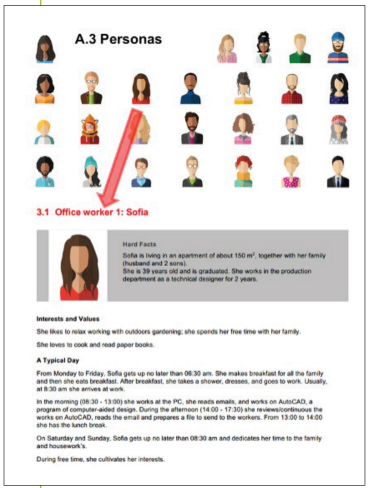
The Best From Both Worlds: Integrated Solutions For Daylight and Electric Lighting

The IEA SHC Programme has worked on different lighting aspects over the years. The first SHC Tasks looked solely into the benefits of efficient daylight usage then shifted to a broader focus beginning with SHC Task 50: Advanced Lighting Solutions for Retrofitting Buildings, which addressed lighting retrofits. The most recent lighting project, IEA SHC Task 61: Integrated Solutions for Daylighting and Electric Lighting, a collaborative project with IEA EBC, looked specifically at the interfaces of electric lighting and daylighting. Up until now, both were often treated as different trades in practice and research – although people work and live in one encompassing lighting environment. This said, the success of highly energy-efficient lighting designs hinges on more than technological ingenuity. Other key make-or-break factors are smart control strategies and the interaction of lighting users with the built environment. These "other" factors were analyzed over the last three and half years by 55 experts from 37 research institutes, universities, and businesses in 17 countries. This article summarizes the key accomplishments and conclusions of SHC Task 61/ EBC Annex 77: Integrated Solutions for Daylighting and Electric Lighting.

Improving the Understanding of Human Lighting Requirements as Targets for Integrated Lighting Design

A key component of this Task was to examine how people impact lighting use, which in the end, resulted in a new way of describing user impact on lighting use. Task experts began with the question, **What light (radiation) do users actually need?** To begin to answer this question, Task participants conducted a comprehensive literature overview of more than 100 articles from which 28 criteria in four main categories on the perception of light, visual comfort, psychological aspects of lighting, and non-image forming aspects were analyzed. Based on this work, electric lighting and daylighting can now be more easily compared and optimized.

Next, the Task participants identified typical user groups for a number of building types and analyzed their lighting-related behavior. The researchers' aim was to paint a picture of different user personas as opposed to illustrating behavior only by numbers and statistics. Each Persona was embedded in a narrative describing the behavior of a group of individuals within a distinct setting. An example is a typical office worker, who was even given a name and an identity, whose workday is described in terms of what she is doing, the light sources (e.g., computer screens), and the software programs she uses. The report, Personas, detailing a total of 26 Persona to design lighting systems based on a more holistic view of a user's impact, that is, their lighting needs and behavior, will soon be posted online.


A.3 Personas

3.1 Office worker 1: Sofia

Hard Facts

Sofia is living in an apartment of about 150 m², together with her family (husband and 2 sons).
She is 39 years old and is graduated. She works in the production department as a technical designer for 2 years.

Interests and Values

She likes to relax working with outdoors gardening; she spends her free time with her family.

She loves to cook and read paper books.

A Typical Day

From Monday to Friday, Sofia gets up no later than 06:30 am. She makes breakfast for all the family and then she eats breakfast. After breakfast, she takes a shower, dresses, and goes to work. Usually, at 8:30 am she arrives at work.

In the morning (08:30 - 13:00) she works at the PC, she reads emails, and works on AutoCAD, a program of computer-aided design. During the afternoon (14:00 - 17:30) she reviews/continuous the works on AutoCAD, reads the email and prepares a file to send to the workers. From 13:00 to 14:00 she has the lunch break.

On Saturday and Sunday, Sofia gets up no later than 08:30 am and dedicates her time to the family and housework's.

During free time, she cultivates her interests.

▲ **The typical office worker is one of 26 Personas.** (Source: IEA SHC/EBC Task 61 Report, Personas)

Controls are the Key Technology to Implement Integrated Lighting Solutions

Another major aim of SHC Task 61 was to identify promising lighting control solutions for integrating lighting – solutions that could minimize the electricity demand and better meet the needs of users and facility managers. The question asked to start this work was, **What drives practitioners?** The first step in this process was to undertake an extensive survey among more than 100 professionals, most of them facility managers, to try to understand what influences their decision to implement and use lighting control systems.

From the large number of solutions available on the market, Task experts chose 16 specific lighting control protocols – some wired and some wireless – and analyzed their potential and barriers before giving recommendations on how to smartly adjust them for high comfort and good

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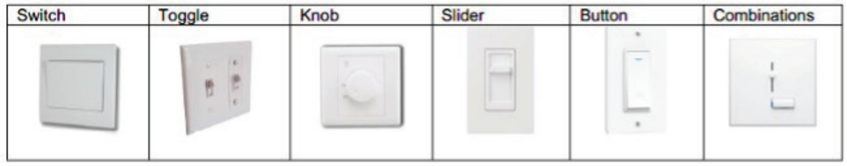
energy performance. This in-depth analysis of user interfaces shows the need for well-designed, simple-to-understand front-end interfaces.



Looking at R&D pipelines shows that challenges for new systems lie in the multi-criterial optimization of lighting needs and other building needs, such as solar gain protection. Bringing the electric lighting and daylighting control systems directly to the workplace (to the computer screen) gives the user direct control. In this Task, three new approaches from leading European brands were examined and discussed in the soon to be published report, Review of New Systems and Trends.

Throughout the Task, the participants also looked at standardizing market implementation, which is vital for the widespread and proper use of integrated controls. For example, a review showed that the two areas – control of daylight and control of electric lighting – are still treated separately but desperately need a comprehensive standard for integrated controls. You can read the details in the soon to be published report, Standardization Issues Related to Lighting and Daylighting Control Systems.

▲ **Variety of user interfaces investigated: from analog to fully digital embedded devices.** (Source: IEA SHC/EBC Task 61 Report, User Interfaces)

New Design Processes Help Bring Integrated Lighting Solutions onto Designers' Desktops

Planning and design processes have a long-lasting impact on a building's energy usage and performance. Therefore, they are of utmost importance, so for this work, the question to answer was, How to plan integrated lighting? To begin, Task participants collected and discussed typical workflows, which provided detailed insights into planning integrated lighting. Then, the workflow and application of 12 software tools were compared in three state-of-the-art buildings in Austria, Germany, and China.

Another relatively future-proof aspect of Task 61 is in the field of photometric modeling to simulate facades and the sky. The façade modeling work included:

- A summary of the current state-of-the-art in the field of characterization of daylighting and shading systems by bidirectional scattering distribution functions (BSDFs). You can read more in the soon to be published report, Analysis and Evaluation of BSDF Characterization of Daylighting Systems.
- A White Paper, BSDF Generation Procedures for Daylighting Systems, to trigger standardization.

▼ **Conventional lighting controls detect and regulate horizontal illuminance levels (upper left picture), but the user comfort is predominantly in the vertical field of vision (upper right picture). Workplace orientated sensor controlling both daylighting and electric lighting (lower picture).** (Source: IEA SHC/EBC Task 61 Report, Standardization Issues Related to Lighting and Daylighting Control Systems ©Fraunhofer IBP)

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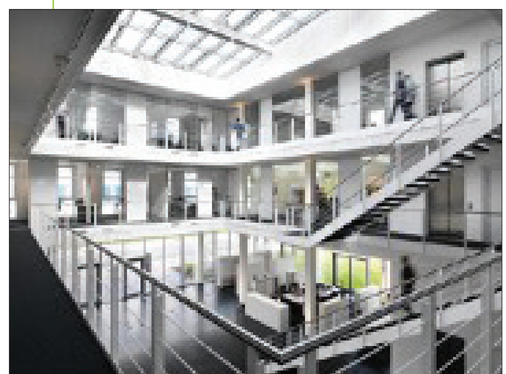
- An extensive round-robin test in six labs showed high data assessment and post-processing quality, which means that complex fenestration systems can be practically planned with high confidence.

Applying new data models to simulate the sky is a big step forward. So far, daylight simulation tools have featured only monochromatic models. In this Task, spectral sky measurements and existing models were reviewed and merged into a simplified model for practical applications. This research can be applied to extend classical monochromatic sky models to support color-dependent design processes and improve the understanding and modeling of daylight's non-visual effects in the built environment. The Task report, Spectral Sky Models for Advanced Daylight Solutions, summarizes the existing color models and discusses their use in three different simulation tools (LARK, ALFA, and RADIANCE).

Continuing the Task work on modeling, participants worked on an integrated energy rating level, developing a new hourly-based rating method for the energy demand

	Applies to Software + = yes, o = partly, -- = no												
	AGi32	ElumTools	DALEC	DIALux	DIAL+	DIVA-for-Rhino	FENER	GB SWARE Dali	Ladybug / Honeybee	PKPM	Radiance	RELUX	Remarks / explanations
DAYLIGHTING													
Point-in-time simulation	+	+	--	+	+	+	+	+	+	+	+	+	
Climate-based annual simulation	--	--	+	--	+	+	+	--	+	+	+	--	
Illuminance values	+	+	+	+	+	+	+	+	+	+	+	+	
Luminance values	+	+	+	+	+	+	--	+	+	+	+	+	
Daylight factor values	+	+	--	+	+	+	+	+	+	+	+	+	
Daylight autonomy (DA, cDA, sDA)	--	--	+	--	+	+	+	+	+	+	o[11]	o[12]	11: calculation from annual illuminance values (post processing) 12: calculation of daylight autonomy depending on daylight factor for the sensor
Glare calculations (DGP, DGI, …)	--	--	--	--	--	+	+	+	+	+	+	--	
CIE sky models	+	+	o[3]	+	+	+	--	+	+	+	+	+	3: diffuse part modeled as CIE uniform sky
Perez sky model	+	+	--	--	+	+	+	+	+	+	+	--	
Sensible to orientation	+	+	+	+	+	+	+	+	+	+	+	+	
Consideration of daylight systems as geometry	+	+	--	+	+	+	+	+	o[9]	o[10]	+	+	9,10: partly considered; model complexity and calculation accuracy depend on the settings of the engine (Radiance)
Import of daylighting systems as BSDF data	--	--	+[3]	+[4]	--	--	+	+	+	--	+	+[12]	3: XML import in Klems format in next release 4: import of DDLS and ODLS format; includes measured BSDF data 12: import available in Radiance format
Data base of daylight systems	--	--	+	+	--	--	+	+	--	+	--	+	
Consideration of outdoor obstructions	+	+	o[3]	o[4]	+	+	+	+	+	+	+	+	3: horizontal obstruction or overhang possible as exterior shading 4: reflection of outdoor surfaces not considered

Bartenbach R&D office in Aldrans, Austria



DIAL Corporation Building in Lüdenscheid, Germany

CABR NZEB in Beijing, China

▲ **Detailed analysis of design workflows in three buildings. Comparison of 12 software tools used in designing integrated lighting solutions with respect to daylight. Other criteria were Algorithms / Engines, Electric Lighting, and Control Systems.** (Source: IEA SHC/EBC Task 61 Report, *Workflows and Software for the Design of Integrated Lighting Solutions*)

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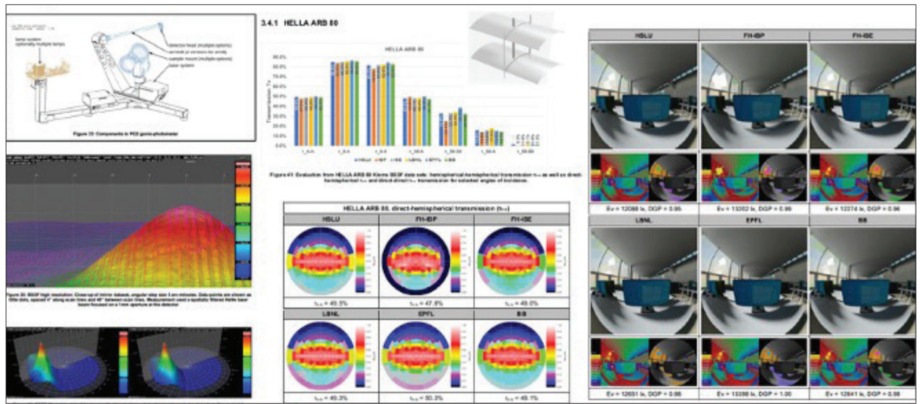
of integrated lighting solutions, which is closely aligned with building automation and control system (BACS) structures and definitions. This new approach allows for an integrated workflow in lighting design and commissioning installations while avoiding future double specifications. The method is being implemented in ISO Standard 10916: Calculation of the impact of daylight utilization on the net and final energy demand for lighting. In addition, core functionalities will be included in a simple web-based tool and the well-known freeware lighting software environment DIALux Evo in early 2022, which has 700,000+ users worldwide – bringing the new rating capability directly onto the desktops of designers.

Another Task work area focused on using VR systems in building design practice. Four case studies highlight the capabilities of VR-based presentations of integrated lighting scenarios. This approach holds enormous potential for the future as it allows for a more realistic, intrinsic understanding of lighting concepts. A VR decision guide will be available on the Task website in early 2022.

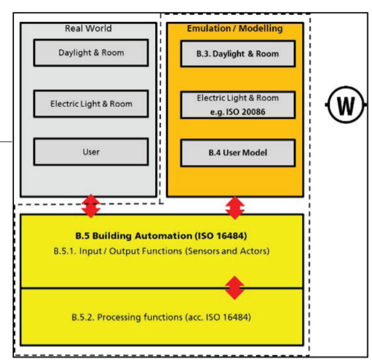


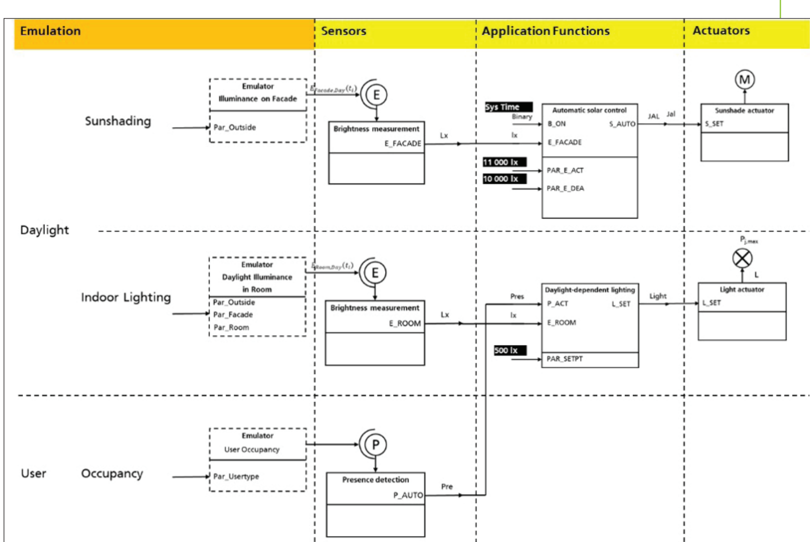
▲ **Round robin test on the characterization of sun shading and daylighting systems performed for two typical samples with data and software from 6 labs.** (Source: IEA SHC/EBC Task 61 Report, Analysis and Evaluation of BSDF Characterization of Daylighting Systems)

▲ **Spectral sky scanner at daylight measuring site at the Technische Universität Berlin.** (Source: IEA SHC/EBC Task 61 Report, *Spectral Sky Models for Advanced Daylight Solutions*)

25 Field Study Assessments Show What Is Working and What Is Not

In the end, practice beats theory. Experiences from 25 case studies (office, retail, sport/recreation, health, residential) from 12 countries were collected and cross analyzed, verifying, and in parts, showing drawbacks in applied integrated approaches. To have the appropriate tools at hand, a new monitoring framework had to be developed to properly assess the performance of lighting solutions. This protocol covers the assessment of energy use (electrical lighting





New hourly-based rating method for the energy demand of integrated lighting solutions, closely aligned with building automation and control system (BACS) structures and definitions. (Source: IEA SHC/EBC Task 61 Report, Hourly Rating Method for the Energy Demand of Integrated Lighting Solutions, to be published)

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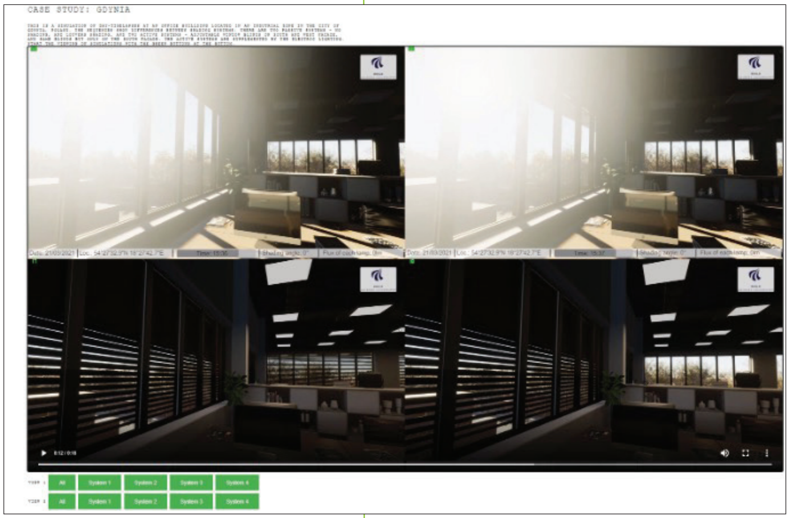
systems), visual effects (Indoor lighting environment/photometry), non-visual effects (circadian potential), and the user (subjective/surveys and observations). Its application helped extract lessons learned from the case studies, which are documented in four-page Fact Sheets targeting a professional audience. What the case studies showed was that:

- The energy demand for lighting can drastically be reduced thanks to the combined effect of more efficient light sources, advances in controls, and raised awareness about the integration of daylighting and electric lighting. Annual lighting energy use as low as 3-4 kWh/m²a is now possible but still far from the standard in ordinary projects. Recommissioning, monitoring, and validation are central to achieving the energy results.
- Integrative lighting (often also referred to as 'human-centric lighting,' aiming at eliciting human circadian response) is driving lighting technology innovation, and wider implementation is expected as knowledge expands in the field of non-visual requirements for lighting. Electric lighting will be able to support non-visual requirements when daylight is insufficient.
- In practice, integrative lighting is hardly integrated with daylighting. Up to today, there has been a lack of tools and knowledge for designers to implement daylight in integrative lighting schemes.
- Integrative lighting may result in significant energy rebounds because it is often designed without regard to daylight. As a result, electric lighting loads increase to reach appropriate lighting levels for users during the day despite daylight being sufficiently available means – more delivered lumens and lower luminous efficacies, thus jeopardizing energy performance.
- Daylighting integration is of utmost importance for achieving quality beyond energy saving as underscored by occupant satisfaction being, for example, strongly linked to having a view of the outdoors.
- Integrated design is facing new challenges, so questions about comfort and health need to be answered now. There needs to be a shift to designing for user needs rather than for the physical space.

You can learn more about this Task's work and find all the reports by visiting https://task61.iea-shc.org/.

▲ **Core functionalities of the new hourly-based rating method for the energy demand of integrated lighting solutions implemented into the software DIALux Evo. It encompasses an energy tachometer that ranks the current design to an optimal theoretical design, indicating designer potentials for improvement.**



▲ **Screenshot of the VR-Decision guide software shows a lighting scene's views in different technical configurations from various positions within the space. The software mimics glare and will be available on the Task website in early 2022.**

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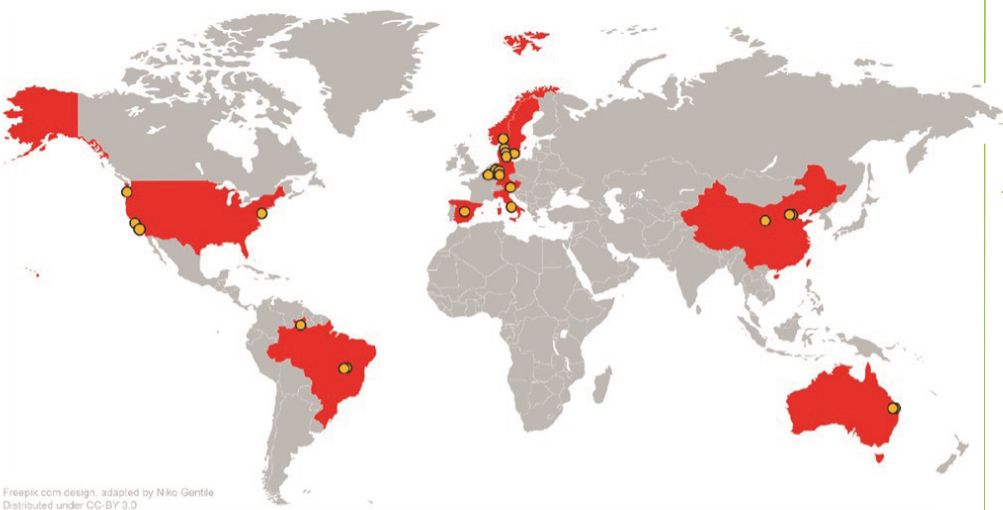
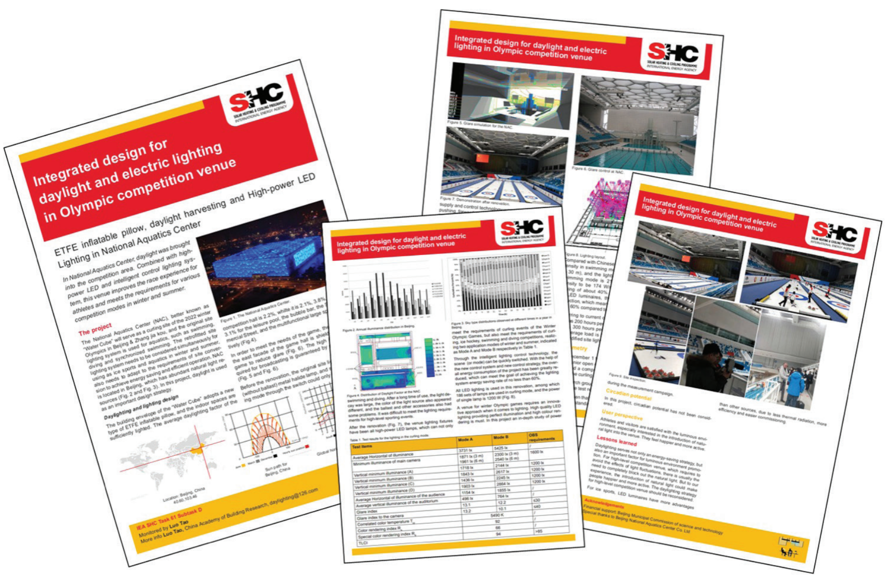


Locations of the 25 case studies covering different latitudes and longitudes. (Source: IEA SHC/EBC Task 61 Report, *Integrating Daylighting and Lighting in Practice*)



Fact Sheets for each of the 25 case studies representing different building types and technologies. (Source: IEA SHC/EBC Task 61 Report, *Integrating Daylighting and Lighting in Practice*)

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