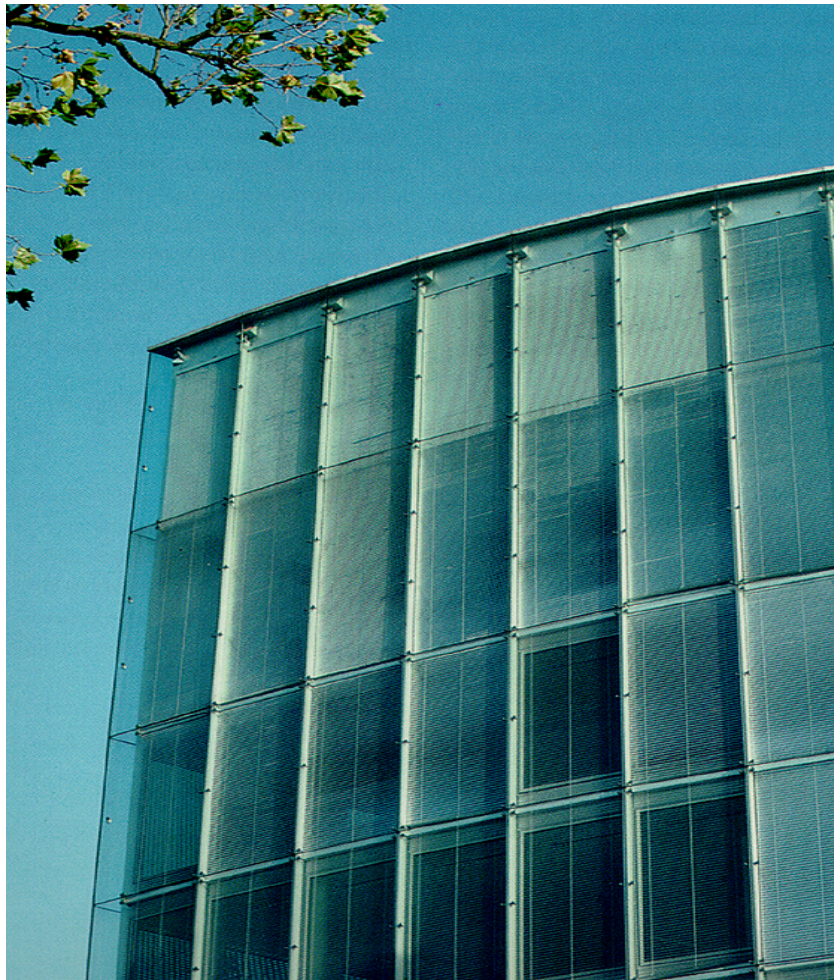
Daylight or "Natural Light" = Market Advantage?

Two Contrasting Views of Energy Efficiency

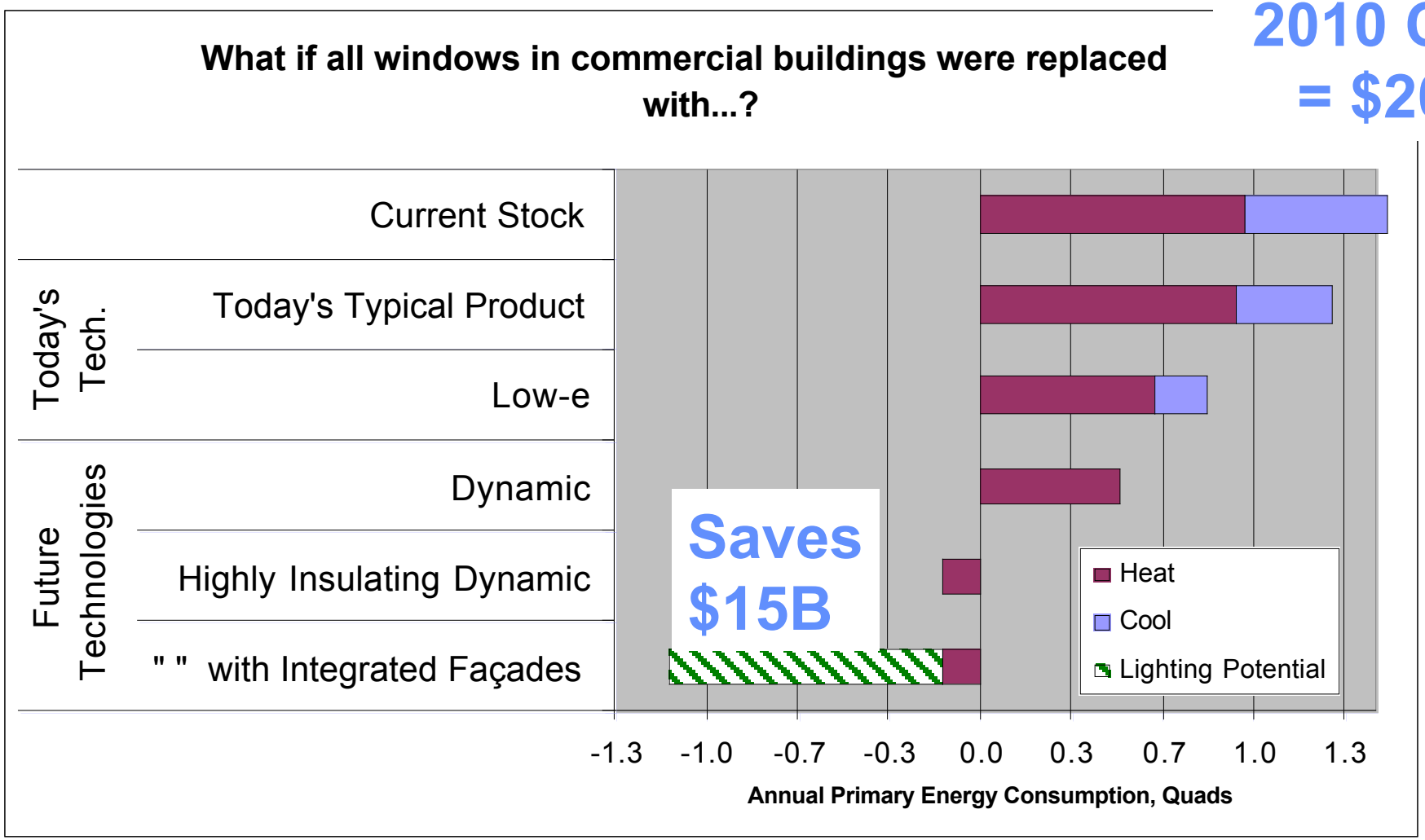
1976 Perspective: Code Official's View of the Ideal Windows

2010 Perspective: Architect's View of the Ideal Windows



Commercial Building Window Energy Use

2010 Cost = $20B



Vision: "Zero-Energy Building"
Facades: Energy Losers --> Neutral --> Suppliers

- Heating climates
  - Reduce heat losses so that ambient solar energy balances and exceeds loss
  - Need lower heat loss technologies
- Cooling climates
  - Reduce cooling loads
  - Static control -> dynamic control
- All climates
  - Replace electric lighting with daylight
- Electricity supply options?
  - Photovoltaics-building skin as power source

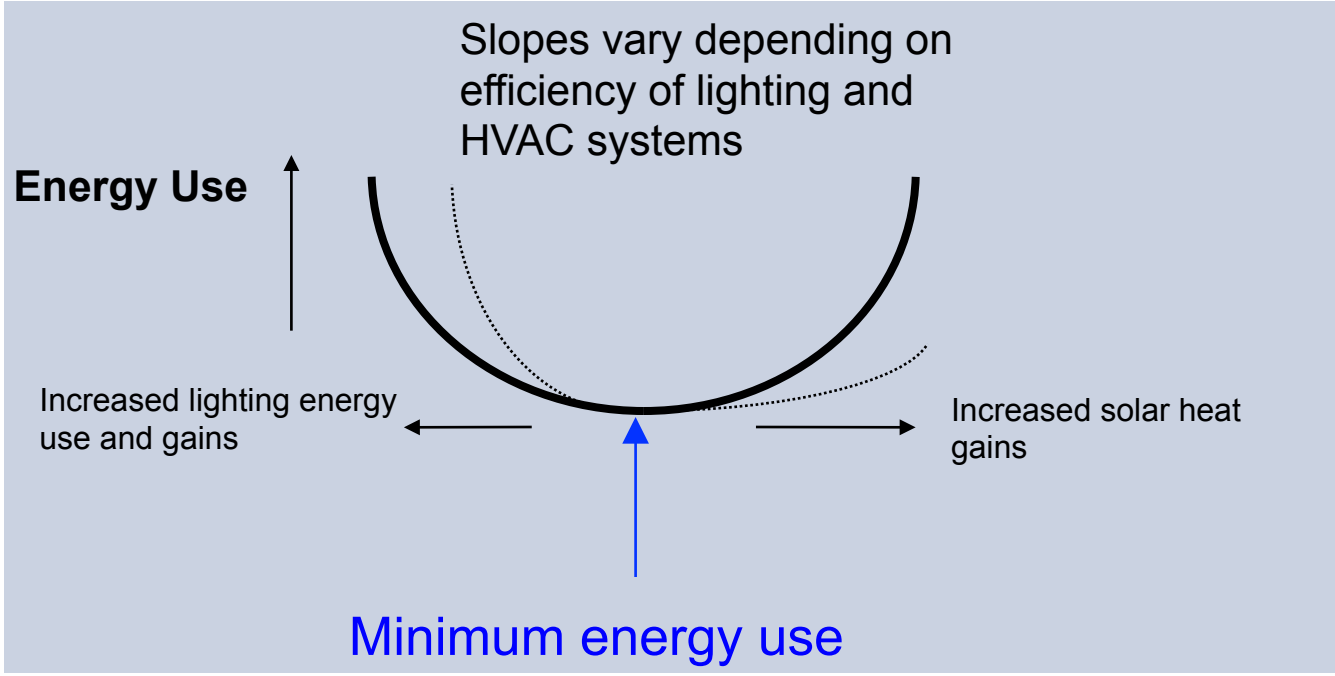
Optimizing Energy in Integrated Facades

Dependent on a number of parameters

- Climate
- Orientation
- Building Type
- Fenestration area
- Glass type
- Operations
- Daylight
- Shading
- ……

Need to balance between a number of issues

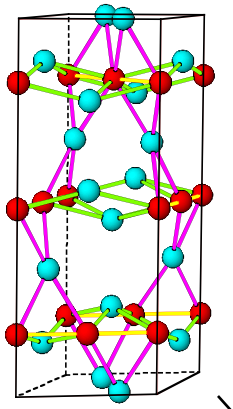
- Energy
- Demand
- Carbon
- Peak Cooling
- Comfort: visual/thermal
- View
- Appearance
- ……



- *Ideal:* Integrated approach to façade-lighting-HVAC building systems to achieve optimum energy-efficiency and comfort.

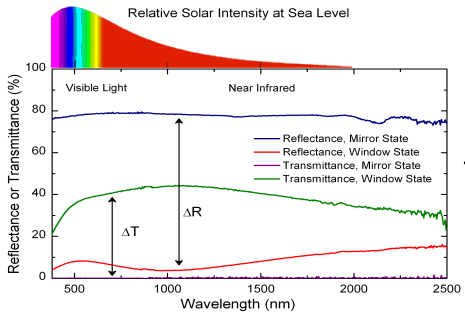
… It's Complicated!!

Integrated R&D Strategy: Electrochromic Devices

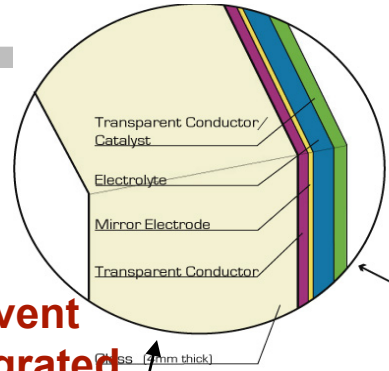


Mg_2Ni

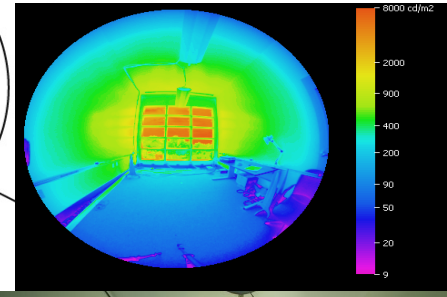
Invent New Materials

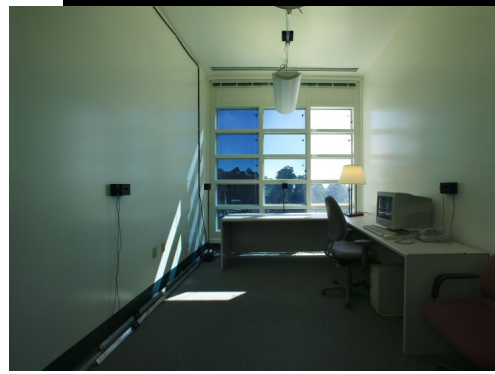


Characterize Coating Performance

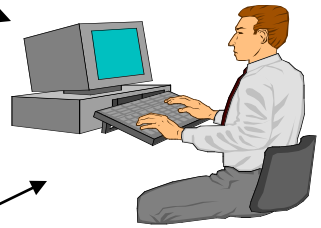


Invent Integrated Window

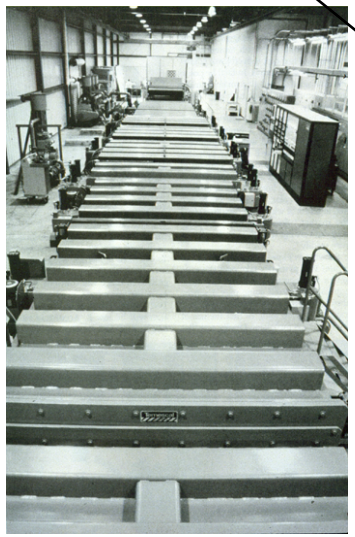




Assess Human Factors



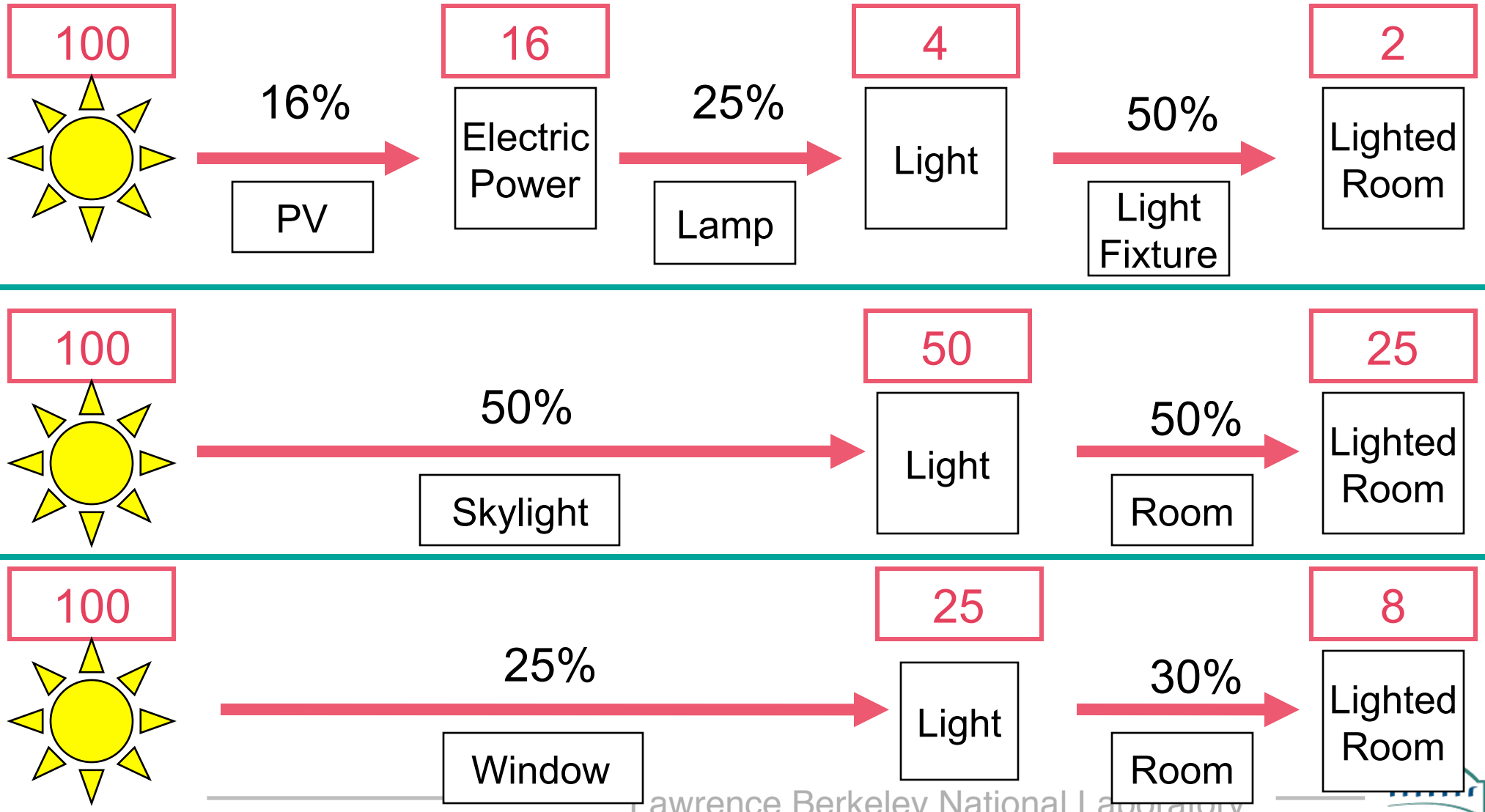
Assess Savings

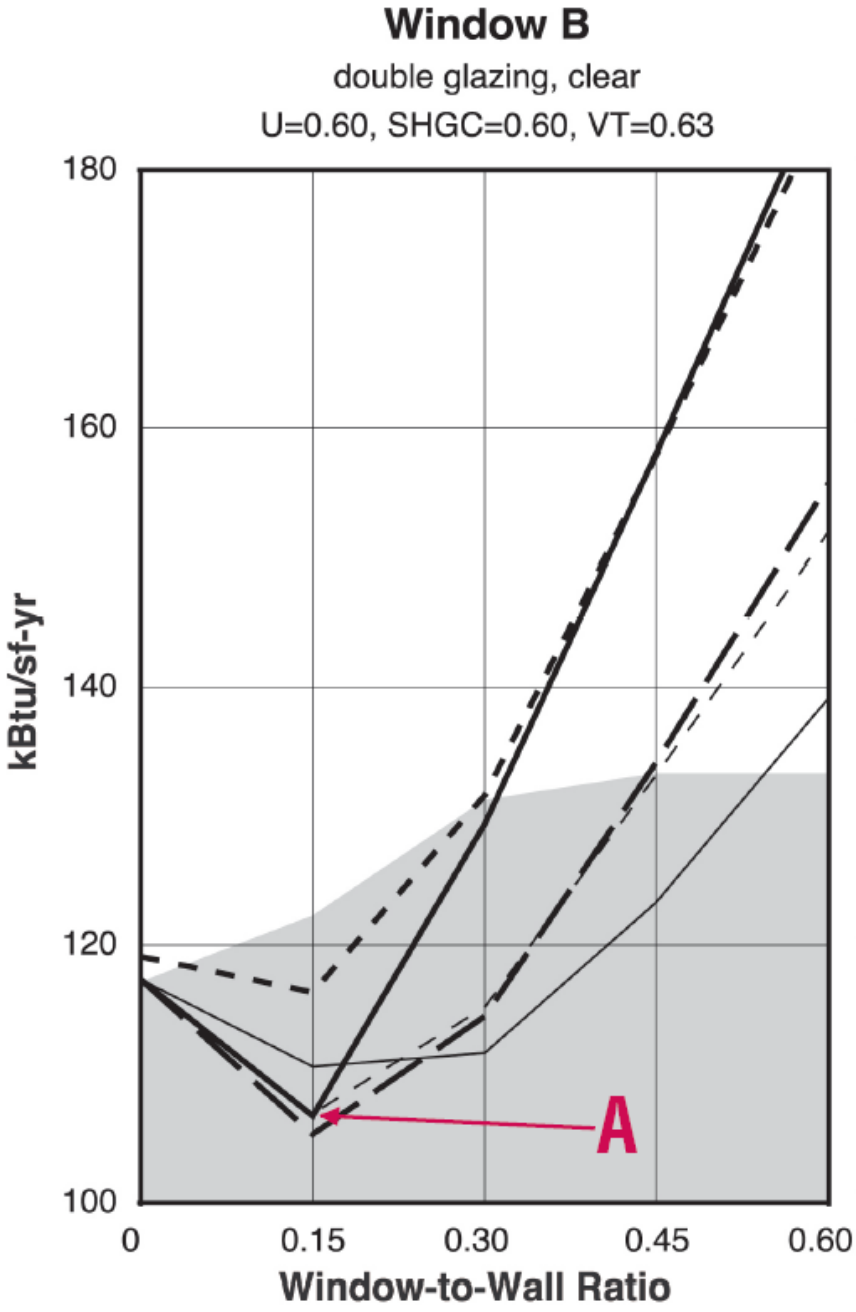


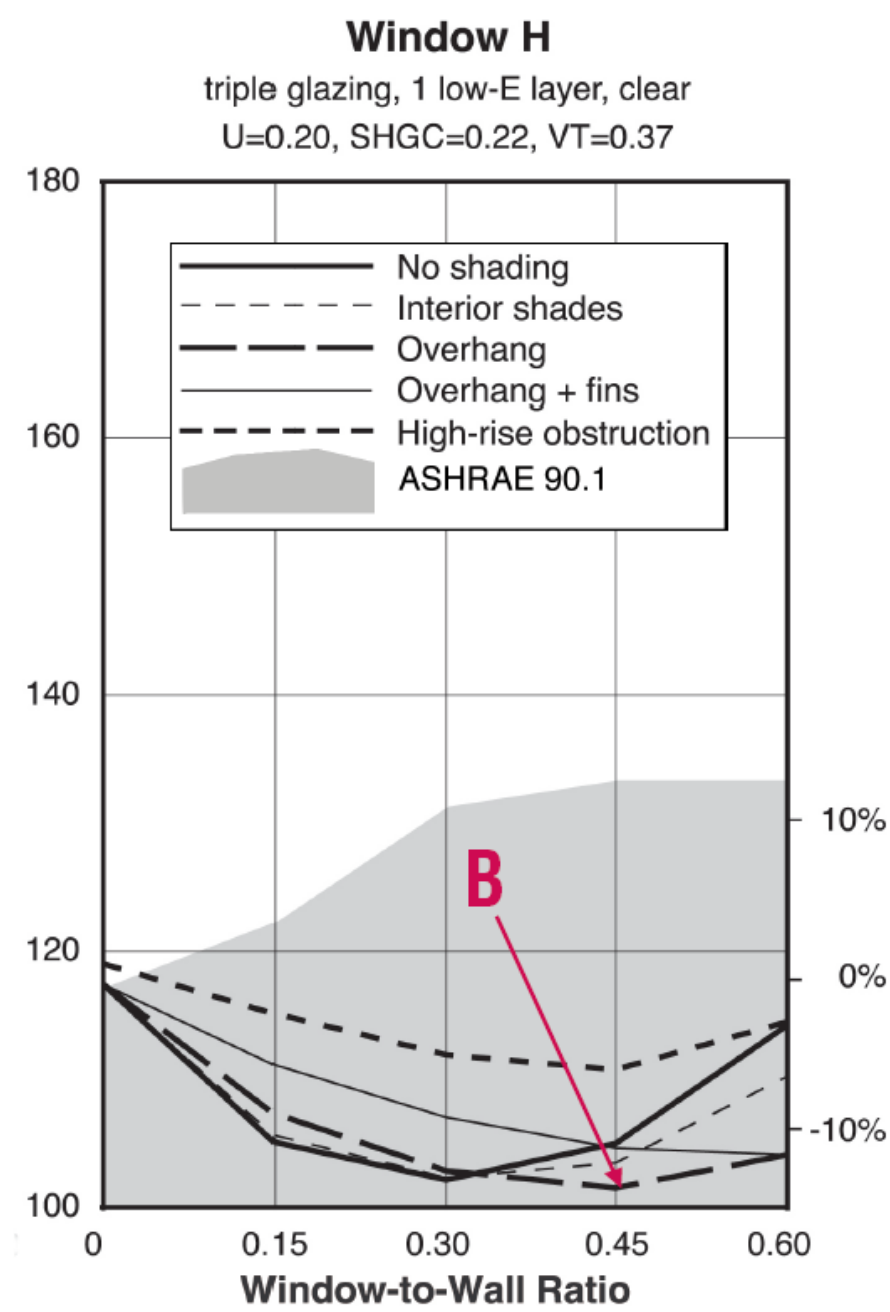
Invent Innovative Manufacturing Process

Invent/Test Integrated Systems

Using Sunlight Effectively?
Electric conversion vs Direct Use





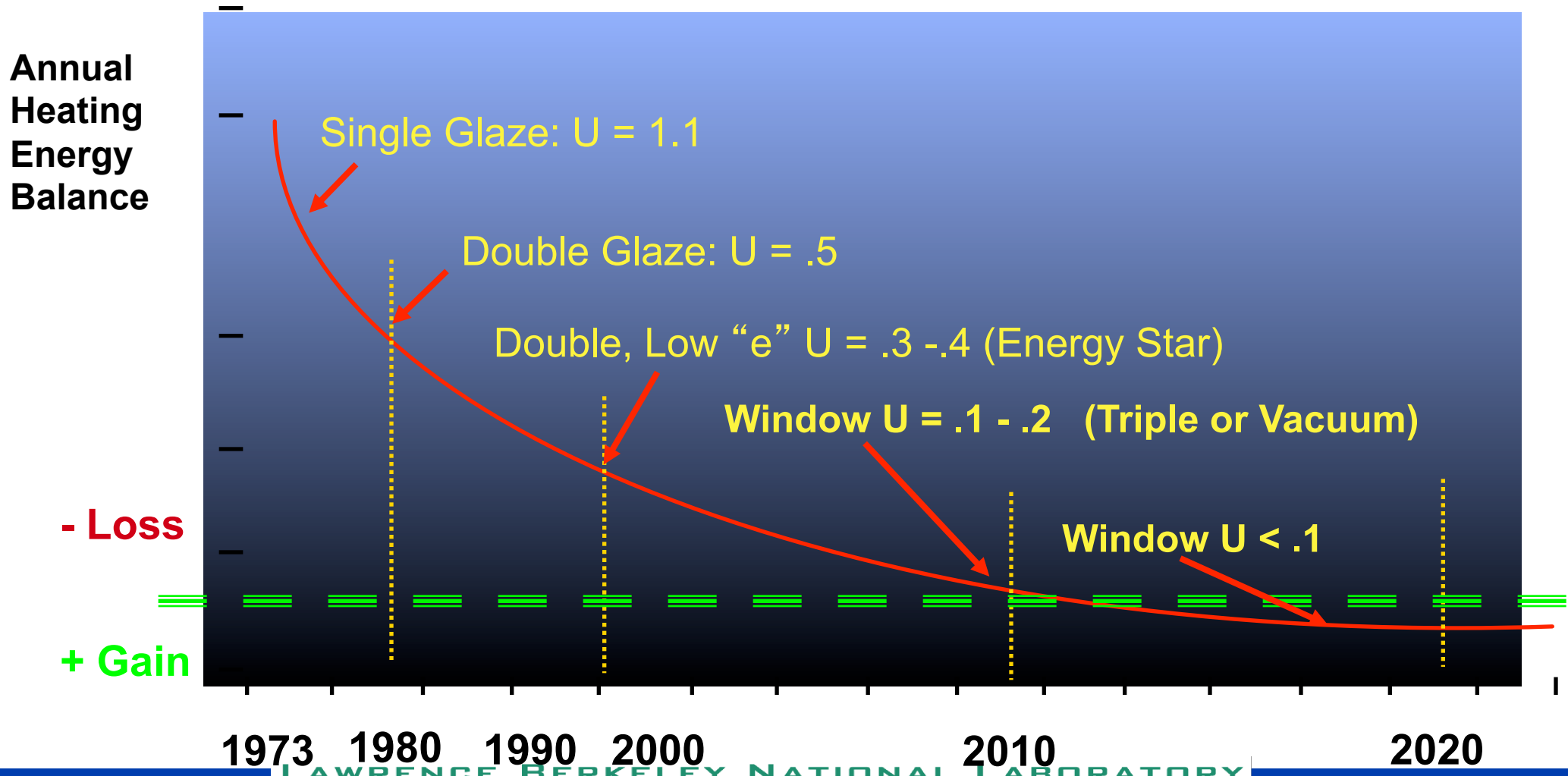


Cold Climates: Chicago, IL

3 Pathways for Use of Glass in Commercial Buildings

- **Just meet the code**
  - Small Windows, prescriptive properties, e.g. double
  - No special shading or daylighting
- **Conventional "good" solutions: (prescriptive packages)**
  - Modest sized windows, skylights
  - Double glazing
  - Spectrally selective glass
  - Manually operated Interior shading
  - On-off lighting controls
- **Architectural Solution with "Transparent Intelligent Façade"**
  - Highly glazed façade; extended daylighted zone
  - Reliable tools reduce risk
  - High Performance technology with Systems Integration
  - **Dynamic, smart control- automated shading, dimmable lights**
  - Economic from Life cycle perspective
  - Optimized for people and for energy, electric demand

Insulating Windows Can Become Energy Producers in Cold Climates



Successes in U.S. Window Markets
(Example: Residential market)

- 1973: Typical Window:
  - clear, single glazed,
  - double or storm window in north,
  - $U_{average}$ = .85 BTU/hr-F-sq.ft.
- 2003: Typical Window:
  - 95% double glazed
  - 50% have a low-E coating
  - 30-65% energy savings vs. 1973
  - $U_{average}$ = .45 BTU/hr-F-sq.ft.
- 2030: Future Window:
  - Zero net energy use (typical)
    - Net winter gain; 80% cooling savings
  - $U_{average}$ = .10 BTU/hr-F-sq.ft.
  - Dynamic solar control

Spectrally Selective "Cool" Glazings

- **Spectral control- transmit light, reject near-IR heat**
- **Equal daylight with only 50% of solar gain**
- **IG to minimize SHGC**

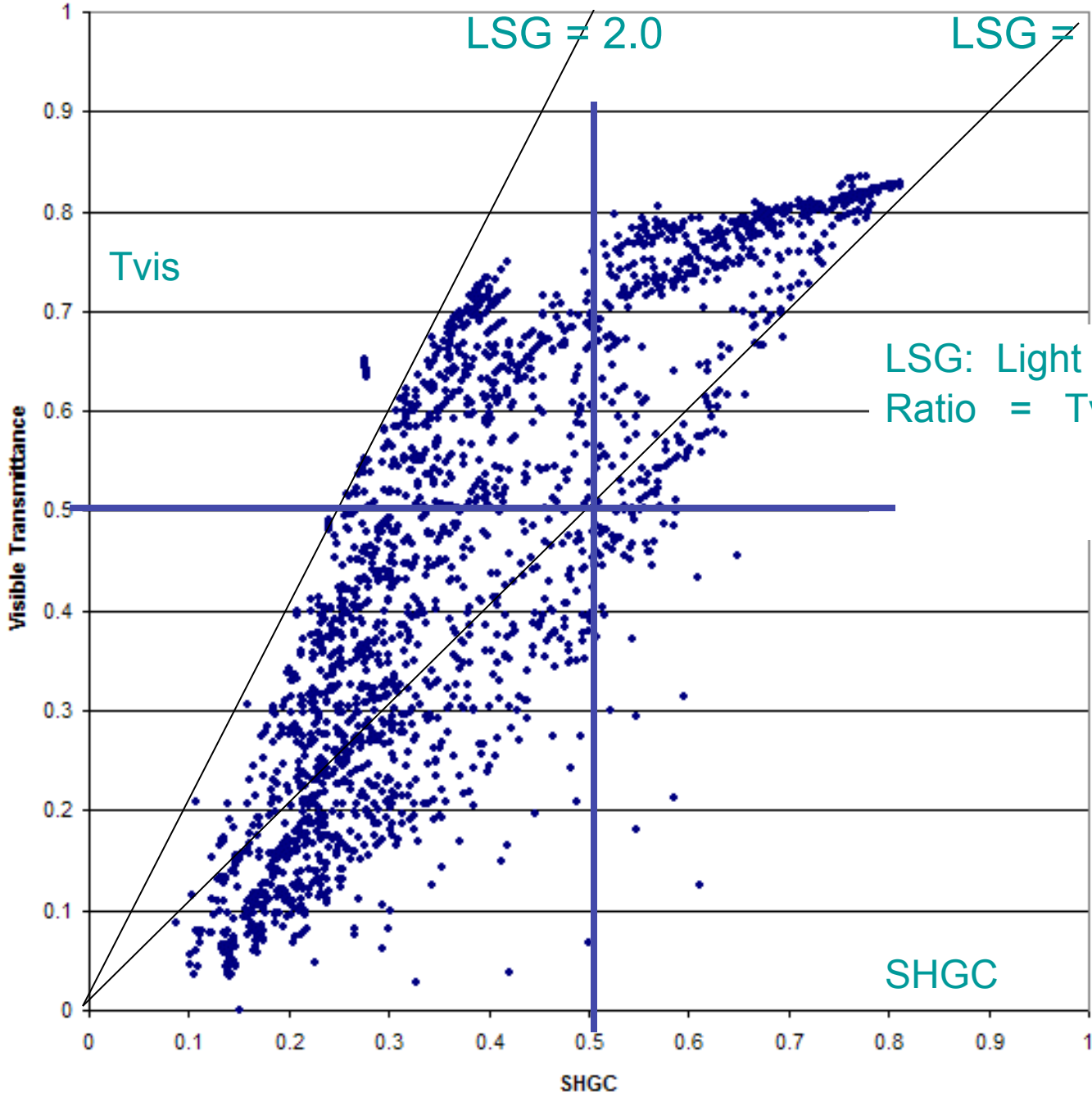
Technology:

- **Selective Absorbers**
  - **blue-green tints**
- **Selective reflectors**
  - **modified low-E coatings**
  - **coated glass and plastic**
  - **Multilayer dielectric**

Transmittance -vs- Wavelength

Light to Solar Gain Ratio

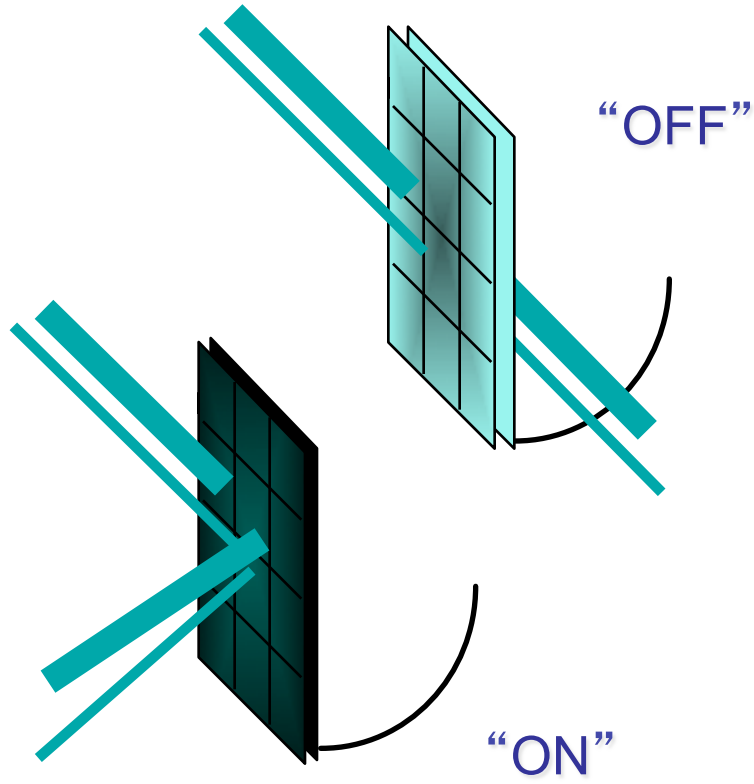
Light to Solar Gain Ratio for insulating glass units for all glasses in LBNL IGDB



Smart Coatings for Dynamic Control of Windows

Balancing Cooling and Daylighting

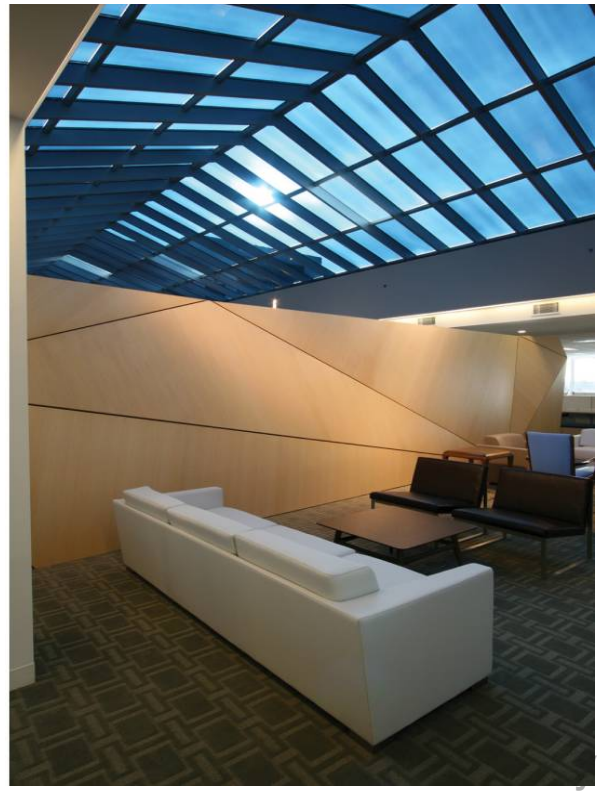
- **Flexible, optimized control of solar gain and daylight**
- **Passive control**
  - Photochromic - light sensitive
  - Thermochromic - heat sensitive
- **Active control**
  - Liquid Crystal
  - Suspended particle display (SPD)
  - **Electrochromic**
- **Active control preferred; but requires wiring windows for power and control**



Engineering and Occupant Response Studies with Switchable Electrochromic Windows

- LBNL Façade Field Test Facility

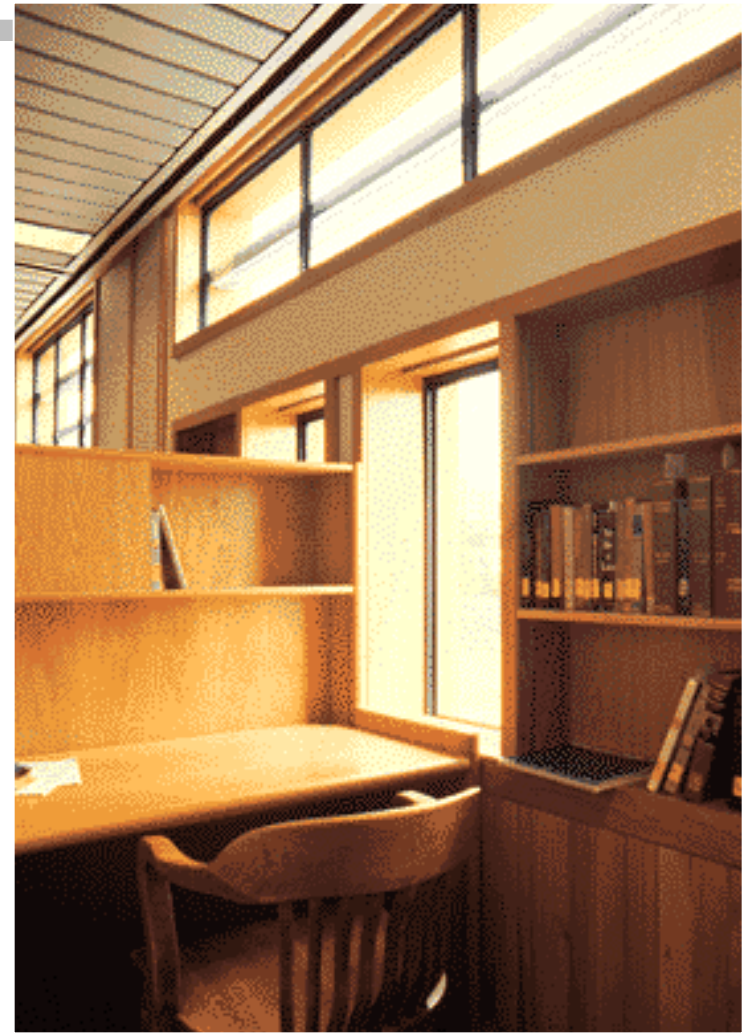
Electrochromic Windows: 20+ years of R&D Progress Towards the Marketplace



Daylighting

- Improve distribution of light within the room to reduce glare,
- Increase room cavity brightness,
- Increase %year daylit to reduce electric lighting energy

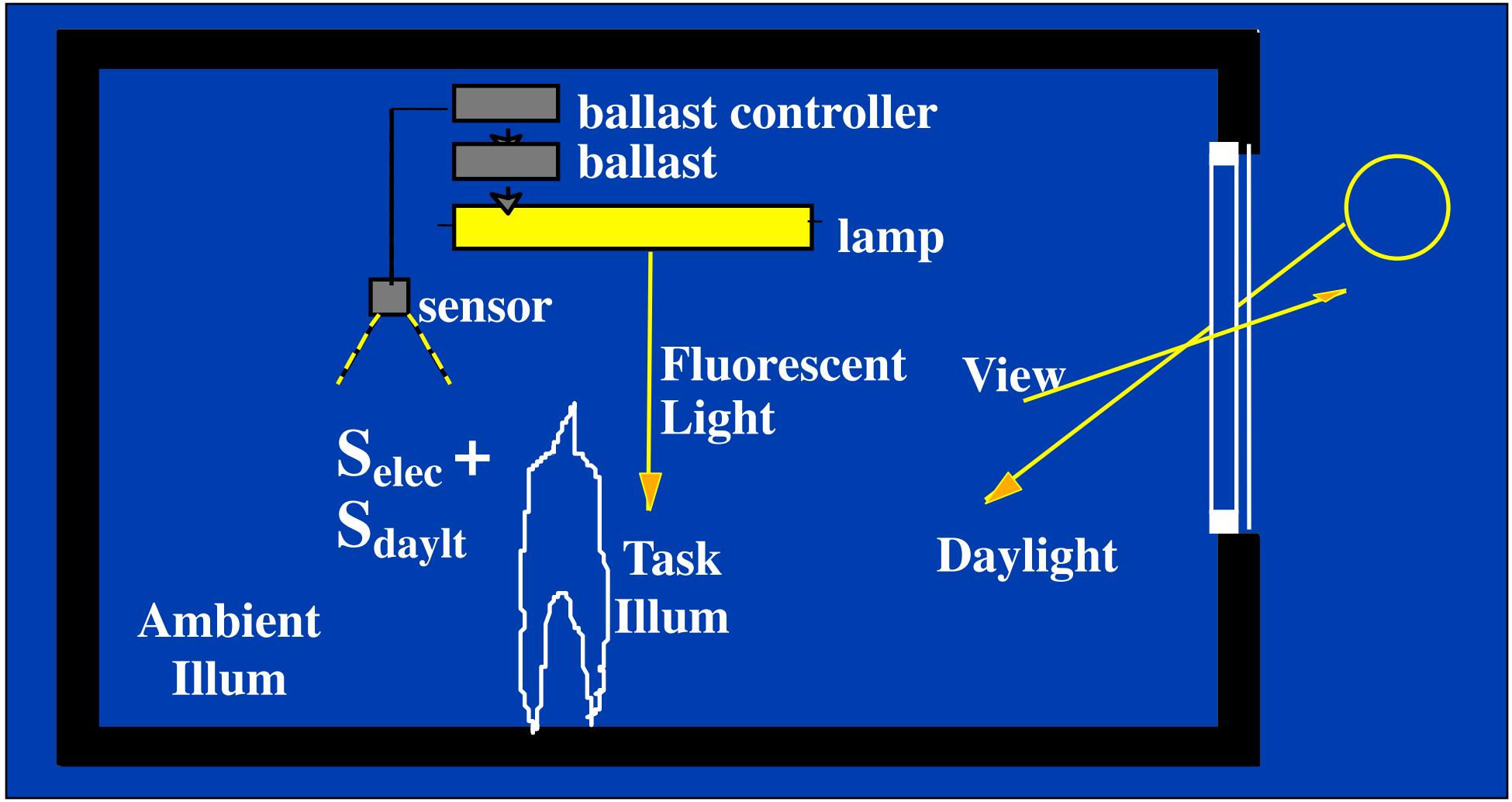
- Architectural strategies
- Light-redirecting technologies
- Energy savings strategies



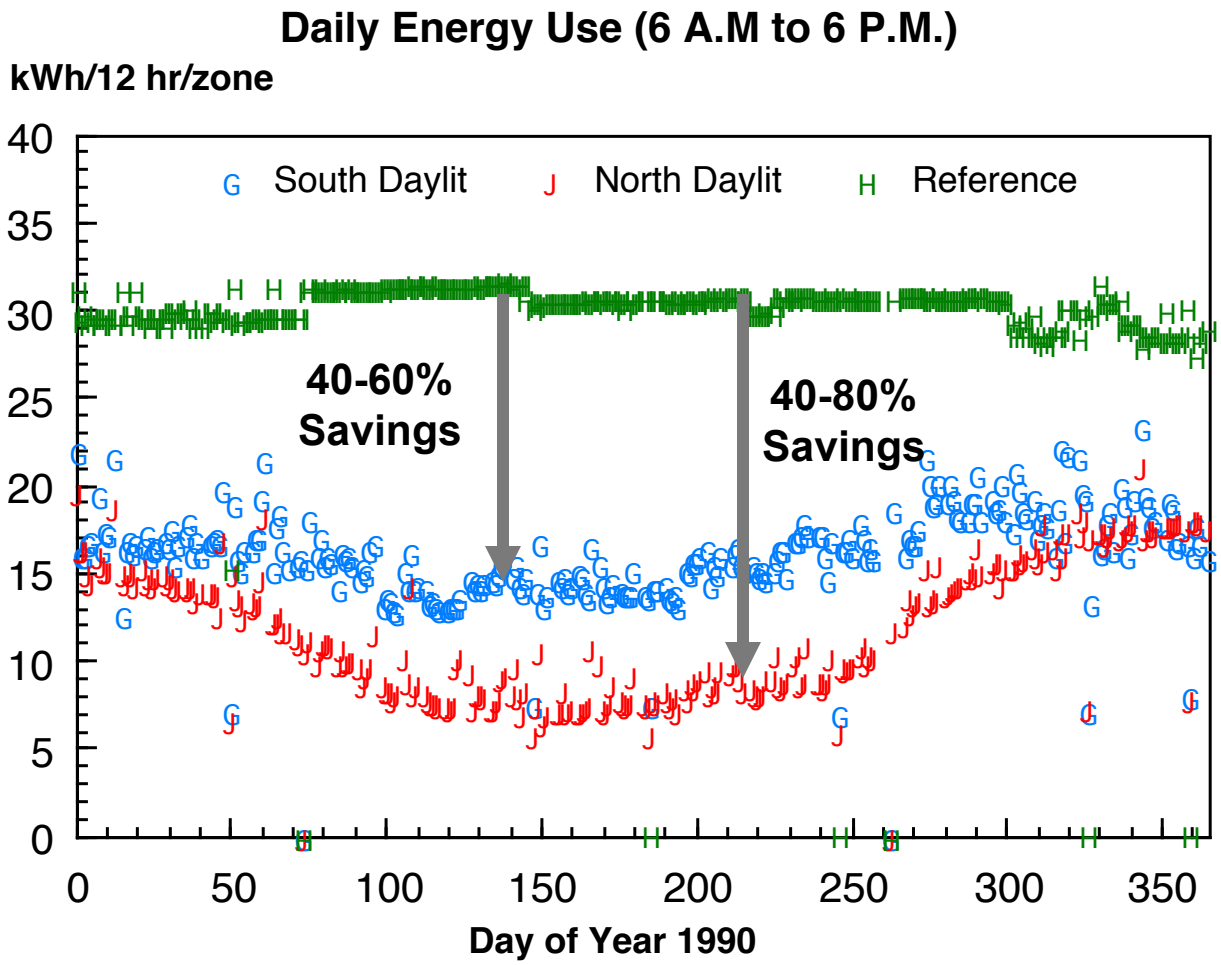
GTU Library, UC Berkeley

(Day)Lighting Control Elements

A Systems Integration Issue



Good Lighting Controls (Daylight Dimming) Work



Data from advanced lighting controls demonstration in Emeryville, CA (1990) **!!!**

Energy Use before retrofit:

After retrofit:
South zone:
North zone:

Dimming is 3% of lighting sales

“In God We Trust”,
All Others Bring Data

An understanding of what to do in the future should be built on a foundation what works and how well, either based on, or derived from, measured performance.

Design intent, expectations, and wishful thinking will not reduce energy and carbon use

LBNL Façade Testbed Facility

Highly instrumented, assess occupant response as well as energy balance

2003-2006
Electrochromic windows w/ daylighting

Industry Advisory Group:

Manufacturers
Glazing, Shading Framing, Lighting Controls

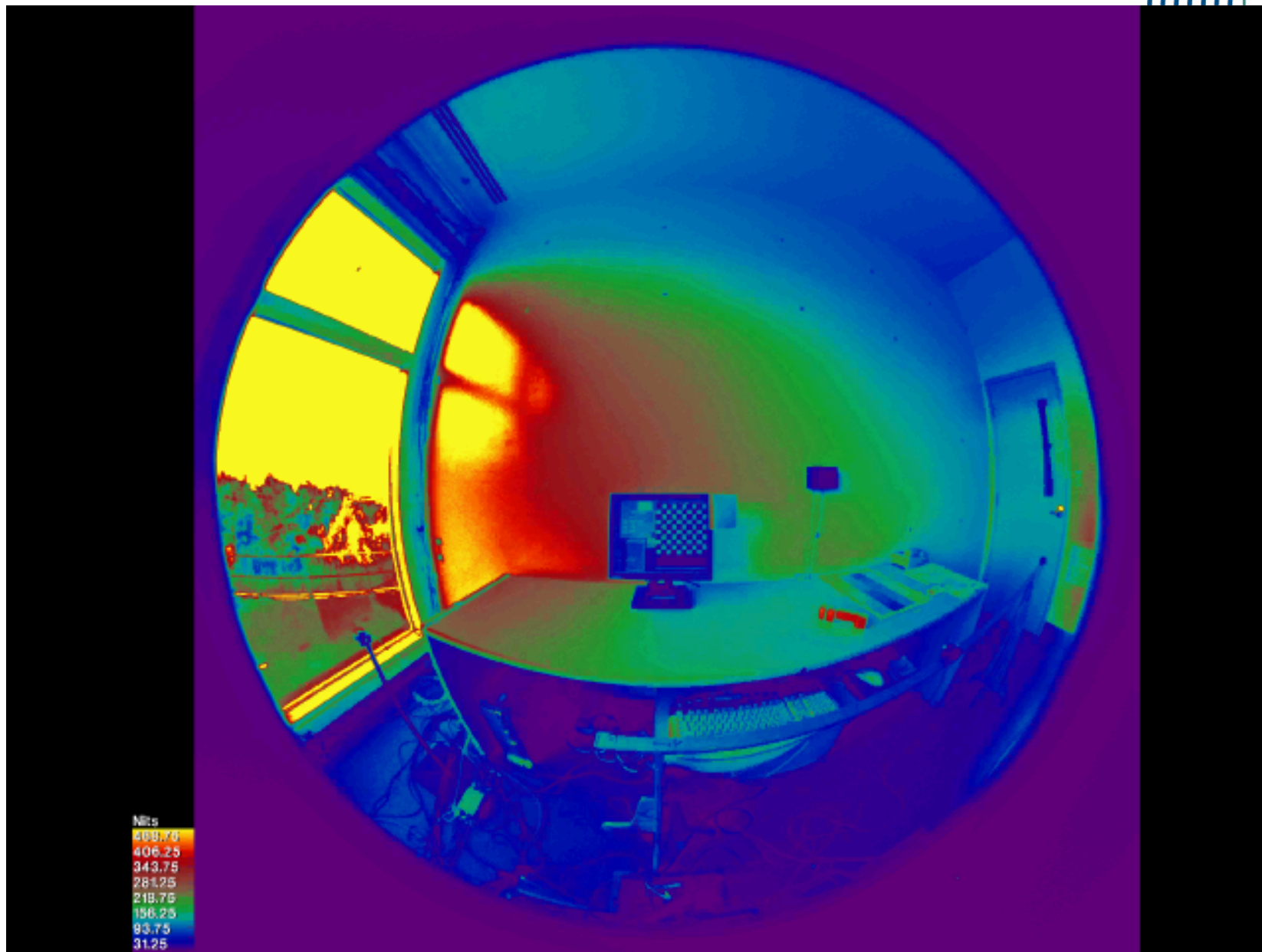
Designers
Architects, Engineers Specifiers

Owner/Operators
Public, Private

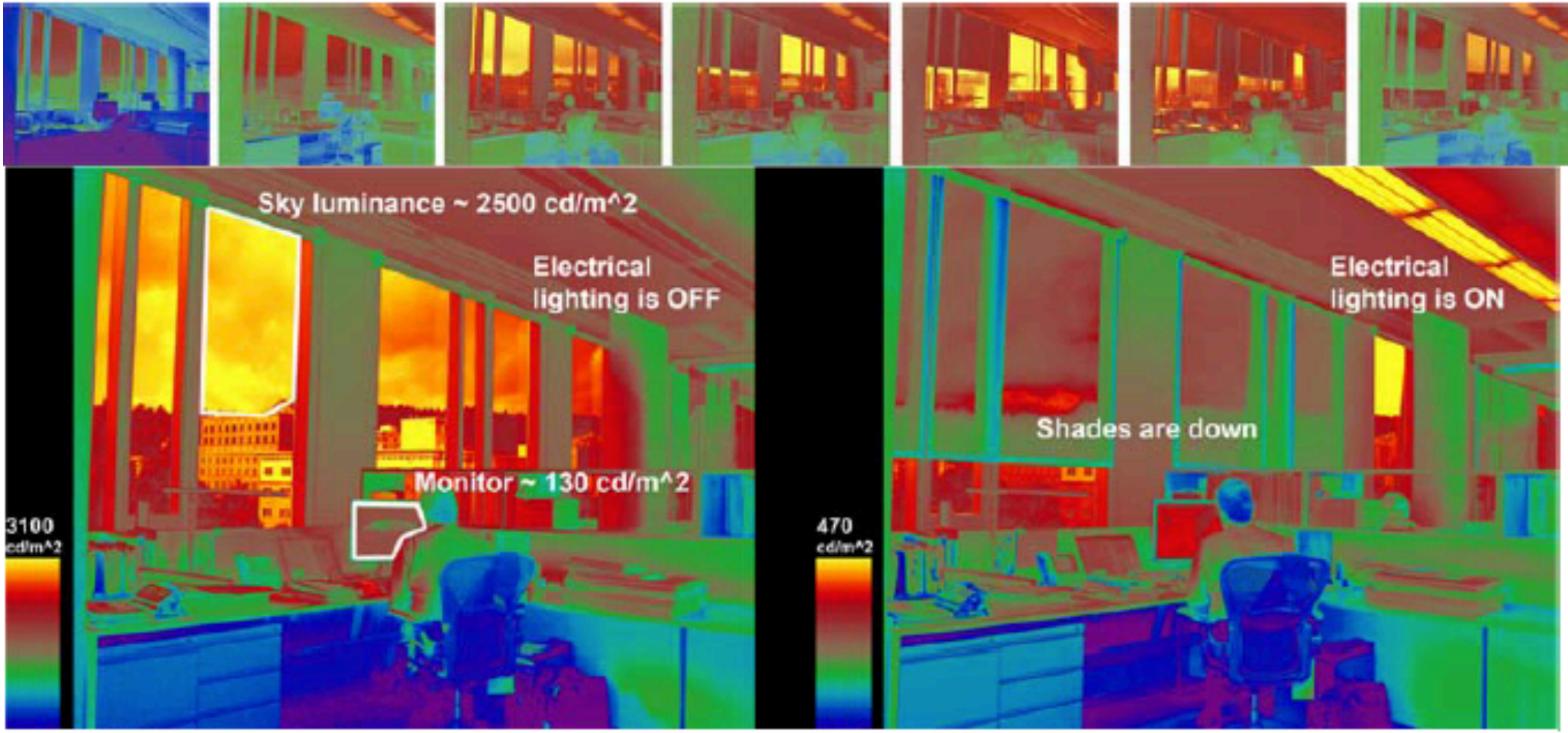
Utilities

2007-20011
Automated Shades w/ daylighting

Time Lapse of Interior Room Luminance with Dynamic Shading



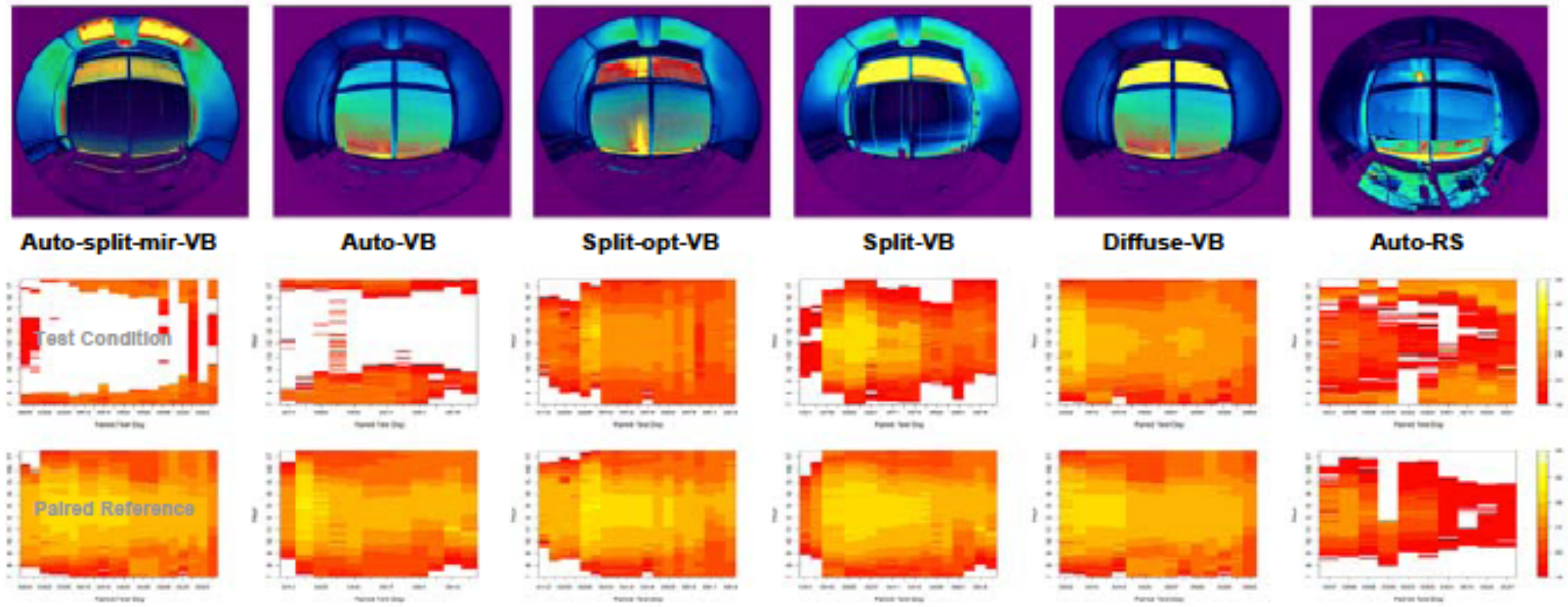
How do we reduce lighting energy use with daylight when there is glare?



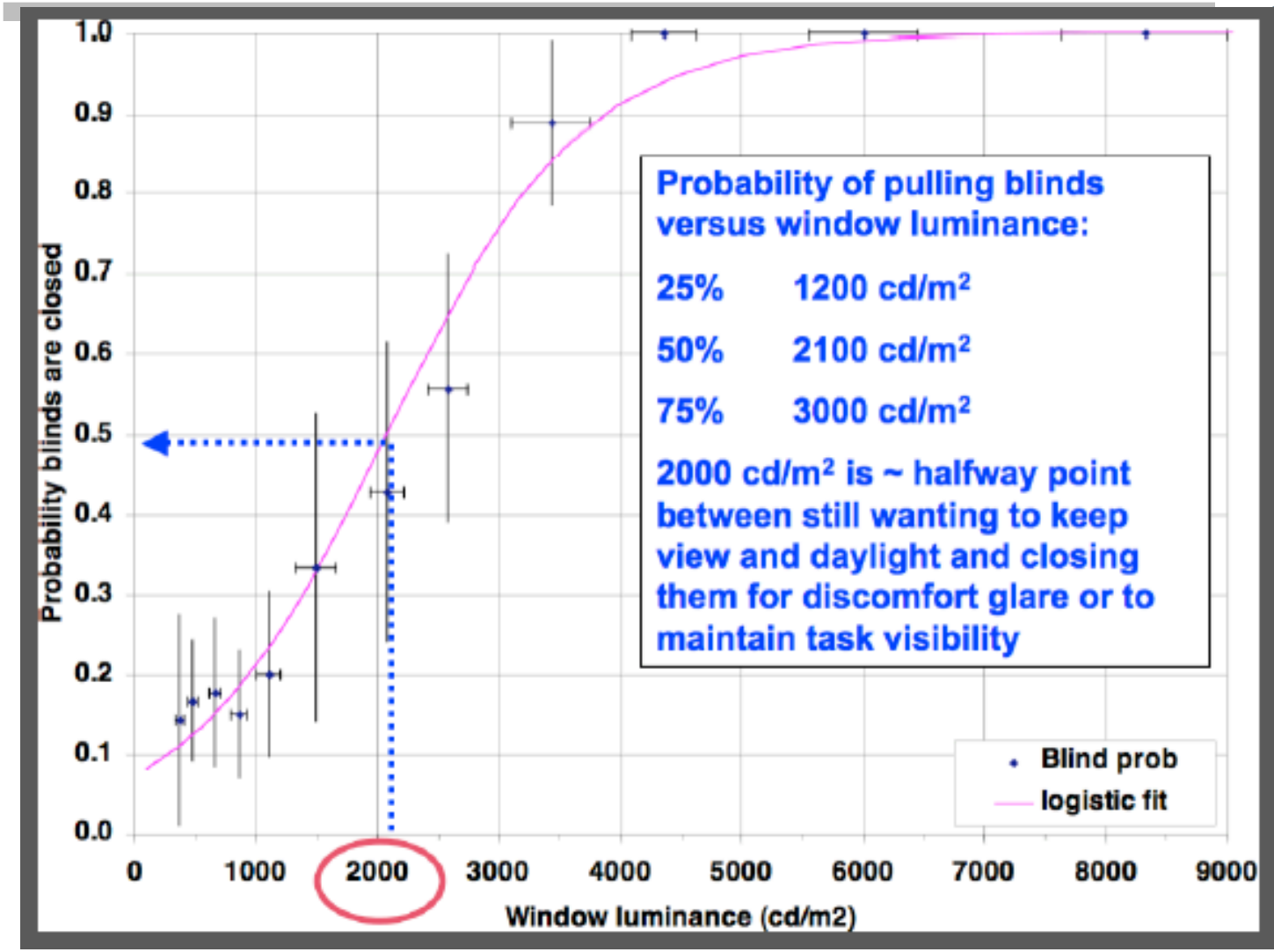
Kyle Konis, UCB/ LBNL

Automated daylight blind: concave-up slats with mirrored coating in upper zone and light grey finish in lower zone

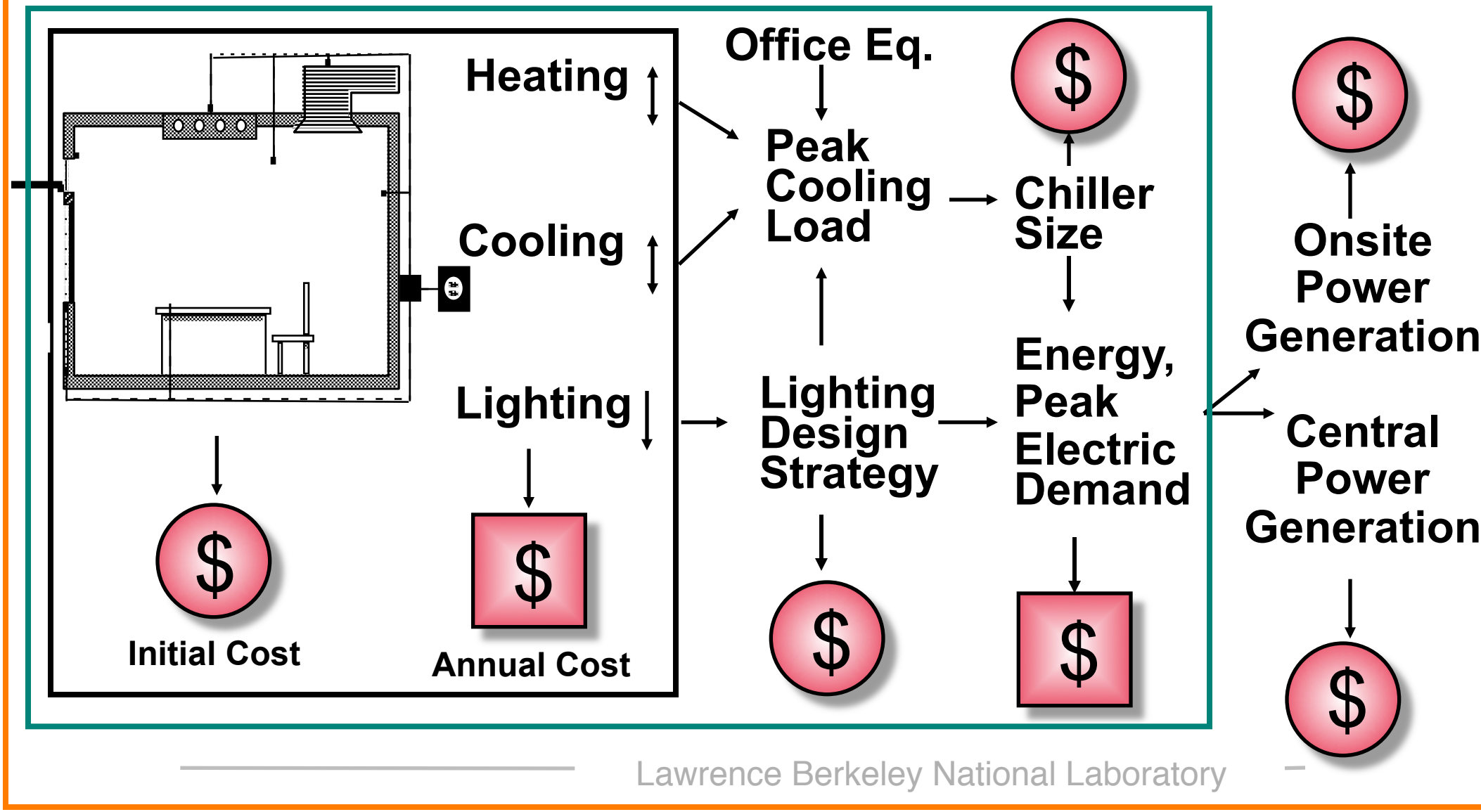
Comparative Glare Performance



When to (automatically) Close the Blinds….



System Integration: Investment Tradeoffs

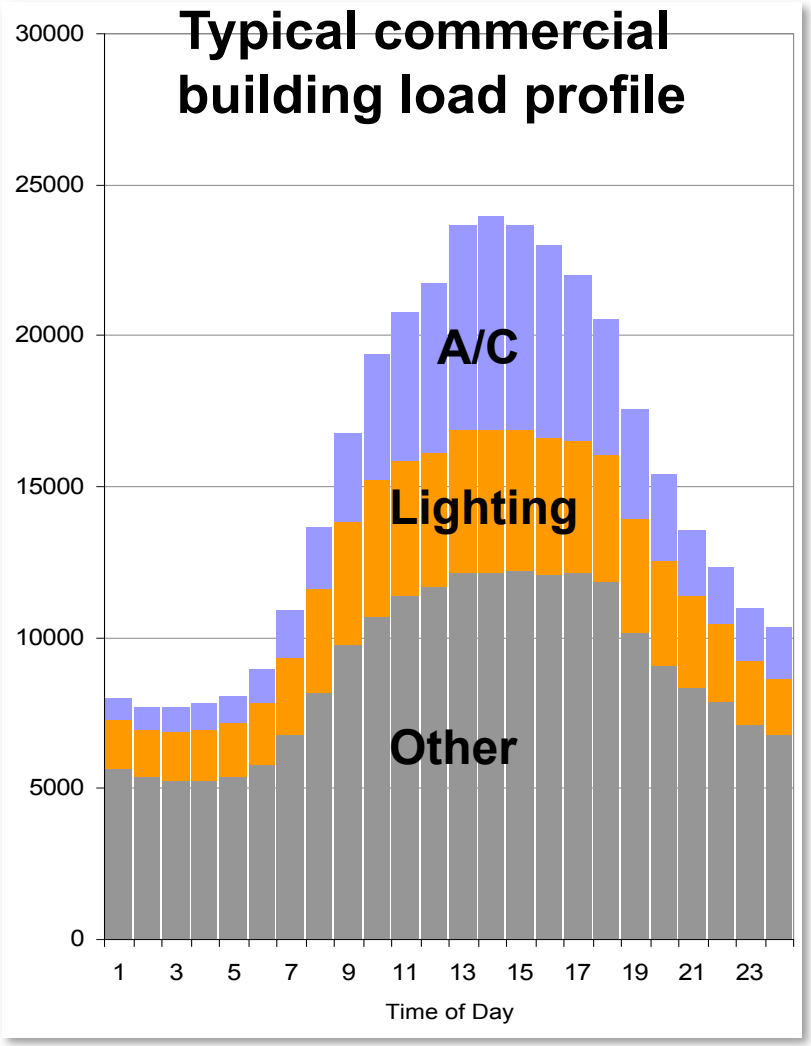


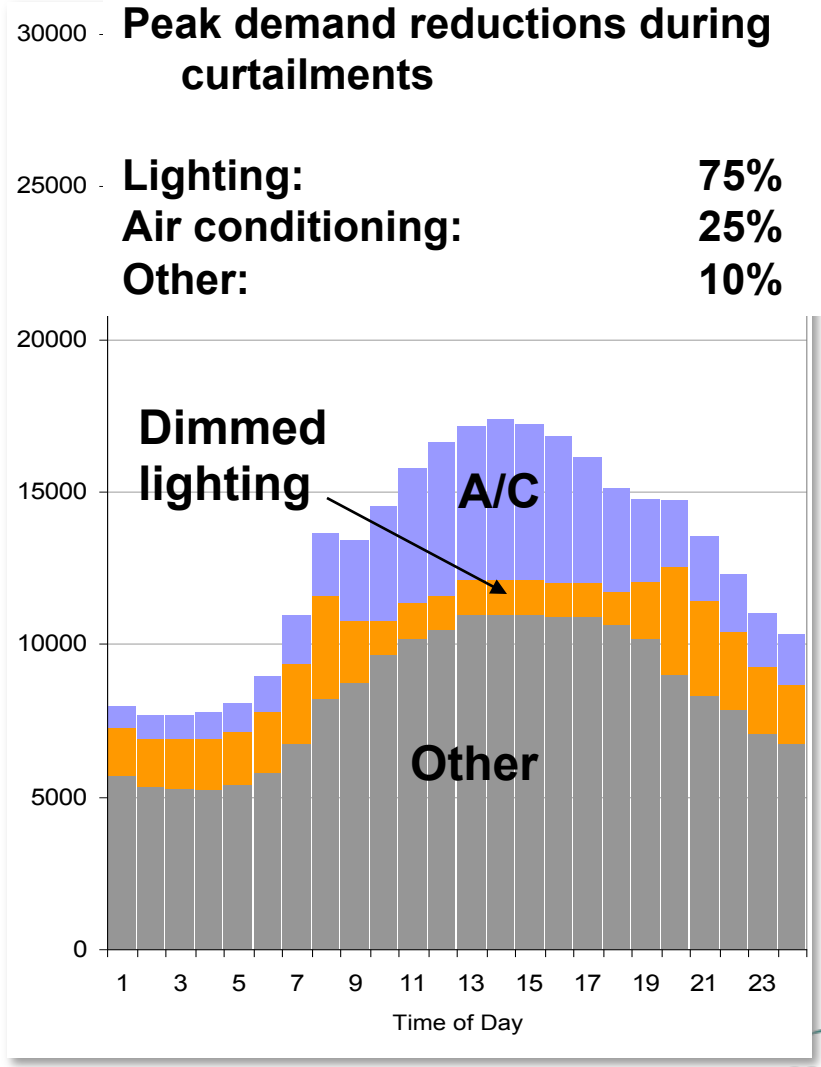
Annual Energy Costs in Perspective

Cost / Sq. M. Floor -Year

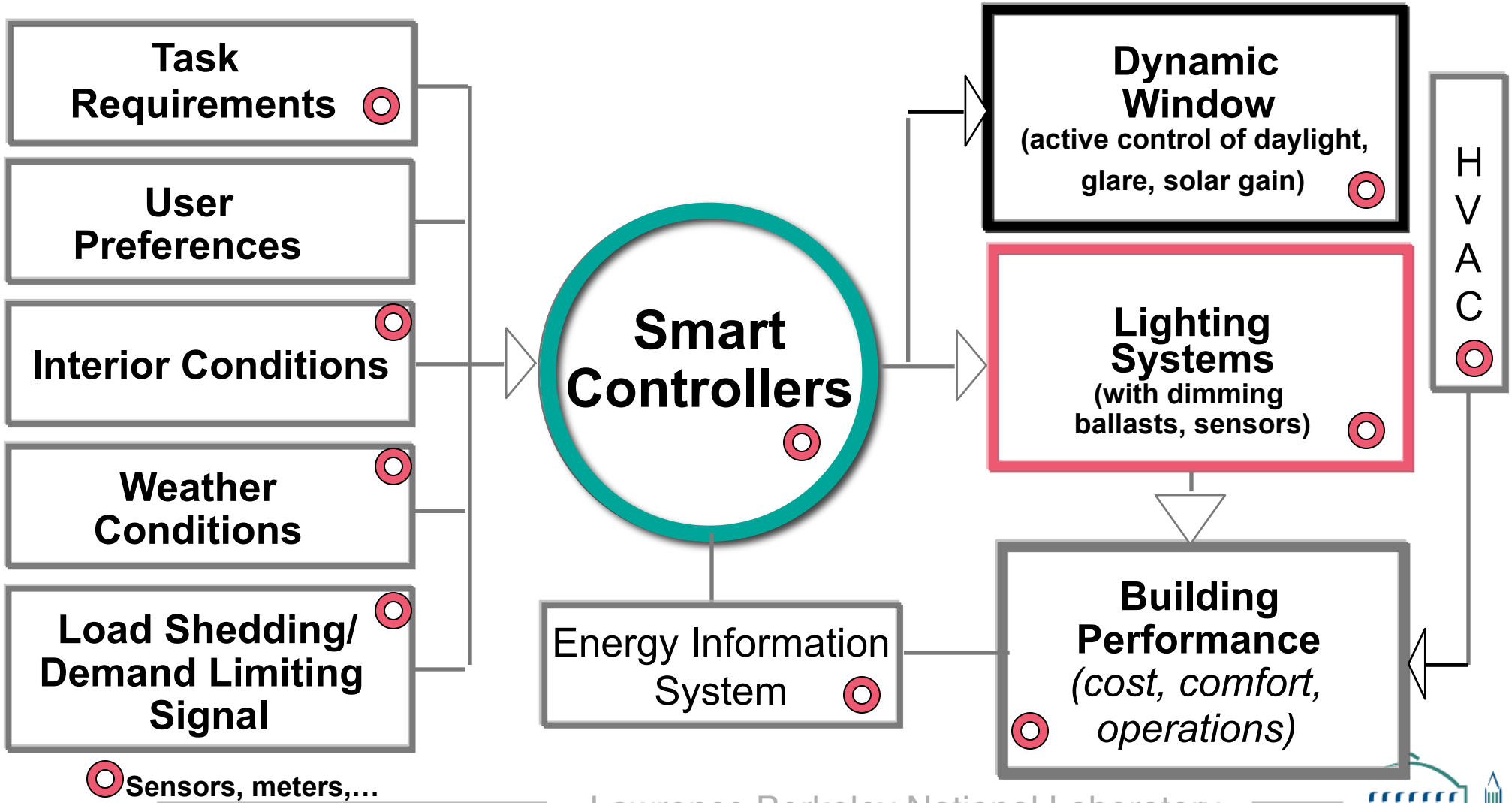
- Energy Cost: $20.00
- Maintenance: $30.00
- Taxes: $30.00
- Rent: $300.00
- “Productivity” $3000.00

Managing glazing and lighting for Electric Load Management





Exploring Intelligent Control Systems



The New York Times HQ Building

Testbeds - > Market Impact

Owners program:

- Highly glazed façade gives workers views and allows the city to see "news" at work
- But glare, cooling, visibility etc

Need/Goal:

- Develop integrated , automated shading and dimmable lighting system
  - Affordable, reliable and robust
- Transform the market- push these solutions toward widespread use

Challenge:

- How to develop a workable, affordable integrated hardware/software solution
- How to "guarantee" that such a solution will work in practice

Renzo Piano/ Fox & Fowle/ Gensler/ Flack+Kurtz/ Susan Brady Lighting

Façade Layers

External layer: Fixed
-- Shading, light diffusion

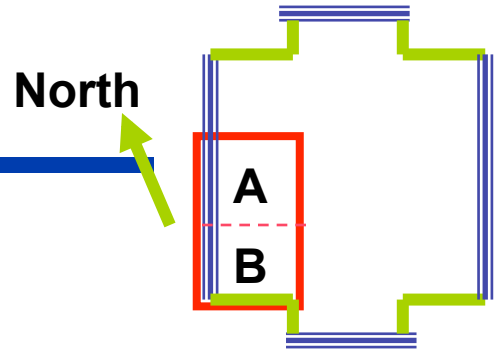
Glazing layer: Fixed
-- Low-E, spectrally selective
- thermal control
- solar gain control

-- Frit - solar, glare control

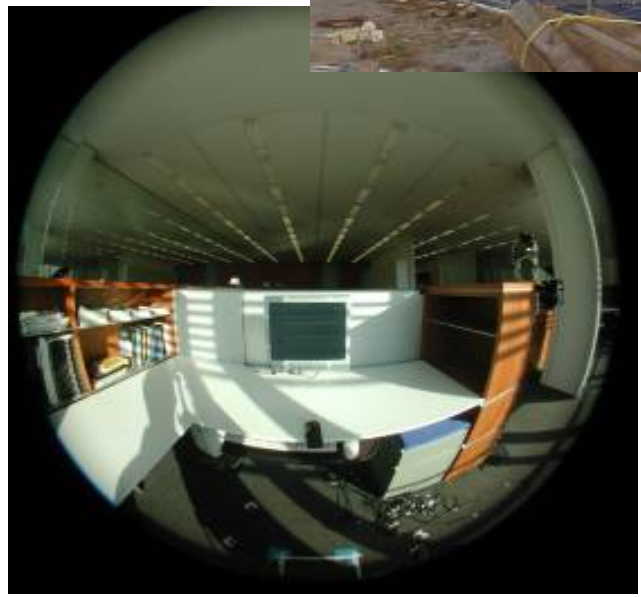
Internal layer: Dynamic
-- Motorized Shade system
-- Solar control
-- Glare control

Façade Layers: Floor to Floor
floor to desk
desk to head
head to ceiling
plenum

Approach: Test Performance in a Full-Scale Mockup

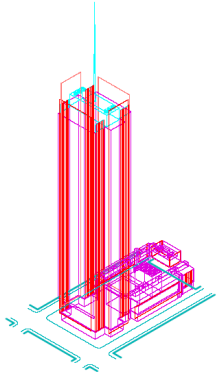


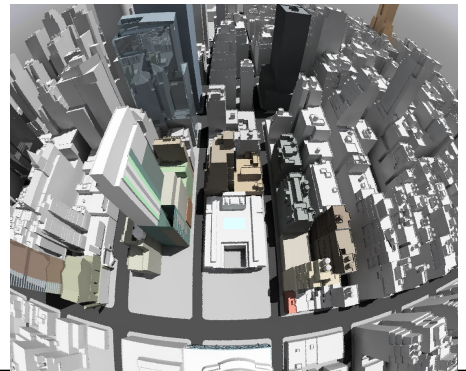
- Shading, daylighting, employee feedback and constructability: ~4500 s mockup
- Concerns with glass facade:
  - — Window glare (Tv=0.75)
  - — Control of solar gain/cooling
  - — Daylight harvesting potential
- Real sun and sky conditions near construction site, 12-month monitored period

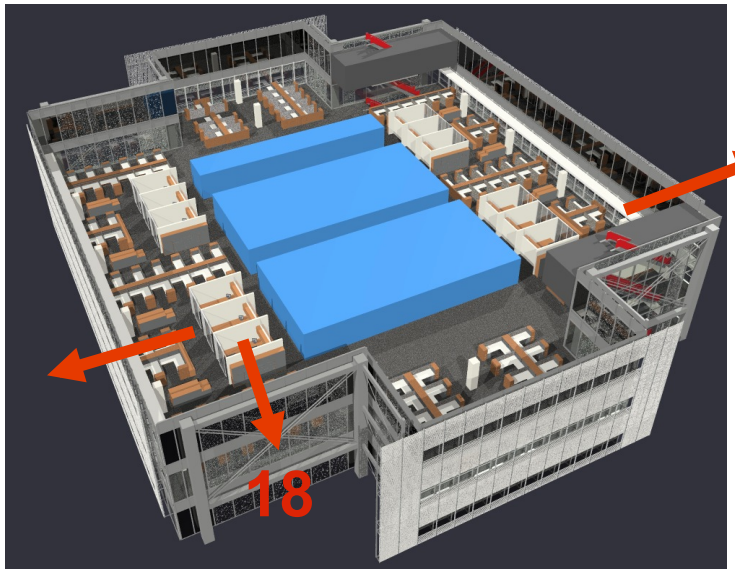


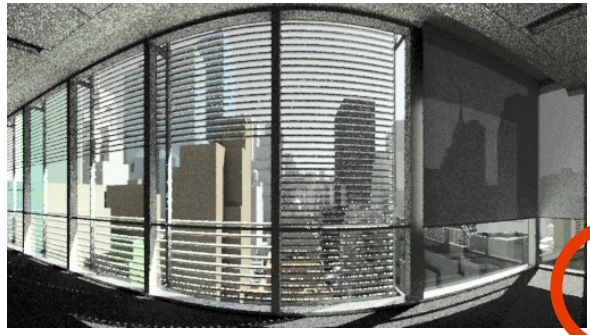
Developing Shade Control Algorithms for Motorized Shades using Simulation

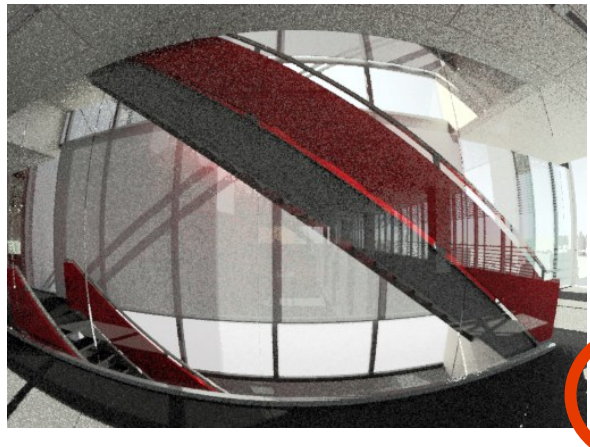
- Each shade system has its own sensor and motors
- Performance will vary with orientation, floor elevation, view out, and neighboring buildings.
- How to address performance with this variance?
- **Build a virtual model of the building in its ' an context using hourly weather data ulate performance**











Simulated Views from 3 of 22 view positions

Intelligent Lighting and Shade Control

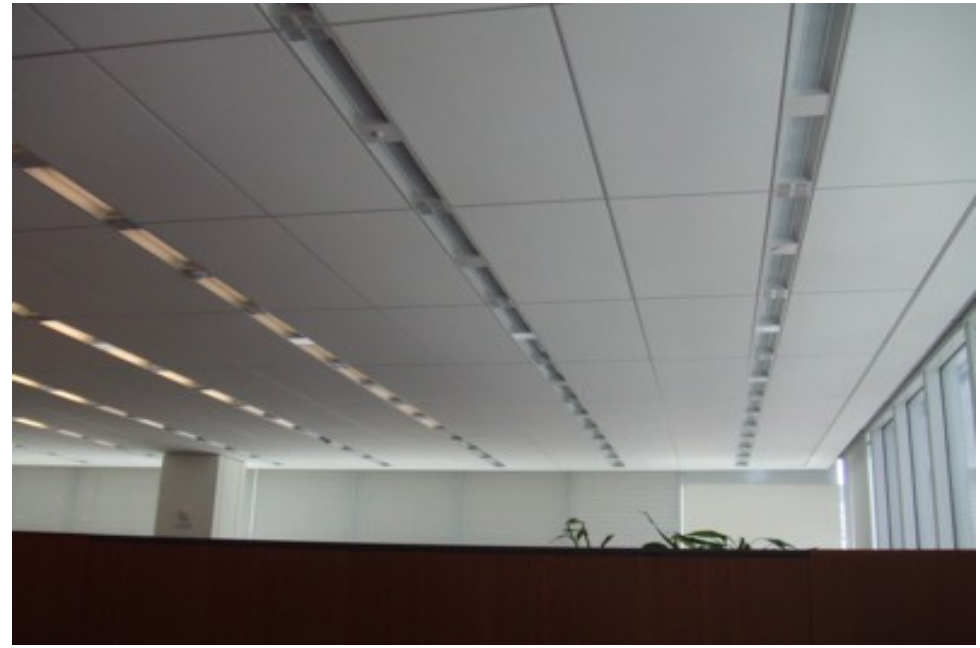
- Automated Shaded
- (Multifunctional)

Occupied 2007

- Dimmable lighting
- Addressable
- (Affordable)

(1/3 original cost estimate)

- (Multifunctional)



New York Times office with dimmable lights and automated shading

Controlling "Stuff" in Buildings

- ~1970
  - Lighting
    - ~ 3-5 W/sf
    - 3000-8000 hrs/yr
  - All other uses
    - ~ 1-2 W/sf; 1000- 4000hrs/yr
- ~2010
  - Lighting
    - ~1 W/sf
    - 1000- 3000 hrs/yr
  - All other uses
    - ~1 – 10W/sf; 1000-8000hrs/yr

Reducing Lighting Energy Use by a Factor of 5: "New" Approaches to Efficient Lighting

1. **Use more efficient lamps and fixtures**, best suited to specific tasks

2. But, **Lighting design, operation and energy use** (**should also**)
   - **Vary with task**
     - Task lighting needs- e.g. talking on phone vs brain surgery
     - Task vs Ambient lighting needs
   - **Vary with location in building**
   - **Vary with user**
     - Age, use of glasses, medical conditions,….
   - **Vary with time**
     - e.g. available daylight, load management need,….
     - Contrast: night vs day
   - **Address perception in the space** as well as more easily measurable engineering units, e.g. lux or footcandles

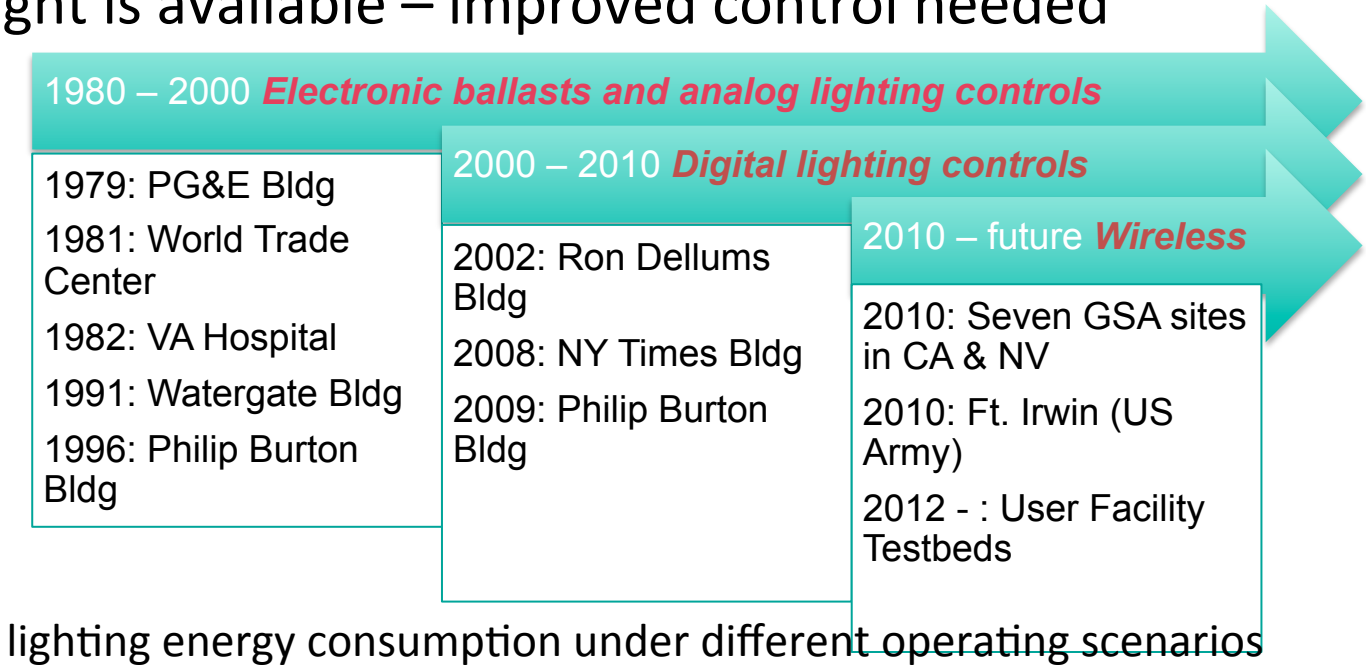
----> "Adjust quantity/quality of light to varying needs"

"Communicate with every light fixture"
"Control its light output"

Lighting and Daylighting Control in Commercial Buildings

Problem Lighting energy is wasted when space is unoccupied and daylight is available – improved control needed

Projects



1. Measure lighting energy consumption under different operating scenarios
   - Power meters installed on selected circuits
   - Detailed analysis of lighting control system data
2. Document lighting conditions under different conditions
   - Standard photometric surveys
   - High dynamic range (HDR) photometry
3. Evaluate user acceptance with occupant surveys

High Performance Windows need Skilled Architects & Engineers

- Do architects and engineers have the expertise and/or tools to "optimize" designs of intelligent facades?

- Other impacts:
  - Specification
  - Construction
  - Commissioning and Acceptance
  - Occupant training
  - Facility manager training

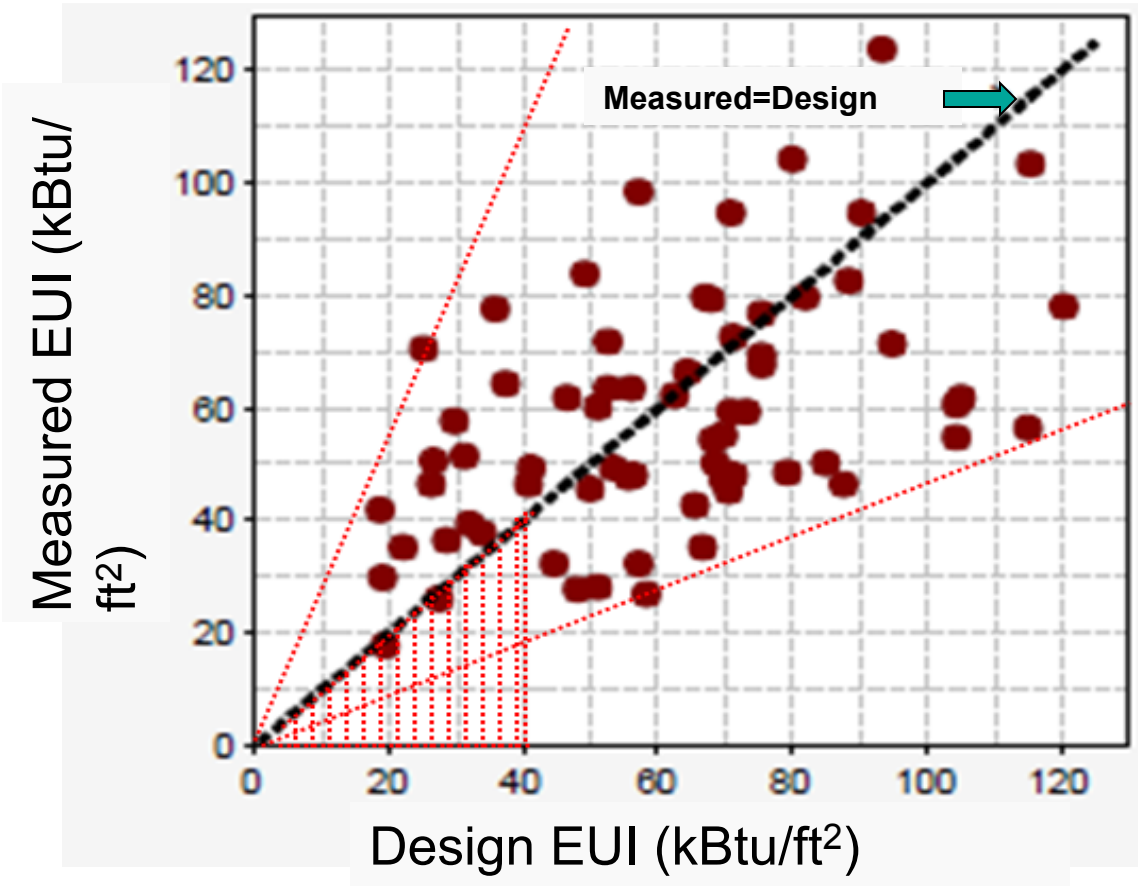
Glazing and Façade Simulation Tools

- **Design Guides, Selection tools**
  - Homeowners
  - Builders, contractors
  - Point of sale

- **Building Design Tools**
  - Allow integration strategies to be explored
  - Allows façade performance to be optimized
  - HVAC – Façade - Lighting tradeoffs
  - Explore commissioning and operational issues

- **Glazing, Window and Façade Tools - Manufacturers**
  - Essential for design of new products
  - Supplement, replace testing - virtual product development

US/China Clean Energy Research Center
Building Energy Performance Simulation and Monitoring



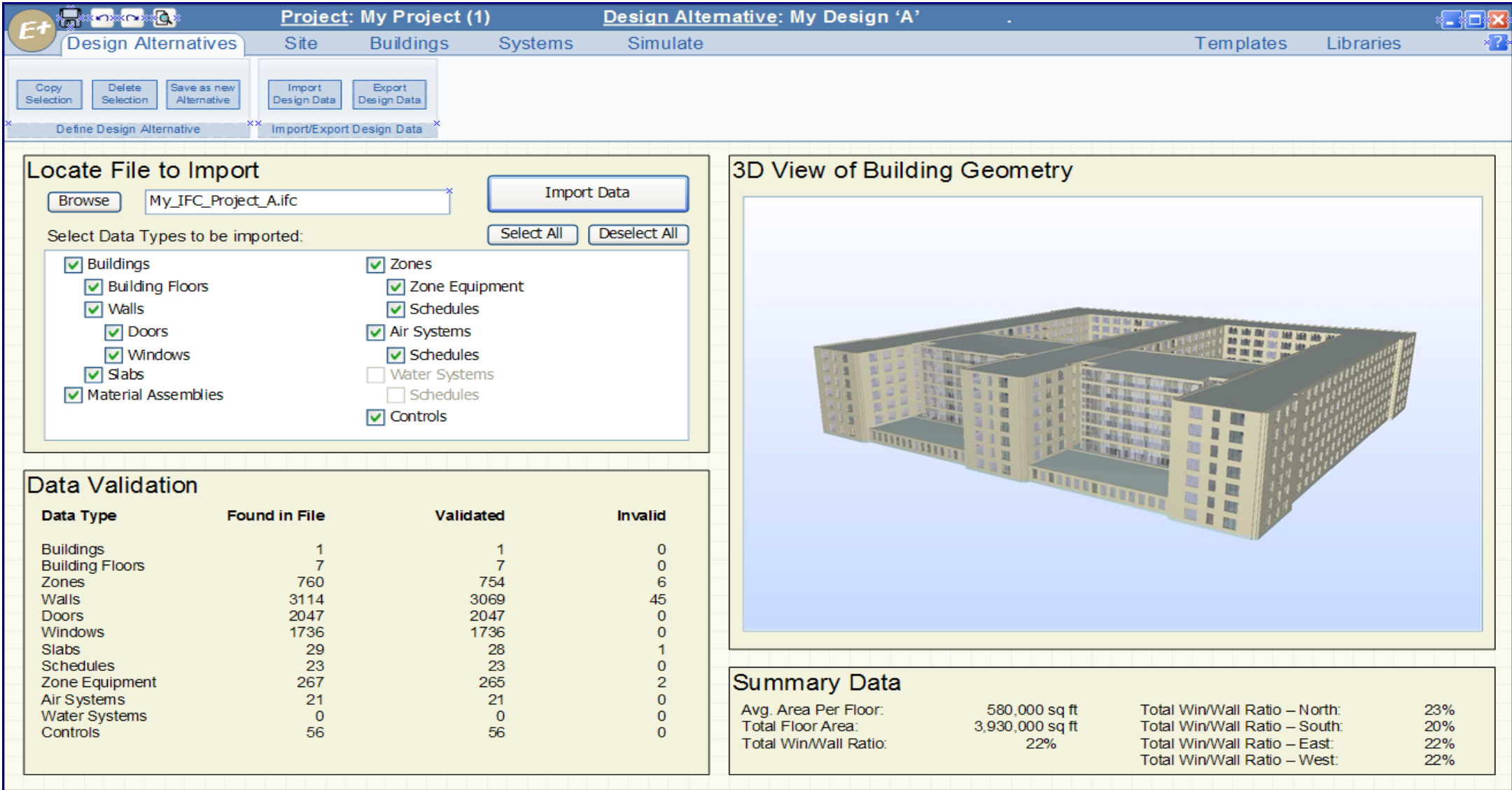
Source: Energy performance of LEED-NC buildings, NBI, 2008

A few facts:

1. Various building types, ages, locations
2. Average over all projects not bad
3. Max over-predict by **120%**
4. Max under-predict by **65%**
5. **Almost all under-predicted for low energy designs** (red triangle: EUI <= 40)
6. Uncalibrated simulated results

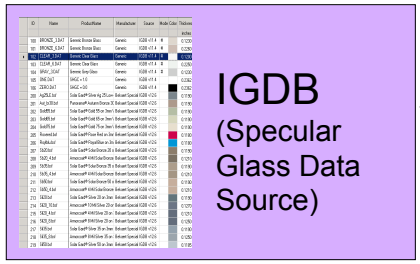
U.S.–China Clean Energy Research Center
中美清洁能源研究中心

EnergyPlus Graphical User Interface
Import from BIM

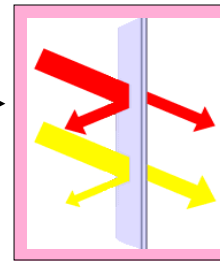


Glazing and Façade Decision Support Tools

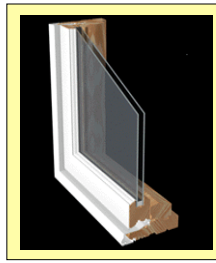
Download http://windows.lbl.gov/software/ FY10 ~ 37,000 Downloads



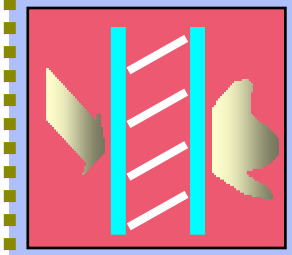
IGDB
(Specular Glass Data Source)



Optics
(Window Glass)



THERM
(Window Frame)

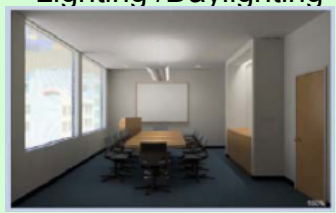


CGDB
(Complex Glazing Data Base)

WINDOW
(Whole Window)

NFRC Ratings and Labels

Radiance
Lighting /Daylighting



COMFEN
(Whole Building Commercial)

RESFEN
(Whole Building Residential)

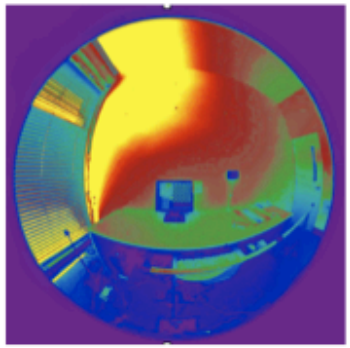
Commercial Windows Website Design /Simulation Tools

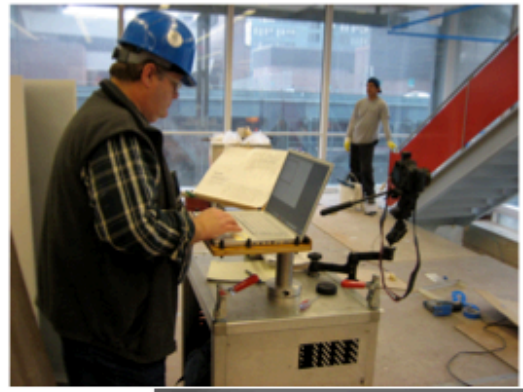
Efficient Windows Website

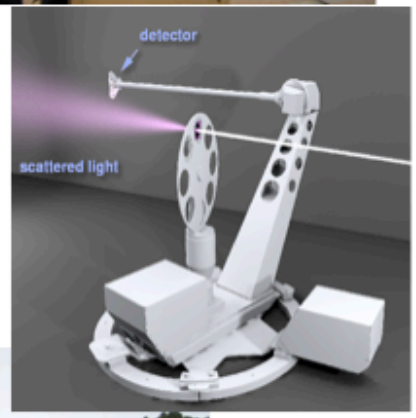
Glazing/Shading/Daylighting Measurement and Validation

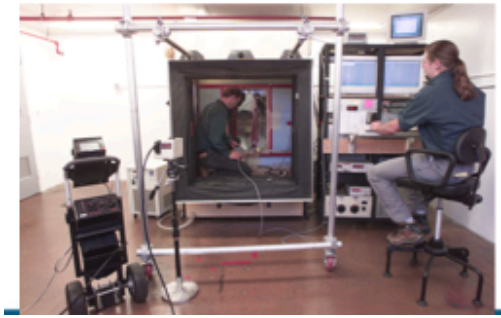
- **Façade/daylighting test facility**
- **Integrated Systems testbeds**
- Mobile Thermal Test Facility
- IR Thermography chamber
- Large integrating sphere
- Optics laboratory
- **Scanning Goniophotometer**
- HDR Imaging
- Field Data Collection systems
- Commissioning systems

- Virtual Building Controls Testbed
- Daylighting controls laboratory



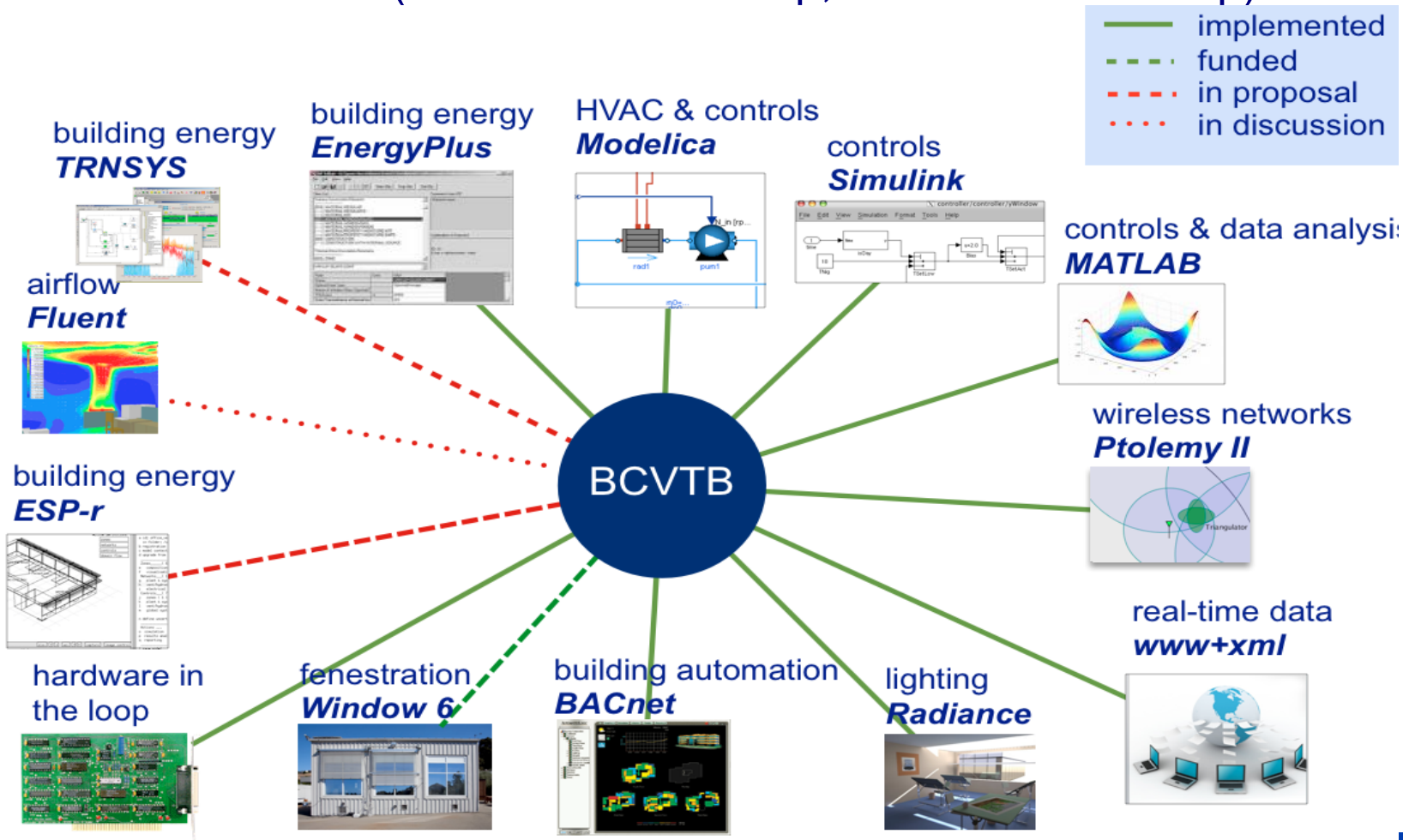




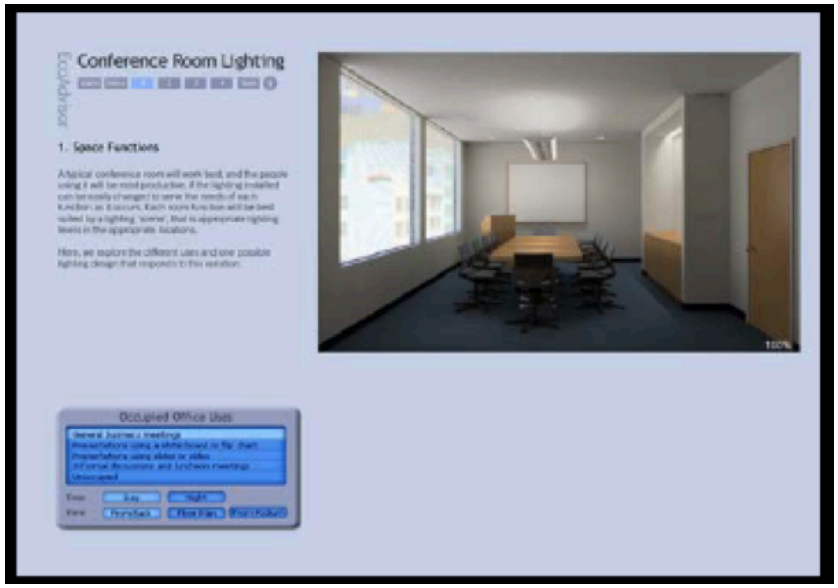


Building Controls Virtual Test Bed (BCVTB)

Open-source middle-ware for
- co-simulation
- real-time simulation (hardware in the loop, software in the loop)



eLAD: eLearning Platform for Lighting and Daylighting

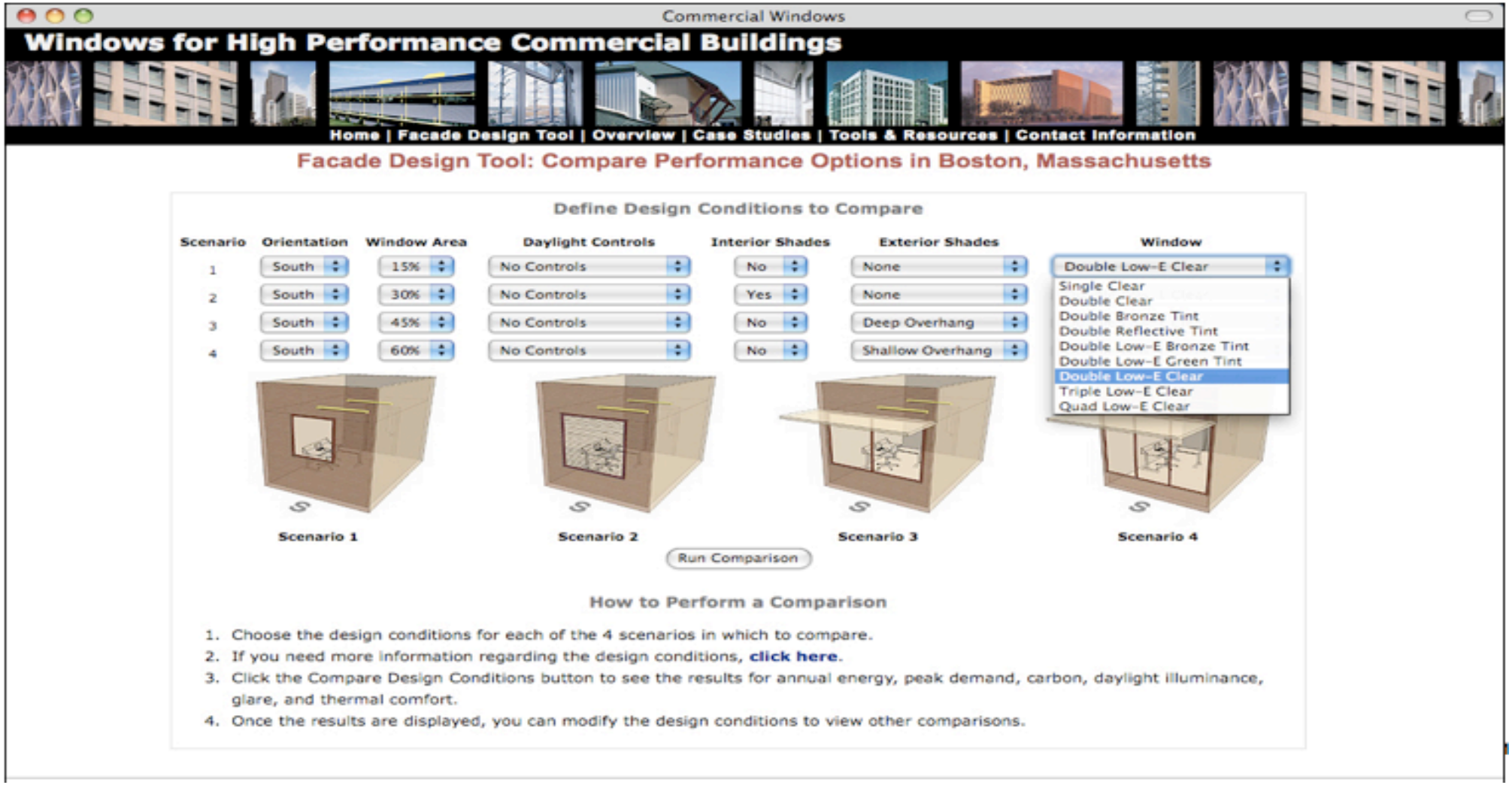


Example: Conference Room Lighting Controls Virtual Testbed

Sample results based on daylight conditions and alternate controls use

Web-based Façade Design Tool

w/ Univ of Minnesota: http://www.commercialwindows.org



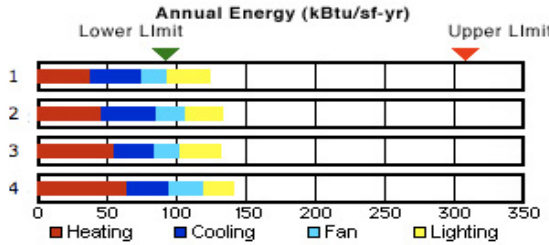
Windows for High Performance Commercial Buildings

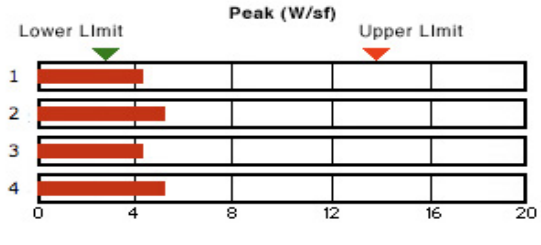
Facade Design Tool: Compare Performance Options in Boston, Massachusetts

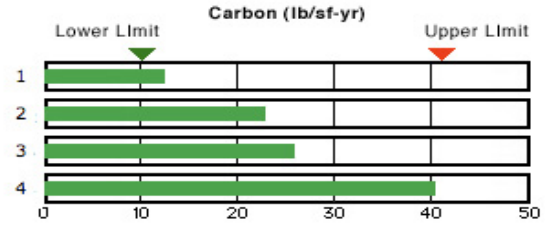
Define Design Conditions to Compare

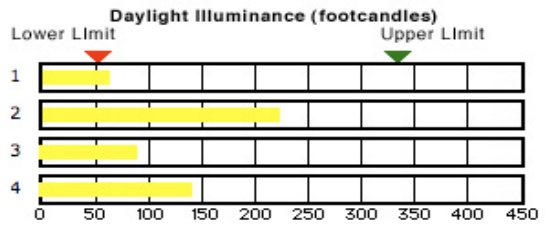
Scenario	Orientation	Window Area	Daylight Controls	Interior Shades	Exterior Shades	Window
1	North	30%	No Controls	No	None	Double Low-E Clear
2	East	30%	No Controls	No	None	Double Low-E Clear
3	South	30%	No Controls	No	None	Double Low-E Clear
4	West	30%	No Controls	No	None	Double Low-E Clear

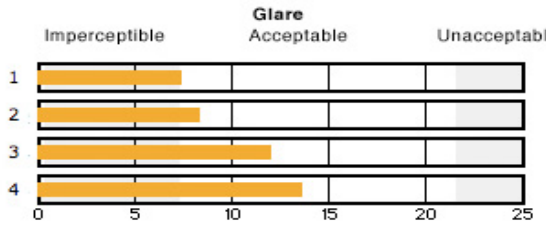
Run Comparison

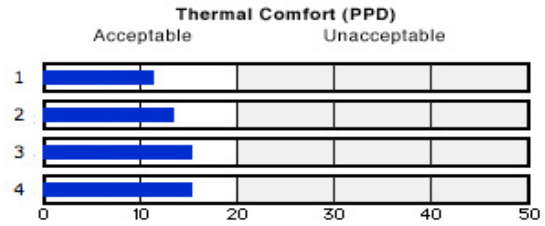












COMFEN: Estimating Energy and Daylighting Impacts in Early Design

COMFEN 3.1 (C:\Users\mark.perepelitza\AppData\LBNL\COMFEN3_1\db\comfen.sqlite)

COMFEN Project Scenarios Libraries Help

IP

Project: LF demo_office_Portland

Bldg. Type : Office Location : USA OR Portland

Scenarios Libraries

ID	Name
96	baseline: N 60 WWR no light control
98	baseline: E 60 WWR no light control
99	baseline: S 60 WWR no light control
100	baseline: W 60 WWR no light control
105	N 60 WWR_ext HS
106	E 60 WWR_ext HS
107	S 60 WWR_ext HS
108	W 60 WWR_ext HS
119	N 20 WWR_ext HS
123	E 20 WWR_ext HS
124	S 20 WWR_ext HS
125	W 20 WWR_ext HS
127	N 60 WWR_ext HS+VS
138	E 60 WWR_ext HS+VS
139	S 60 WWR_ext HS+VS
140	W 60 WWR_ext HS+VS
141	blank scenario
146	S 60 WWR_ext VB
159	W 60 WWR_ext VB

Overview Climate Comparison

BASE CASE: 100. baseline: W 60 WWR no ...

140. W 60 WWR_ext HS+VS

159. W 60 WWR_ext VB

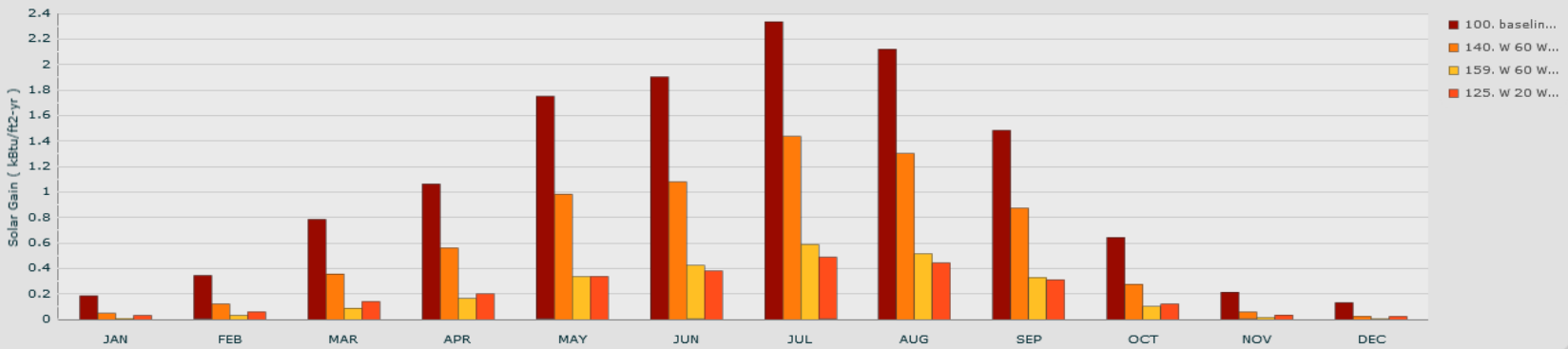
125. W 20 WWR_ext HS

Summary Energy Facade Window Comfort Daylight Glare Tabular

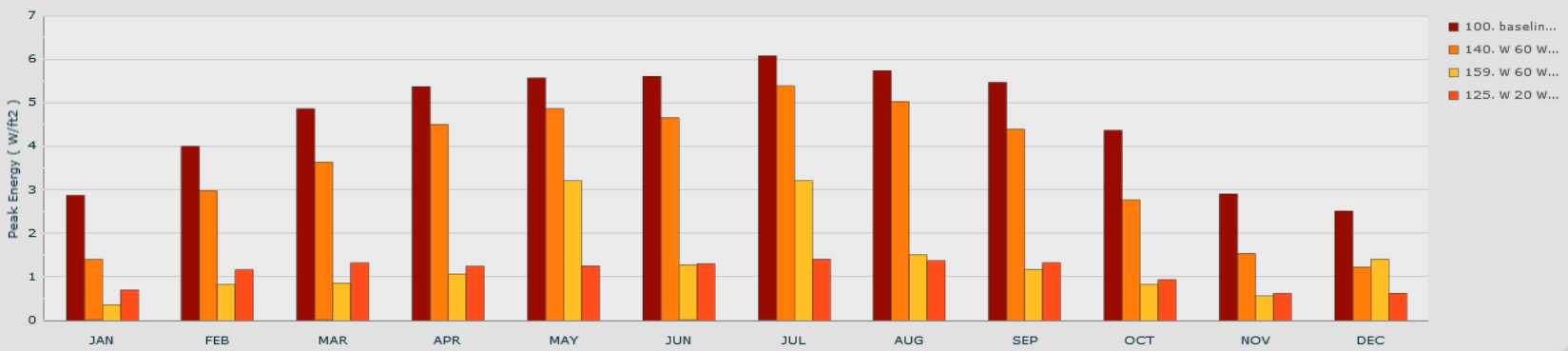
Zone Monthly Zone Monthly Facade

Peak Days	H JAN	C JUL
	22	30
	21	30
	21	27
	7	27

Monthly Solar Gain for All Windows (per Unit Floor Area)



Monthly Peak Gain Energy for All Windows (per Unit Floor Area)



COMFEN 3.1 (C:\Users\mark.perepelitza\AppData\LBNL\COMFEN3_1\db\comfen.sqlite)

COMFEN Project Scenarios Libraries Help

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Bldg. Type : Office Location : USA OR Portland

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96	baseline: N 60 WWR no light control
98	baseline: E 60 WWR no light control
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106	E 60 WWR_ext HS
107	S 60 WWR_ext HS
108	W 60 WWR_ext HS
119	N 20 WWR_ext HS
123	E 20 WWR_ext HS
124	S 20 WWR_ext HS
125	W 20 WWR_ext HS
127	N 60 WWR_ext HS+VS
138	E 60 WWR_ext HS+VS
139	S 60 WWR_ext HS+VS
140	W 60 WWR_ext HS+VS
141	blank scenario
146	S 60 WWR_ext VB
159	W 60 WWR_ext VB

Overview Climate Comparison

BASE CASE: 100. baseline: W 60 WWR no ...

140. W 60 WWR_ext HS+VS

159. W 60 WWR_ext VB

125. W 20 WWR_ext HS

Summary Energy Facade Window Comfort Daylight Glare Tabular

Solar Gain

Solar Gain for Individual Windows

W/ft2 0 1 1.5 2 2.5 3 3.5 4 4.5 5 +

100. baseline: W 60 WWR no light control Win

355:60_daylight window w_clear glazing

140. W 60 WWR_ext HS+VS Window Solar Gai

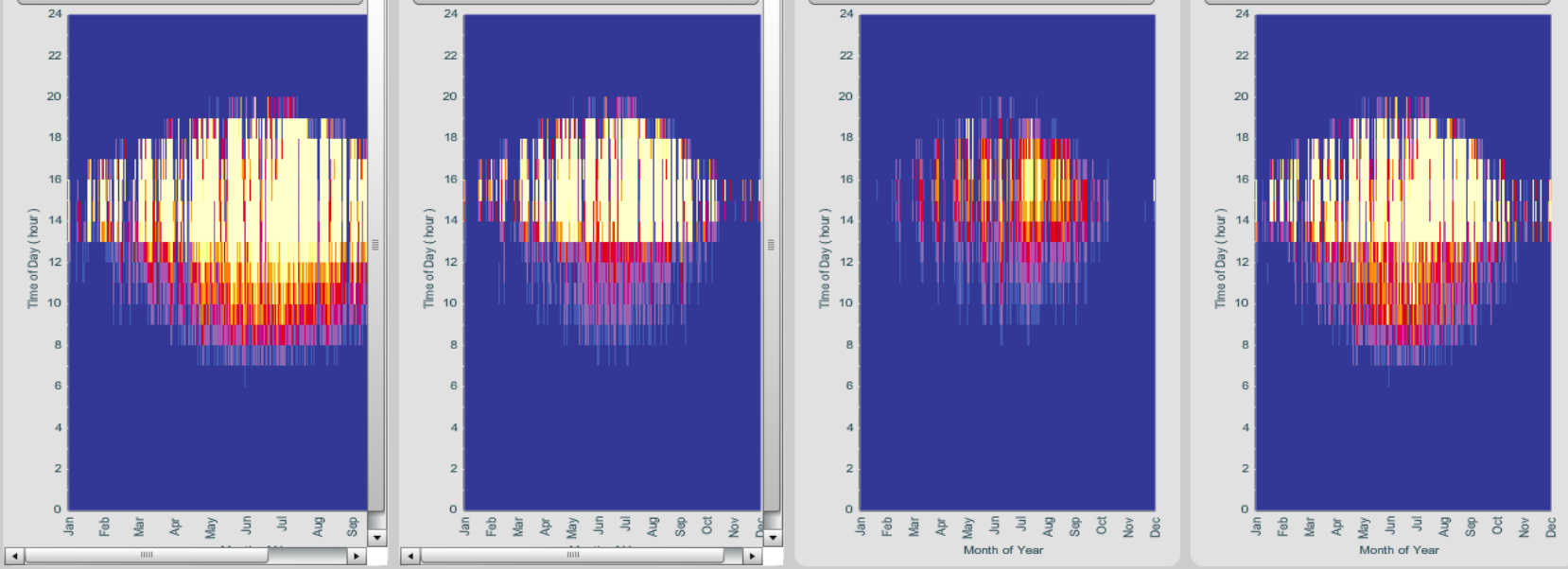
434:60_daylight window w_clear glazing

159. W 60 WWR_ext VB Window Solar Gain

482:60_daylight window w_clear glazing

125. W 20 WWR_ext HS Window Solar Gain

409:20_daylight window w_clear glazing



Scenario	Window	Frame U-Value	Glz.Sys. SHGC	Glz.Sys. U-Value (Btu/h...	Glz.Sys. T-Vis
100. baseline: W 60					
140. W 60 WWR_ext					
159. W 60 WWR_ext					
125. W 20 WWR_ext					

COMFEN 3.1 (C:\Users\mark.perepelitza\AppData\LBNL\COMFEN3_1\db\comfen.sqlite)

COMFEN Project Scenarios Libraries Help

IP

Project: LF demo_office_Portland

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Overview Climate Comparison

BASE CASE: 100. baseline: W 60 WWR no light control

140. W 60 WWR_ext HS+VS

159. W 60 WWR_ext VB

125. W 20 WWR_ext HS

Summary Energy Facade Window Comfort Daylight Glare Tabular

Useful Illum. Clear Sky Diffuse Sky

Render Visualizations

Date: Mar 21

Fidelity: high

Exposure: standard

Falsecolor:

Camera:

DGI

Falsecolor

9 AM

DGI: 15 DGI: 14.3 DGI: 0 DGI: 16.3

12 PM

DGI: 8.6 DGI: 13.6 DGI: 0 DGI: 15.1

3 PM

DGI: 8.6 DGI: 8 DGI: 0 DGI: 16.9

A Path Toward Future High Performance Window Systems

- **Use what we have today intelligently!!**
- **"Tweak the Market"- NFRC, EnergyStar, Tax Credits, Standards, LEED,**

- **Innovation:** Materials science, coating, devices
- Integrated, dynamic, intelligent systems
  - Envelope, lighting, HVAC

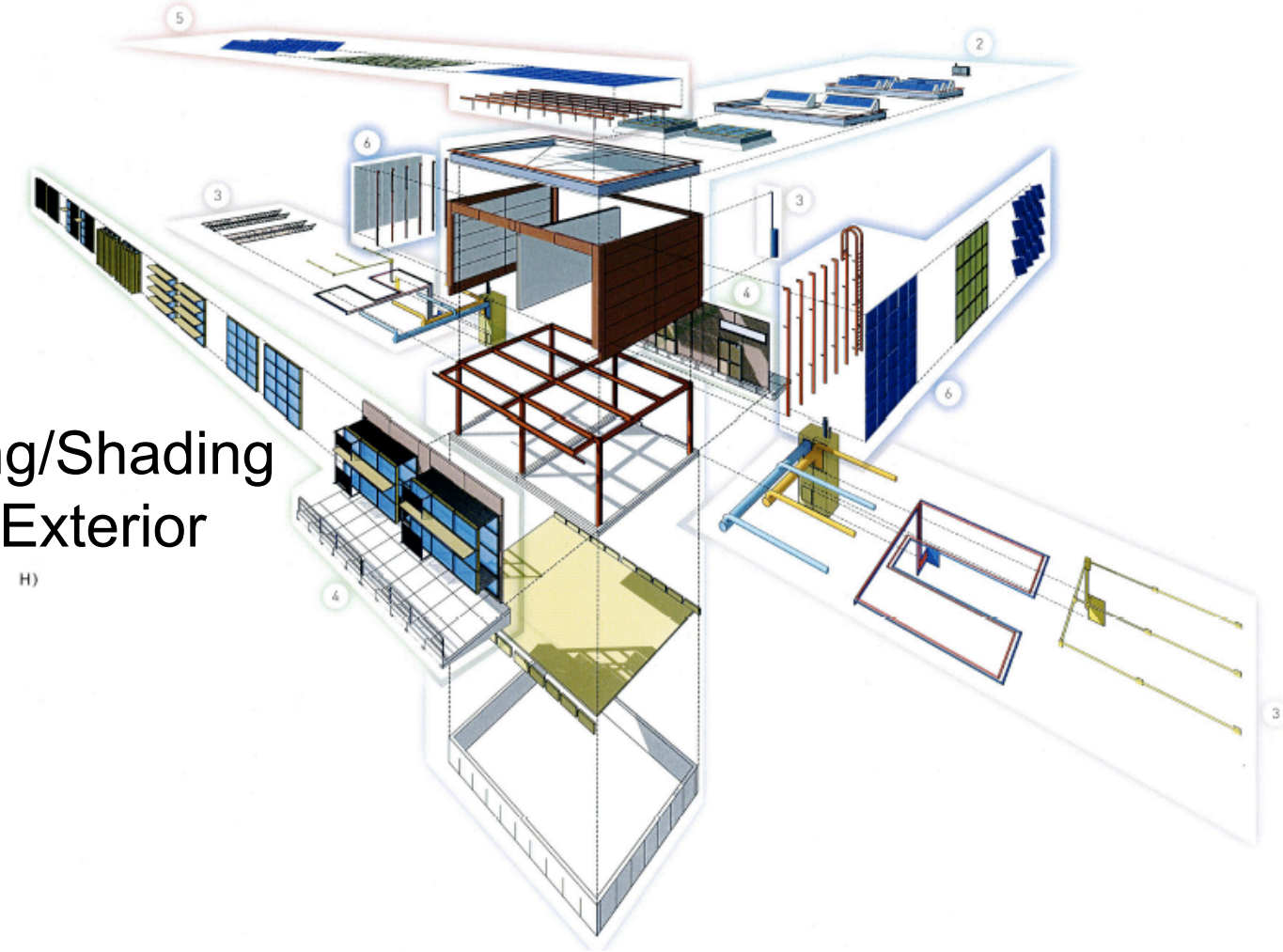
- **Greater functionality (energy, comfort) with equal or lower net system cost and better reliability**
  - Displace more energy consuming HVAC and lighting system

- **Many solutions for new and existing buildings: Tensions:**
  - **Climate and orientation dependent**
  - **Simple prescriptive vs performance based**
  - **Static -- dynamic**

User Test Bed Research Facilities

Scope: Construct eight new test beds to measure integrated building systems performance.

Concept Design for Reconfigurable Test Module



- Structure
- Façade/Glazing/Shading
- Walls: Interior/Exterior
- Roof/Skylights
- Interior space
- HVAC
- Lighting