Improving Lighting Retrofits

IEA SHC wrapped up its lighting project, Task 50: Advanced Lighting Solutions for Retrofitting Buildings, in which experts worked on improving the lighting refurbishment process in non-residential buildings in order to unleash energy saving potentials while at the same time improving lighting quality.

The recent IEA SHC Task on lighting set out to accelerate retrofitting of daylighting and electric lighting solutions in the non-domestic sector using cost effective, best practice approaches that could be used on a wide range of typical existing buildings.
Task participants collaborated to:

- Develop a sound overview of the lighting retrofit market.
- Trigger discussion, initiate revision and enhancement of local and national regulations, certifications and loan programs.
- Increase robustness of daylight and electric lighting retrofit approaches technically, ecologically and economically.
- Increase understanding of lighting retrofit processes by providing adequate tools for different stakeholders.
- Demonstrate state-of-the-art lighting retrofits.
- Develop an electronic interactive Source Book with design inspirations, design advice, decision tools and design tools.

STATUS OF MARKET AND POLICIES FOR LIGHTING RETROFITS

Global Economic Models: TCO and Payback Analysis for Typical Applications

Financial data relative to lighting installations before and after retrofits was generated and analyzed. The data was calculated over many years so as to include the installation costs, maintenance, and energy use. To learn more on this work download the report, *Global Economic Models*.

The general principle was to compare the running costs of a “do nothing” approach (keeping the installation as it is and let it die gradually) and the costs associated with a retrofit with highly efficient equipment.

Long-term costs of an installation are quite sensitive to the initial cost, and the combined cost of electricity and energy efficiency. Therefore Total Costs of Ownership (TCO) of lighting installations were calculated for various types of buildings: offices (see Figures 1 and 2), schools, homes and industrial buildings, and the data was used to address the following issues:

- Which installations are low hanging fruits (with shortest payback time)?
- For which type of building are retrofit operations more profitable?
- How do various parameters influence the payback time (investment costs, efficacy of luminaires and sources, cost of electricity, etc.)?
- In case of high electricity costs, and low cost lighting equipment, duration of payback time is below 5 years, which is attractive since new SSL equipment will operate for 5 to 20 years typically.

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JAN DE BOER
SHC Task 50 Operating Agent

continued on page 7

Lighting Retrofit *from page 6*

- TCO calculations are very sensitive to parameters such as product lighting equipment cost, electricity rates, and annual duration of operation.
- In schools, refurbishment requires very low cost products (installation costs below 10€/m^2) since lighting equipment operates a rather short period of the time.

Building Energy Regulation and Certification

Buildings are designed, constructed and operated in a context of standards, regulations or labels. The normative context of the building concerning energy performance suggests performance indices for lighting installations. Such specifications are not always coherent and consistent with other aspects. For instance, facade window dimension and technologies are directly or indirectly suggested, but optimal performance (daylighting, heat gains, heat losses) cannot always be achieved within the respective codes.

SHC Task 50 conducted a critical analysis of regulation and certification documents to identify some of the possible incoherencies as well as the opportunities for progress, and has proposed some adjustments to these reference documents. You can read more in the report, Barriers and Benefits: Building Regulation and Certification.

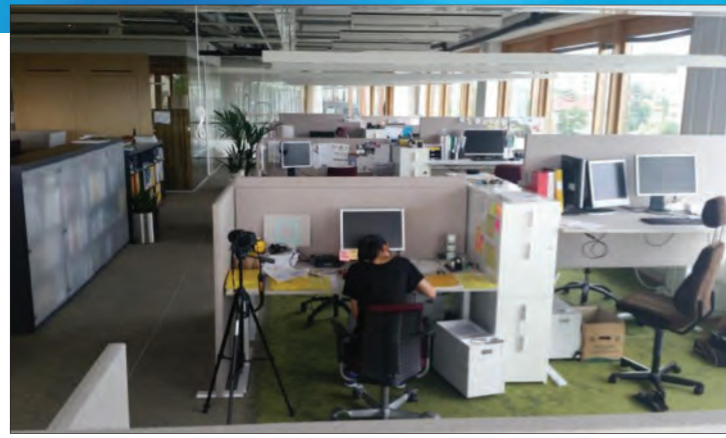
Proposals of Actions Concerning the Value Chain

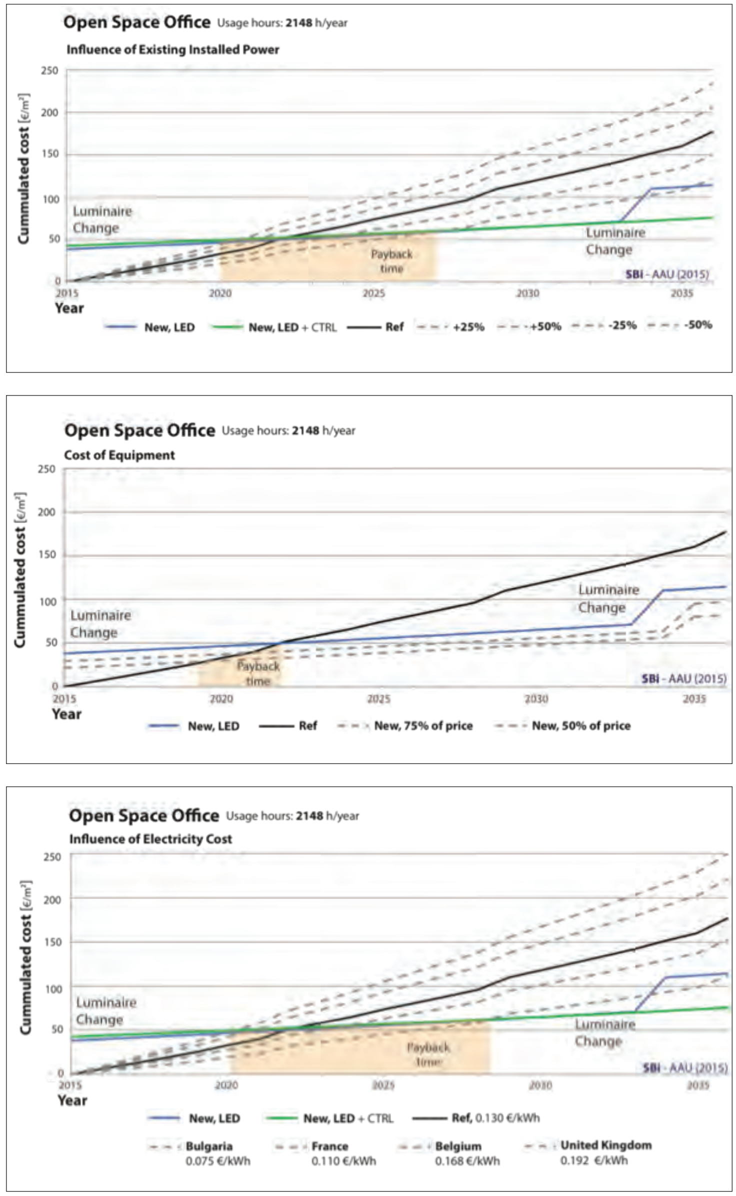
Studies used in SHC Task 50 identified new possible financing options to accelerate replacement of existing installations with financing by the building owner, by an ESCO (assisted by a bank) or by specialized leasing company. From our observations, it seems that the leasing model is the most promising, not only in relation to the added simplicity for the building owner (who does not own the lighting installation or is in charge of its maintenance), but also because it integrates a guarantee of service. It is interesting to note that this new approach triggers a new kind of competition – manufacturers, installers, utilities, facility managers are moving to this field and creating financial pressure on the costs of products, but fortunately, on their reliability and quality as well. Proposal of Actions Concerning the Value Chain.

RETROFIT TECHNIQUES

SHC Task 50 also assessed existing and new technical retrofit solutions in the field of façade and daylighting technology, electric lighting and lighting controls. The main result is the source book, Daylight and Electric Lighting Retrofit Solutions. The source book provides information for those involved in the development of retrofit products or in the decision making process of a retrofit project, such as buildings owners, authorities, designers and consultants, as well as the lighting and façade industry.

In contrast to other retrofit guides, this source book addresses both electric lighting solutions and daylighting solutions, and offers a method to compare these retrofit solutions on a





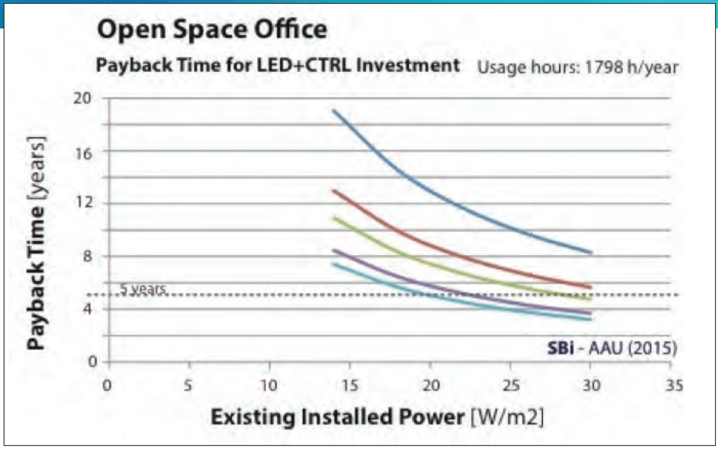
▲ **Figure 1. Cumulated costs for typical open space offices as a function of existing installed power, equipment cost and electricity costs. The same representations were generated, for personal offices, manufacturing halls and wholesale / retail.**

continued on page 8

Lighting Retrofit *from page 7*

common basis, including a wide range of quality criteria of cost-related and lighting quality aspects.

Simple retrofits, such as replacing a lamp or adding interior blinds, are widely accepted and often applied because of their low initial costs or short payback periods. The work presented in the book aims at promoting state-of-the-art and new lighting retrofit approaches that might cost more, but offer a further reduction in energy consumption while improving lighting quality to a greater extent. A higher lighting quality can increase health, self-assessed performance, and lead to a higher job satisfaction and thus productivity in the work environment. In this book, the use of daylight is specifically promoted as an optimized daylighting design as the use of innovative daylighting systems are rarely taken into consideration in the retrofit processes of buildings, and daylight utilization both reduces energy consumption for electric lighting as well as increases user well-being.



▲ **Figure 2. Payback time for typical open spaces offices as function of energy price. The same representations were generated, for personal offices, manufacturing halls and wholesale / retail.**

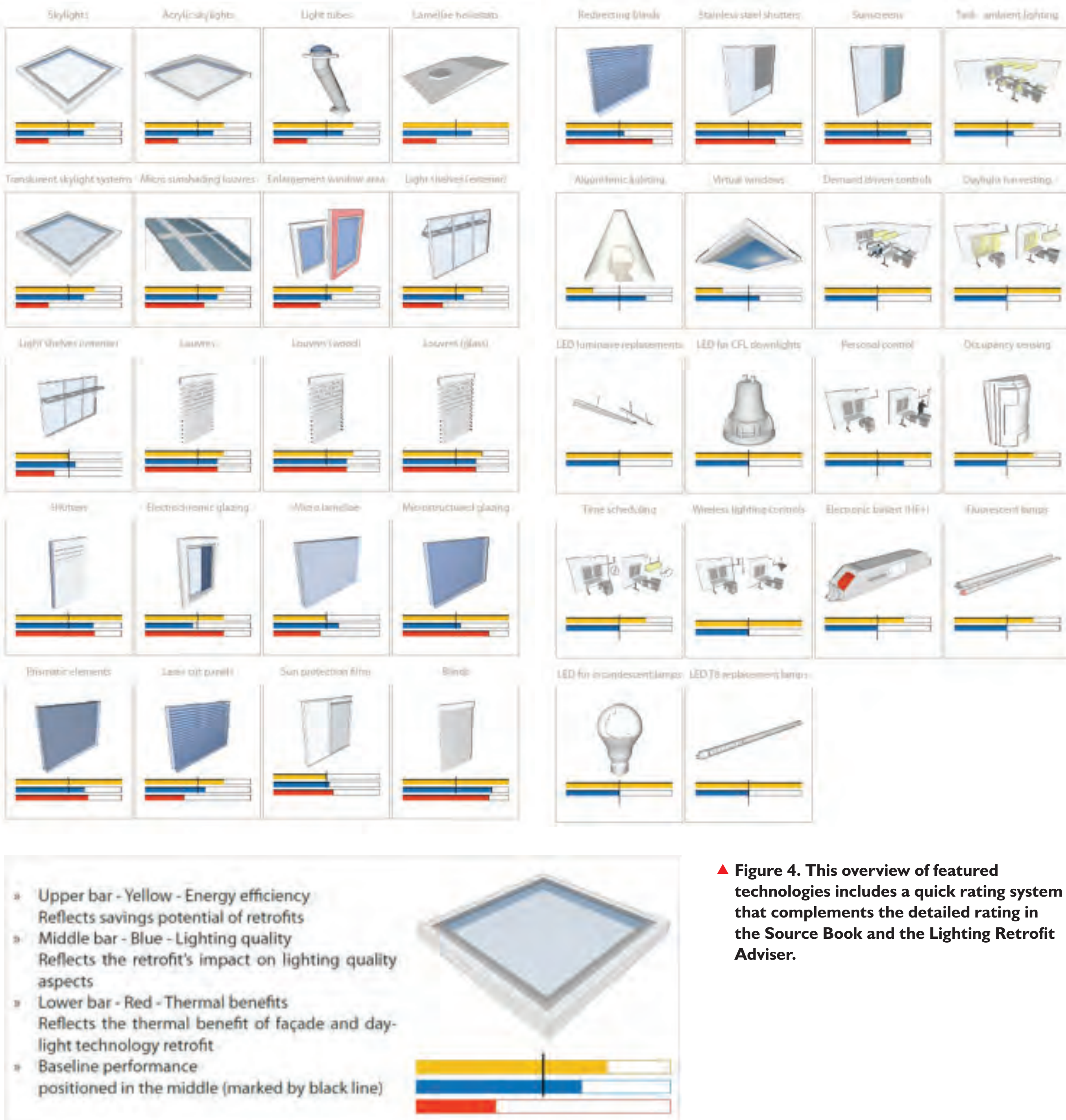
▼ **Figure 3. Possible benefits associated with an improvement of lighting installations.**

	Typology / best solutions	TCO of lighting €/m²	Electricity costs* kWh/m²	Value benefit	Energy benefit	Function benefit	Human benefit
1	Offices	36,7 €/m²	11 kWh/m² 1.4 €/m²	2000 €/m²(value) Rental 200-600 €/m² year	2 €/m².yr (lighting) 4€/m².yr (cooling & lighting)	Higher productivity 300€every year is about 1% improvement in productivity or 30 €/m2 is one worker per 10m²	Less stress Extra hours of comfortable work. Check with medical staff. €/m²
2	Schools	36,7 €/m²	3 kWh/m² 0.4 €/m²	€/m² (value) €/m² (efficiency of education)	5 €/m².yr	Faster learning 1 % of total costs, including staff (200 €/m²) is 2€/m².	Less stress Higher concentration Extra hours without glare €/m²
3	Industrial buildings	14 €/m²	16 kWh/m² 2 €/m²	Rental value	1 €/m².yr	Gains in productivity % of income 3€/m2 if one worker per 100 m2.	Higher comfort Less stress due to daylight Extra hours of comfortable work €/m²
4	Shops	36,7 €/m²	33 kWh/m² 4.3 €/m²	> 1% of income	5€/m².yr	Higher % of income	Daylit shopping area, increased attractiveness by customers
5	Supermarkets	36,7 €/m²	33 kWh/m² 4.3 €/m²	€/m²	1€/ m².yr	Higher % of income	Daylit shopping area, increased attractiveness by customers €/m²

* *calculated for electricity price 0.13 €/kWh*

continued on page 9

Lighting Retrofit *from page 8*



▲ **Figure 4. This overview of featured technologies includes a quick rating system that complements the detailed rating in the Source Book and the Lighting Retrofit Adviser.**

continued on page 10

TOOLS AND METHODS

Taking a closer look into the workflows of professionals and the state-of-the-art lighting retrofit tools and methods, the SHC Task 50 participants conducted the following activities.

Lighting Retrofit in Current Practice - Evaluation of an International Survey

Surveys and socio-professional studies carried out at national and international levels contributed to a better understanding of the lighting retrofit process. The surveys provided clear insights about the workflow of building professionals and led to a better understanding of their needs in terms of computer methods and tools.

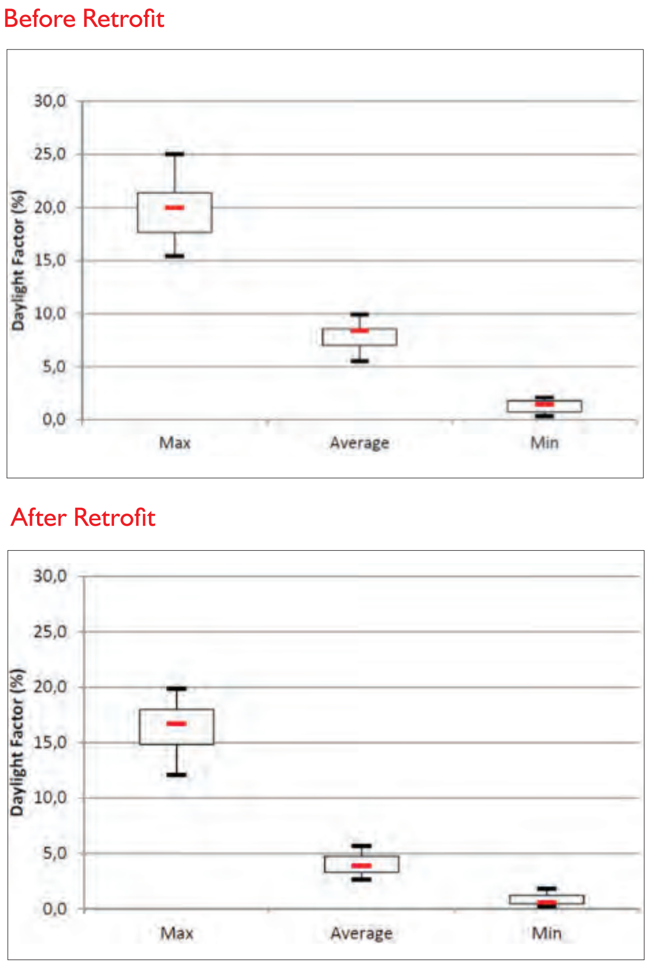
One of the main outcomes of the survey is that retrofitting strategies used in practice essentially focus on electric lighting actions, such as of luminaires replacement and the use of controls. Generally, daylighting strategies are not rated as the highest priority. The results also indicate that practitioners mainly rely on their own experience and rarely involve external consultants in the lighting retrofit process. Furthermore, the survey results suggest that practitioners are interested in user-friendly tools for quick evaluations of their project that provide a good compromise between cost and accuracy and produce reports that can be directly presented to their client. The survey also emphasized that the main barriers in using simulation tools are essentially their complexity and the amount of time it takes to perform a study. Practitioners are keen to use tools during the preliminary design stage and would like to be able to estimate the cost and other key figures (energy consumption and lighting levels). From the survey, recommendations for the building software developers to address the needs of practitioners in a more suitable way were deduced.

Methods and Tools or Lighting Retrofits - State of the Art Review

A review of the state-of-the-art of the methods and tools available on the market to support practitioners in the process of lighting retrofits was conducted. As a starting point, the most used software was taken from the above-mentioned survey. The methods and tools were categorized in four categories:

1. Facility management tools (global diagnostic tool including economic aspects)
2. Computer-assisted architectural drawing / Computer-aided design tools
3. Visualization tools
4. Simulation tools

In total, 20 software tools were described and their main features compared for a quick reference. Results (see Figure 5) indicate a rather large dispersion for daylighting results between the different tools even though the case study was described with great care. However, on electric lighting the results remain within the 10-15% range from the median value. The obtained results indicate that practitioners can rely on illuminance values computed by the tools for nighttime, but that the combination of



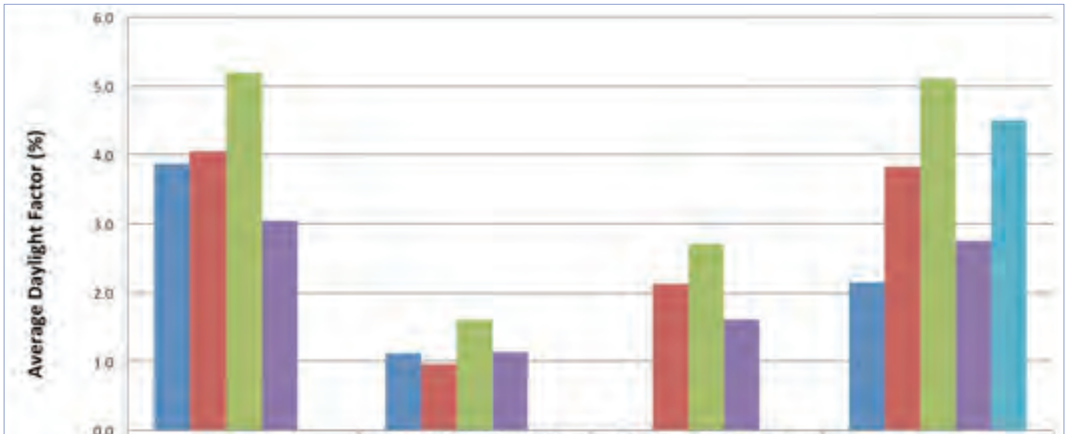
▲ **Figure 5. Exemplary results from the state-of-the-art review of 13 simulation tools. The graphs above show the calculated daylight factors for a test scenario before and after retrofit. The general drop of the daylight factor due to lower light transmittance of new glazing systems (due to low coating) is shown. Plus, the review shows quite a significant spread in the calculation results.**

continued on page 11

daylight and electric light remains a challenge for simulation tools.

Advanced and Future Simulation Tools

This study, Advanced and Future Simulation Tools, looked at software that is able to simulate Complex Fenestration Systems (CFS) composed of solar shading and daylight redirection systems. These systems can have complex light transmission properties named Bidirectional Transmission Distribution Functions (BTDF) that is monitored using goniophotometers or simulated using retracing tools. The results showed a large discrepancy in the results for the daylight factor values, indicating the difficulty to simulate daylight likewise in the state of the art review (as described above).



	Double clear glass	Double clear glass with diffuse blinds	Double clear glass with vertical blinds	Laser Cut Panel
DIALux evo	3.9	1.1		2.1
FENER	4.1	1.0	2.1	3.8
Geronimo	5.2	1.6	2.7	5.1
Radiance	3.0	1.2	1.6	2.8
ReluxPro				4.5

▲ **Figure 6. Daylight Factor obtained with different advanced simulation tools for four different complex fenestration systems.**

The renderings with sunny conditions let the user of the tools appreciate the deviation effect of the laser cut panel for instance, but the obtained images are bound to the intrinsic resolution of the monitored BTDF, which may be coarse depending on the source of data. The advanced and future simulation tools can give an interesting indication of the light distribution through CFS, but practitioners should remain aware of the limits of the method using monitored data bound to a defined resolution. The results are satisfactory enough to get an idea of illuminance profiles or even heat transmission, but not for tasks that require a precise luminance distribution, such as with a glare index calculation.

LESSONS LEARNED FROM 24 CASE STUDIES

A new monitoring protocol developed for non-residential buildings retrofitted with electric lighting and/or daylighting, Monitoring Protocol Lighting and Daylighting Retrofits, was applied to 24 non-residential buildings in 10 countries (see Figure 8). These case studies are presented with monitored data and key conclusions in the Task 50 *Lighting Retrofit Adviser*.

Main conclusions from this work include:

- Cross analysis showed that the energy demand for lighting could be cut on average by 50%. Before retrofit the average energy demand was at 27,1 kWh/m^2 after retrofit it dropped to 14,3 kWh/m^2
- All retrofits monitored achieved improvements in either energy efficiency or lighting quality or both. Replacing older fluorescent with appropriate LED lighting systems can lead to substantial energy savings for electric lighting. Lighting quality and user satisfaction can also be improved at the same time by providing better visual conditions in the spaces. It is, however, not recommended to just replace fluorescent tubes with LED tubes in existing luminaires.
- Control systems for electric lighting or solar shading devices, are frequently found to be poorly implemented, calibrated or commissioned, or perhaps too complex, resulting in reduced energy savings, annoyance of users or even in complete deactivation of the

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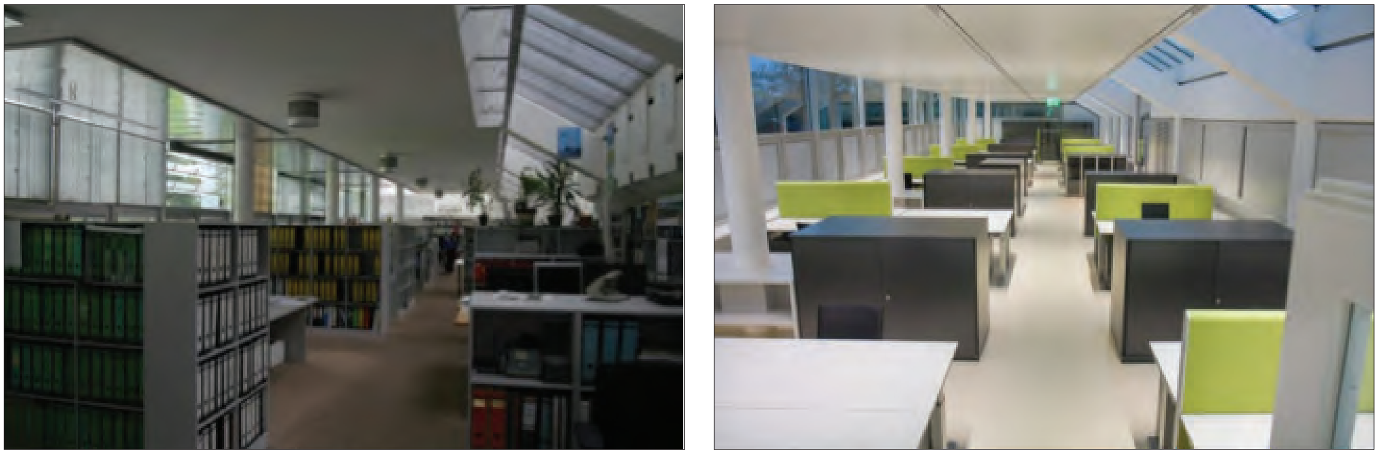

▲ **Figure 7. Pre- and post-retrofit of the Bartenbach R&D office in Austria.**

control system. This highlights the need for better guidance on the installation, commissioning and operation of lighting control systems.

- In general, the users prefer to have the possibility to manually override of the control system.

This article was contributed by Jan de Boer of Fraunhofer Institute for Building Physics and Task Operating Agent for IEA SHC Task 50: Advanced Lighting So-lutions for Retrofitting Buildings, jan.deboer@ibp.fraunhofer.de; Marc Fontoynont, Aalborg University, Denmark; Martine Knoop, Technische Universi-tät Berlin, Germany; and Bernard Paule and Jérôme Kaempf, Estia SA / kaemco LLC / EPFL, Switzerland. Marie-Claude Dubois, Lund University, Sweden.

▲ **Figure 8. Lighting retrofits installed in the 24 case studies.**