Daylighting and Energy Efficient Buildings: Challenges and Opportunities

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Daylight or "Natural Light" = Market Advantage?

FOR LEASE
Office space
Competitive rentals
Excellent natural light
Carparking

Hamish Stallworthy
025 359 842
Stephen Maitland
025 443 390

COLLIERS
INTERNATIONAL

473-4413

YORK ST

Two Contrasting Views of Energy Efficiency

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

**2010 Perspective:
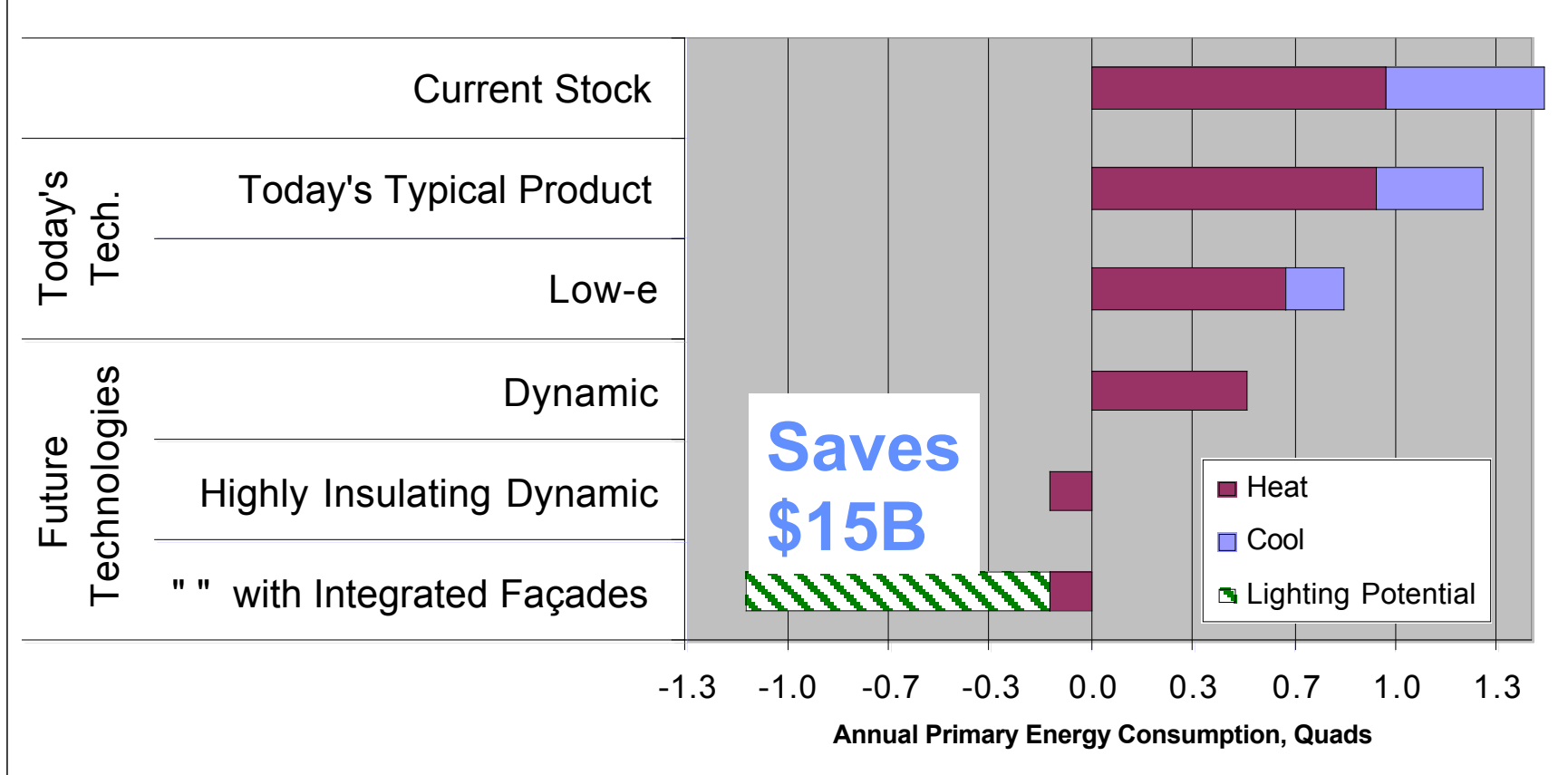Architect's View of the Ideal Windows**

Commercial Building Window Energy Use

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

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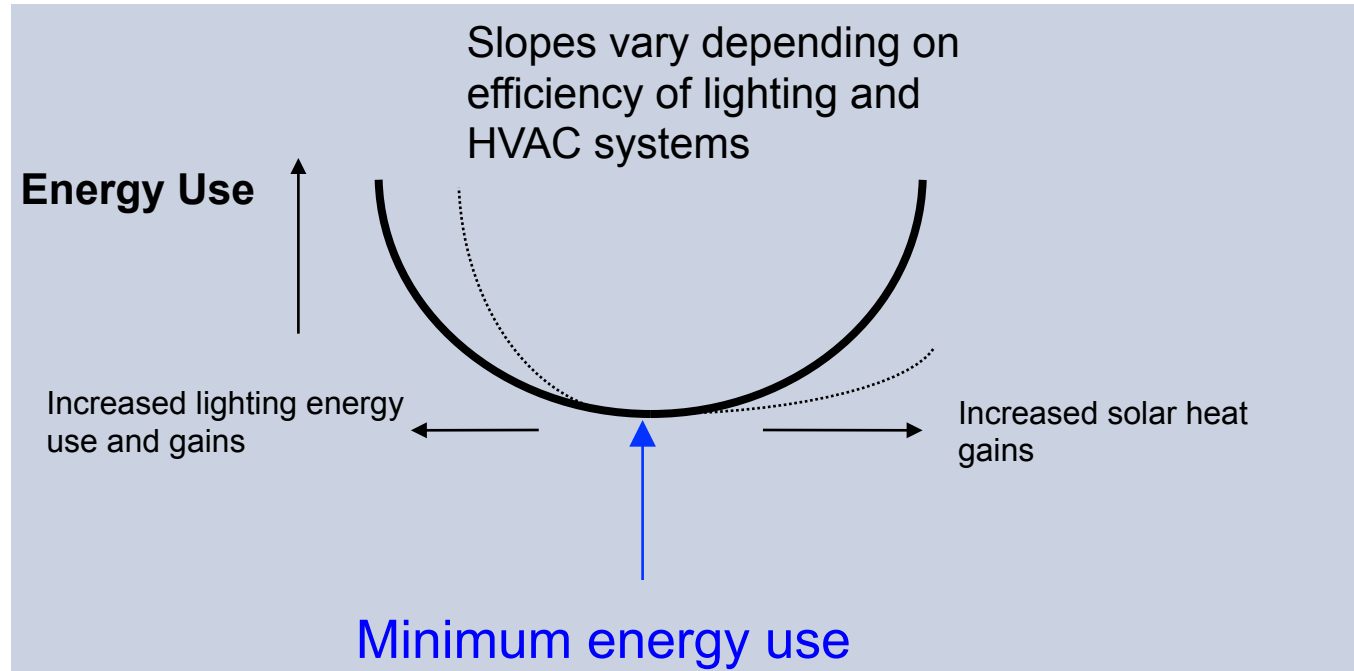 - Photovoltaics-building skin as power source

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
- ......

Slopes vary depending on efficiency of lighting and HVAC systems

Energy Use

Increased lighting energy use and gains

Increased solar heat gains

Minimum energy use

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

... It's Complicated!!

Advanced Facades and Daylighting

Program Goals:

Net Zero Energy Balance for New and Retrofit

Enhanced View and Thermal Comfort

Reliable, cost effective operations

Tools to design, optimize, specify, control

Adoption/diffusion throughout industry

Application:
All climates
All Building types
New-Replacement-Retrofit

Program Activities:
Simulation
Optimization
Lab test
Field Test
Demonstrations
Standards

Advanced Technologies:
Sensors;
Controls;
Hi R windows,
Cool coatings;
Switchable coatings;
Automated Shading;
Daylight-redirecting
Operable windows,

Partners
Manufacturers
Owners
Architects
Engineers
Specifiers
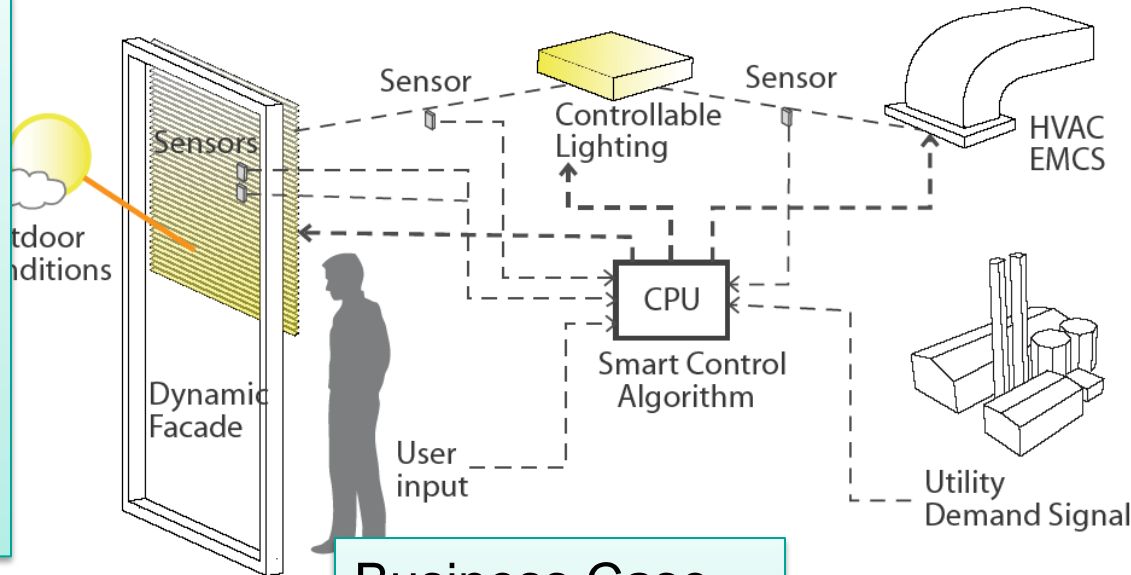Code officials
Contractors
Utilities

Human Factors:
Thermal comfort
Visual comfort
Satisfaction
Performance

Business Case
Manufacturing
Installation
Commissioning
Reliability
Cost

Decision Tools
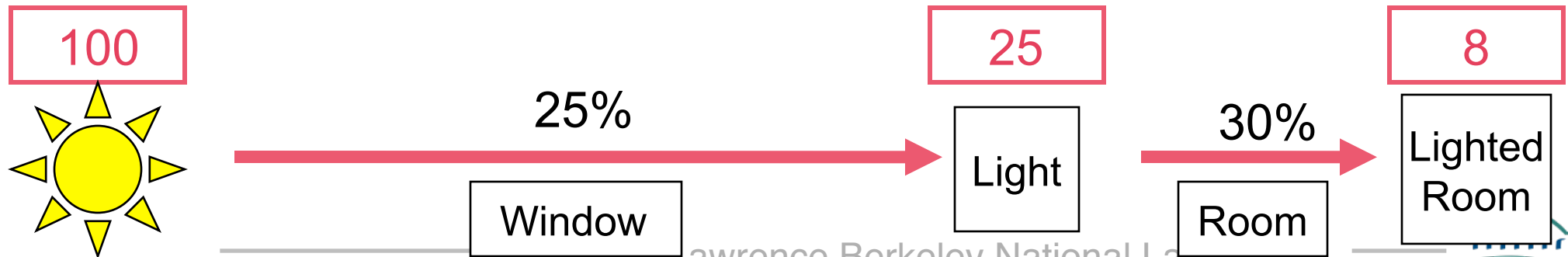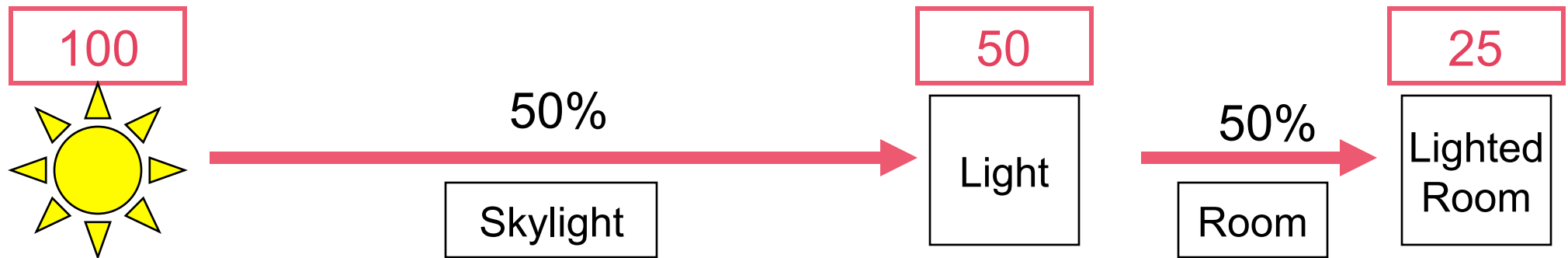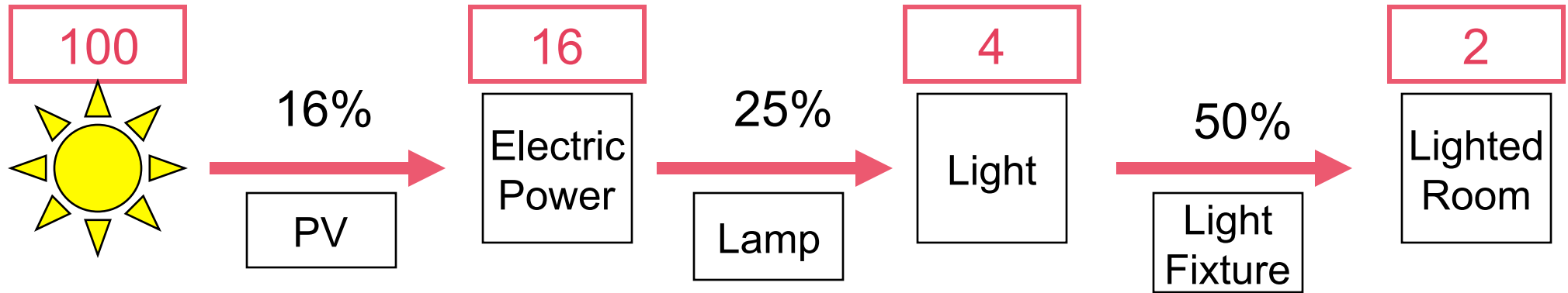Books, Guides
Websites
Simulation Tools
Testbeds

Using Sunlight Effectively?
Electric conversion vs Direct Use

100

16% — PV → 16 — Electric Power

25% — Lamp → 4 — Light

50% — Light Fixture → 2 — Lighted Room

100

50% — Skylight → 50 — Light

50% — Room → 25 — Lighted Room
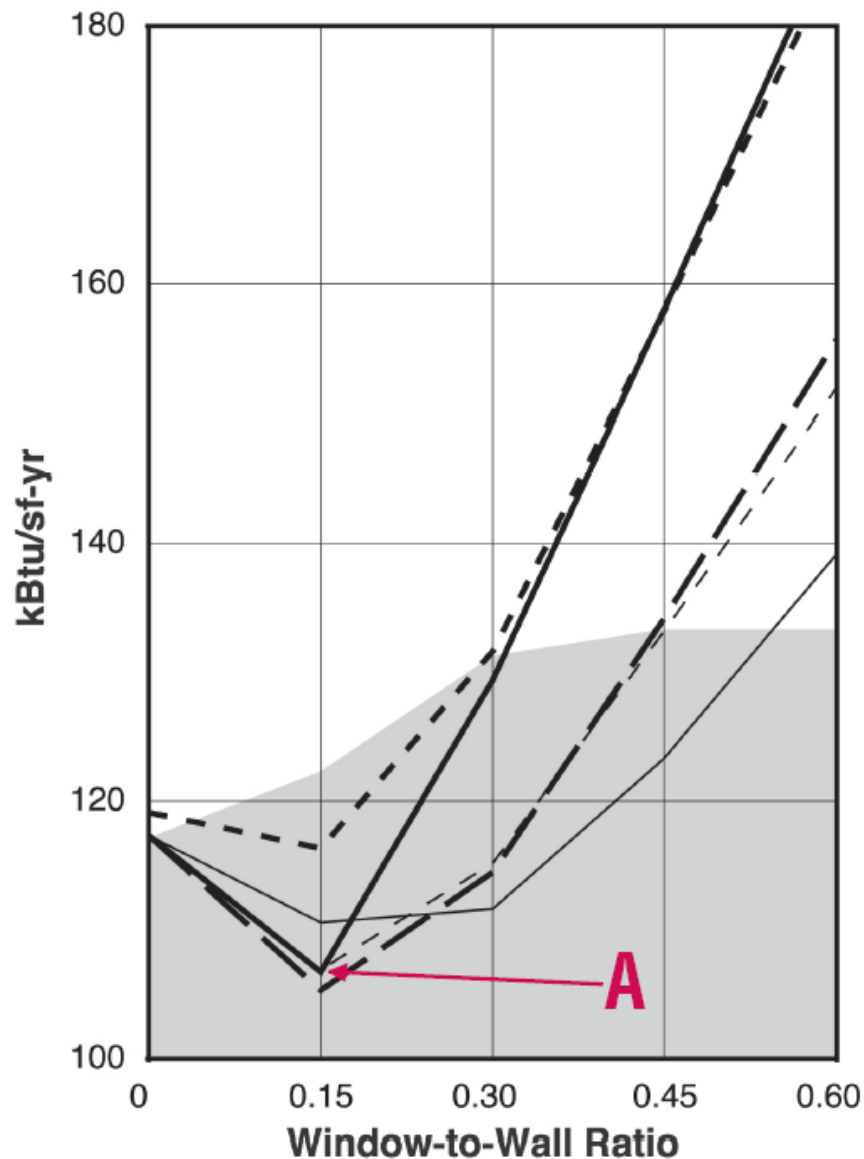

100

25% — Window → 25 — Light

30% — Room → 8 — Lighted Room

Window B
double glazing, clear
U=0.60, SHGC=0.60, VT=0.63

Window H
triple glazing, 1 low-E layer, clear
U=0.20, SHGC=0.22, VT=0.37

Legend:
- No shading
- Interior shades
- Overhang
- Overhang + fins
- High-rise obstruction
- ASHRAE 90.1

y-axis (left chart): kBtu/sf-yr, scale 100–180
x-axis (both): Window-to-Wall Ratio, 0 to 0.60

Cold Climates: Chicago, IL al Laboratory
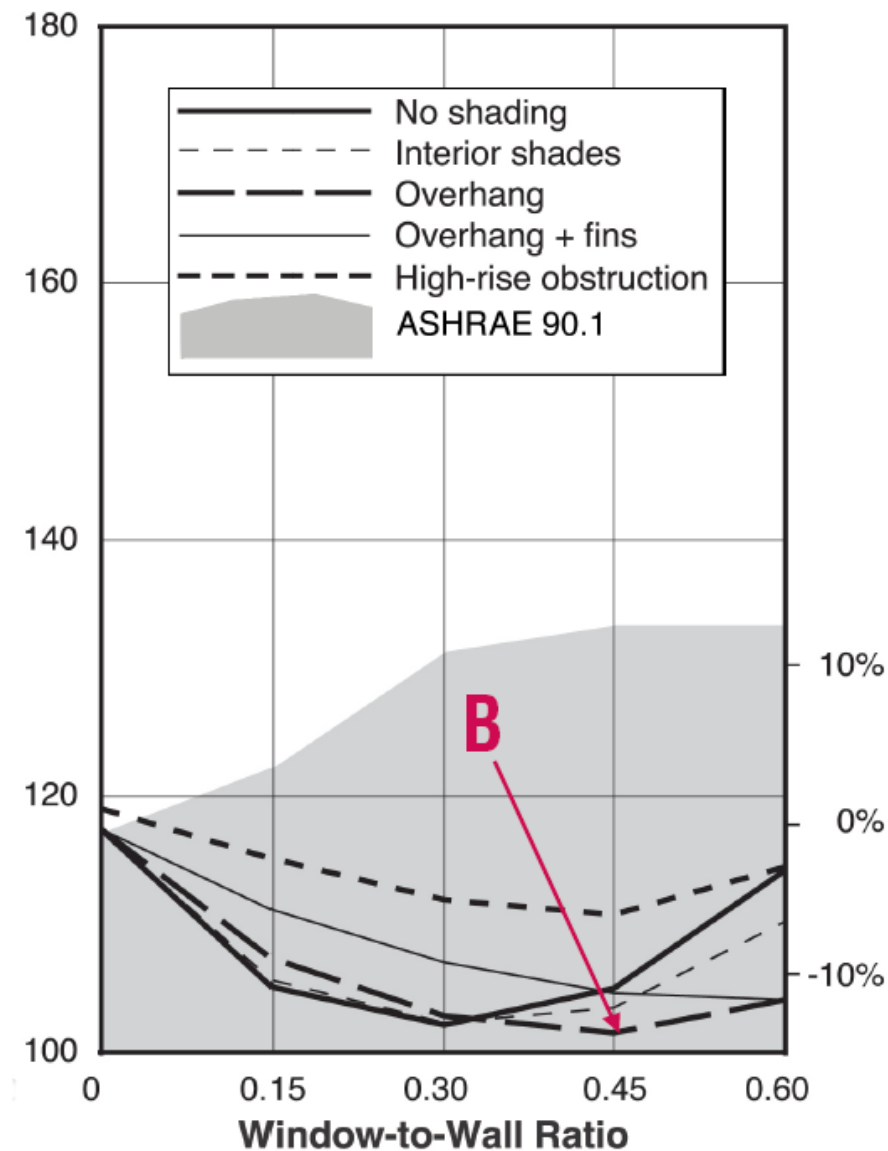
3 Pathways for Use of Glass in Commercial Buildings

- ## 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

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**
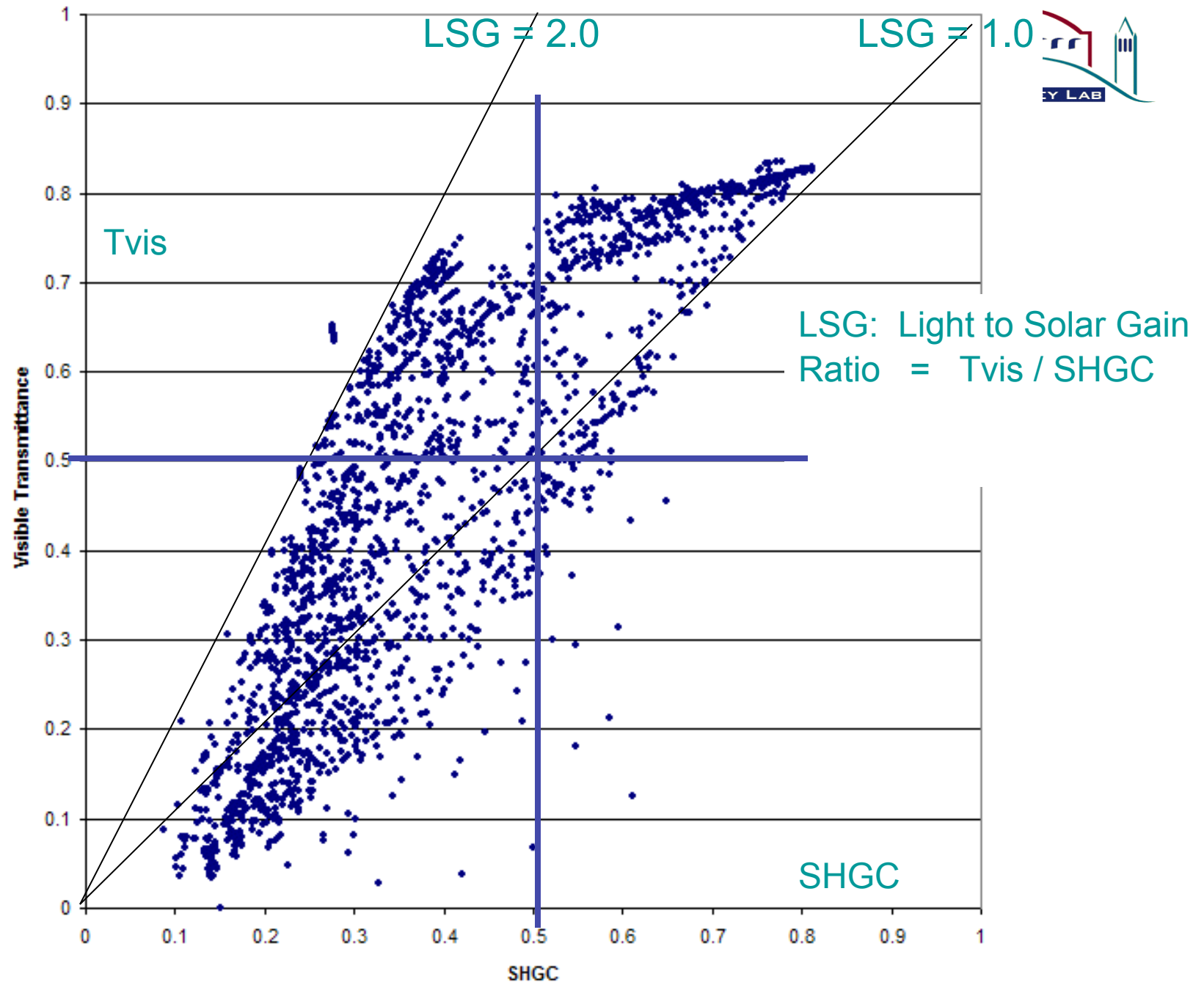 - **coated glass and plastic**
  - **Multilayer dielectric**

Transmittance -vs- Wavelength

Light to Solar Gain Ratio

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

LSG = 2.0

LSG = 1.0

Tvis

LSG: Light to Solar Gain Ratio = Tvis / SHGC

SHGC

*Y-axis:* Visible Transmittance

X-axis: SHGC

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**

"OFF"

"ON"
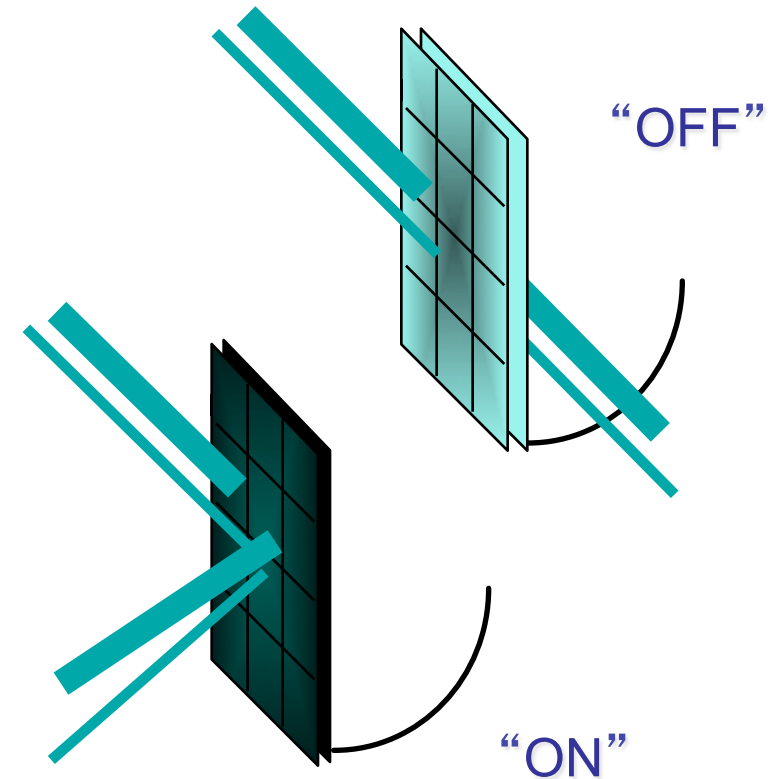
Engineering and Occupant Response Studies with Switchable Electrochromic Windows

- LBNL Façade Field Test Facility

Electrochromic Windows: 20+ years of R&D Progress Towards the Marketplace
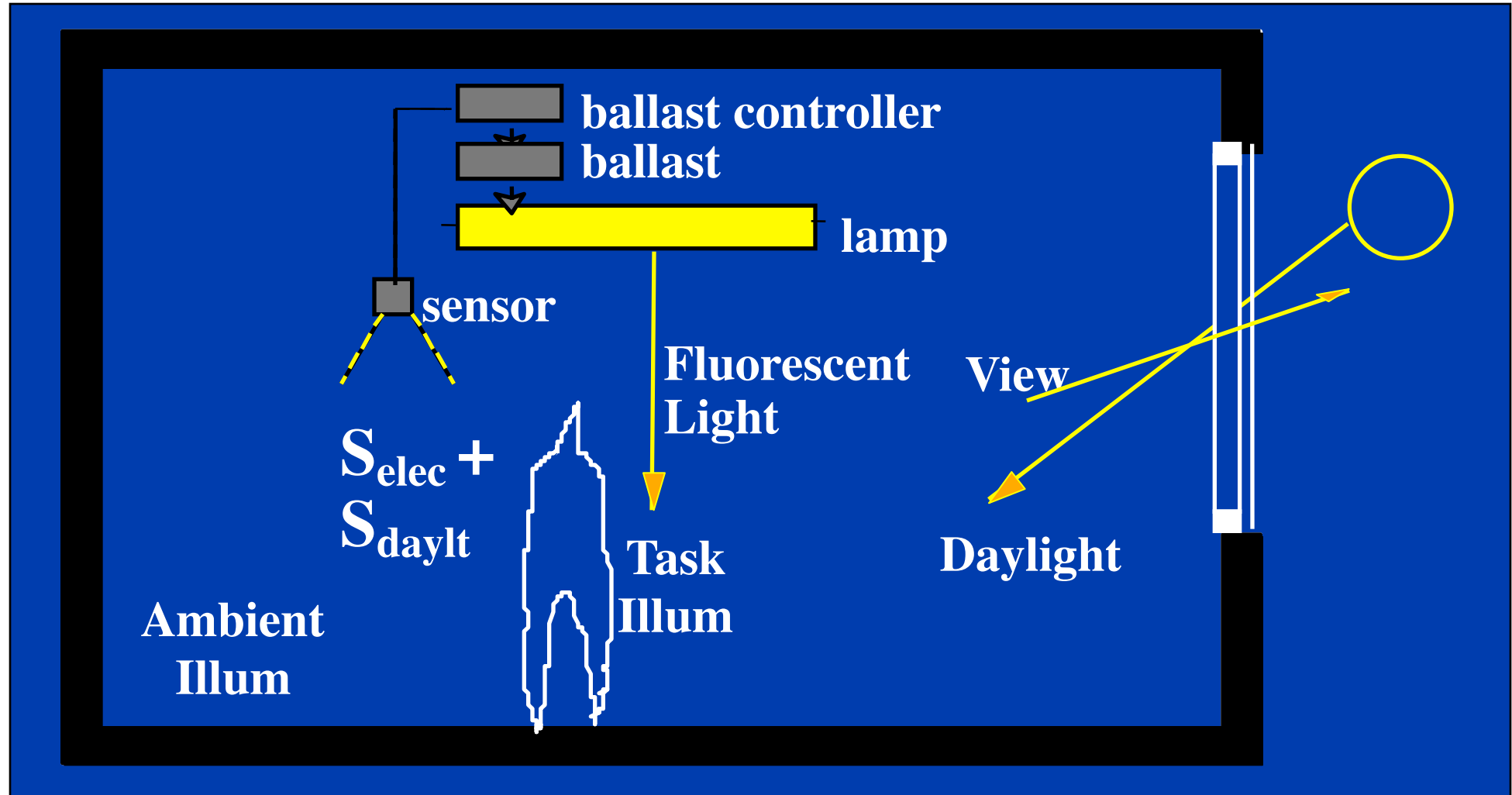
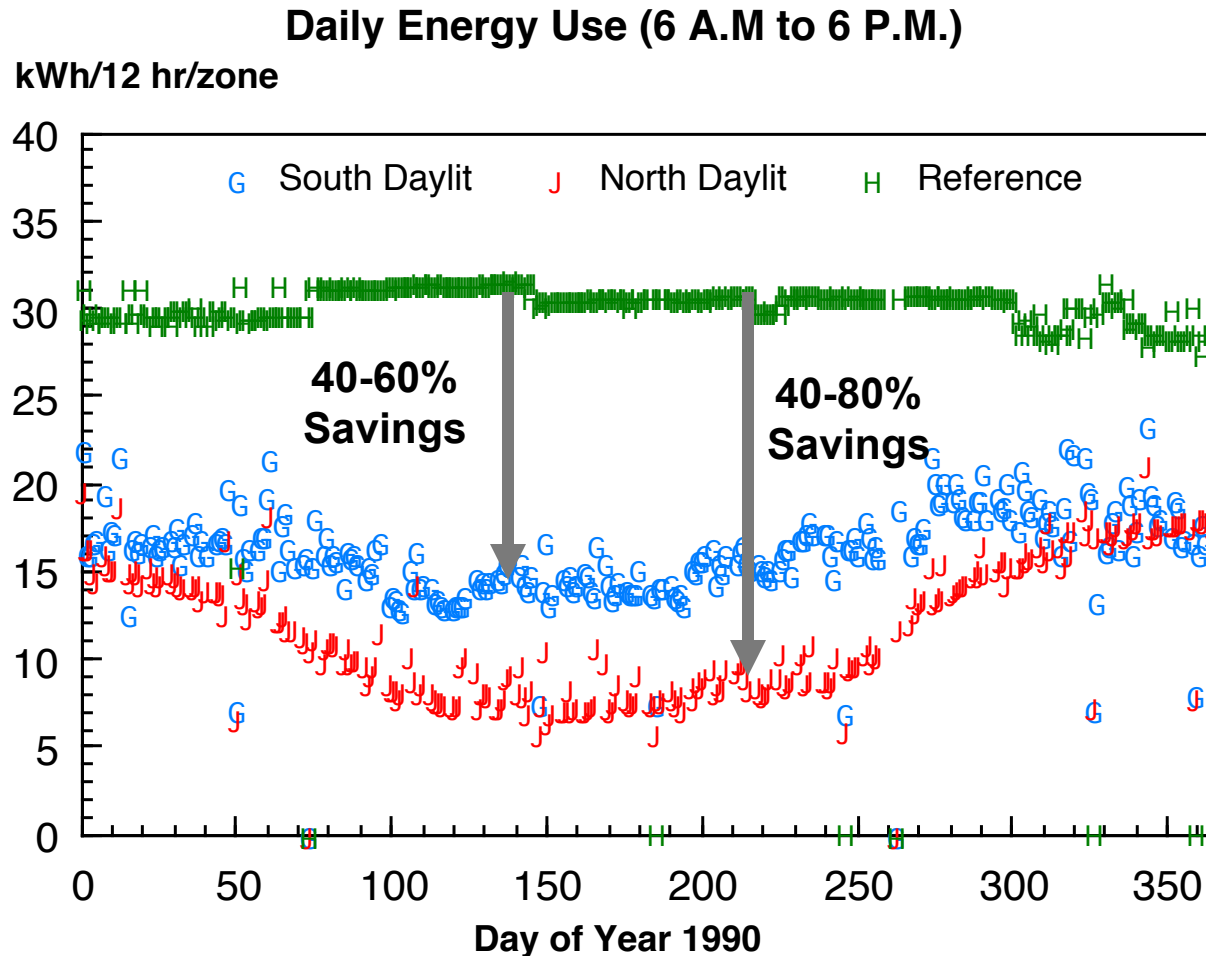# (Day)Lighting Control Elements
A Systems Integration Issue

ballast controller

ballast

lamp

sensor

Fluorescent Light

View

$S_{elec} + S_{daylt}$

Task Illum

Daylight

Ambient Illum

Good Lighting Controls (Daylight Dimming) Work

Daily Energy Use (6 A.M to 6 P.M.)

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

Lawrence Berkeley National Laboratory

"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
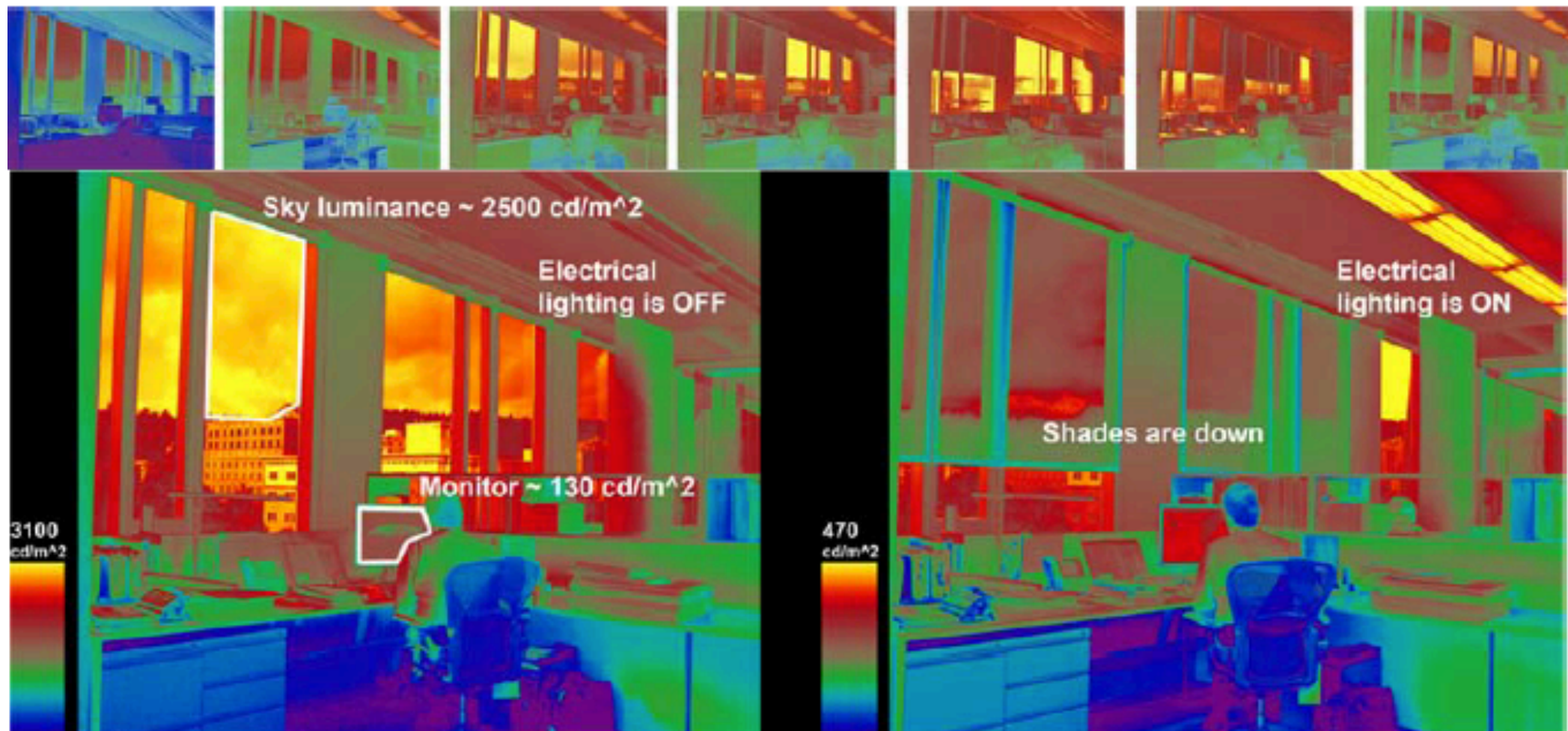Specifiers
Owner/Operators
Public, Private
Utilities

2007-20011
Automated Shades w/ daylighting

al Laboratory

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

Sky luminance ~ 2500 cd/m^2

Electrical lighting is OFF

Monitor ~ 130 cd/m^2

3100 cd/m^2

Electrical lighting is ON

Shades are down

470 cd/m^2

Kyle Konis, UCB/ LBNL

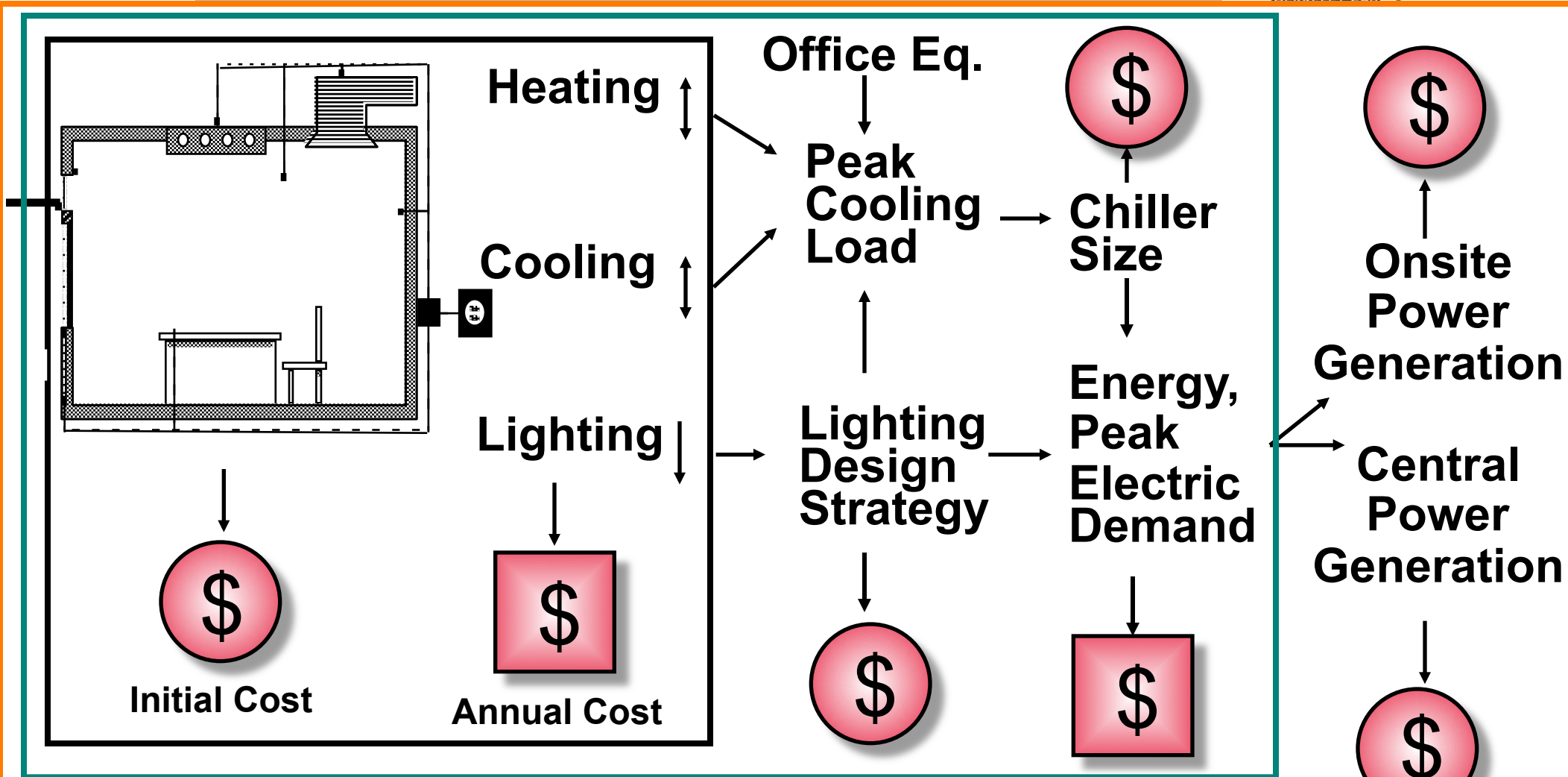Lawrence Berkeley National Laboratory

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

System Integration: Investment Tradeoffs
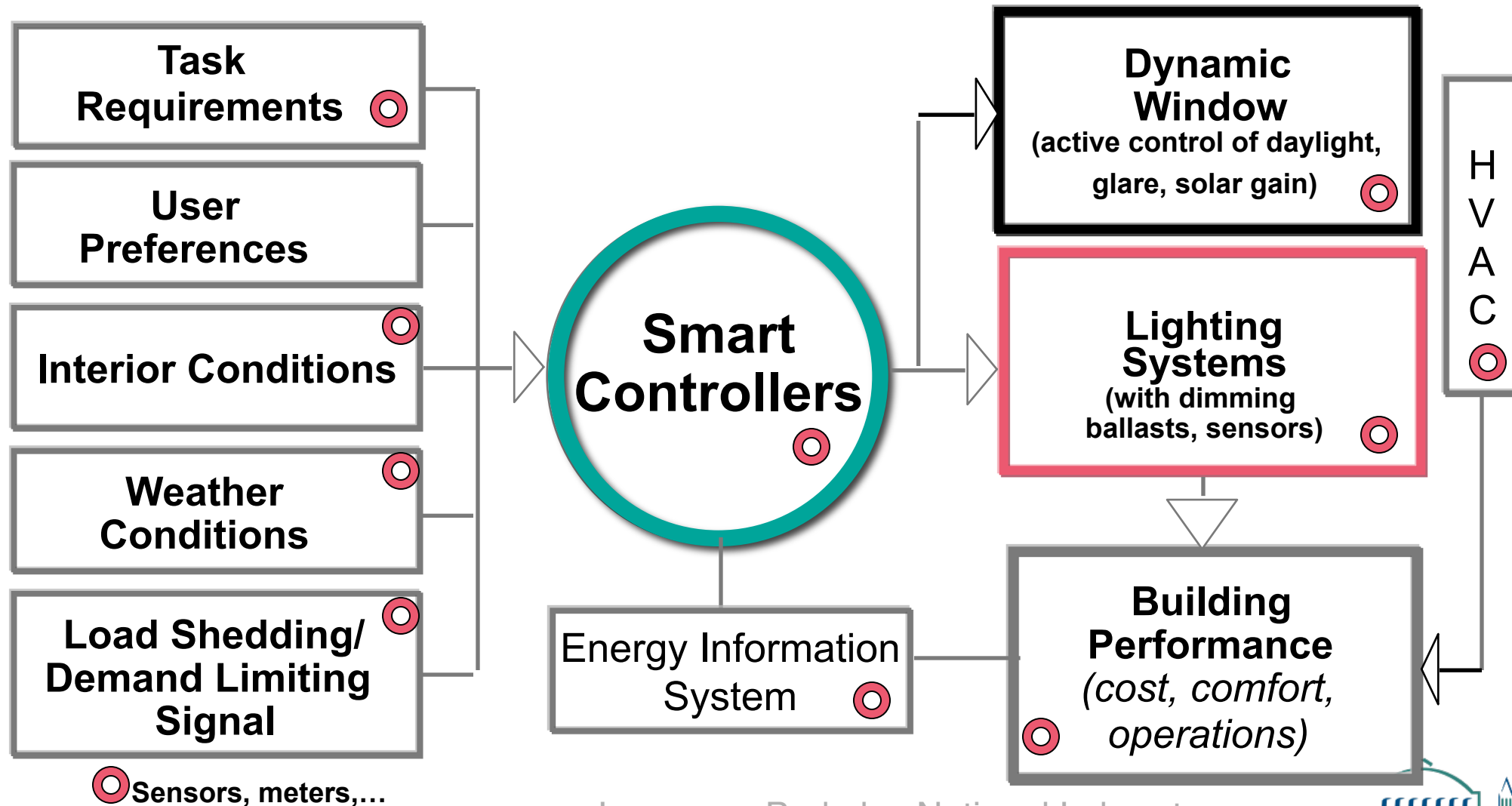
Annual Energy Costs in Perspective

Cost / Sq. M. Floor -Year

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

Exploring Intelligent Control Systems

Task Requirements

User Preferences

Interior Conditions

Weather Conditions

Load Shedding/ Demand Limiting Signal

Sensors, meters,…

Smart Controllers

Energy Information System

Dynamic Window
(active control of daylight, glare, solar gain)

Lighting Systems
(with dimming ballasts, sensors)

H V A C

Building Performance
(cost, comfort, operations)

BERKELEY LAB

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

ONAL LABORATORY

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
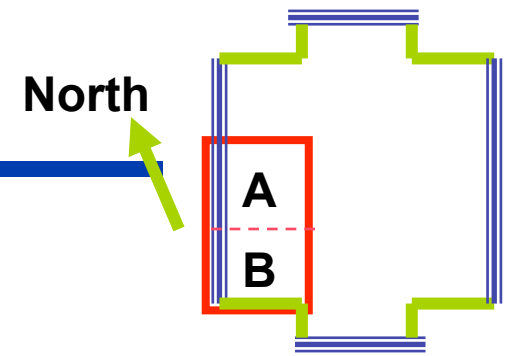   **--** Solar control
    -- Glare control

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**
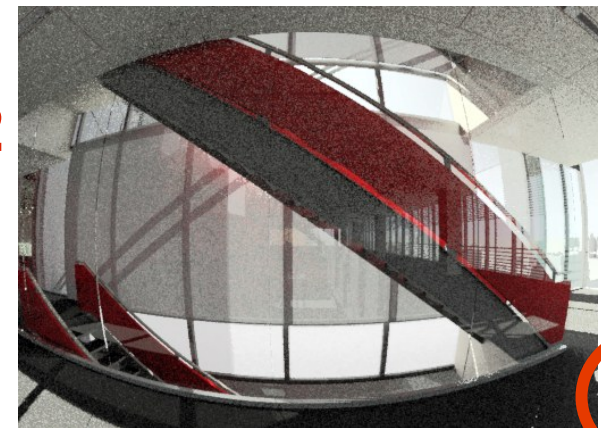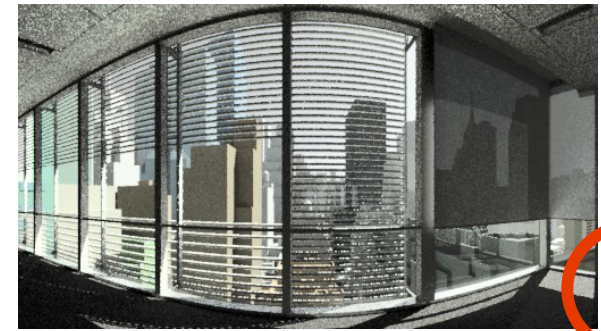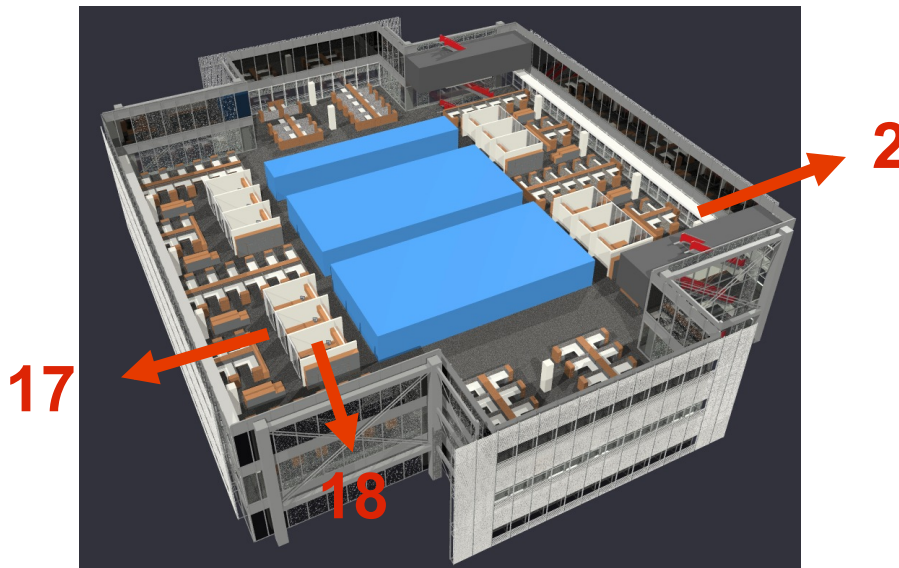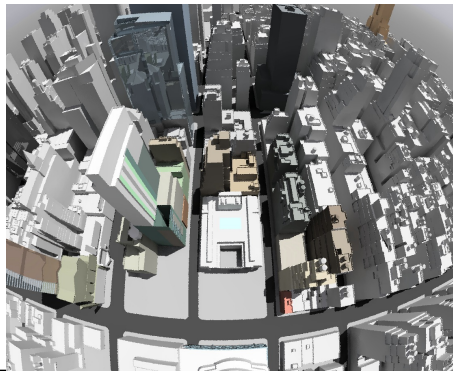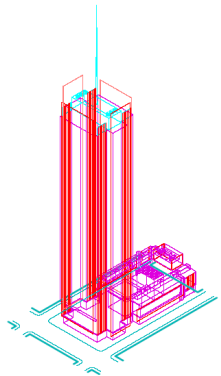
Simulated Views from 3 of 22 view positions

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

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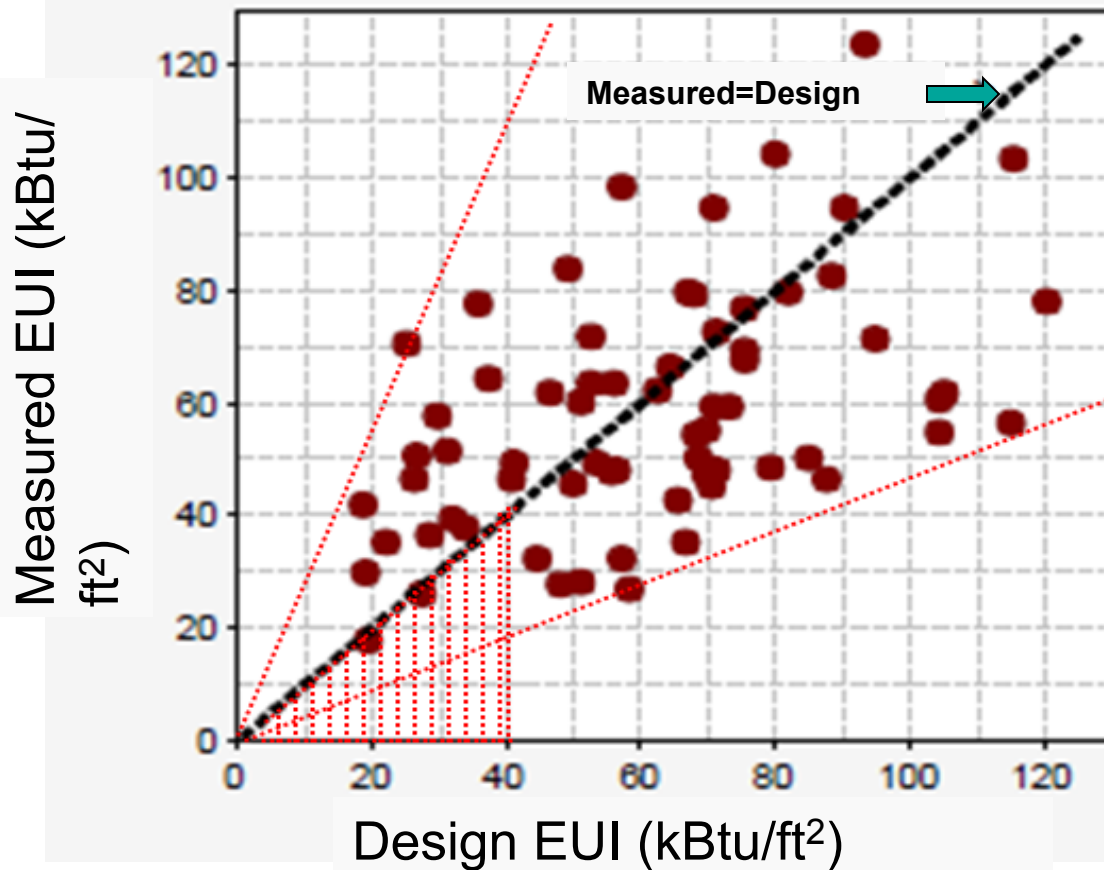
Source: Energy performance of LEED-NC buildings, NBI, 2008

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

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
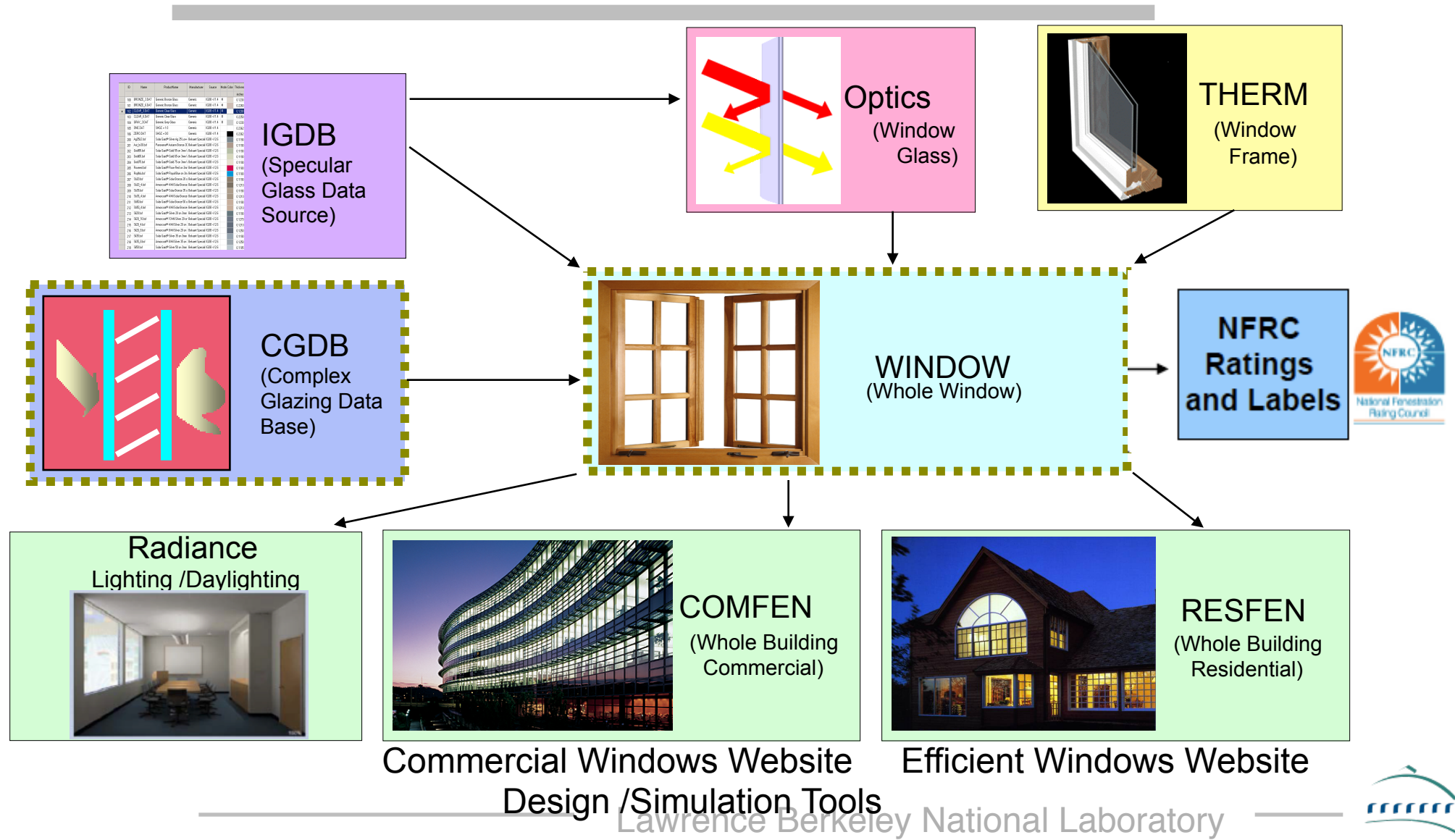
Glazing/Shading/Daylighting Measurement and Validation

- **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
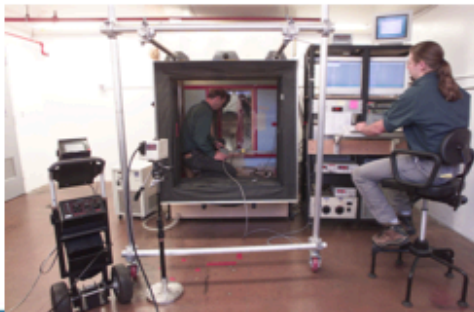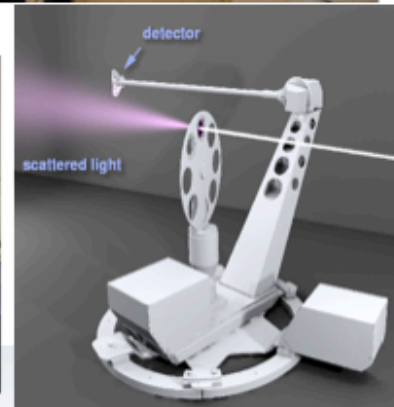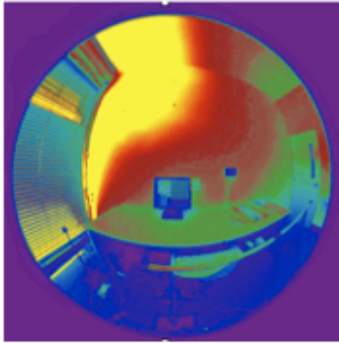
User Test Bed Research Facilities

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
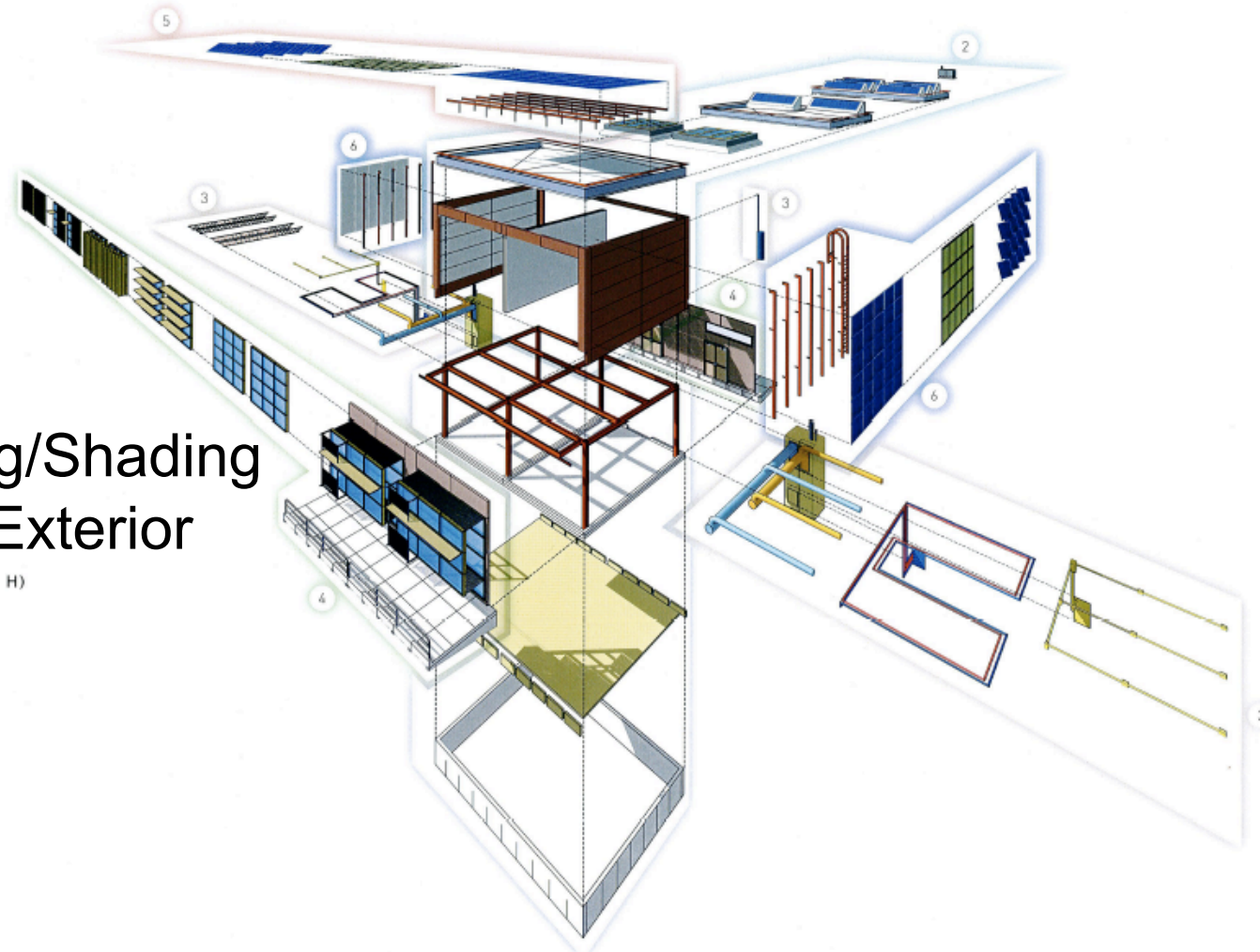
Building Controls Virtual Test Bed (BCVTB)

Open-source middle-ware for
- co-simulation
- real-time simulation (hardware in the loop, software in the loop)
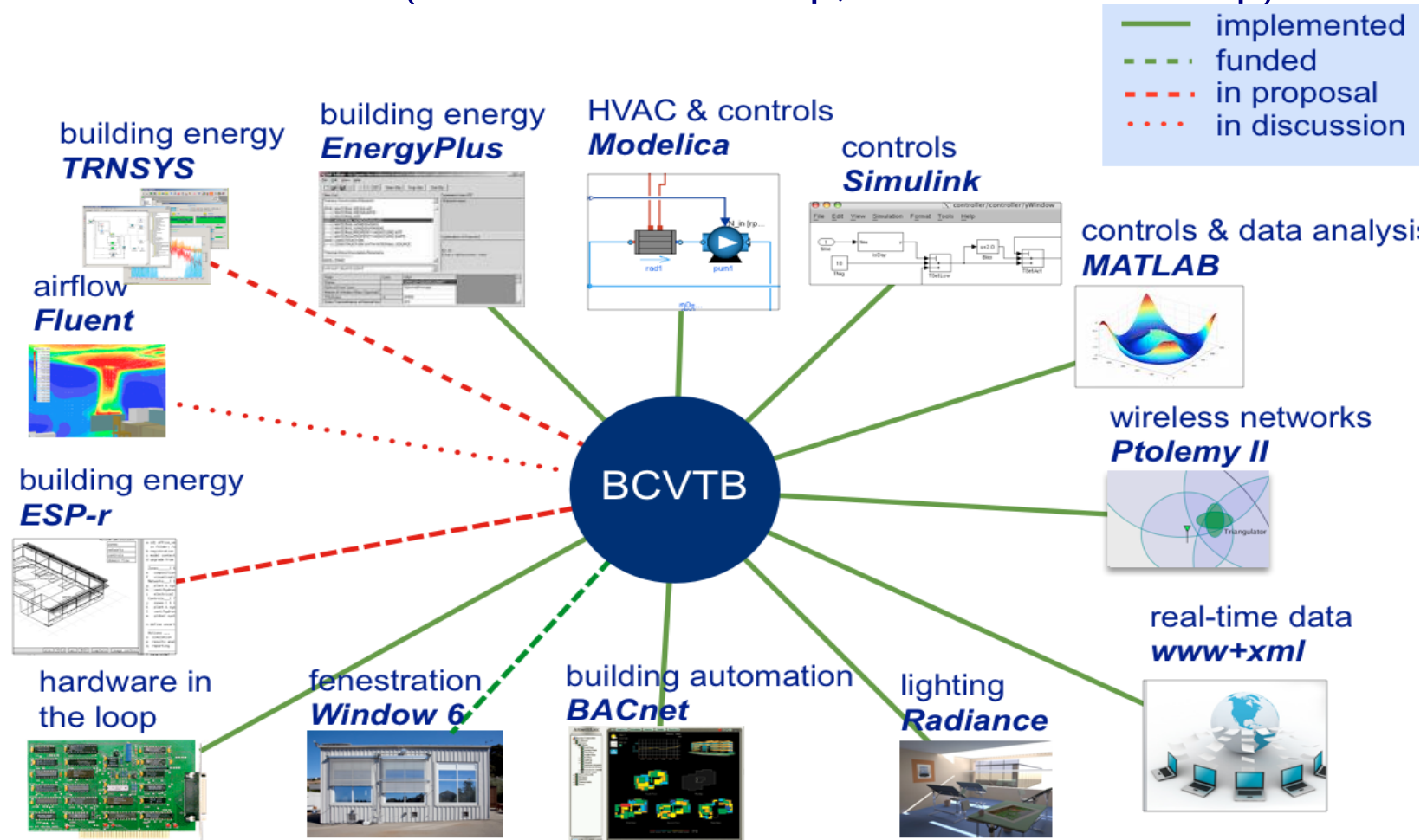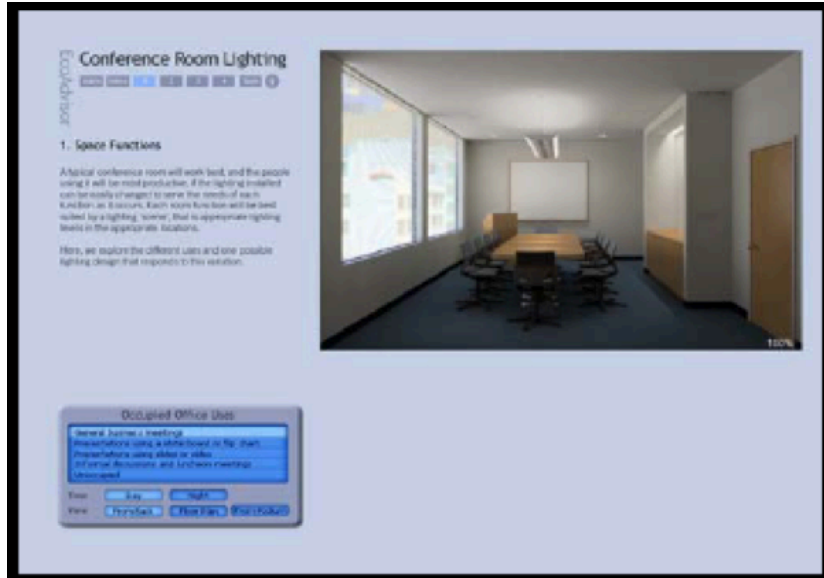
Example: Conference Room Lighting Controls Virtual Testbed

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

Home | Facade Design Tool | Overview | Case Studies | Tools & Resources | Contact Information

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)

Annual Energy (kBtu/sf-yr)
Lower Limit — Upper Limit

■ Heating ■ Cooling □ Fan □ Lighting

Peak (W/sf)
Lower Limit — Upper Limit

Carbon (lb/sf-yr)
Lower Limit — Upper Limit

Daylight Illuminance (footcandles)
Lower Limit — Upper Limit

Glare
Imperceptible — Acceptable — Unacceptable

Thermal Comfort (PPD)
Acceptable — Unacceptable
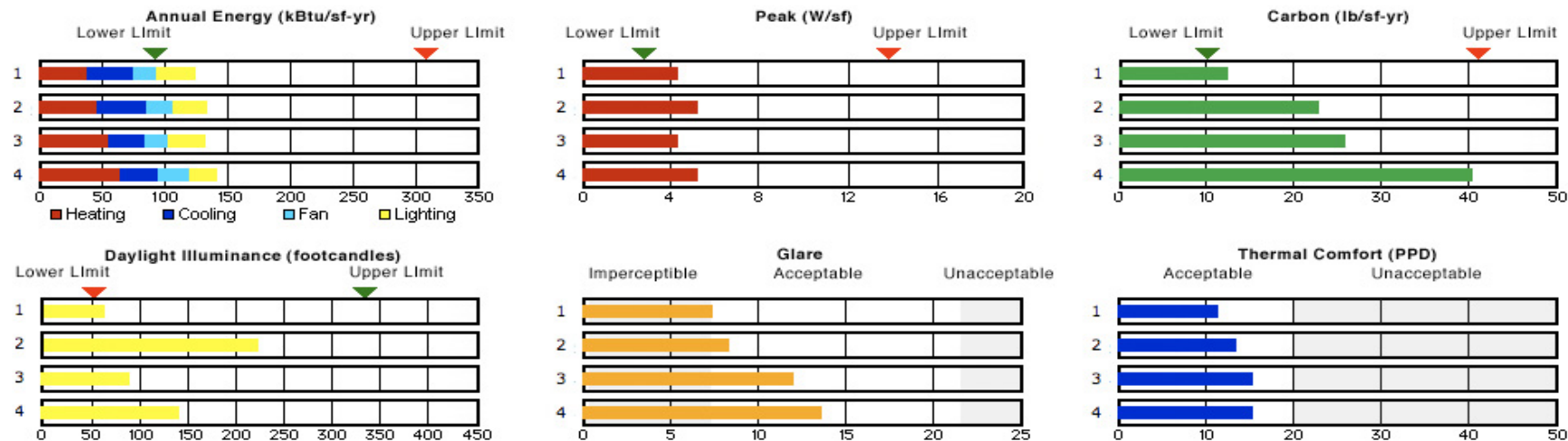
COMFEN: Estimating Energy and Daylighting Impacts in Early Design

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 22   C JUN 30   H JAN 21   C JUL 30   H JAN 21   C JUL 27   H JAN 7   C JUL 27

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

Solar Gain (kBtu/ft2-yr)

■ 100. baselin...
■ 140. W 60 W...
■ 159. W 60 W...
■ 125. W 20 W...

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

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

Peak Energy (W/ft2)

■ 100. baselin...
■ 140. W 60 W...
■ 159. W 60 W...
■ 125. W 20 W...

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

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

COMFEN   Project   Scenarios   Libraries   Help

IP

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Scenarios   **Libraries**

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⚠ 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

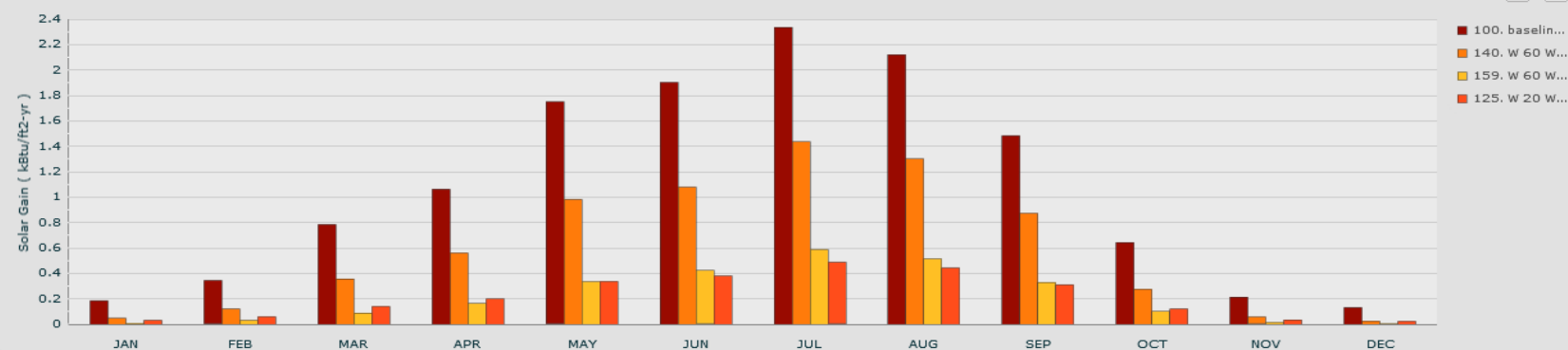Summary   Energy   Facade   **Window**   Comfort   Daylight   Glare   Tabular

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   Wind ▲
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					