Integrated Facades Symposium
Building Facades: Integrating Comfort and Energy Performance
Pacific Energy Center, SF, April 21, 2010

Defining and Measuring Performance For High Performance Buildings

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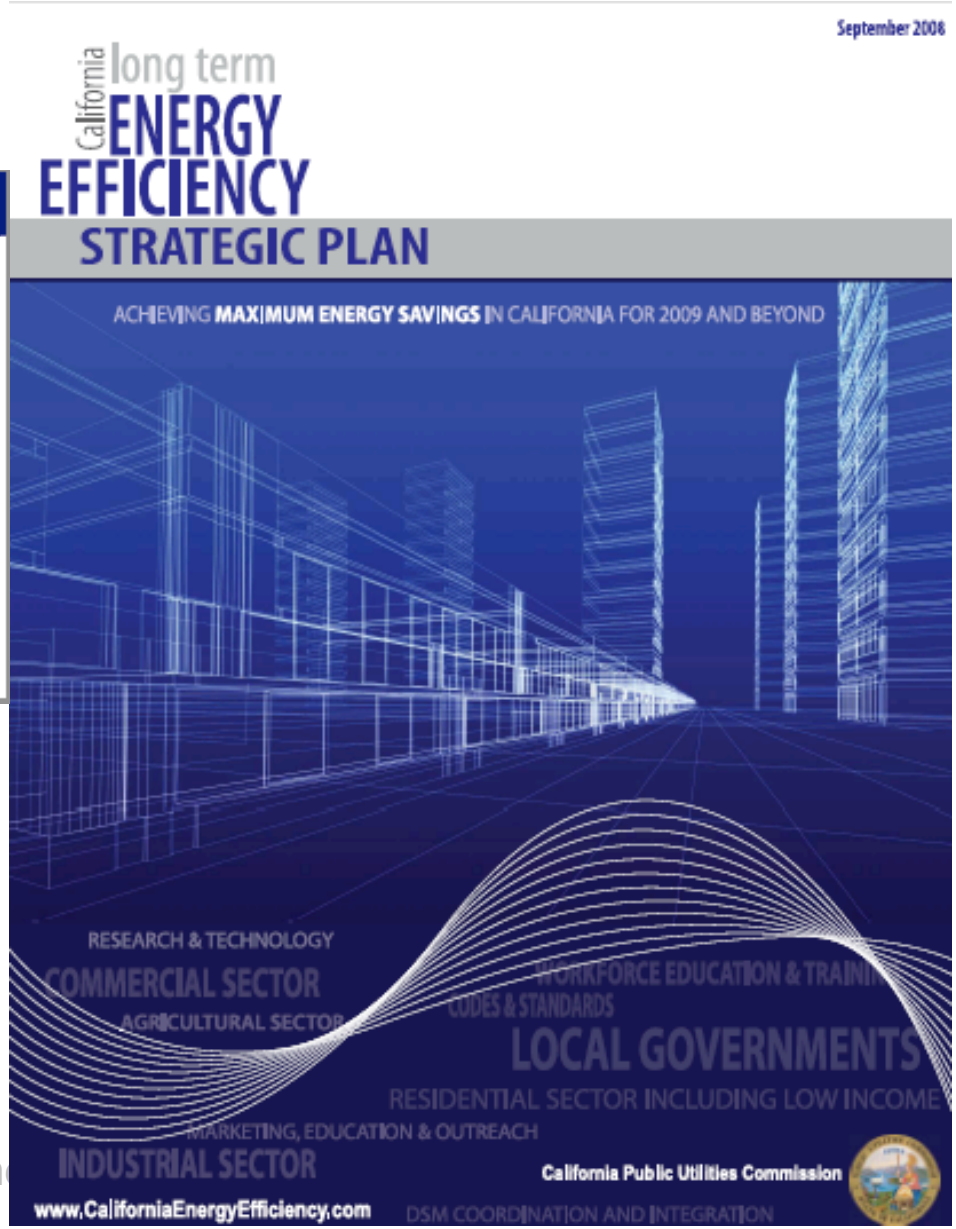
"BIG BOLD" ENERGY EFFICIENCY STRATEGIES




In order to guide market transformation in a number of key sectors, this Plan embraces four specific programmatic goals, known as the "Big Bold Energy Efficiency Strategies," established by the CPUC in D.07-10-032 and D.07-12-051. These goals were selected not only for their potential impact, but also for their easy comprehension and their ability to galvanize market players.

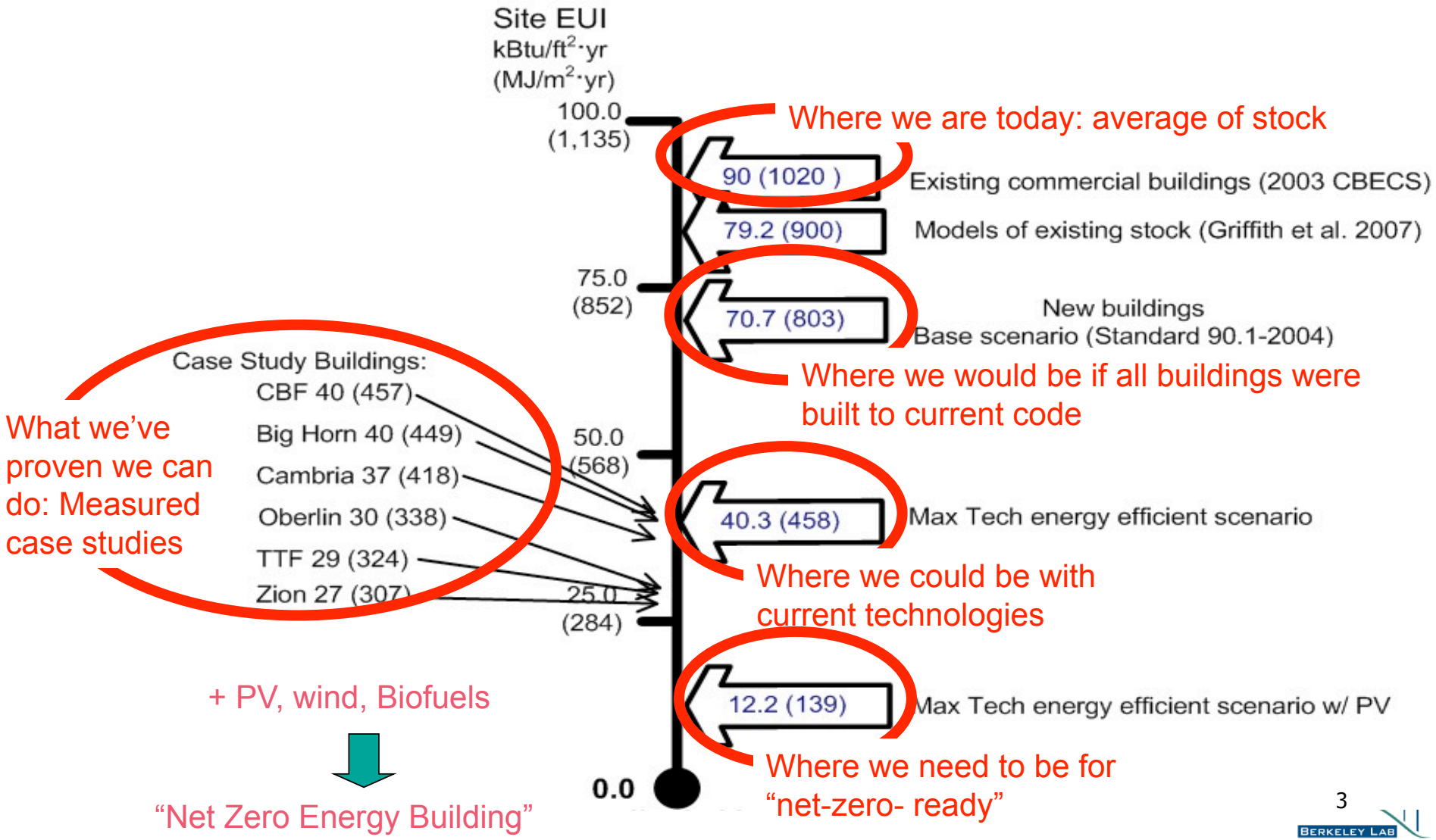
1. All new residential construction in California will be zero net energy by 2020;
2. All new commercial construction in California will be zero net energy by 2030;
3. Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California's climate; and
4. All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020.

All new commercial construction will be zero net energy by 2030



Driving Building Energy Use to "Zero"

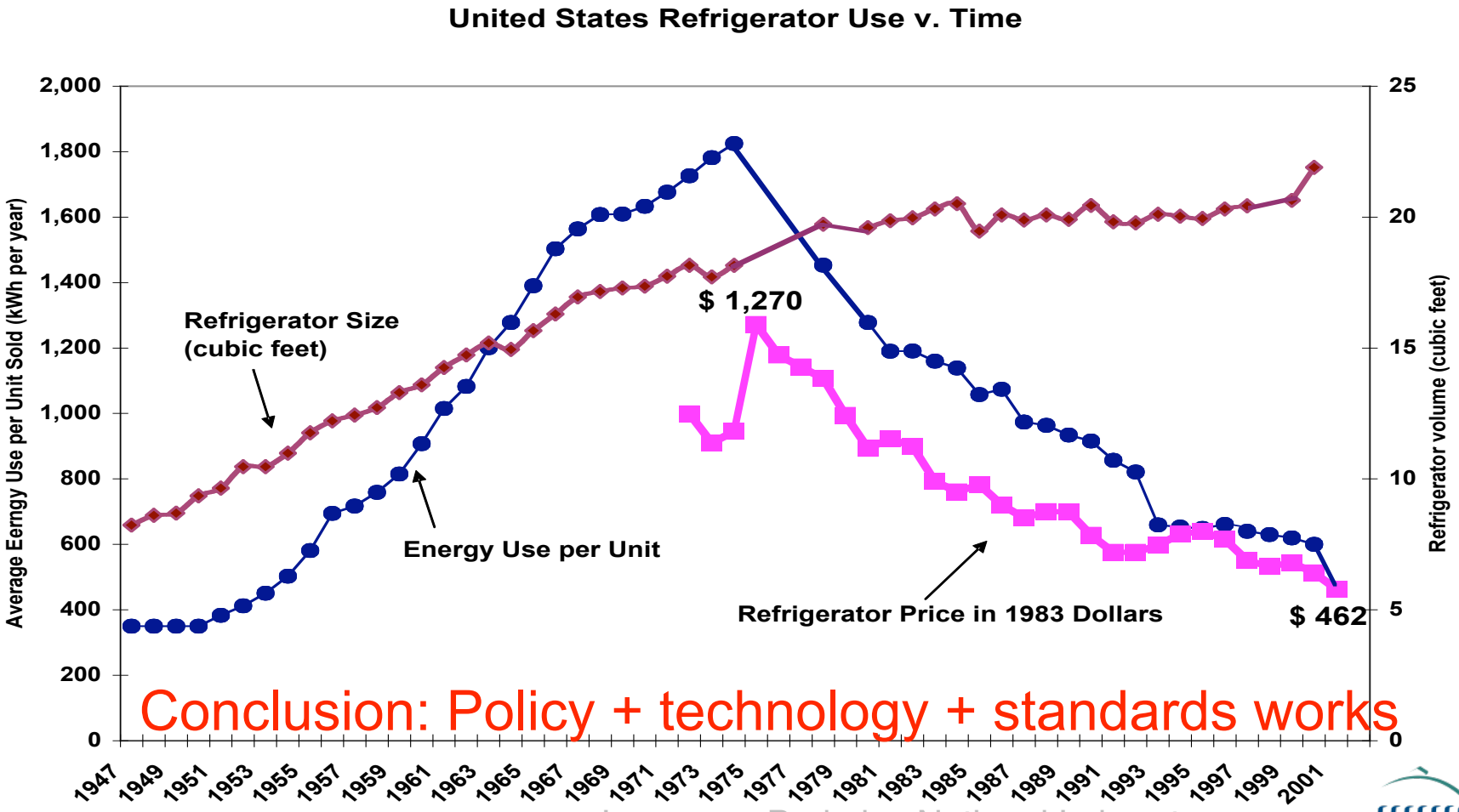
Reducing Commercial Building Energy Use Index (EUI) from 90kBtu -> 15kBtu



BERKELEY LAB

U.S. Refrigerator Energy Use vs. Time:

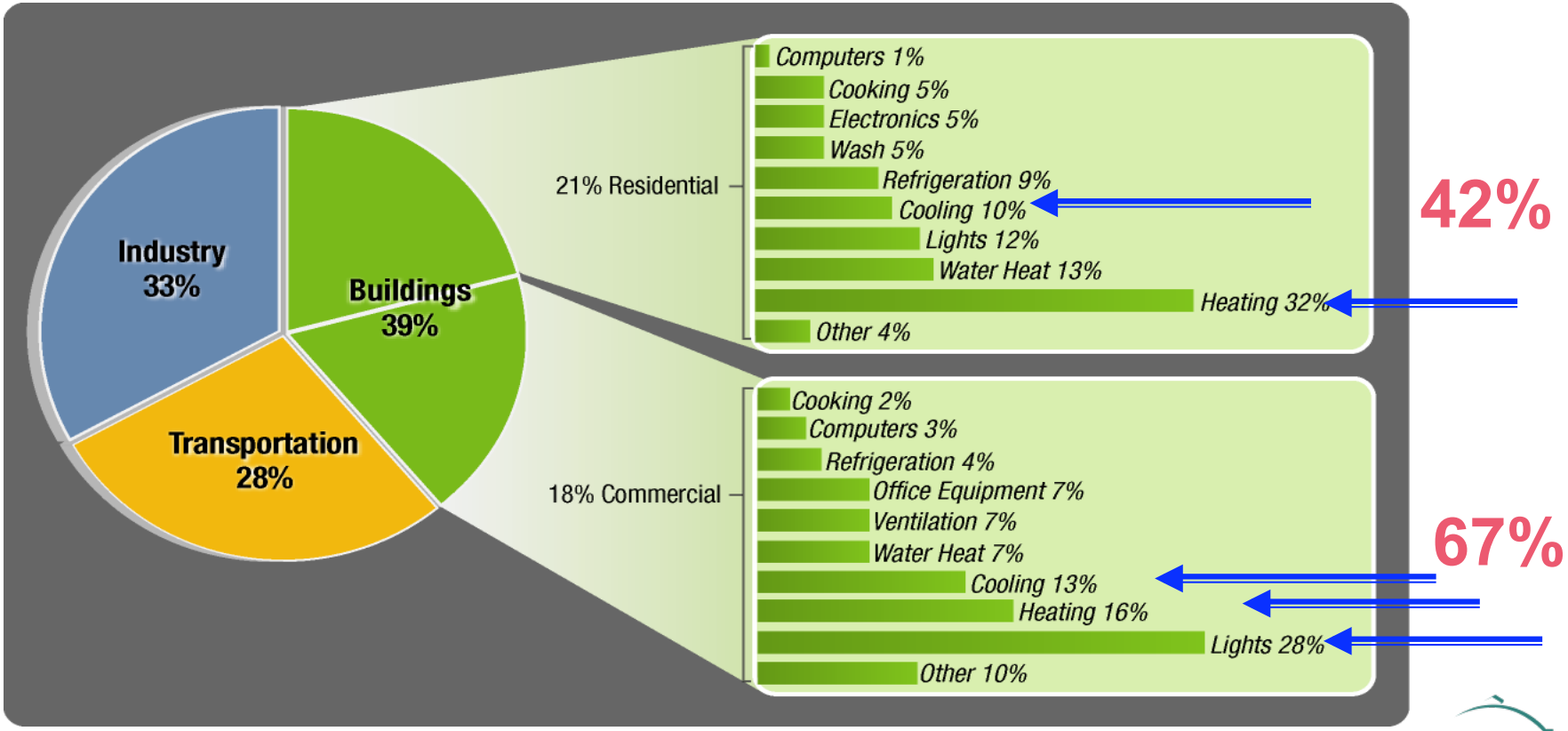
Conclusion: its possible to reduce energy use by >75% and reduce costs!



Fenestration Impacts on Building End Use Energy Consumption

Buildings consume 39% of total U.S. energy

- ***71% of electricity and 54% of natural gas***



Building Innovation "Game Changers" for ZEB

Assumed: cheap, long lasting, reliable, specifiable, affordable, green, ….

MATERIALS AND SYSTEMS

- **Smart Glass/Dynamic Facades**
- **High R Windows, Insulation**
- **Thermal Storage**

- **200 lumen/watt lighting**
- **Daylight integration**
- **Dimming, Addressable Lighting Controls**

- **Task Conditioning HVAC**
- **Climate Integrated HVAC**
- **Building- and Grid- Smart electronics**
- **Electrical Storage**

LIFE-CYCLE OPERATIONS

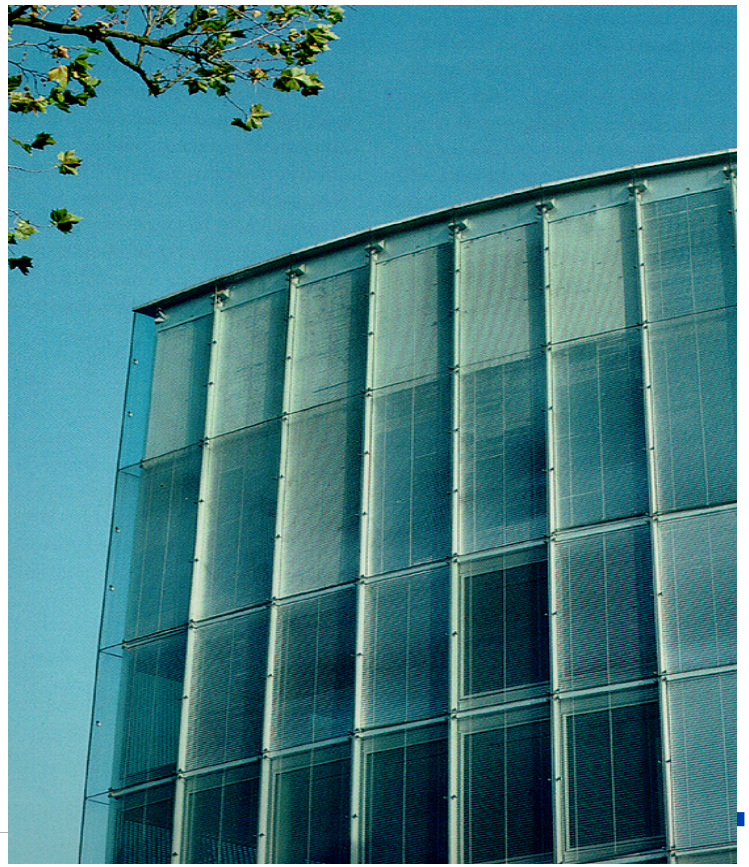
- Building Life Cycle Perspective
- Benchmarks and Metrics
- Building Information Models (BIM)
- Integrated Design Process and Tools
- Building Operating Controls/Platform
- Building Performance Dashboards

- Understanding Occupants
- Facility Operators

Two Contrasting Views of Energy Efficiency

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

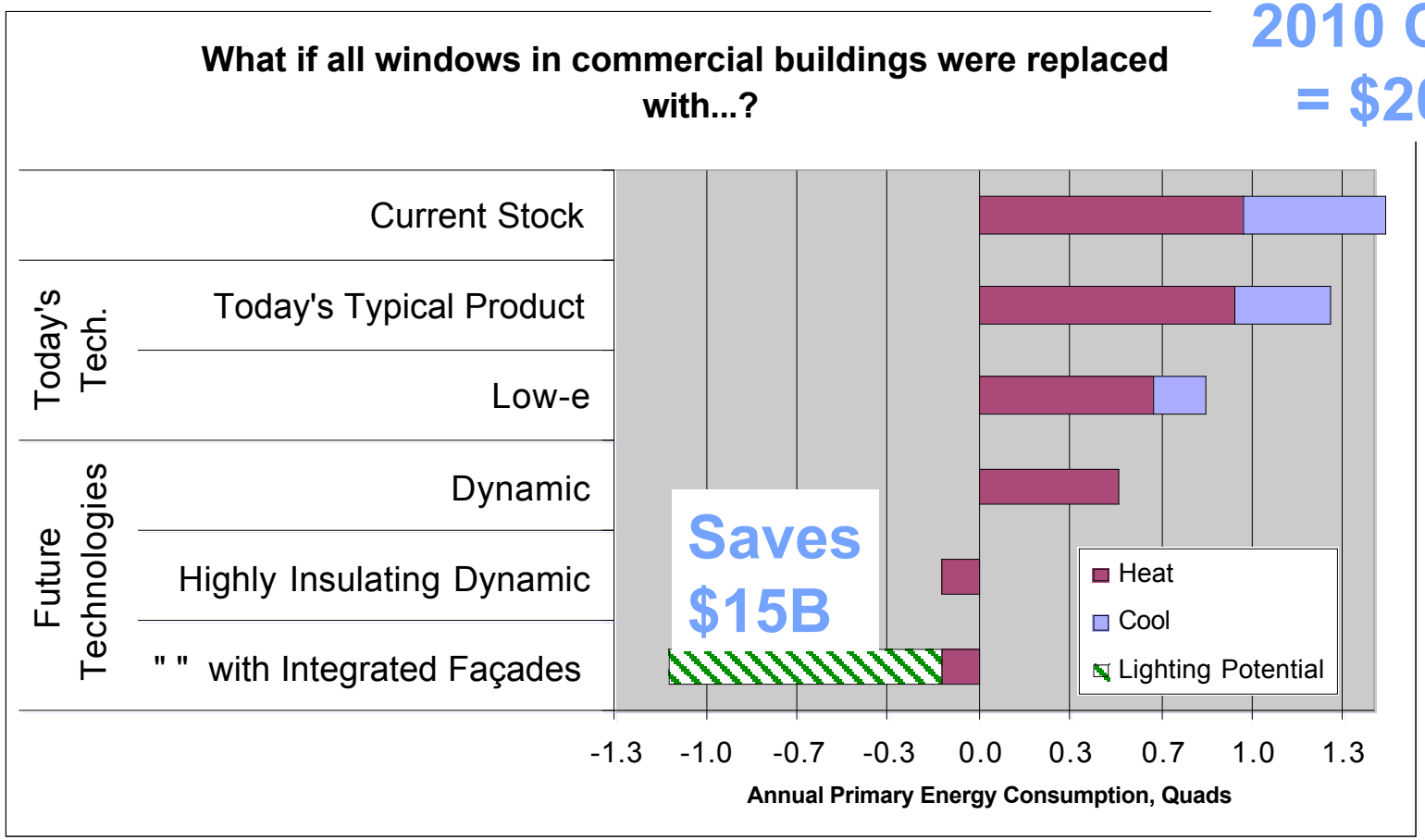
2010 Perspective: Architect's View of the Ideal Windows



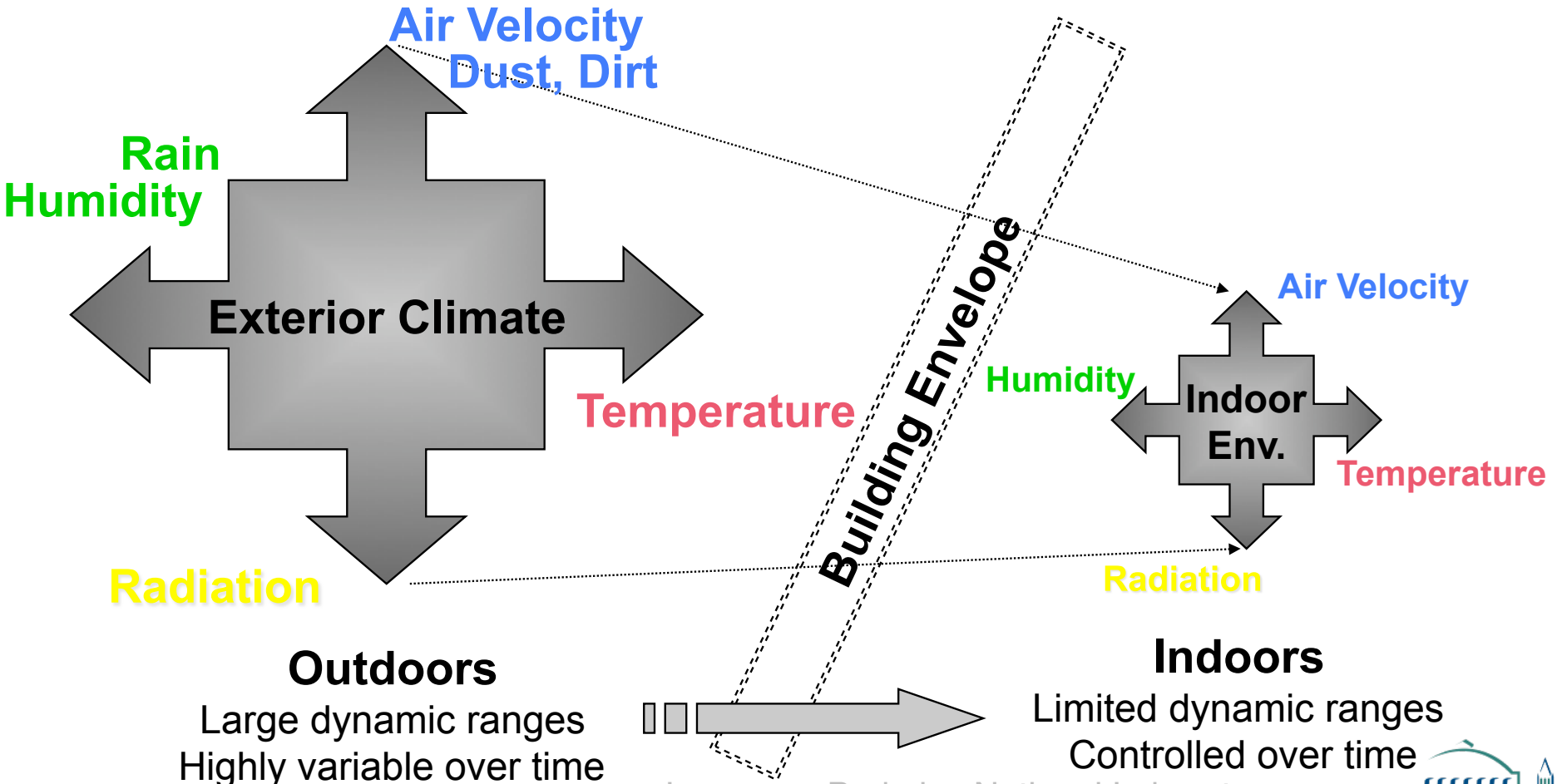
Successes in U.S. Window Markets
(Example: Residential market)

- 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

Commercial Building Window Energy Use



Building Envelope as Dynamic Filter



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

DOE Multiyear Performance Goals

Characteristics	Units	Calendar Year				
		2003 Status	2007 Status	2010 Target	2015 Target	2020 Target
Energy Consumption Improvement*	**Reduction in Window Energy Use**	**Base ENERGY STAR (Low E)**	**20-30%**	**30-40%**	**40-50%**	**40-60%**
1. Dynamic Solar Control	Incremental Price ($/ft^2)	85-100	50	20	8	5
	Size (ft^2)	8	16	20-25	25+	25+
	Visual Transmittance	60 to 4%	60 to 4%	65 to 3%	65 to 2%	65 to 2%
	SHGC	0.50 to 0.10	0.50 to 0.10	0.53 to 0.09	0.53 to 0.09	0.53 to 0.09
	Durability (ASTM Tests)	Medium	High	High	High	High
	Dynamic Response (speed/variable tint)	Slow/on-off	Slow/ On-off	Slow/ On-off	Moderate/ variable	Fast/ variable
2. Highly Insulated Windows	U-Value	0.33-0.50	0.20-0.25	0.17	0.10	0.10
	Incremental Cost ($/ft^2)	IG Base Cost: 3	5	6	4	3
3. Daylight Systems	Lighting Energy Savings	40%	50%	50%	60%	60%
	Perimeter Zone Depth (ft)	12	15	20	20	30
	Incremental Cost ($/ft^2)	3	8	8	6	6
4. Enabling Technology Research for Efficient Products	Tool Capability for Residential (R), Commercial (C) and New Technology (N)	R – Yes C – No N – No	R – Fully C – Partial N – No	R – Fully C – Partial N – Partial	Assess need for industry support	Assess need for industry support

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

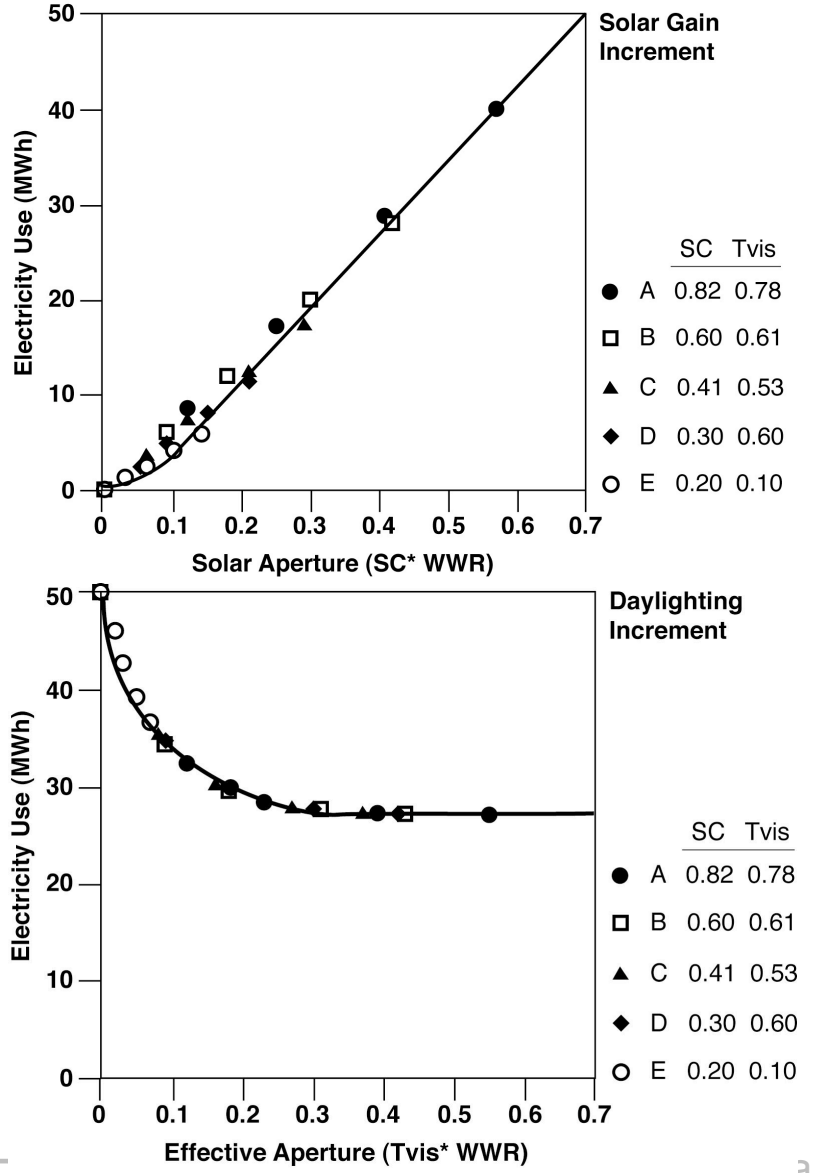
Annual Source Energy Use

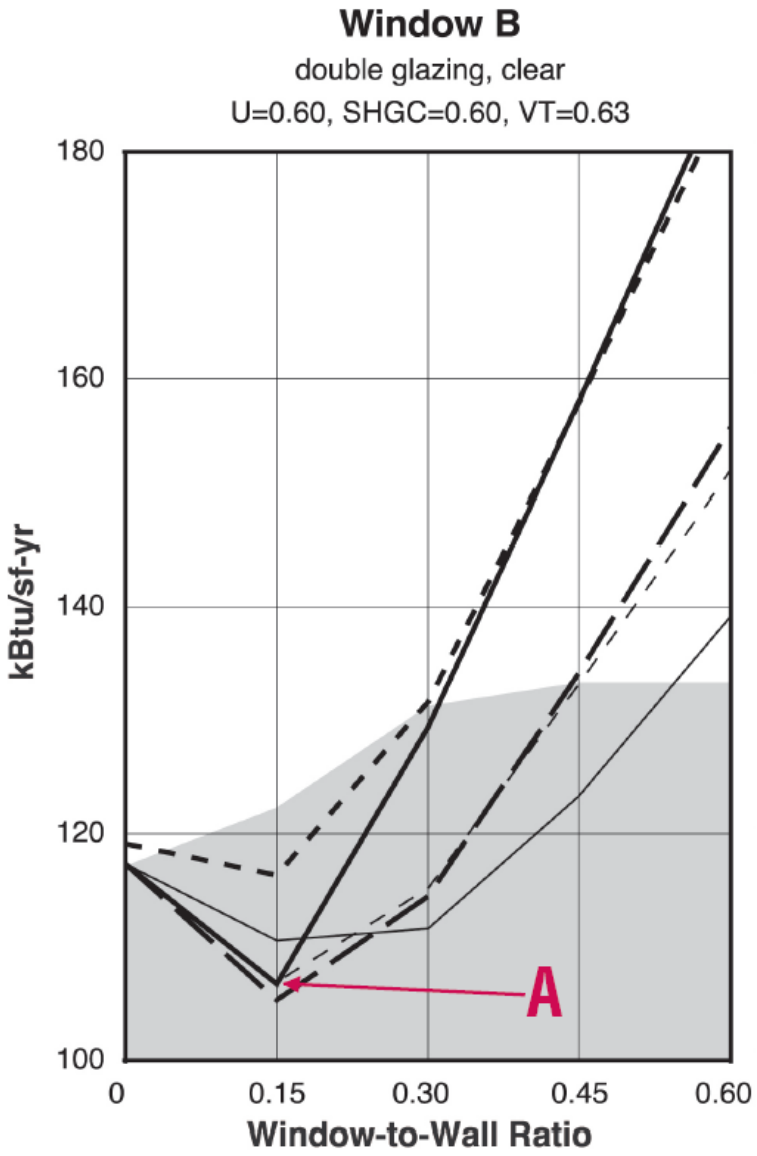
Upper:

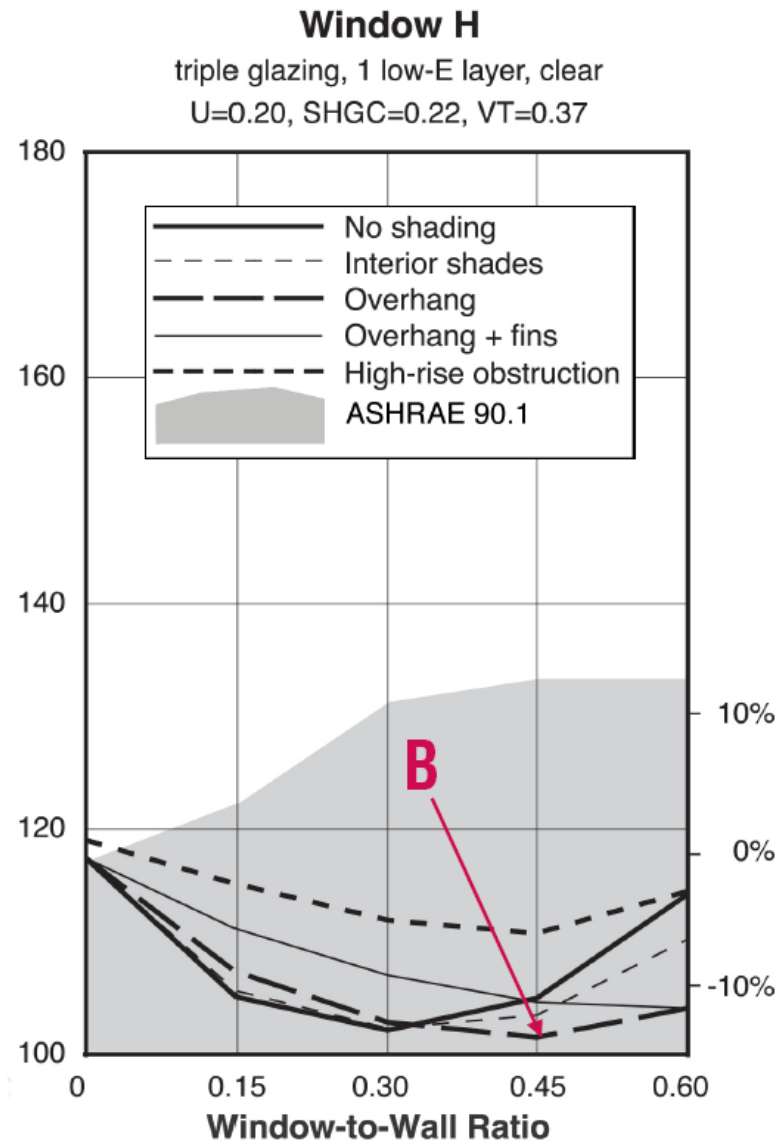
Cooling Energy vs. Solar Aperture

Lower:

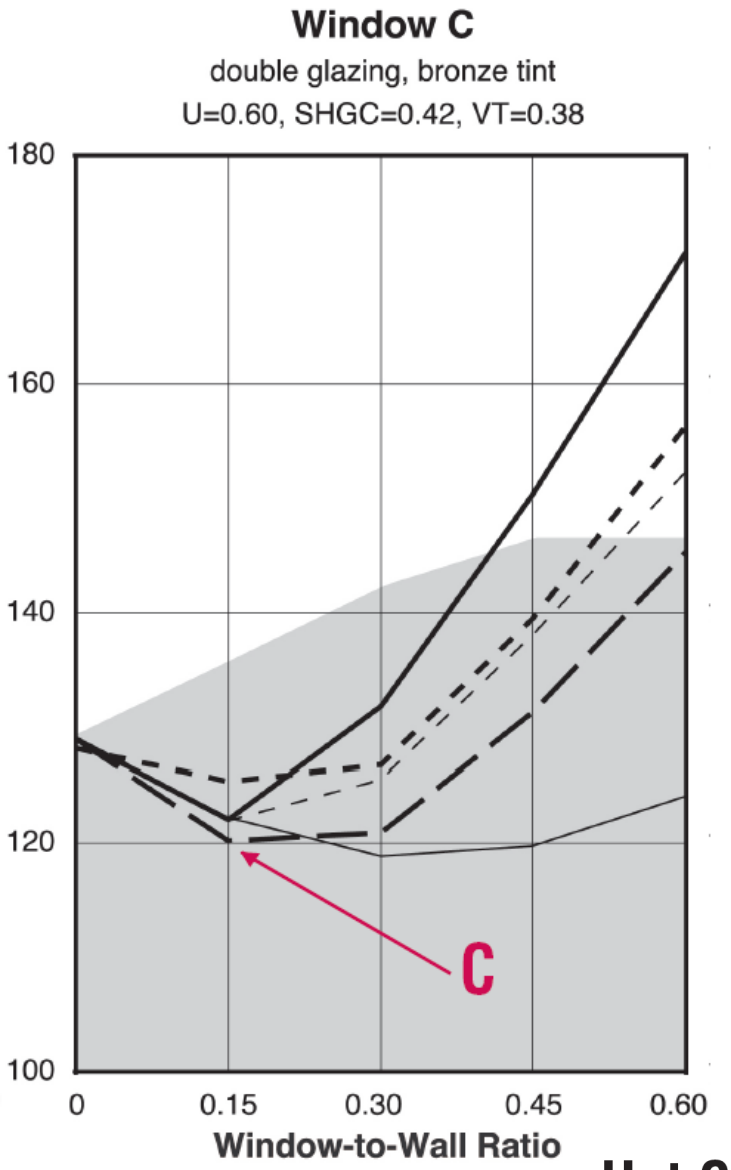
Lighting Energy vs. Effective Aperture

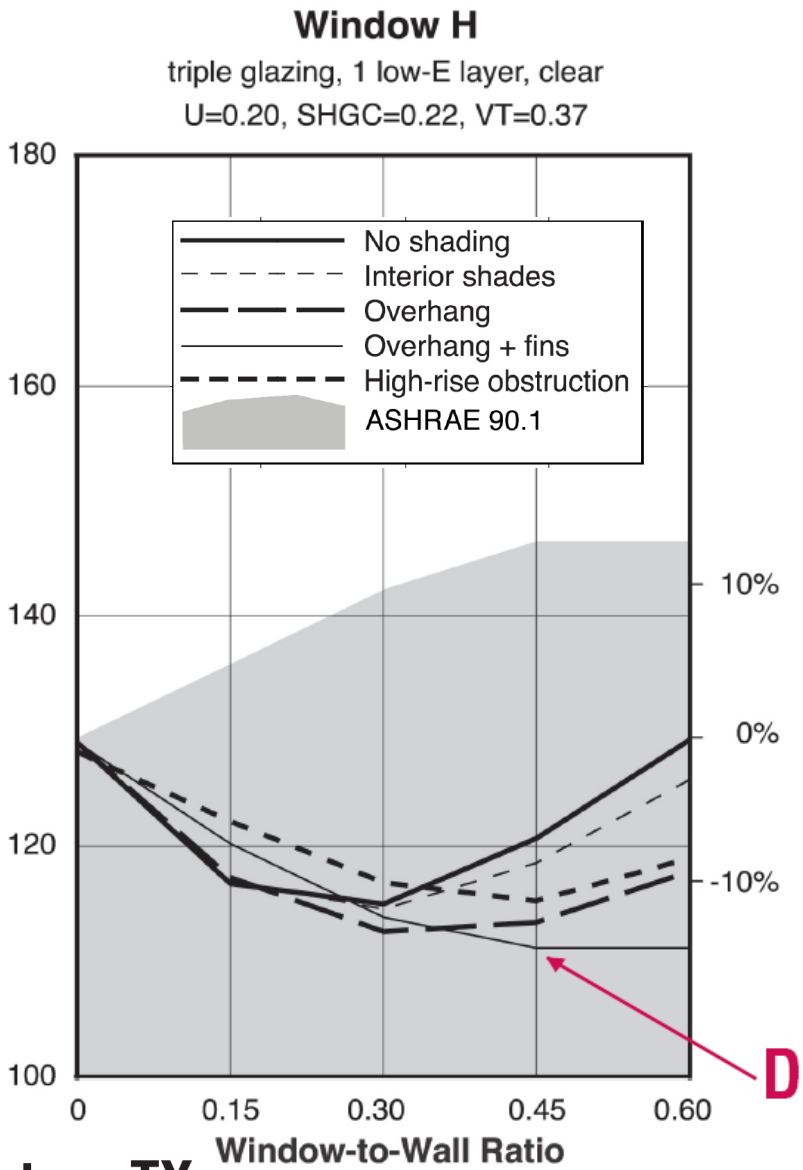






Cold Climates: Chicago, IL



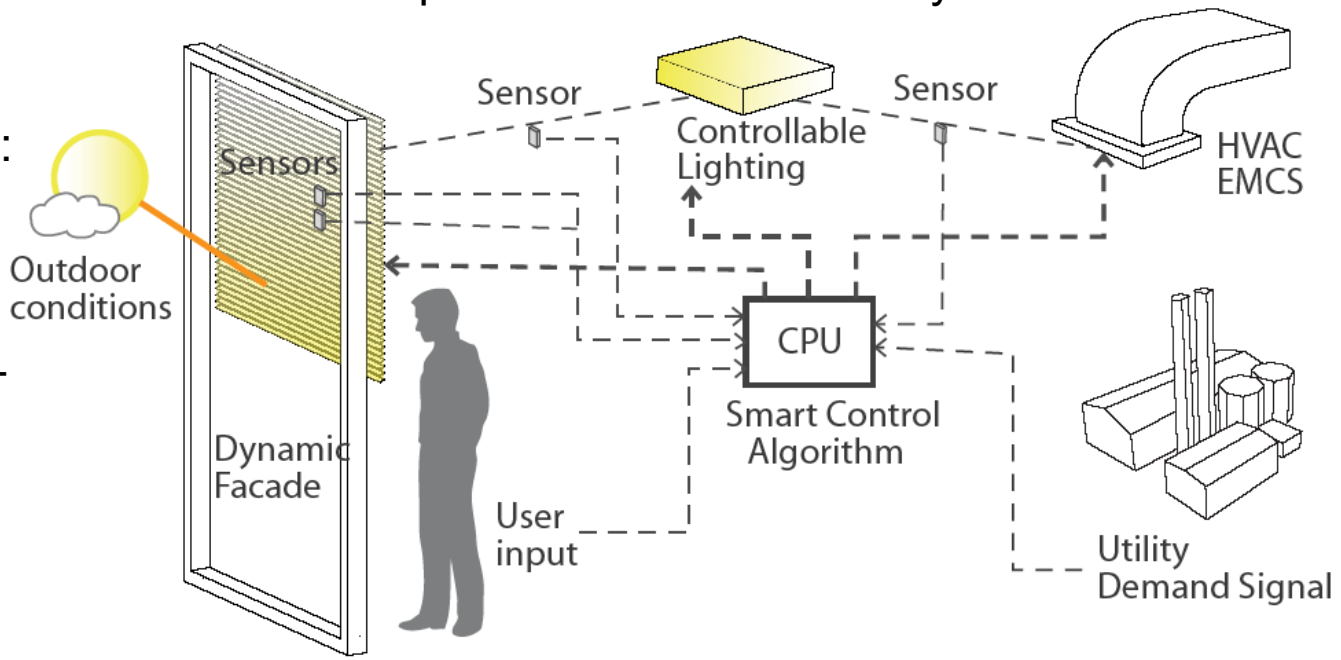


Hot Climates: Houston, TX

Definition of a "Smart", "Dynamic" Building Skin

Interior or exterior **sensors** that measure relevant quantities that are used by the controller

Operable façade components: Motors or actuators for shading devices, light-redirecting elements, operable windows, or switchable glass coatings



Control algorithms: Accepts input from sensors or computations then determines how to position the operable façade components

Challenges!

Glass is “cheap” and “robust”

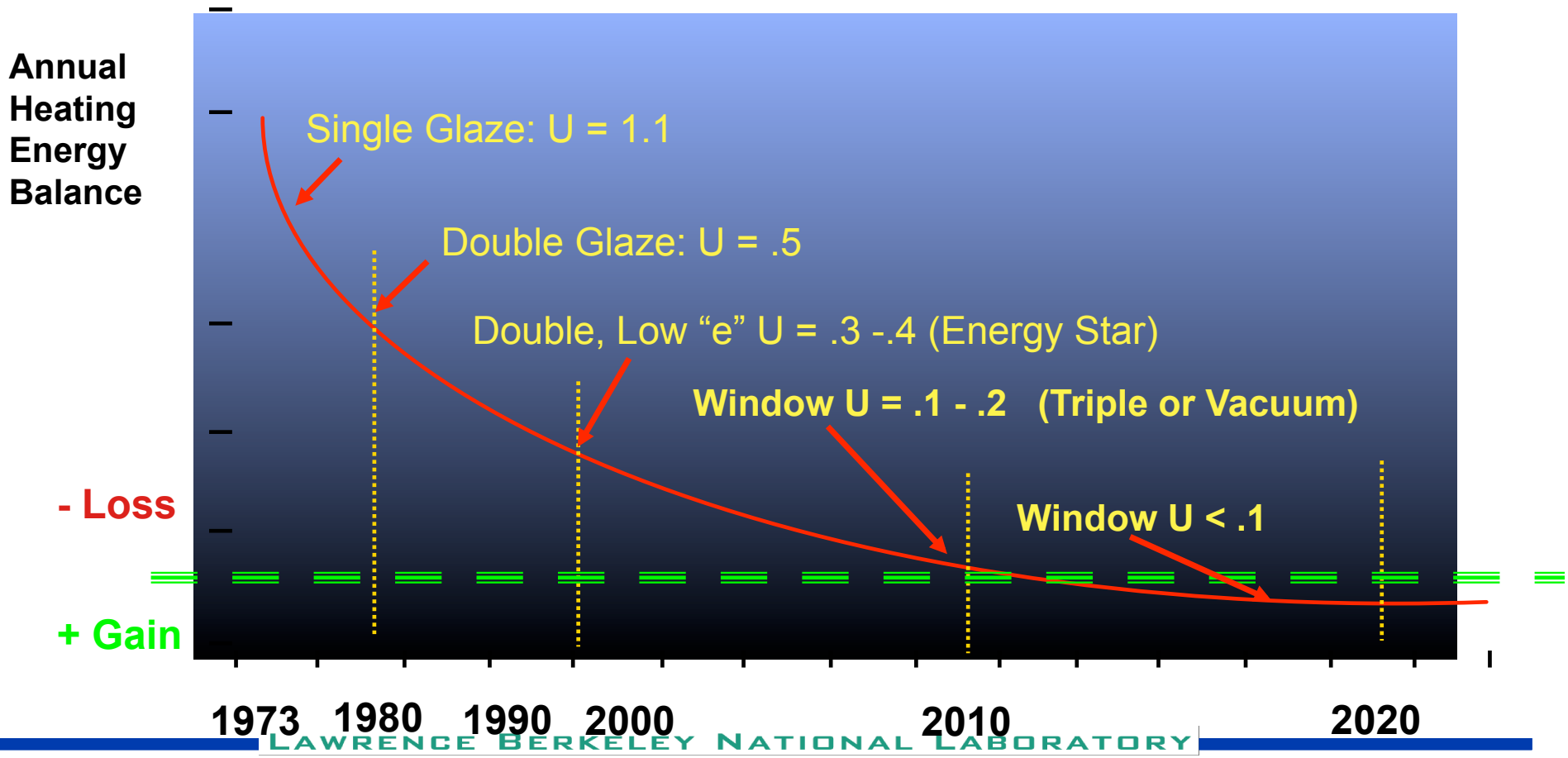
Dynamic Building Skin Issues:

- Complexity
  - Design
  - Installation
  - Operations
- Cost
  - $$
- Robustness, Reliability
  - Routine change, e.g. aging component
  - Unexpected change, e.g. sensor failure

"Evolution" of Advanced Windows

- **Highly insulating systems**
  - Reduces winter heating loads
  - Multiple technologies for glass
    - Aerogel
    - Vacuum glazing
    - Multipane, low-E gas fill
  - Better Frames
  - Climate dependence
  - Cost
- **Dynamic windows for daylight - solar control**
  - Dynamic optical switch from high transmission to low transmission
  - Reduces summer cooling load; reduces glare
  - Multiple technologies
    - Electrochromic, thermochromic, photochromic, LCD,…
  - Integration with window, building
  - Cost
- **Air Flow/Ventilation Control**
  - HVAC/Cooling
  - Comfort

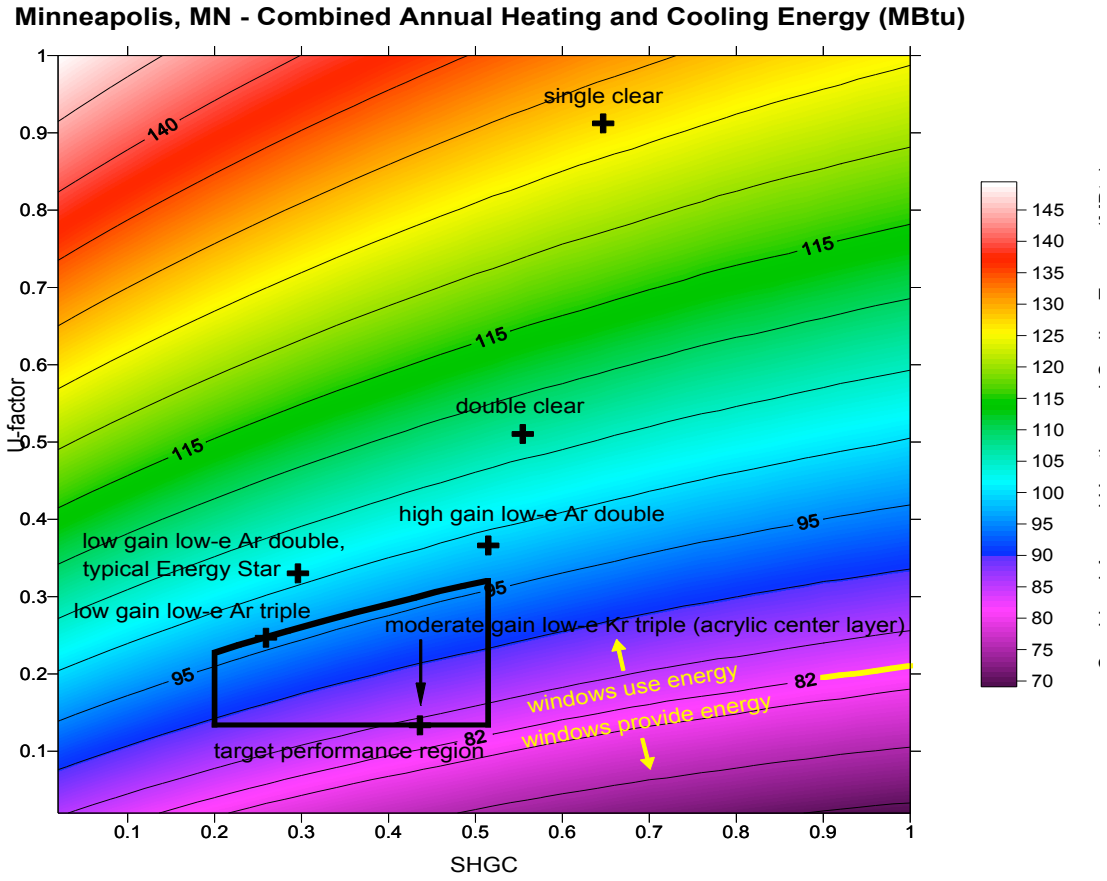
Insulating Windows Can Become Energy Producers in Cold Climates



Minneapolis: Heating Climates:

static high solar, hi-R (U=0.1 Btu/h-ft2-F) can meet ZEH goals

Annual energy use vs. window properties



U

SHGC

Residential Energy Use (MBTU/yr) vs Window Thermal Properties (U, SHGC)

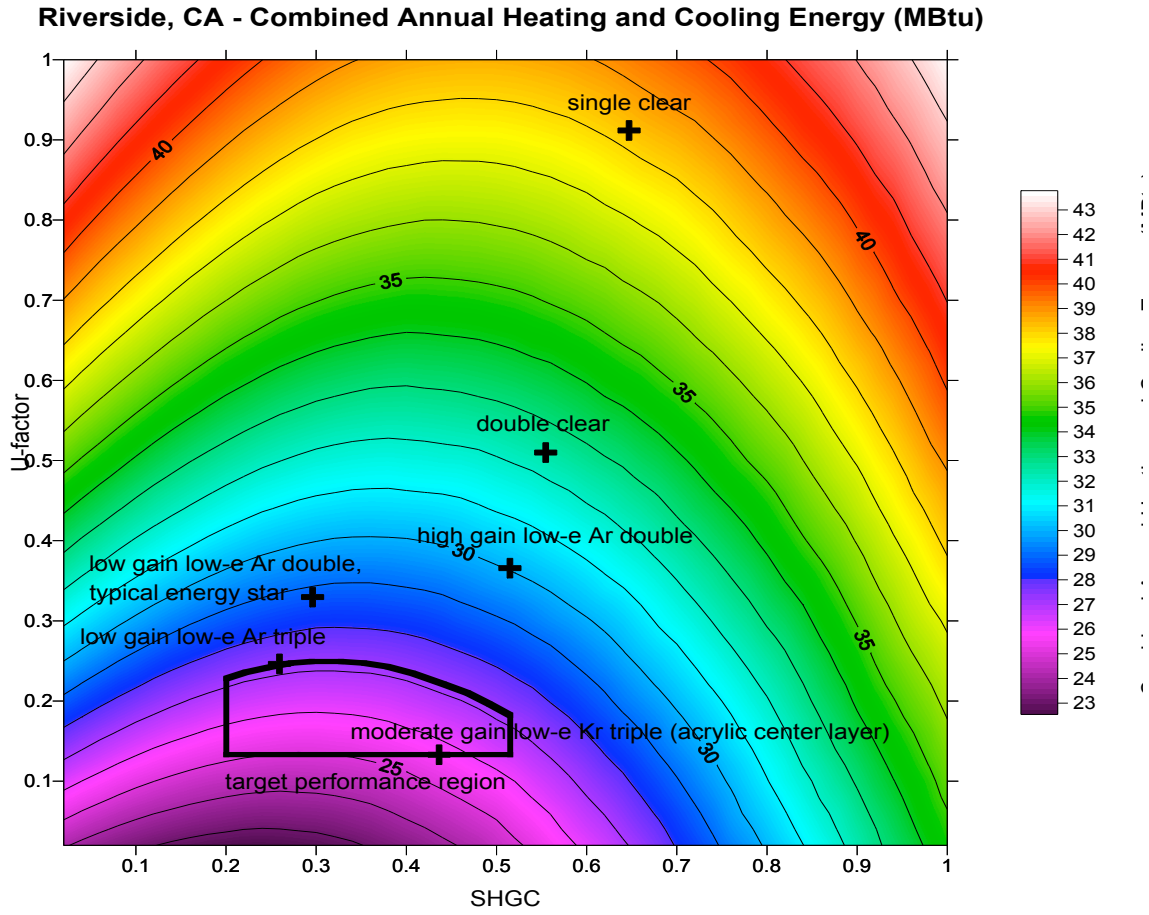
Specific windows plotted on map of iso-energy use

House with no windows uses 82MBTU

Riverside CA - Mixed Climates:

static medium solar, hi-R (U=0.1 Btu/h-ft2-F) can meet ZEH goals

Annual energy use vs. window properties



U

SHGC

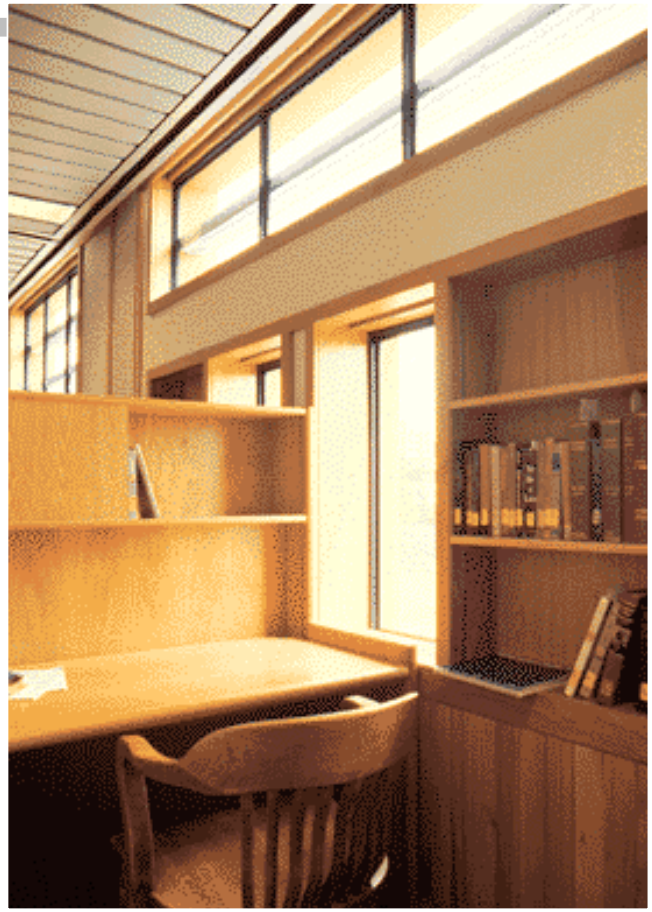
Residential Energy Use (MBTU/yr) vs Window Thermal Properties (U, SHGC)

Specific windows plotted on map of iso-energy use

Daylighting

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

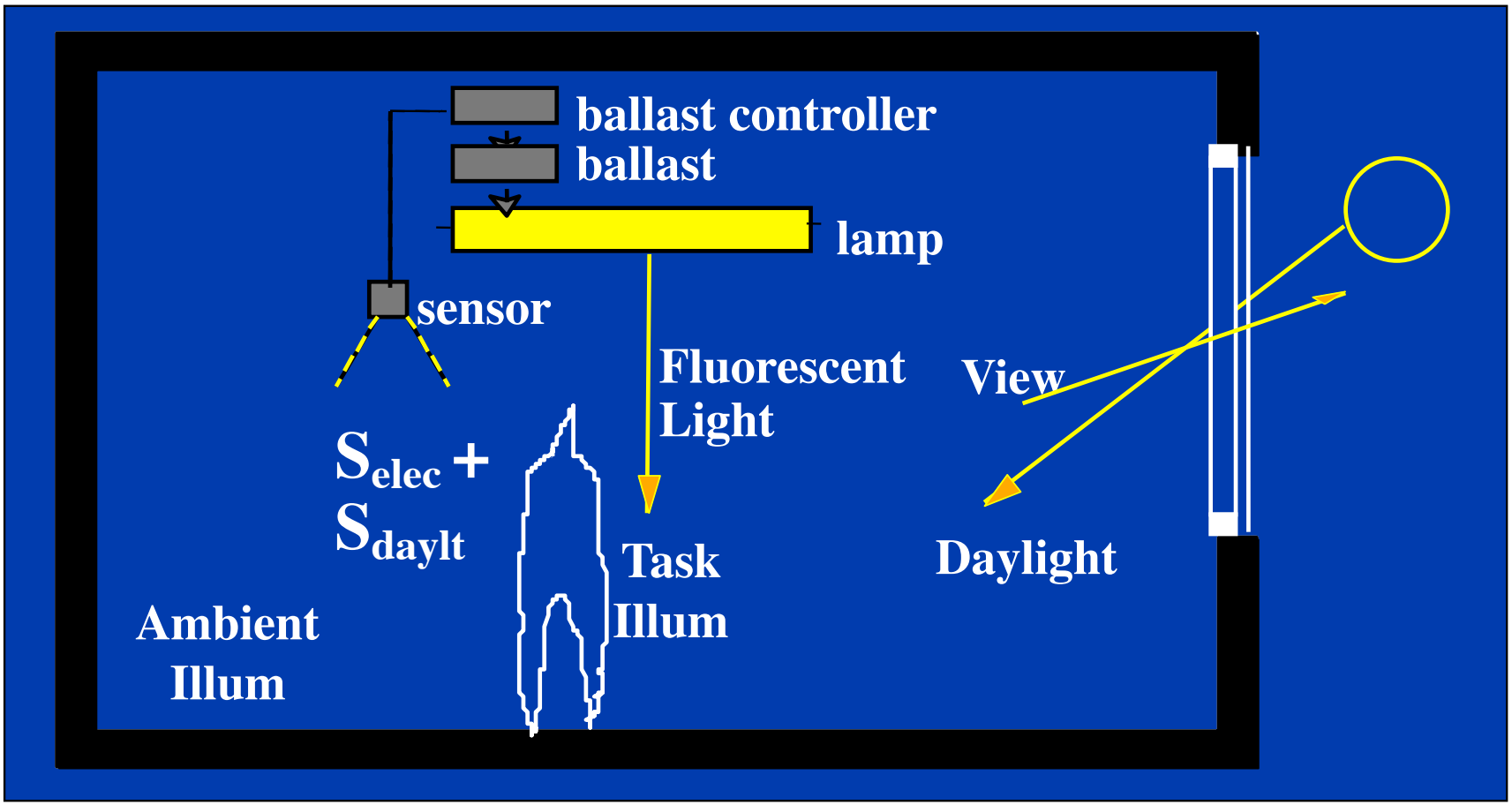
- Architectural strategies
- Light-redirecting technologies
- Energy savings strategies



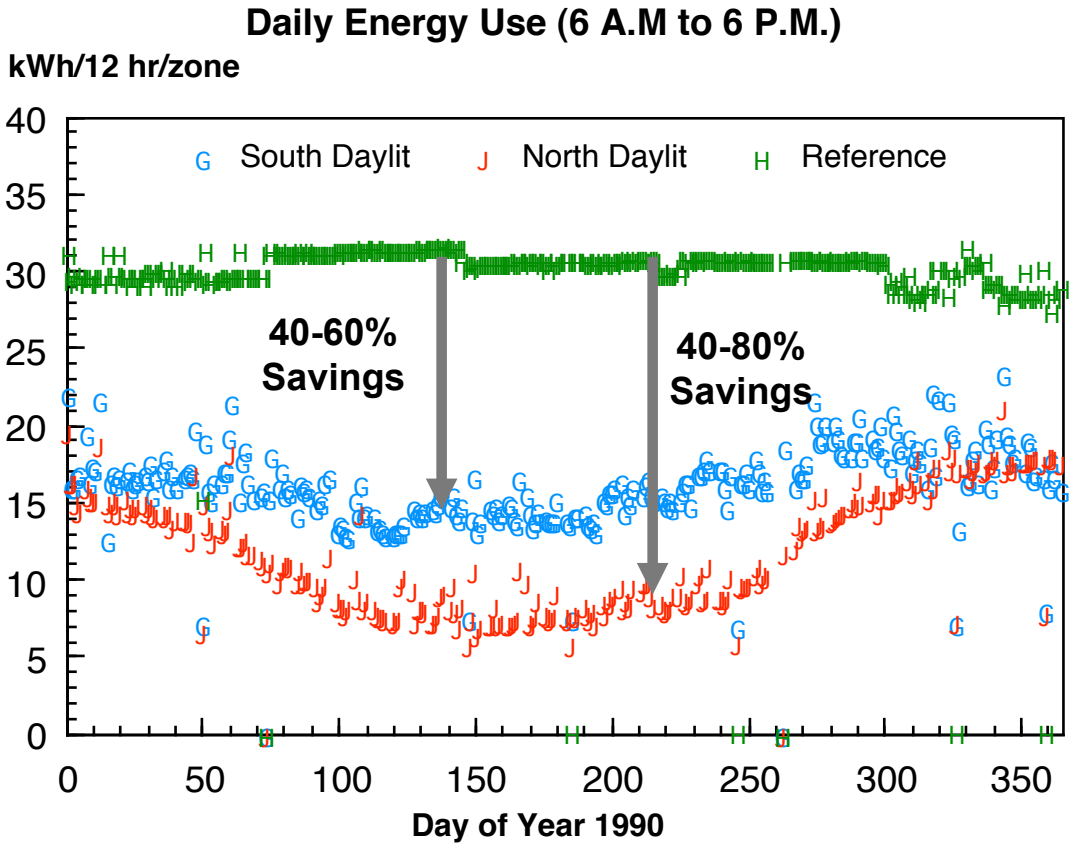
GTU Library, UC Berkeley

(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

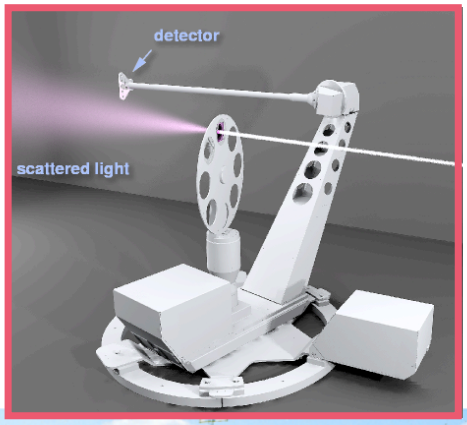
“In God We Trust”,
All Others Bring Data

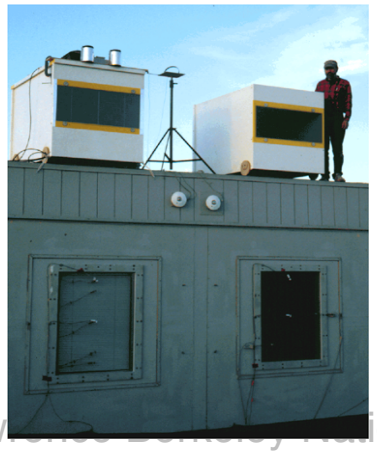
An understanding of what to do in the future should be built on a foundation what works and how well, either based on, or derived from, measured performance. Design intent, expectations, and wishful thinking will not reduce energy and carbon use

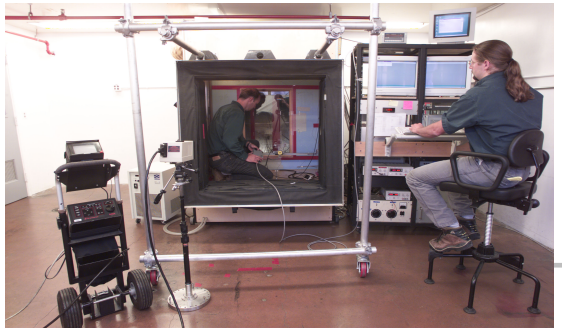
LBNL Glazing/Shading "User Facilities"

- **Façade test facility/testbed**
- 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
- Lighting controls laboratory







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

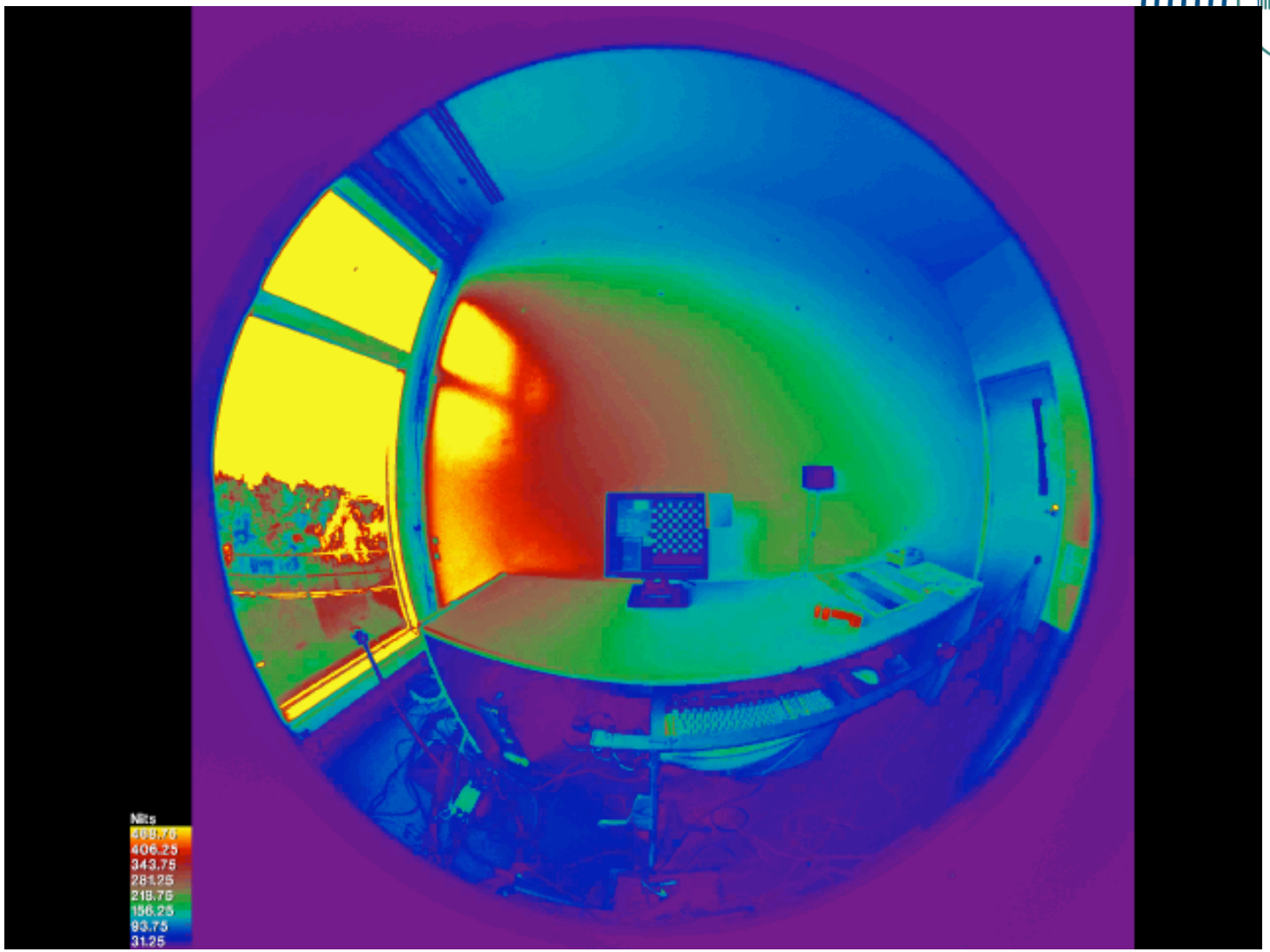
Utilities

2007-2009

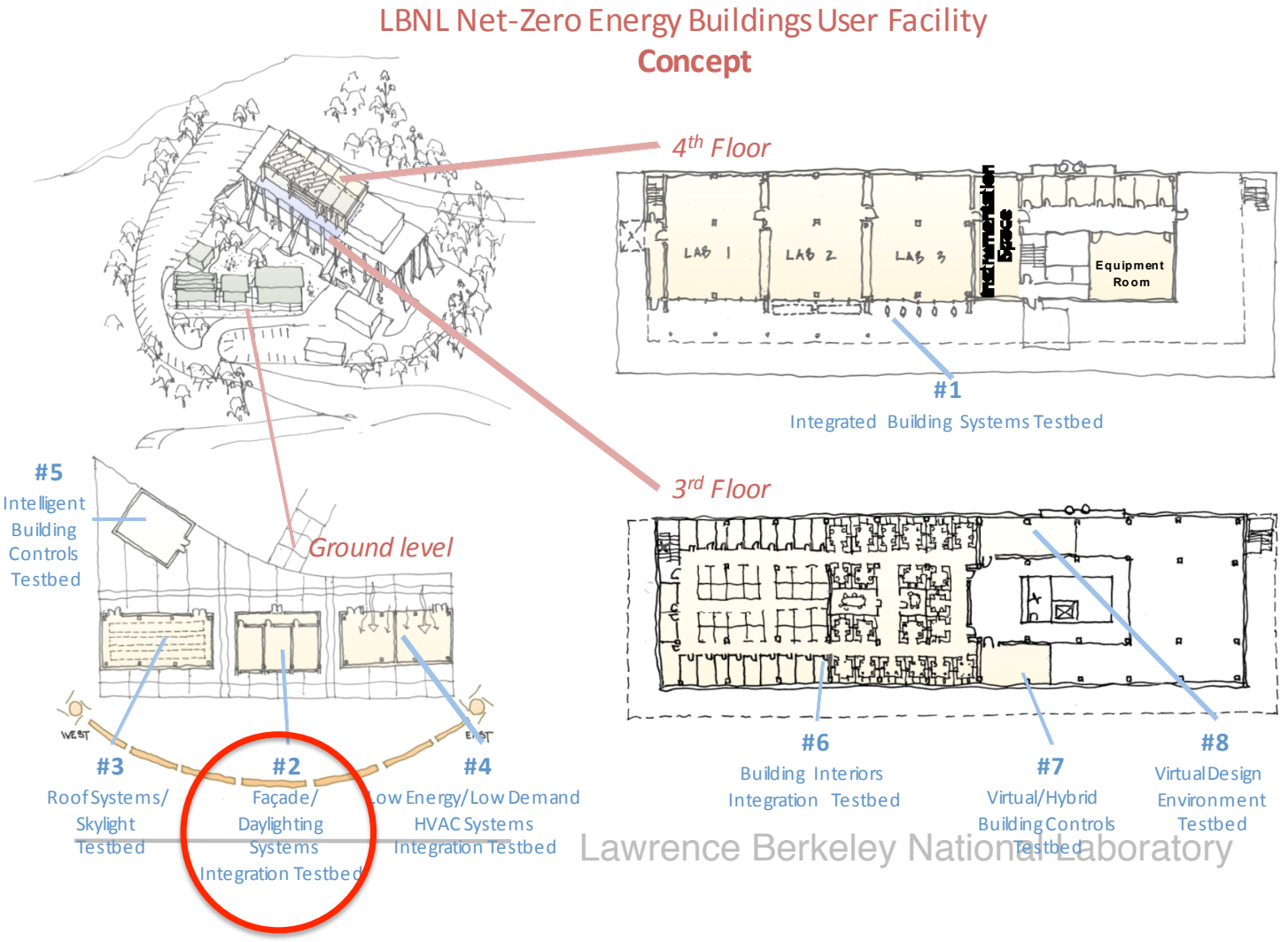
Automated Shades w/ daylighting

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

Time Lapse of Interior Room Luminance with Dynamic Shading



LBNL Integrated Building Systems User Facility
6 New Testbeds under Development

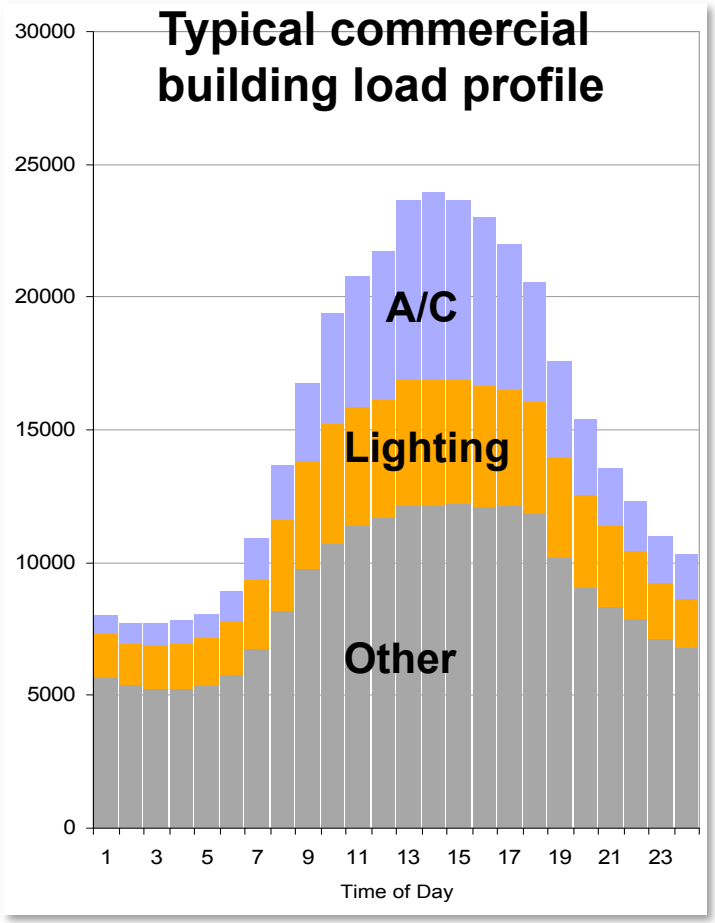


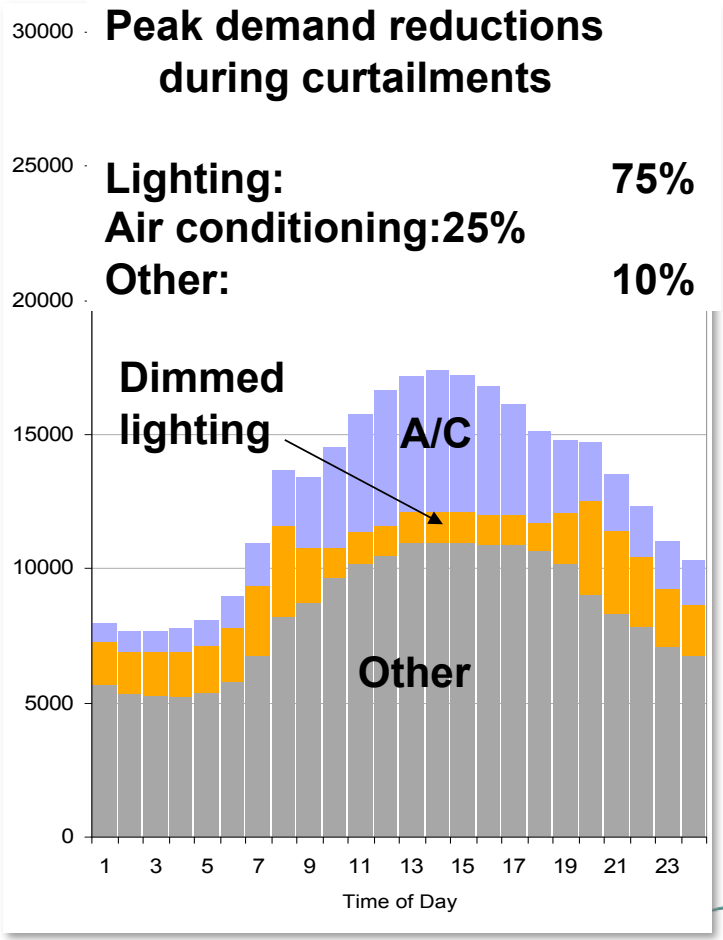
Pilot Demonstration: Emerging Integrated System

- Site: conference room in DOE building; retrofit
- Monitoring underway
- Separate control of view and daylight

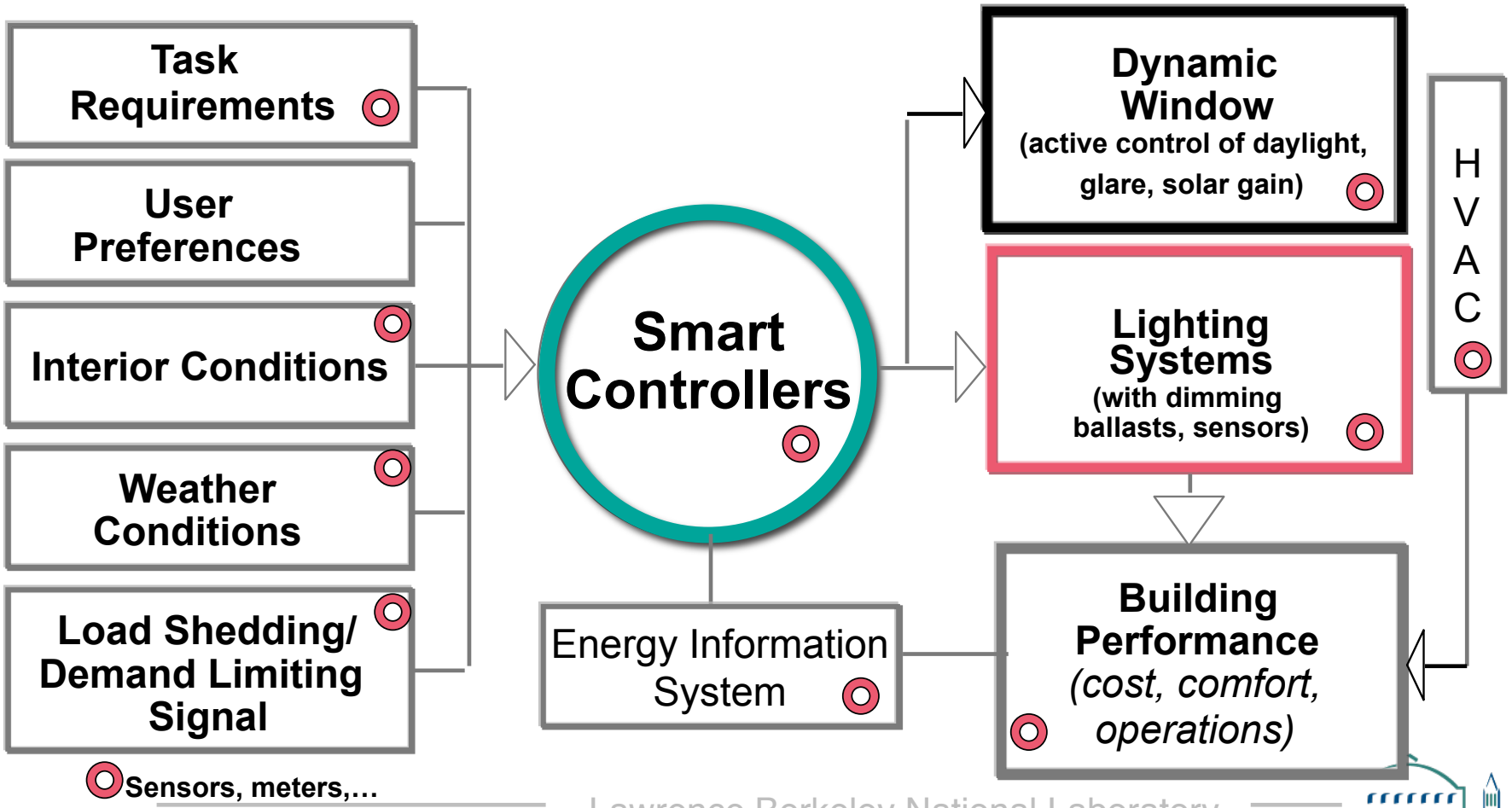
- Electrochromic Windows:
  - Automated control
  - Manual override
- Lighting controls:
  - DALI dimmable ballasts
  - Architectural scenes, occupancy, daylight controls

Managing glazing and lighting for Electric Load Management





Exploring Intelligent Control Systems



Building Controls Virtual Testbed (BCVTB)

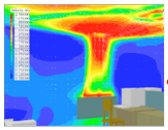
Open-source middle-ware based on UC Berkeley's Ptolemy II program.

Synchronizes and exchanges data as (simulation-)time progresses.

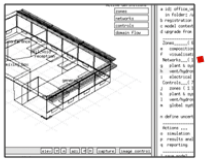
implemented
funded
in proposal
in discussion

building energy
TRNSYS

airflow
Fluent



building energy
ESP-r

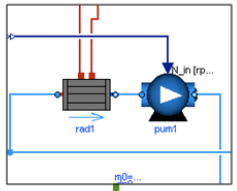


hardware in
the loop

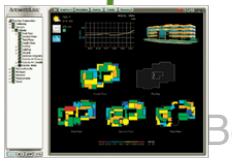
building energy
EnergyPlus

fenestration
Window 6

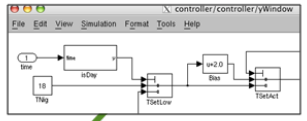
HVAC & controls
Modelica

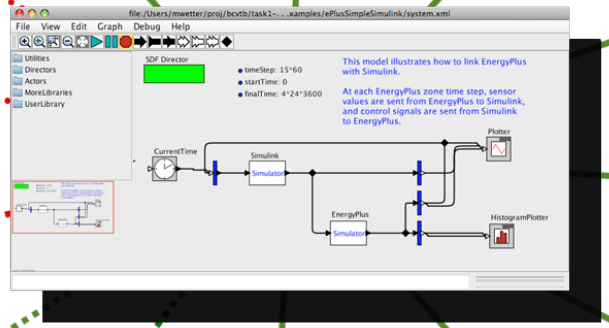


building automation
BACnet



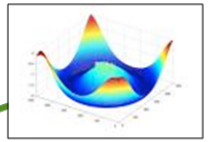
controls
Simulink





lighting
Radiance

controls & data analysis
MATLAB



wireless networks
Ptolemy II

real-time data
www+xml

"Natural Ventilation Cooling System" New GSA SF Federal Building

Active Fenestration Control is key to Cooling Strategy

Morphosis/Arup design/GSA Owner

Outcome: **"Class A" office building;**

- **Comfortable work environment**
- **First cost savings, operating savings**
- **Key: quantify performance and risk**

Status: **Occupied 2007**

Extensive Energy design assessment

- **Extensive climate, energy modeling**
- **Comfort analysis under peak conditions**
- **CFD modeling for air flow details**

— ***Orientation, section, plan optimized***

— ***Automated operable windows and night vent cooling***

— ***Exposed concrete ceiling stores "coolth"***

— ***No mechanical cooling for perimeter offices in tower***

—Control system development, testing

—Commissioning process developed

—Post-occupancy evaluations planned

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

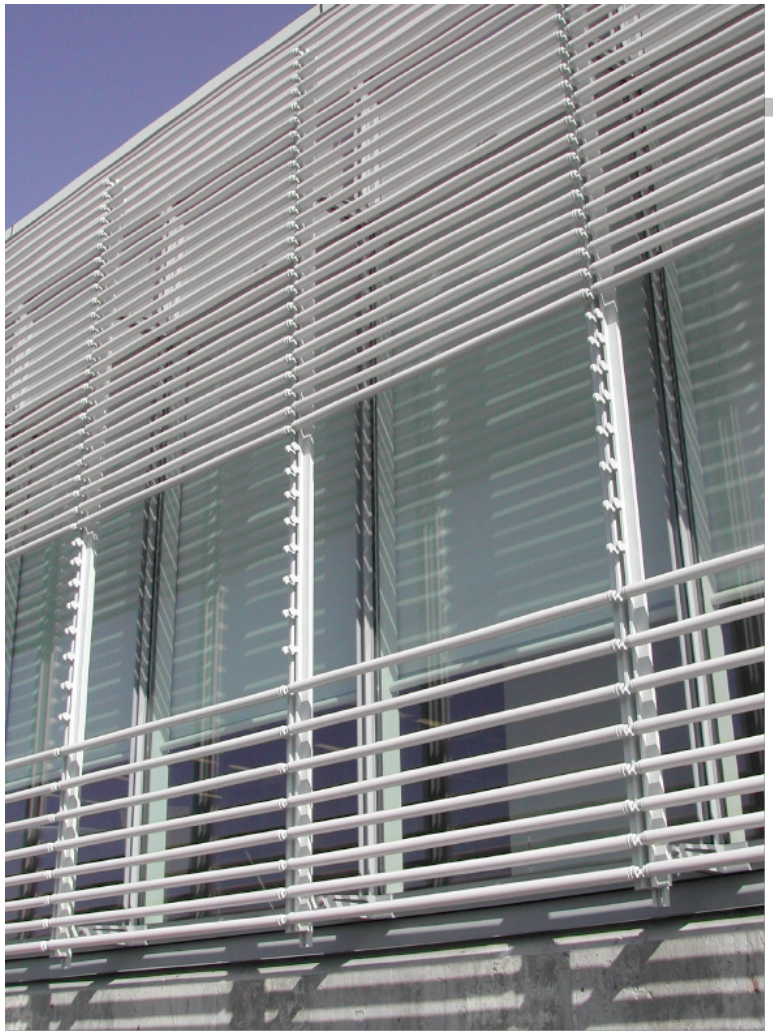
Need/Goal:

- 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

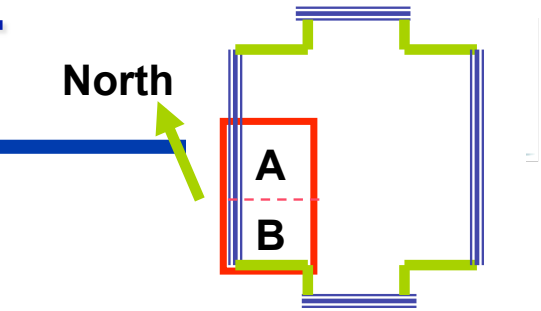
-- Frit - solar, glare control

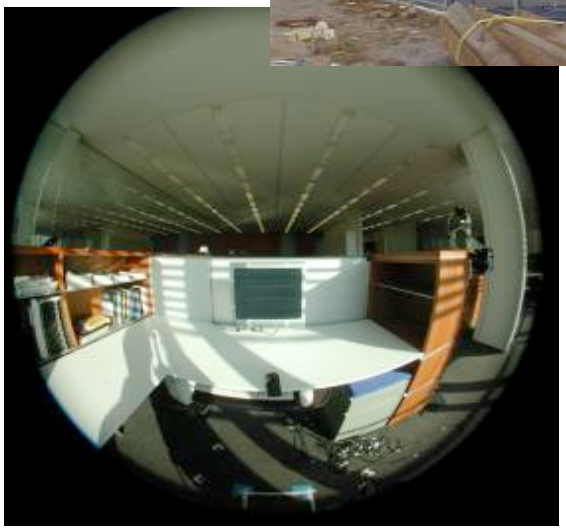
Internal layer: Dynamic
-- Motorized Shade system
-- Solar control
-- Glare control

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 sf 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**





Intelligent Lighting and Shade Control

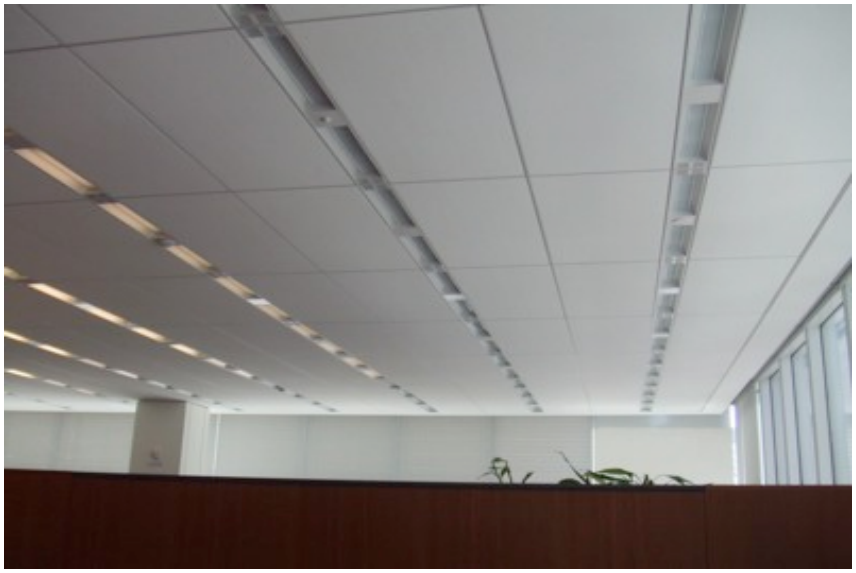
- Automated Shaded
- (Multifunctional)

Occupied 2007

- Dimmable lighting
- Addressable
- (Affordable)

(1/3 original cost estimate)

- (Multifunctional)



New York Times office with dimmable lights and automated shading

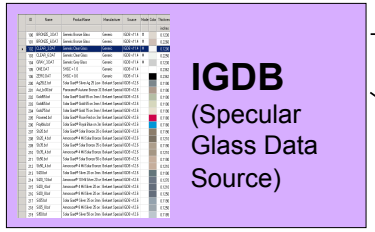
High Performance Windows need Skilled Architects & Engineers

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

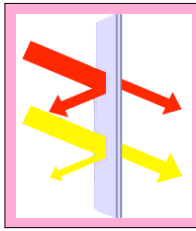
- Other impacts:
  - Specification
  - Construction
  - Commissioning and Acceptance
  - Occupant training
  - Facility manager training

Software Tools

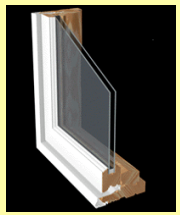
Download from http://windows.lbl.gov/software/



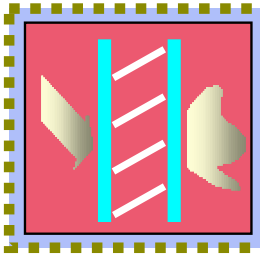
IGDB
(Specular Glass Data Source)



Optics
(Window Glass)



THERM
(Window Frame)



CGDB
(Complex Glazing Data Base)

WINDOW
(Whole Window)

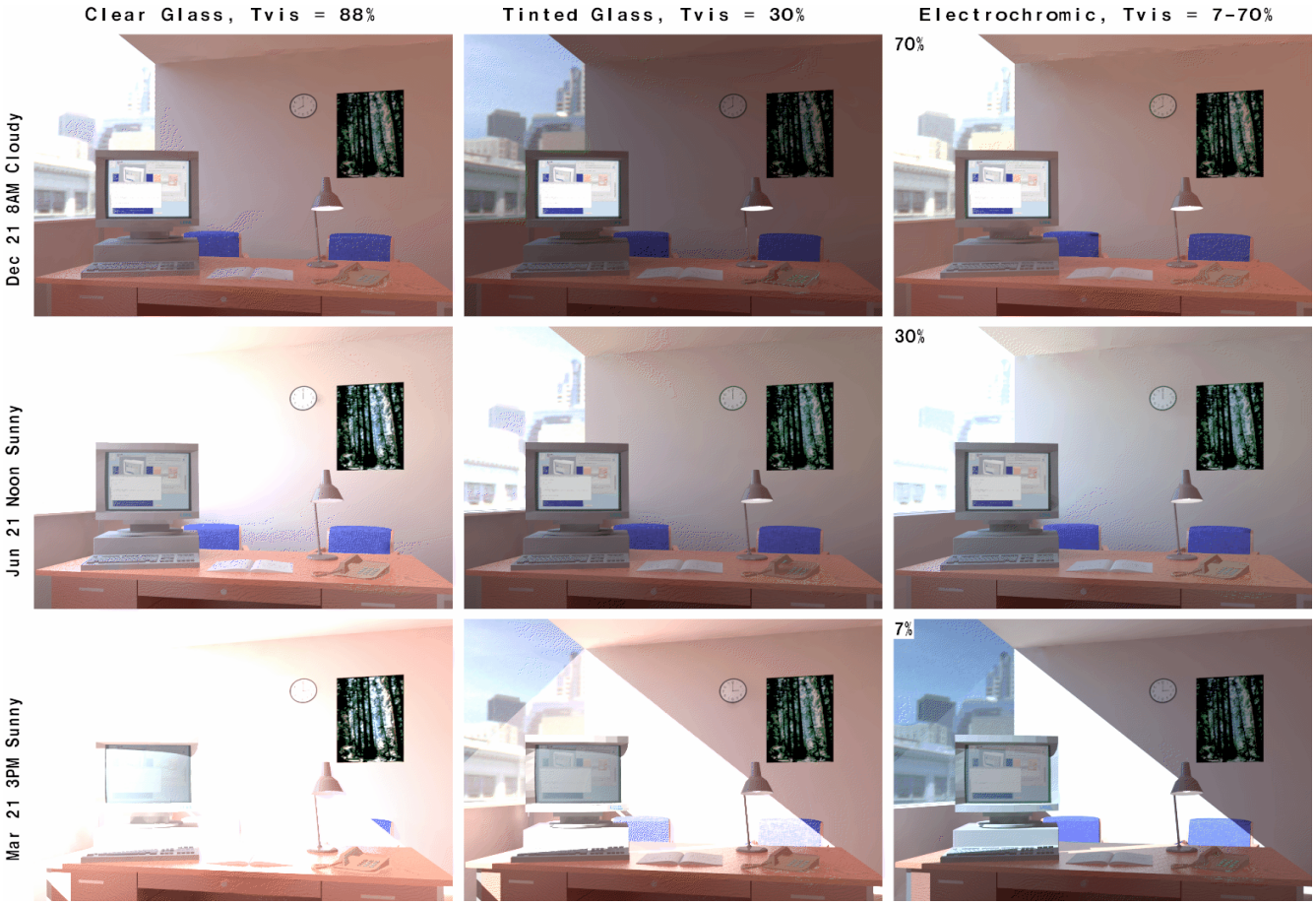
NFRC Ratings and Labels

Design / Simulation Tools
DOE-2, EnergyPlus
Radiance

COMFEN
(Whole Building Commercial)

RESFEN
(Whole Building Residential)

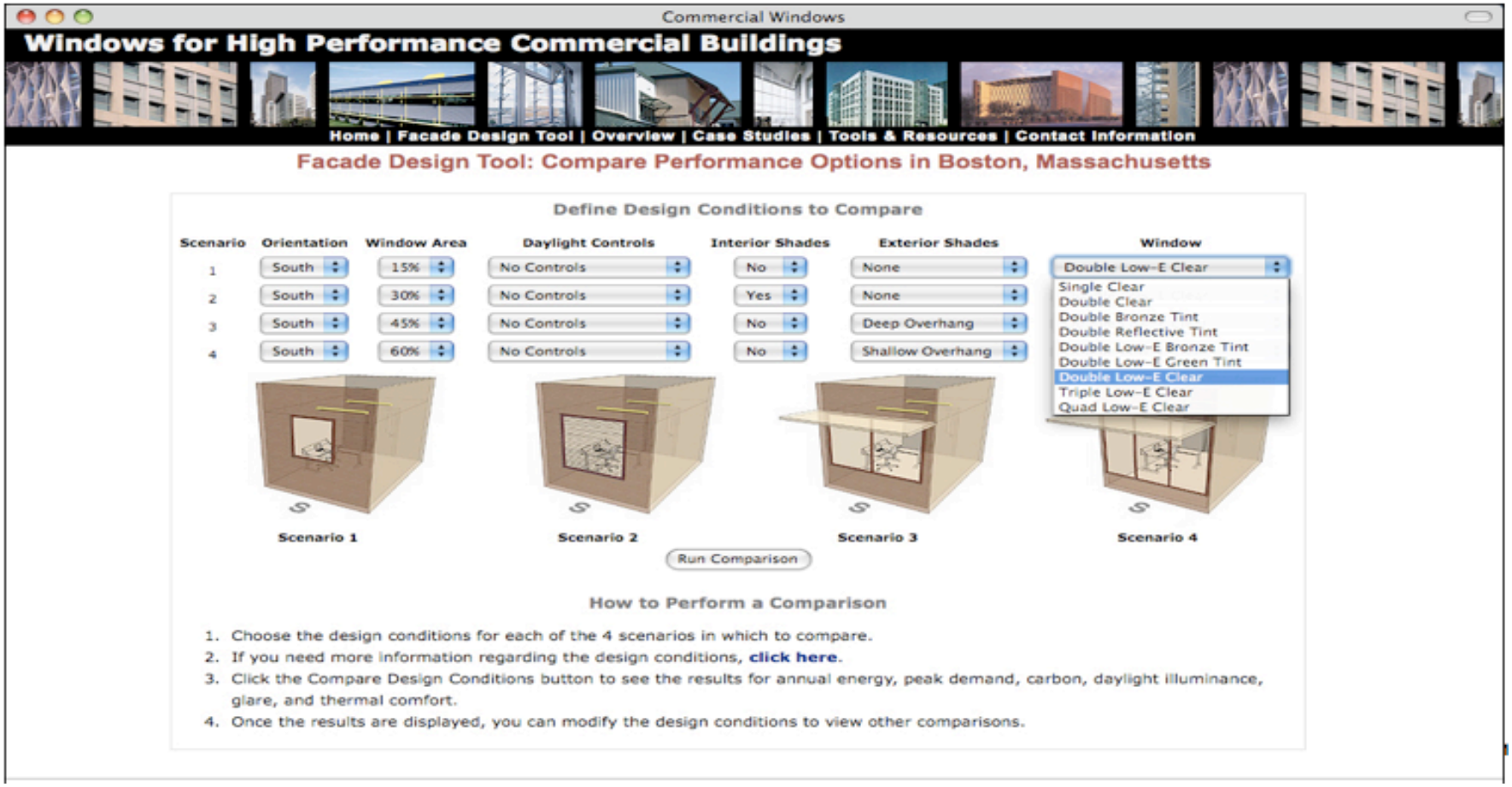
Modeling Visual Performance and Comfort



RADIANCE simulation of conventional and electrochromic windows for different day types and seasons in Phoenix, Arizona.

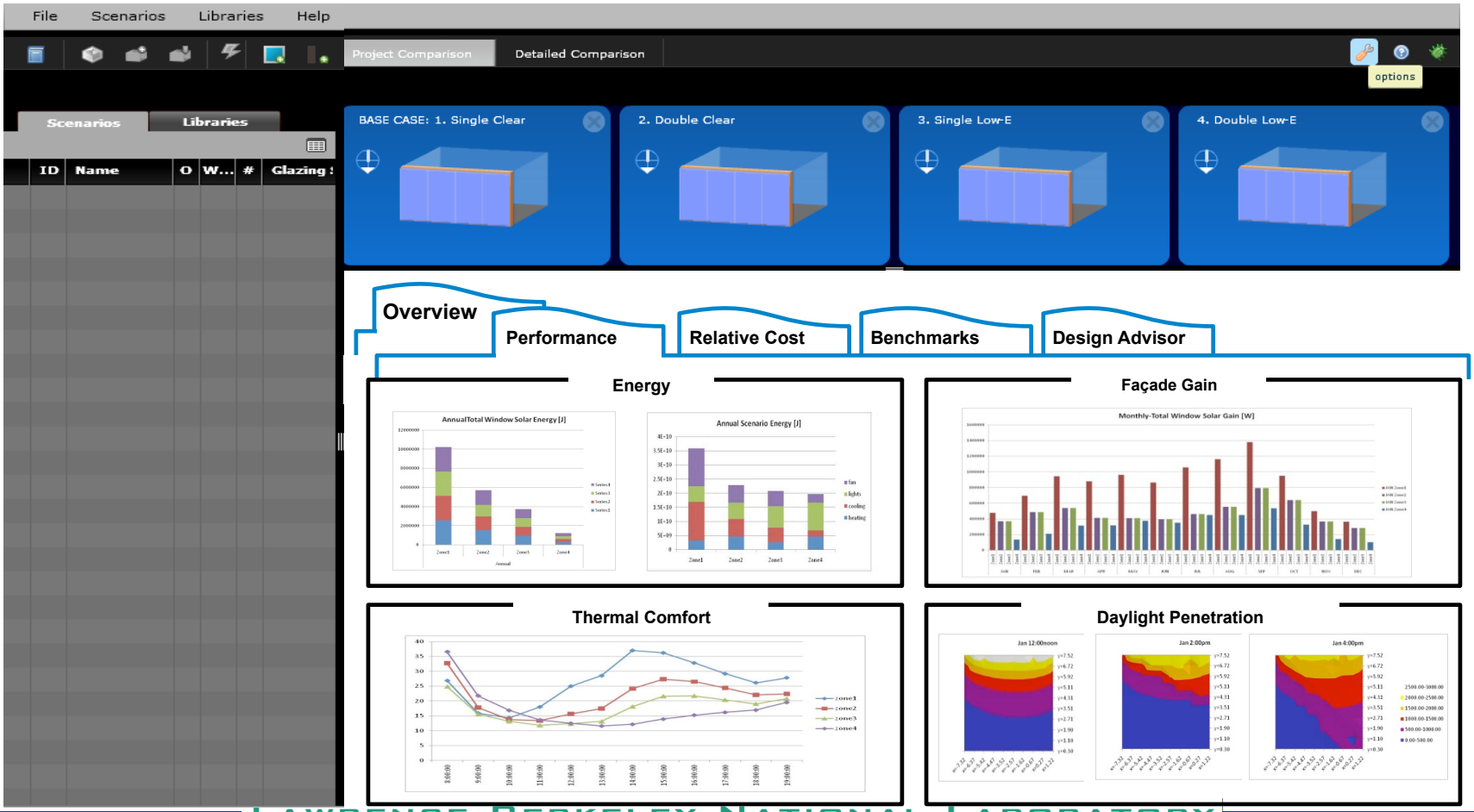
Façade Design Tool

http://www.commercialwindows.org



COMFEN: Estimating Energy and Daylighting Impacts in Early Design

Sample Output



Advanced Façade and Daylighting Systems

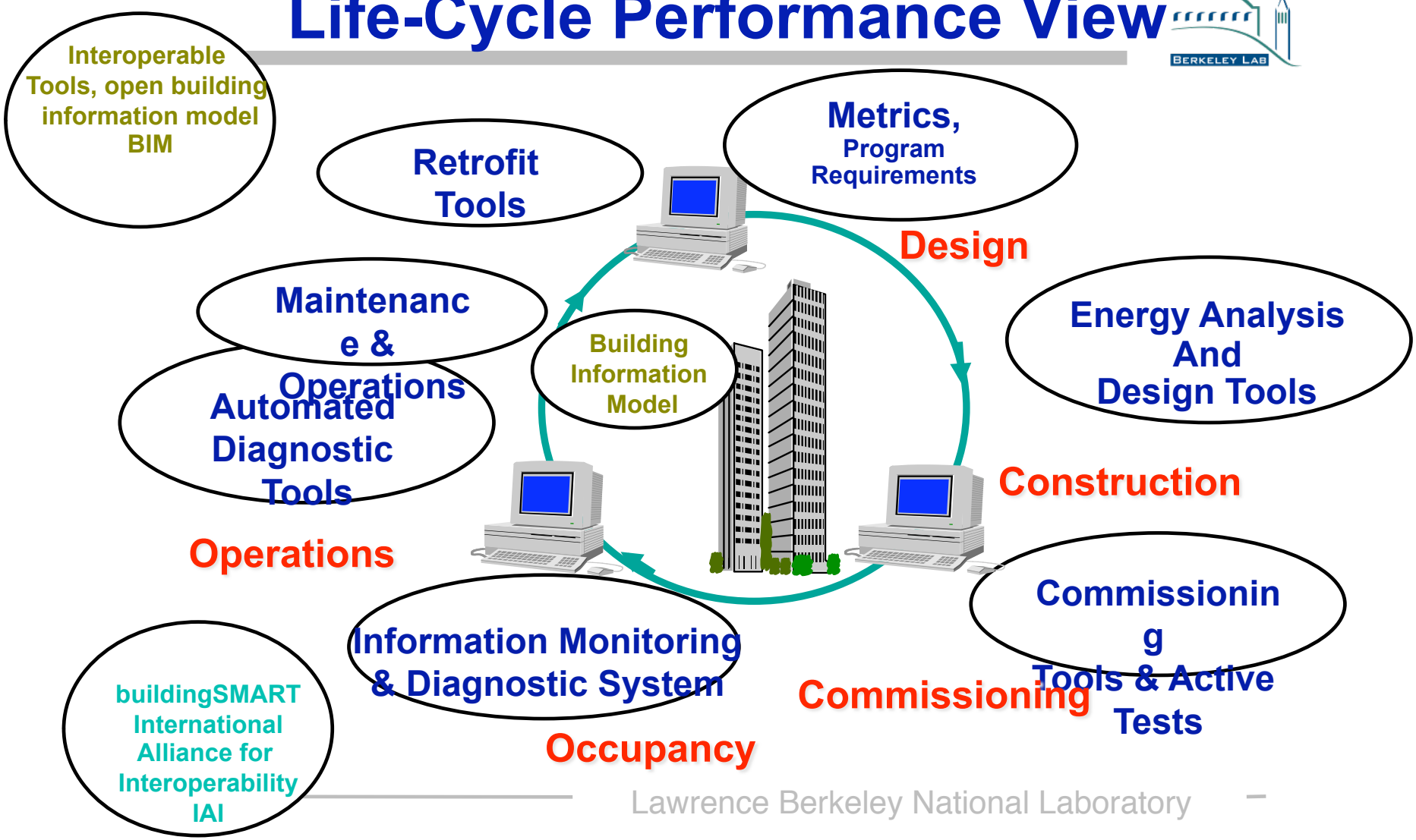
- Tremendous exploratory phase in progress in real projects
  - What works, how well, how to improve?
- Dynamic, Responsive systems essential
  - Maximize energy performance and satisfaction
  - Static systems inadequate, particularly with large glass area
- Areas for Innovation with integration:
  - Sun control, daylight control, glare control
  - Ventilation, Air flow- heat extraction
  - Sensors and controls
- Key Issues:
  - Glass Area “Debate”- optimal size??
  - Engineering vs Occupant Comfort, Satisfaction
  - Design -> engineering -> installation
  - Performance feedback: Operations --> Design
  - Tools for Design, Analysis, Optimization
  - Cost, Reliability

Facades and Zero Energy Building Performance Issues

- Importance of Building Controls
  - "Smart" controls
  - Self-diagnostic
  - Learn from occupants
  - Address "Conflict": Occupant- owner-utility
- Dynamic Load management
  - Electricity cost and availability
  - Rethink relationship of building to "grid", autonomy
- Occupant issues
  - Better environments for people
  - How do people interact with their built environment?
- Understanding and quantifying costs and risks

Commercial Building Performance Issues, Trends, Needs

Information Technology-based Building Life-Cycle Performance View



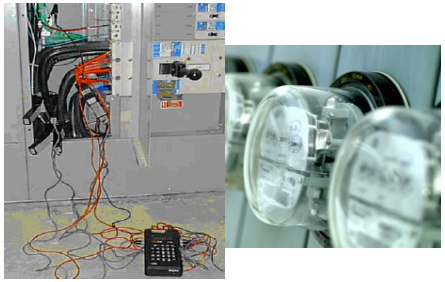
Web-based Decision Support Tool "Action-oriented benchmarking" extends whole-building benchmarking

Whole Building Energy Benchmarking

Screen facilities for overall potential

Minimal data requirements (utility bills, building features)

Action-Oriented Energy Benchmarking



Identifies and prioritizes specific opportunities

Requires sub-metered end-use data; may require additional data logging

Highly applicable for RCx and CCx

Investment-Grade Energy Audit

Estimates savings and cost for specific opportunities

Requires detailed data collection, cost estimation, financial analysis

Necessary for retrofits with capital investments

EnergyIQ Benchmark | MyIQ | MyData Help

Current | Historical

Peer Group Filters
Metric OR Features
Indicators
Views

- Summary Only
- Range Bar
- Ranked Bar Chart
- Frequency Distribution

Facilities

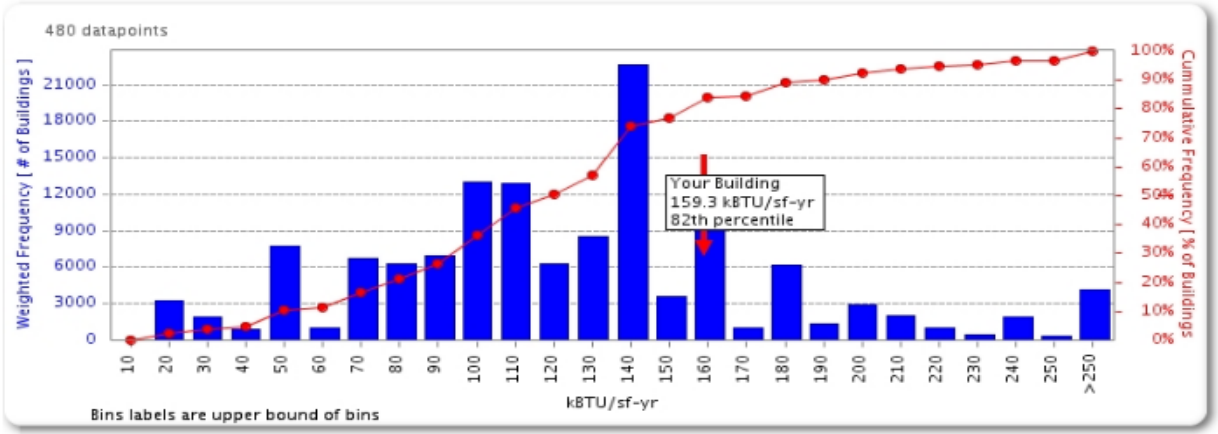
Group: All facilities
edit groups
Facility Name

- [x] Oaks Office Building
- [ ] Fairview Suites
- [ ] Downtown Offices
- [ ] Riverside Shopping Center
- [ ] Stop and Shop Market
- [ ] Marie Calendars

1 Set Filters 2 Select Metric or Feature 3 Select Indicator 4 Select View

This View: ENERGY > Total_Electricity > Source Energy > Freq Dist > kBTU/sf-yr

Data Set: Tabular | Download | Save Peer Group Settings



Summary:

SAMPLE SIZE: 2703

The source energy consumed for typical facilities of the type(s) you've specified is 99.5 kBTU/sf-yr [median value], with a range of 12.0 to 651.2 kBTU/sf-yr [5th to 95th percentiles] for the population. Enter your own facility information at the left to see how yours compares. Try other Views for graphical and tabular detail. This analysis includes population weights for each facility.

Vintage:

1901 through 1940, 1941 through 1978, 1979 through

Filters:

Facility Type:

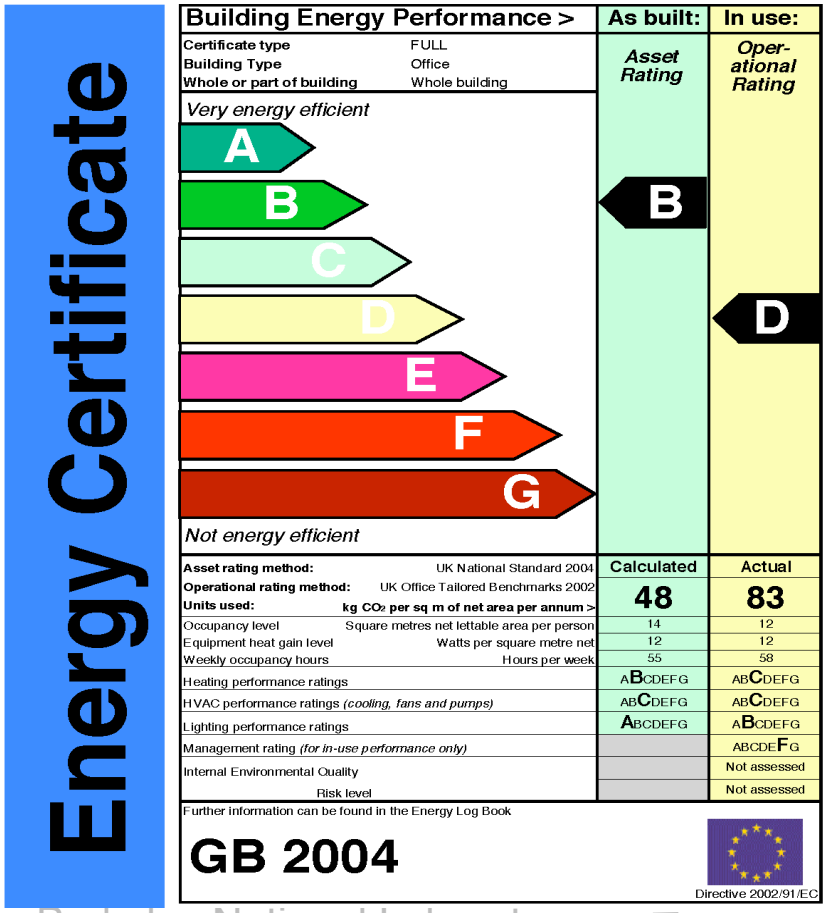
Administration and Management, Assembly / Light Mfg., Assorted/Multi-tenant, Auto Sales, Bar/Tavern/Nightclub /Other, Clinic/Outpatient Care, College or University, Community Center, Conditioned Warehouse, High Bay, Conditioned Warehouse, Low Bay, Conference/Convention Center, Convenience Store, Data Processing/Computer Center, Daycare or Preschool, Department

Facility Size:

0 - 25,000 sf,25,001 - 150,000 sf,Over 150,000 sf

Making Performance Visible
Ex: European building energy certificates

- Display energy certificates based on actual energy use, not just theoretical. *We need to save real, not virtual emissions.*
- Transparency between expectations and outcomes.
- Multiple performance indicators
- California is launching similar initiatives, e.g. AB1103
- **Subtleties:**
  - **Asset Rating**
  - **Operational Rating**



Energy Certificate

Building Energy Performance >		As built:	In use:
Certificate type	FULL	*Asset Rating*	*Oper-ational Rating*
Building Type	Office		
Whole or part of building	Whole building		
Very energy efficient			
A			
B		B	
C			
D			D
E			
F			
G			
Not energy efficient			
Asset rating method:	UK National Standard 2004	Calculated	Actual
Operational rating method:	UK Office Tailored Benchmarks 2002	48	83
Units used:	**kg CO_2 per sq m of net area per annum >**		
Occupancy level	Square metres net lettable area per person	14	12
Equipment heat gain level	Watts per square metre net	12	12
Weekly occupancy hours	Hours per week	55	58
Heating performance ratings		ABCDEFG	ABCDEFG
HVAC performance ratings *(cooling, fans and pumps)*		ABCDEFG	ABCDEFG
Lighting performance ratings		ABCDEFG	ABCDEFG
Management rating *(for in-use performance only)*			ABCDEFG
Internal Environmental Quality			Not assessed
Risk level			Not assessed

Further information can be found in the Energy Log Book

GB 2004

Directive 2002/91/EC

Life-Cycle Owner Costs in Perspective

% of 30-year Total Owner Cost

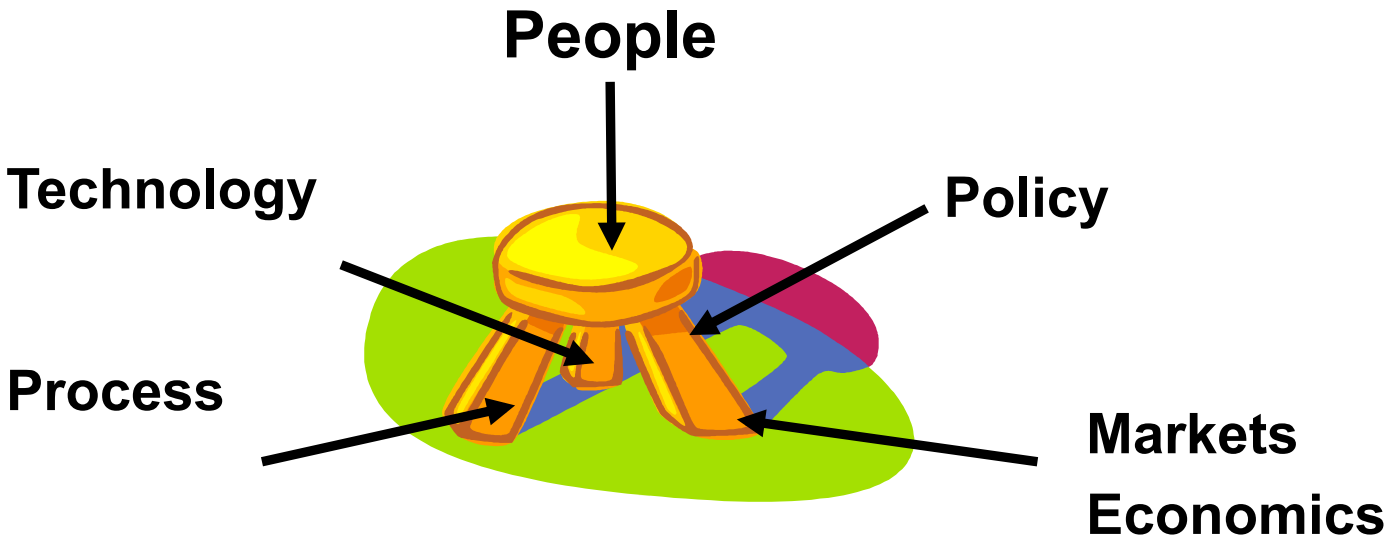
- **Design Fees:** **<1%**
- **Construction:** **4%**
- **Annual operations:** **12%**
- **Staff Salaries** **84%**

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**

Importance of Comprehensive Balanced Program



Solutions fail without this balance

Approaching a Zero Energy Future

- "If I had asked people what they wanted, they would have said faster horses."
  - Henry Ford

- The best way to predict the future is to invent it
  - Alan Kay

- Think Big, Start Small, Act Now

Information Resources

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Lawrence Berkeley National Laboratory
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Berkeley, CA 94720 USA
E-mail: SESelkowitz@lbl.gov

More Info:
http://windows.lbl.gov
New York Times project
http://windows.lbl.gov/comm_perf/newyorktimes.htm
Advanced Facades project
http:lowenergyfacades.lbl.gov
http://gaia.lbl.gov/hpbf
Commercial Web Site
http://www.commercialwindows.org

http://buildings.lbl.gov