respective intensity, distribution and spectral composition. In addition, numerous studies document the high psychological significance of a visual connection to the outside, which is often attributed with the term "daylight." Simplified: Some sort of outlook is better than no outlook.

Further differentiation is that a view of nature is perceived as more recreational and creativity-promoting than a view of a built-up area. And, windows give the perception of more spacious rooms. Specifically, a wider, unobstructed view positively influences the perception of room size and brightness. In general, workplaces close to windows are preferred.

Daylight has a direct biological effect on humans through the control of the circadian rhythm by melatonin suppression. Conventional artificial illumination systems alone cannot or only at a very high cost and use of primary energy contribute the dose required for this effect. For high-quality jobs in the service and manufacturing sectors, the creation of a good daylight supply is an essential design task today. In residential construction, too, a good daylight situation is positively perceived.

Daylight is the major source of regenerative energy for reducing energy consumption for lighting. Electric lighting accounts for approximately 15% of the total electrical power consumption and 5% of greenhouse gas worldwide.[1]

In non-residential construction, daylighting – based on distinct evaluation procedures as in EN 15193-1 and ISO 20086 and integrated into diverse energy saving ordinances – is an energy-quantifiable and plannable light source that can be directly offset against the energy requirements for electrical lighting.

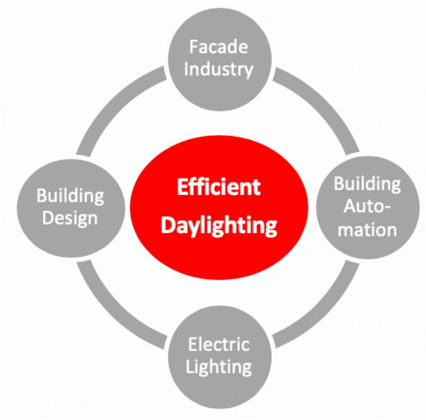

Figure 1: Efficient daylighting, driven by building design and technologies from three industry sectors façade, electric lighting and building automation technology.

[1] UNEP Report, Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING, 2017

Status of the Technology/Industry

Appropriate and energy efficient daylight design is an integrative task. It is driven and orchestrated by the architecture and building design practice and employs technologies from three industry sectors: façade, electric lighting and building automation (Figure 1). A brief overview on the status and current developments in these sectors is given below.

Architecture & building design

Indoor daylight supply strongly depends on architectural parameters like floor plans and façade layout. These parameters are fixed in the very early design phase and are inherent structural building parameters. Building performance is defined by these parameters for the life of a building so mistakes made here are difficult to compensate for later. In contrast, technologies like electric lighting and building management systems have shorter use expectancies and are typically replaced several times over the course of a building lifespan. Therefore, the building design usually plays the most important role when it comes to securing quality daylighting.

The application of daylighting requires specific training of designers. This also encompasses the role of the architect or principal designer to integrate the building's architecture with the client's expectations the building's technical equipment and the building's urban interaction (impacts by densification of cities). In professional practice, this is often accompanied by guidelines, ordinances as well as private partnership agreements, such as criteria within sustainability certificates. To secure an appropriate design, larger architecture companies are first employing automated, parametric software driven design processes. This means they are varying under given constraints, for instance, the window size in the façade design to achieve a sufficient daylight supply. In some advanced cases, even floor plans are modified automatically.

New standards like EN 17037 "Daylight of Buildings" are offering guidelines to designers by introducing new criteria, such as a classification of daylight autonomies, glare from facades, sunlight exposure and views outside. In practice, this standard can improve daylight quality and daylight driven energy efficiency significantly.

Façade technology

The global façade market has grown significantly in the last decades. Today, around 1.3 billion square meters of glazed facades (the equivalent of the area of the city of London) are constructed every year. Innovations in glazings have significantly improved the thermal properties by using new coating techniques and multilayer glazing systems. In recent years, 3-pane glazing systems are becoming the standard option in many countries despite their reduced light transmission. Innovations in sun protection glazing matched coatings show favorable LSG (light-to-solar-gains) close to 2, therefore offering sun protection at still providing a decent source of daylight. As for sunshading, in the 1990s we saw the development of diverse advanced (complex) fenestration systems promising good sun protection and good daylight supply at the same time. From the wide variety of developed systems, only a few had a lasting impact on the market, partly due to practical drawbacks, mainly due to economic reasons. Currently, there are marketing efforts underway to introduce electro-chromic glazing on larger scales. Another trend is the integration of active solar gain systems (photovoltaic as well as thermal collectors) directly into façades.

Both these approaches have to be matched closely with the needs for a sufficient daylight supply in the adjacent indoor spaces. The architectural trend of full glazed facades is generally still prevalent.

On the R&D side, promising developments can be seen in integrating sunshading, glare protection and light redirecting functionality into the glazing layer. Nanostructured mirror systems, such as venetian blinds, are in the test stage. Laboratory work on new micro-optically structured light guiding components is getting close to entering the market. In an earlier development stage are window systems that rely on fluids in-between window panes for cooling purposes as well as sunshading and glare protection. And in the test stage are LED-based glazing systems that allow daylight to penetrate and contribute to electric lighting in times of insufficient natural illumination.

Electric lighting and building automation technology

Daylight dependent control of electric lighting is a technology that has proven to work efficiently and be economical. Nevertheless, the actual implementation rate is still low (e.g., in Germany an estimated 10-15% of new installations). Façade control technology can now be easily integrated into building management systems. Available functionalities include cut-off controls, which provide a good compromise between solar protection, daylight supply and views outside. Other solutions allow for shading control according to sun and shading patterns on the façade. Coupling of facade and occupancy detection integrated in electric lighting control schemes show new energy savings possibilities.

The number of lighting fixtures being equipped with electronics, such as sensors for daylight dependent lighting control, occupancy detection and communication components is increasing. This integration of functionalities helps to lower costs for a more effective use of natural light. On the laboratory level, diverse integral lighting control schemes are being tested to better integrate day- and electric lighting as perceived by the users directly at the workplaces.

Potential

Daylighting is for electric lighting consumption the main energy sink and should be considered a regenerative energy source.
In the non-residential building sector, energy saving opportunities related to daylighting are significant, as illustrated below for two dominant usage types: offices (laterally lit) and halls (horizontally lit by rooflights) [2]:

- In open plan office structures with limited daylight access only at the façade perimeters, annual lighting energy demands easily add up to 30 kWh/m²a end-use energy. State of the art office design with the majority of workplaces

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[2]Based on state-of-the-art electric lighting technology. Generally favorable (at least not adverse) impact on the heating and cooling in the overall energy balances. Values for central Europe may vary depending on climate and location.

close to the façade, daylight dependent lighting control and appropriate façade design brings down demand into the range of 8 kWh/m²a or lower. Daylight usage is responsible for about 70% lower consumption.
- In manufacturing halls without daylight usage (i.e., closed roofs) and a typical two-shift operation, end-use energy demand is in the order of magnitude of 40 kWh/m²a. By adding daylight with rooflights and lighting controls energy demand is cut by half, 20 kWh/m²a or less. Here electrical lighting consumption of less than 50% can be attributed to daylight usage.[3]

Current Barriers

Costs, upfront investments and cost models

As in other fields, deployment of energy efficient technology depends on the cost model used and acceptance by the client. Energy savings and reduced maintenance costs should be included in the decision-making process by using total cost of ownership (TCO) ratings rather than purely looking at the initial investments. This nevertheless depends on the client. In general terms, the private sector demands shorter payback times than the public sector.

Awareness and market integration

When managing daylighting issues in projects there is seldom one specific "caretaker" or project manager. Unlike in the electric lighting industry where there is a clear business model to promote and sell light in the form of fixtures. Good daylighting solutions are an integrative task undertaken by several players. There is an imminent risk that daylighting is taken for granted, and in the worst case that it is not considered at all.

Better integration of the relevant stakeholder perspectives (designer, industry representative, educator) is necessary to understand the common goals for the sake of energy efficiency while creating promising business opportunities. The newly launched activity of the IEA addresses this point – IEA SHC Task 61/EBC Annex 77 "Integrated solutions for daylighting - and electric lighting: from component to user centered system efficiency."

Education

Training daylighting design and technology still is not included sufficiently in most college curricula, particularly in architecture and construction engineering courses.

Current regulations, standards, and certifications

Innovative façade technologies with respect to daylighting are often not addressed in current regulations, standards and certifications. Therefore focus on façade design is too often only on solar protection while daylighting solutions are neglected. Several studies show that lighting controls schemes are effective and their economic feasibility should be requested as well as energy efficient electric lighting (i.e., LED systems).

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[3] In one-shift operations even higher relative savings potential exists, as there is a smaller portion of building operation at night time.

The lack of advanced energy calculation and rating method impedes the design of innovative lighting installations integrating daylighting into “Human Centric Lighting” and “Smart & connected Light“ concepts.

Actions Needed

The following actions by governmental, non-governmental organization (“NGO”) and private entities could significantly drive this market up.

Governments

- *Daylight as “renewable energy source”:* Recognition of daylight – which can be sufficiently quantified as an offset for electric lighting- as a "renewable energy source," included for instance in subsidy programs as a known from other market sectors (PV, wind, etc.).
- *Revision of ordinances:* Revision of ordinances to demand the incorporation of technically working and economically advantageous daylighting solutions:
  - *Floor plans/architecture:* Where not yet implemented, specification of a minimal ratio of window to floor area of spaces (for instance in central Europe between 1/8 – 1/10). Specifications for minimum view out.
  - *Façade technology:* Inclusion of light redirection technologies in the façade. Selection of daylighting supportive combinations of glazing and sunshading / glare protection devices.
  - *Building Management Systems:* Usage of daylight dependent electric lighting controls. Control of sunshading / glare protection dependent on indoor space occupancy sensing (visual comfort driven when occupied, solar gain driven when unoccupied: i.e., maximum gains in winter, minimum in summer).

NGOs and private public partnerships

- *Sustainability certificates:* Use sustainability certificates to promote daylighting. Introduce daylighting if not included yet or revisit existing older certificates and update.
- *Memoranda of understanding of key players in the market:* Agreement on reduction goal for lighting energy consumption with a fixed time horizon. Daylight will have to play a key role in this. A recent Swiss initiative to reduce by half the energy consumption for lighting by 2025 could serve as a template, http://www.slg.ch/de/

Private sector (design, industry)

- *Design process:* Introduction of processes ensuring certain daylight quality levels (e.g., by parametric, automated design tools). Deployment of concepts from new daylighting standards like EN 17037 “Daylight of Buildings.”
- *Design tools:* Establishment of more refined rating methods in standards and design tools supporting new product features and integrated building management.
- *Integrating day- and electric lighting:* Better integration of daylighting and electric lighting in a holistic lighting design approach is an important lever for increasing efficiency and better matching lighting to the user’s needs (refer also to http://task61.iea-shc.org/)