Dynamic light-redirecting technology: One look into the future

2019 Daylighting Symposium
April 29th, 2019

Luís Fernandes
Building Technology Department
Building Technology and Urban Systems Division

Lawrence Berkeley National Laboratory (LBNL)

- Funded by the US Department of Energy through the Office of Science
- Managed by the University of California
- Unclassified research across a range of scientific disciplines
- Employs 4,000+ scientists, engineers, support staff and students (13 Nobel Laureates)

Windows & Daylighting

- Research, development and technical support for energy efficient window products, and daylighting
- Measurement Facilities
  - Thermal measurement lab
  - Mobile Window Test Facility (MoWiTT)
  - Optical Measurement Lab (Optics lab)
  - Advanced Façade Test Bed Facility
- Window software tools development and support
- Algorithm and standards development
- Thermal performance and energy modeling
- Fenestration rating support

Several current trends impact daylighting

- Automation, sensing, controls
  - Less expensive
  - More familiar to building occupants and operators
- Energy efficiency, GHG reduction
  - More familiar and acceptable to occupants
- Health and well-being in buildings
  - Concerns/awareness related to daylight exposure more prevalent in the R&D and design communities
- Electric lighting
  - More efficient/cost-effective but also better able to take advantage of daylight

What's possible in daylighting is expanding

- More cost-effective, reliable automated systems
- Increased occupant embrace of changes in the indoor environment that can be attributed to
  - Concern for the environment
  - Concern for health and well-being
- Focus includes but not limited to energy savings
  - Health and well-being
  - Resilience

Developing a new type of dynamic daylighting system

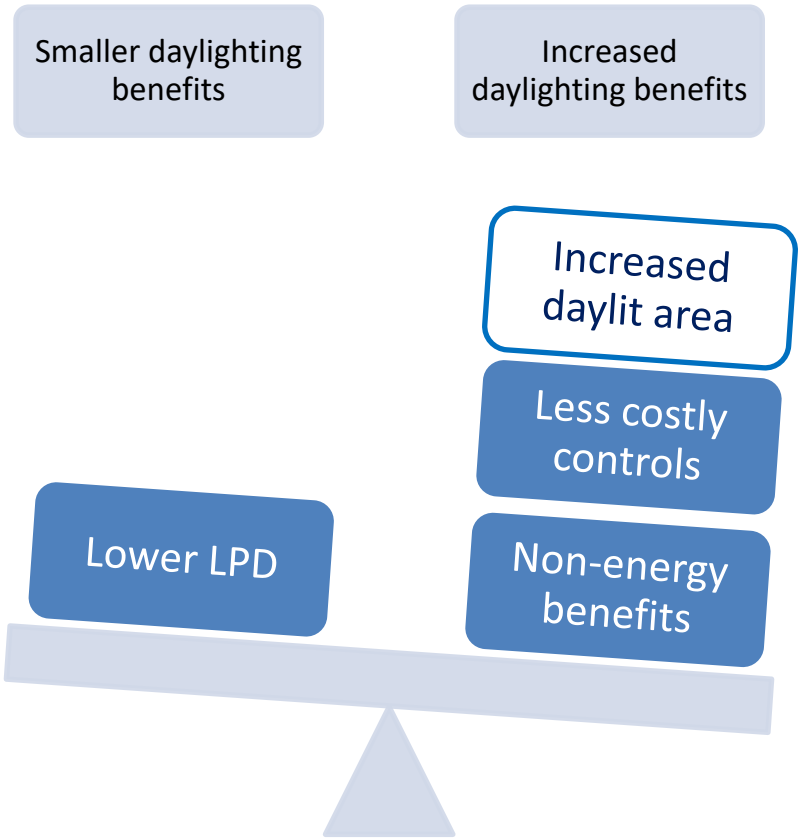
- Part of larger-scale 3-year project funded by the California Energy Commission
- Overall goals included:
  - Develop new window and façade technologies
  - Develop tools and methodologies to facilitate innovation
- One task focused on daylight redirecting systems

Daylight Redirecting Systems Team

- Eleanor Lee (PI)
- Luís Fernandes (PM/technical lead, computer simulation)
- Howdy Goudey, Ray Karam, Ben Karcher (prototype development)
- Anothai Thanachareonkit, Joshua Mouledoux (experimental testing)

Tilting the daylighting balancing act towards more benefits

- LEDs reducing LPD from 1+ W/ft^2 to 0.75 W/ft^2 or less
- Cost/complexity of sensing, controls, dimming greatly reduced
- Greater awareness of health, wellness benefits of daylight
- Significant benefits if daylight delivered beyond perimeter (i.e., deeper than 15 ft from window



Initial goals

- Goal
  - Cost-effective light-redirecting system
  - Deliver daylight to depth of 15-40 ft
  - No glare
- Point of departure
  - Variable-spacing venetian blind concept (Rosenfeld, A.H., Selkowitz, S.E., Beam daylighting: an alternative illumination technique, Energy and Buildings 1(1977):43-50.)
  - All incident sunlight is reflected in the right direction!
  - Established principle (venetian blinds) but requires automation
  - Higher likelihood of being cost-effective in 2018 due to greatly reduced automation/controls costs

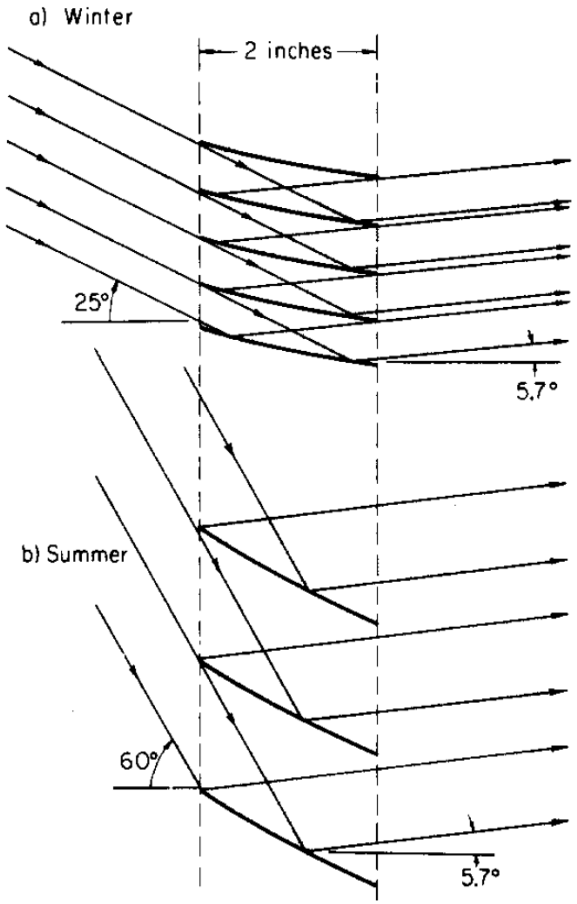
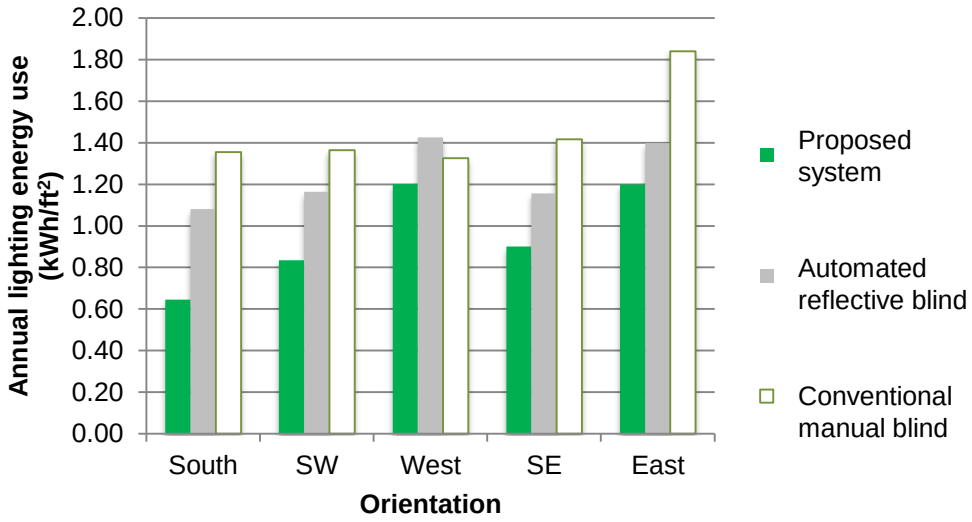
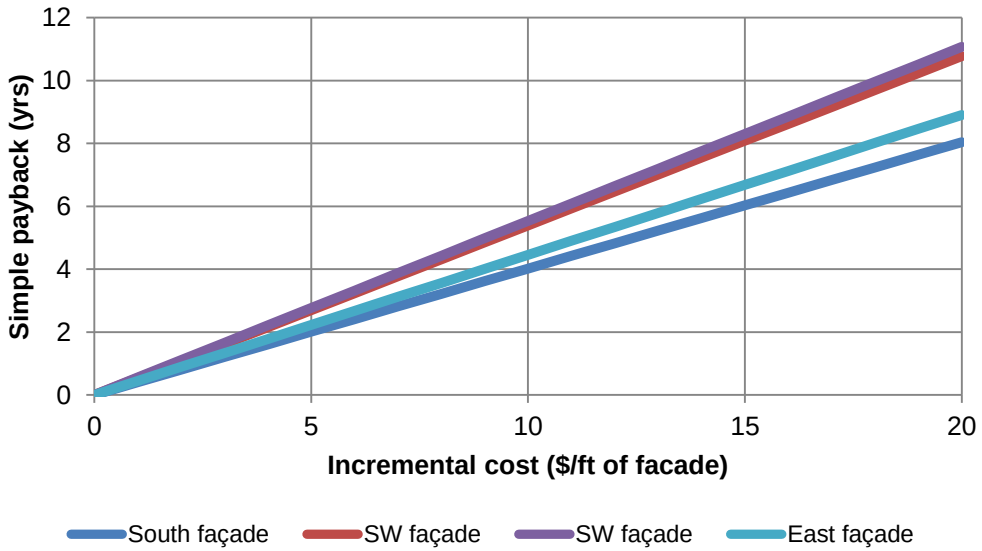


Fig. 7. Tilt and spacing for reflecting slats for typical winter and summer incident light conditions, for a 20 ft deep room at 40 °N.

Significant lighting energy savings

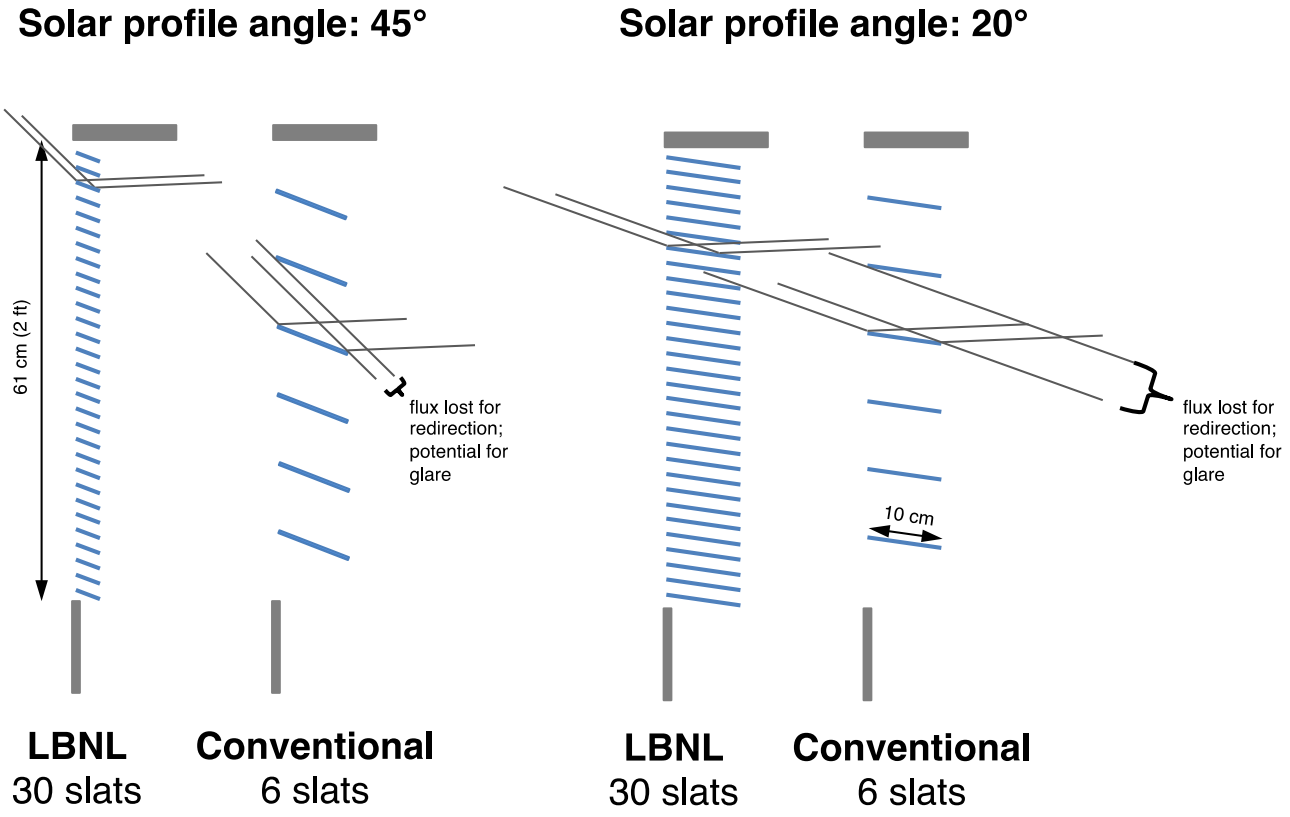
- Simulations show:
  - Significant daylight delivered to 15-40 ft zone from a 2-ft-high clerestory window
  - 0.20-0.46 kWh/ft^2, or 14%-42%, vs. automated reflective blind
  - 0.13-0.73 kWh/ft^2, or 9%-54%, vs. conventional manual blind
  - Glare under control
  - Cost-effective for moderate incremental costs over conventional blinds





Variable slat width implementation feasible

- Variable width configuration has same optical efficiency as variable spacing

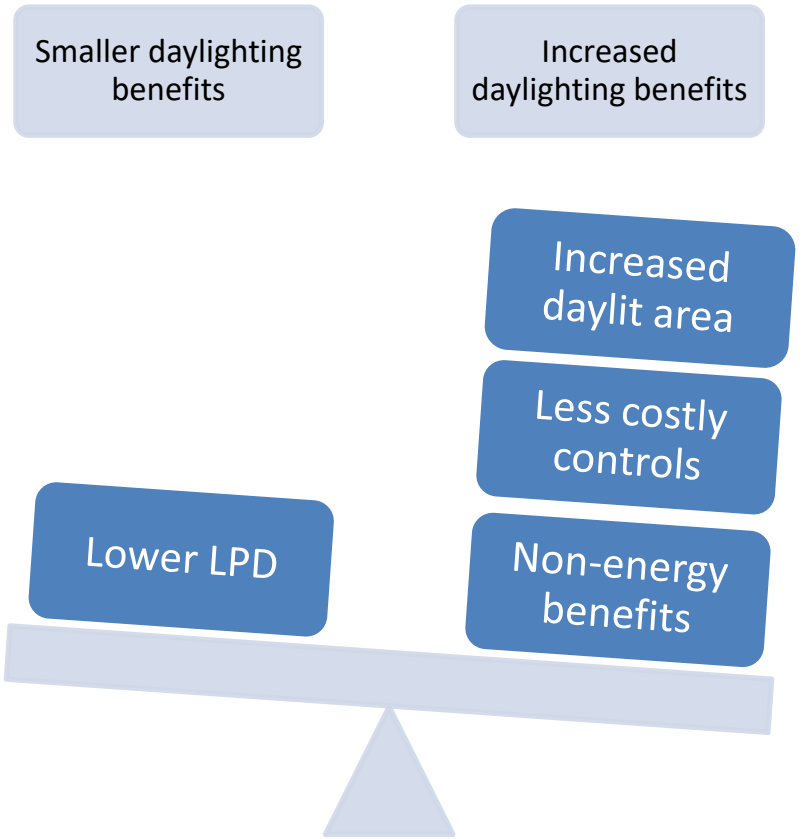


Mirrored, flat slats appear best

- Laboratory tests showed:
  - Flat slats provide better control of ceiling reflections than curved slats (reflective film courtesy of 3M)
  - Mirrored slats provide more effective light redirection than prismatic slats

Conclusions/Benefits to ratepayers

- A new option for providing more daylight deeper into spaces without glare
- Expands daylight harvesting area by factor of 3
- System is located at the façade and doesn't require additional envelope openings
- Automation cost is reduced by using off-the-shelf control and actuation components



Recommendations/Next steps

- Technical development
  - Test robustness of controls and actuation solution
  - Optimize slat material, geometry and surface finishes
  - Develop options for miniaturization and integration into glazing
- Commercial development
  - Continue pursuing commercial development options
  - Refine mature product cost estimates

Key takeaways

- What's possible in daylighting is expanding
- An automated redirecting blind system can expand sidelit area threefold

Thank You

Lawrence Berkeley National Laboratory

Luís Fernandes

llfernandes@lbl.gov