Daylighting Window Film Shows Potential to Significantly Reduce Lighting Energy Use in Buildings

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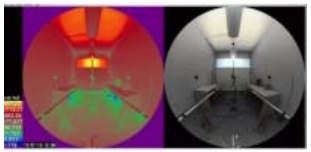
Daylighting is the strategy of admitting light from the sun and sky to reduce use of electric lighting in buildings. Since lighting energy use represents 13 percent of the total primary energy used by buildings in the United States or 5.42 quadrillion Btus in 2010, these technologies can play a significant role towards meeting U.S. and state energy-efficiency and greenhouse gas emission reduction goals. Conventional windows cannot provide useful daylight beyond about one to one and a half times the head height of a window because interior shades, when lowered to control direct sun and glare, diminish daylight penetration. Daylight technologies counter this problem, increasing illuminance deeper in the room from vertical clerestory windows by redirecting sunlight (and diffuse light) towards the ceiling plane. Lack of performance data has severely limited the uptake of these technologies into the marketplace and slowed innovation. Architects, engineers, and building owners are typically unwilling to take the risk of adopting emerging technologies without clear evidence that they perform well.

Lawrence Berkeley National Laboratory (Berkeley Lab) has been collaborating with

Outdoor view of the windows testbed facility. Click to enlarge.



Indoor view showing how sunlight is redirected to the ceiling on a sunny day in December at noon. The daylighting film is installed in the upper clerestory window. Click to enlarge.

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the window industry to develop and evaluate innovative daylighting technologies that can reduce lighting energy use by as much as 50 percent up to 40 feet from windows. Since lighting is often the single largest energy use in commercial buildings, these technologies could make a significant contribution to reducing the nation's energy use. Researchers in Berkeley Lab's Environmental Energy Technologies Division (EETD) are using simulation tools (Radiance, Window, EnergyPlus, COMFEN) and new measurement facilities to accurately assess where and how much solar radiation and daylight flux can be effectively controlled by innovative new optical materials and systems as they are redirected into the building's interior. Using these tools, calculations of energy use and visual discomfort can be done more accurately and in a fraction of the time needed in the past. As a result, industry partners can now determine how well new optical designs will work long before they invest a lot of time and resources into prototype fabrication and testing in the field.

"There's a large potential to speed up the time to market and reduce the cost of development of new energy-efficient technologies through the use of these simulation tools," says Andrew McNeil, Senior Scientific Engineering Associate in EETD.

An example of the benefits of this approach is a collaboration Berkeley Lab has developed with the 3M Corporation. 3M developed a microstructured prismatic film consisting of linear multi-sided prisms 50 to 250 micrometers high. Results from simulation analysis indicate that a small clerestory window with the 3M dual-film system and a lower window with conventional shades can daylight a 40-feet deep perimeter zone facing south, east, or west in virtually all U.S. climates and save up to 40 percent of annual lighting energy compared to the same zone with no daylighting controls. EETD researchers corroborated these findings with measured data in Berkeley Lab's Advanced Windows Testbed facility. 3M has initiated partnerships with window manufacturers to incorporate their new film in new and retrofit applications in commercial and residential buildings.

"We are very excited to have been able to collaborate with Berkeley Lab over these past three years. When we launch our product in Fall 2013, we hope to see accelerated adoption of our products since we will be able to explain the energy-efficiency and comfort impacts of this innovation with confidence to potential customers," said Raghunath Padiyath, Lead Product Development Specialist of the 3M Renewable Energy Division.

Because calculation speed was vastly increased with the new software, McNeil was able to derive a more optimized single-film design using the power of Berkeley Lab's cluster computing farm of 128 parallel processors, genetic algorithms, and some pretty fancy coding. This design is expected to produce the same level of performance at lower cost, pending outcomes from field studies that are now in progress. 3M is evaluating this design for production.

The U.S. Department of Energy and the California Energy Commission through its Public Interest Energy Research (PIER) Program provided funding for both the development of the simulation tools and field tests conducted on behalf of industry. The simulation tools are available to the public at no cost and have been used to assist other U.S. and California-based manufacturers with new product developments. These clean technology investments are designed to create jobs and make businesses in U.S. and California more competitive worldwide, and help achieve aggressive federal and state energy and greenhouse gas reduction goals, which benefit consumers and businesses through lower utility bills.

This study was conducted by: Andrew McNeil, Jacob Jonsson, Anothai Thanachareonkit, and Principal Investigator, Eleanor Lee (Berkeley Lab) in collaboration with Raghunath Padiyath, Doug Huntley, (3M Renewable Energy Division), Bing Hao (3M Corporate Research Materials Laboratory) with support from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy and the California Energy Commission through its Public Interest Energy Research (PIER) Program.

Notes

Site lighting energy use with a small clerestory aperture (WWR=0.18) over a 40-ft deep perimeter zone facing south, east, or west in northern and southern US climates. Occurrence of discomfort glare is less than 5% of annual occupied hours. Simple payback is 5 years, the IRR is 19%, and CCE is $0.08/kWh, assuming an installed cost of $20/ft^2, $0.20/kWh, 30 year life, and 6% discount rate.

Reports:

3M performance

- A. Thanachareonkit, E.S. Lee, A. McNeil, Empirical assessment of a prismatic daylight-redirecting window film in a full-scale office testbed, Accepted for presentation to the IESNA 2013 Annual Conference, Huntington Beach, CA, October 26-29, 2013 and for publication in Leukos, the journal of the IESNA. [PDF]
- A. McNeil, E.S. Lee, J.C. Jonsson, Daylight performance of a microstructured prismatic window film in deep plan open plan offices, to be submitted to Solar Energy. Summary. [PDF]

Simulation Tools

- A. McNeil, A., E.S. Lee. A validation of the Radiance three-phase simulation method for modeling annual daylight performance of optically complex fenestration systems. *Journal of Building Performance Simulation* 2012: 1-14. LBNL-5606E.
- G. Ward, R. Mistrick, E.S. Lee, A. McNeil, J.C. Jonsson, Simulating the daylight performance of complex fenestration systems using bidirectional scattering distribution functions within Radiance. *Leukos, Journal of the Illuminating Engineering Society of North America* 7(4) 2010. LBNL-4414E. [PDF]

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