Philips Visit to LBNL

2 April 2007

Energy Efficiency Opportunities: Glazing, Windows and Facades

Stephen Selkowitz

Department Head, Building Technologies Department

Lawrence Berkeley National Laboratory

U.S. Energy Use - Windows

- **Building Energy Use** = 34.6 Quads, (U.S. = 96.2 Quads)
  - Residential Buildings = 19.2 Quads
  - Commercial Buildings = 15.4 Quads
- **Windows = 5.7 Quads or 5% US Energy (15% Bldgs)**
  - Energy consumption impacts:
    - Residential Heating: 2.6 Quads
    - Residential Cooling: 0.8 Quads
    - Commercial Heating: 0.7 Quads
    - Commercial Cooling: 0.6 Quads
    - *Commercial Lighting: 1.0 Quads (potential from 3.8 Q total)*
  - **Economic Impact:**
    - **Annual energy cost: $40B**
    - **Annual window sales: $20B??**

(based on data in US DOE Core Data Book, 2001, Tables 1.1.1, 1.1.2, 1.1.3, 1.2.3, 1.2.10, 1.3.3, 1.3.9)

DOE Vision: Energy Losers --> Neutral --> Net Energy Suppliers

- Heating climates
  - Reduce heat losses (U) so that ambient solar energy balances and exceeds loss
  - Need very low U but moderate solar gain
- Cooling climates
  - Reduce cooling loads: very low SHGF
  - Static control -> dynamic control
- Mixed climates
  - Requires dynamic solar control
- All climates
  - Replace electric lighting with daylight
- Electricity supply options
  - Integrate Photovoltaics with Glazing

Zero Energy Window Concept:
Heating Climate

Single Glazed w/Storm

Energy = $1310

Double Glazed

Energy = $1218

Double w/Low-E

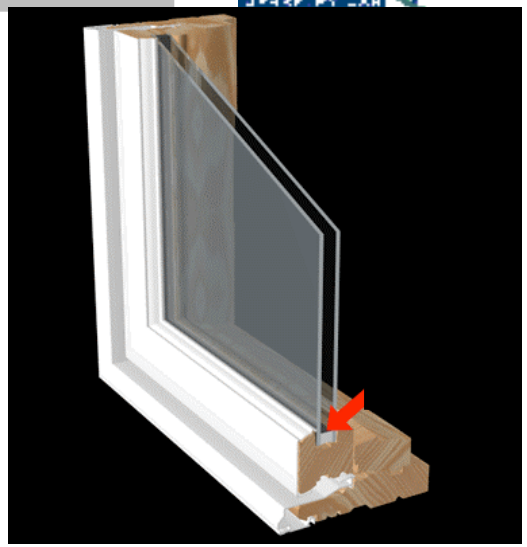
Energy = $1120

"SuperWindow"

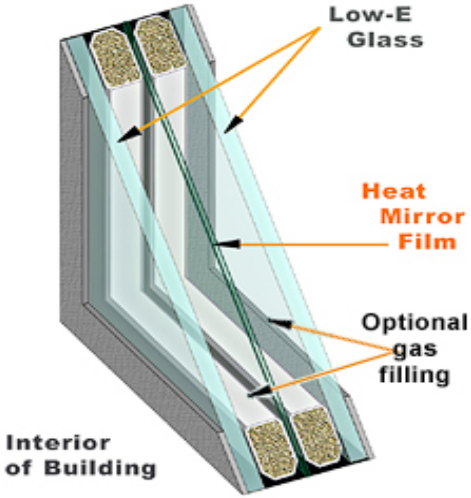
Energy = $960

(Better than House with no windows: $1000/yr)

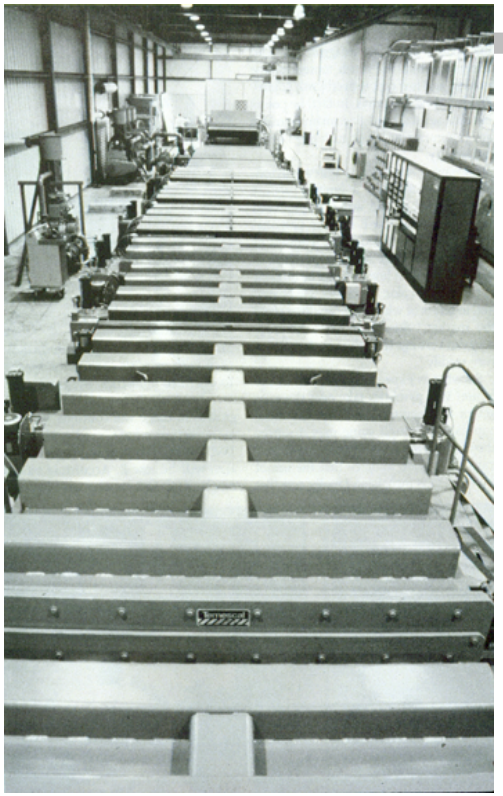
Low-Emissivity (Low-E) Coatings



- Single most significant technology change in window industry in last 20 years
- **Thin coating on glass or plastic that reflects long-wave infrared radiation, thus reducing overall heat loss**
  - Sputtered: multilayer, silver based coating applied in vacuum chamber after glass is made, must be protected
  - Pyrolytic: single layer coating applied to molten glass as the glass is made, can be exposed
- **Manufacturing cost: < $.50/sq ft.**



Efficiency = Energy Supply



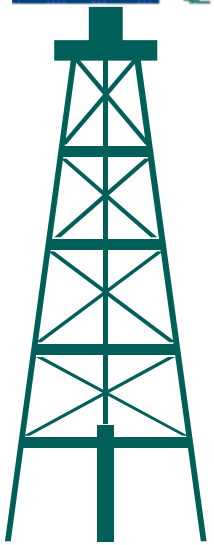
A $10 million investment in low-e coating system…

→

over 10 years creates glass for 200 million square feet of efficient windows...

over their life…

=



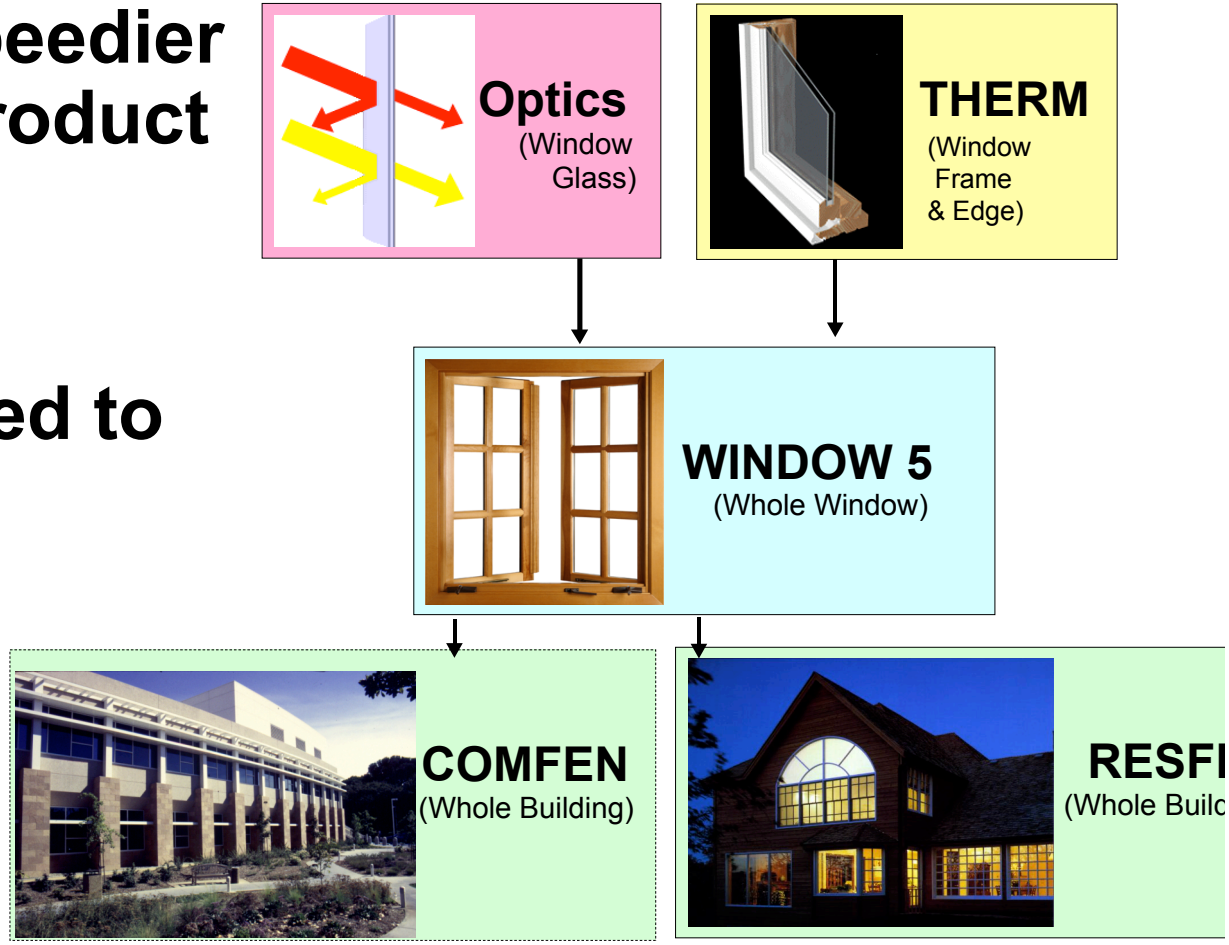
saves energy equivalent of 36 million barrels of oil,

= 1 offshore oil platform in 10 years

Tools for Manufacturers: "Window" Software Suite

- **Manufacturers--> speedier innovation, faster product development cycle**

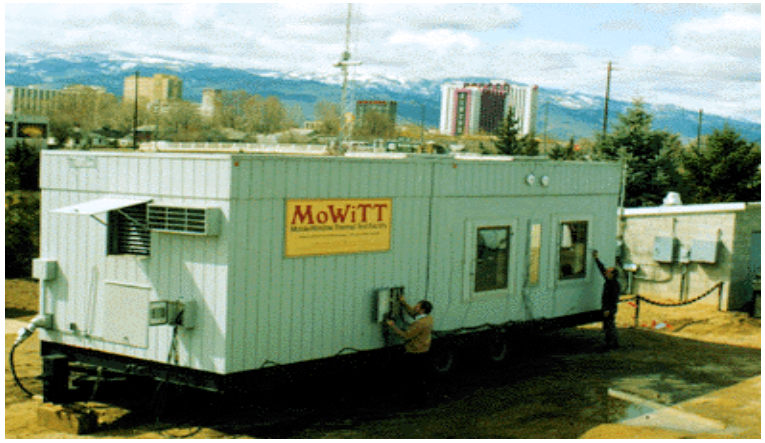
- **Simulation (compared to testing) is:**
  - **Cheaper**
  - **Faster**
  - **More consistent**
  - **More accurate**



LBNL: Unique National User Facilities for Building Energy Efficiency

Materials Characterization

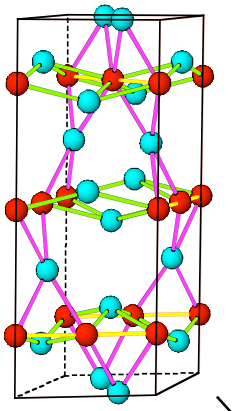
IR Thermography Lab



Window Field Test Facility

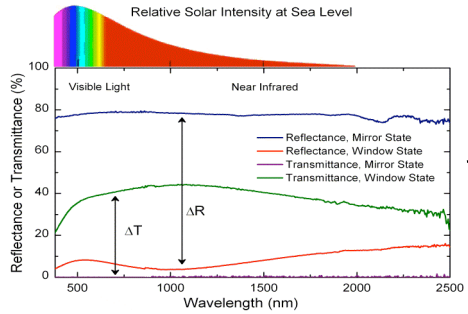
Smart Window Test Facility

Electrochromic Testbed and Smart Glazings Laboratory

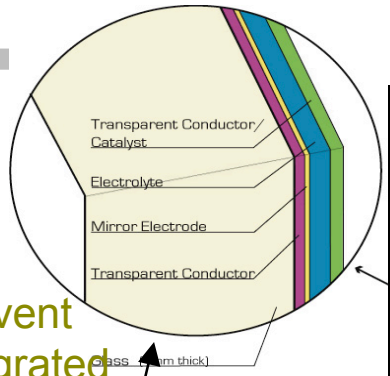


Mg_2Ni

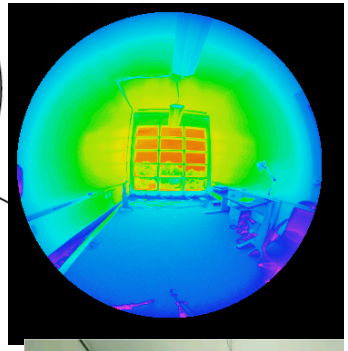
Invent New Materials



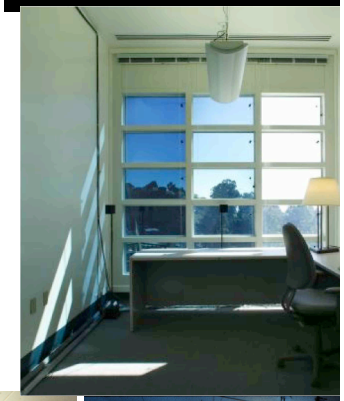
Characterize Coating Performance

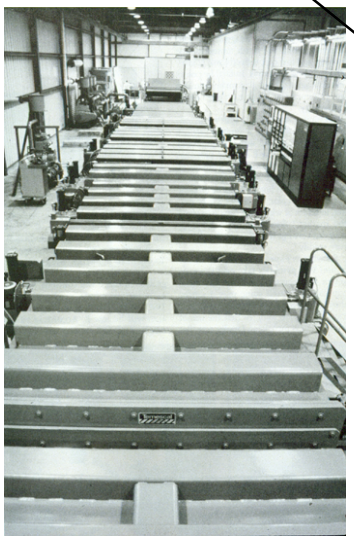


Invent Integrated Window

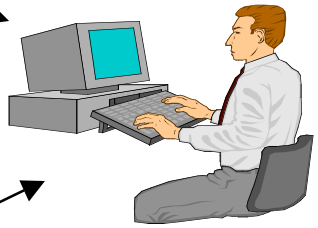


Assess Human Factors

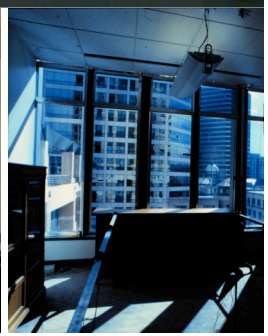




Invent Innovative Manufacturing Process



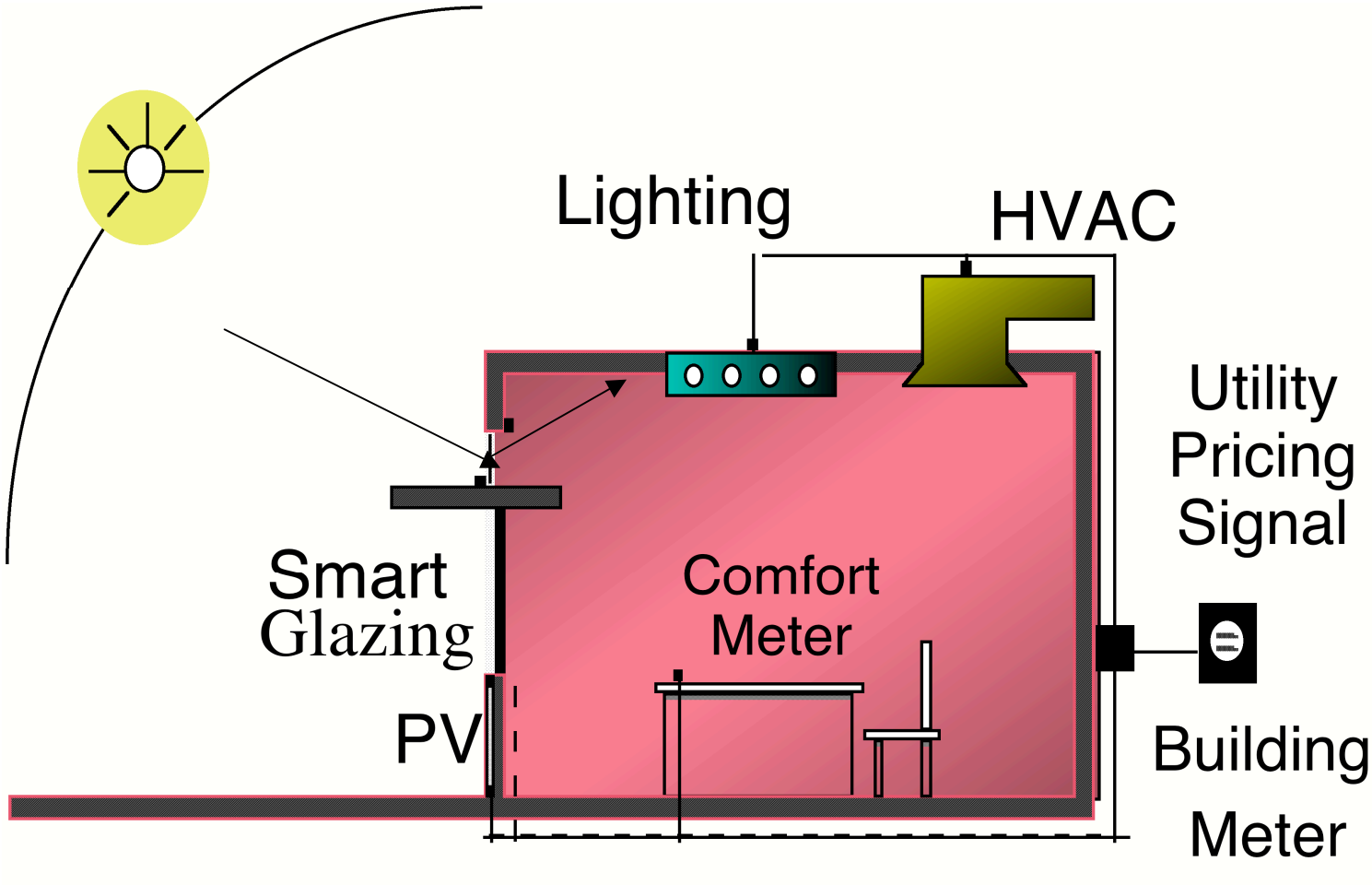
Assess Savings



Invent/Test Integrated Systems

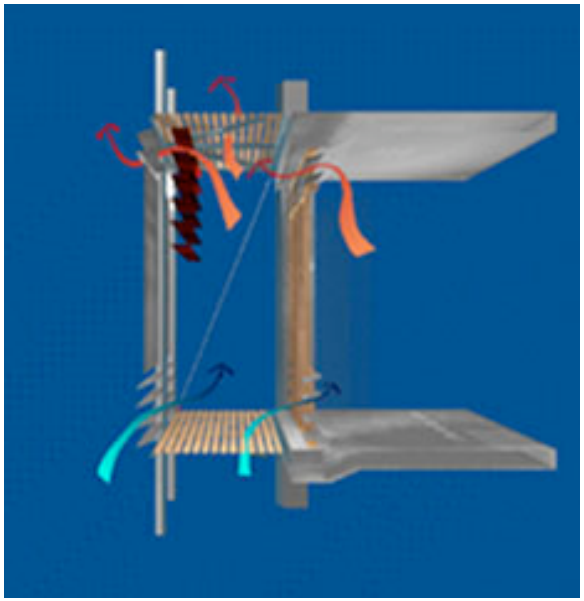
Energy Efficienct Buildings?

Conceptual Design for a Carbon-Neutral Office using an Integrated Building Facade Systems



Advanced Interactive Intelligent Facades

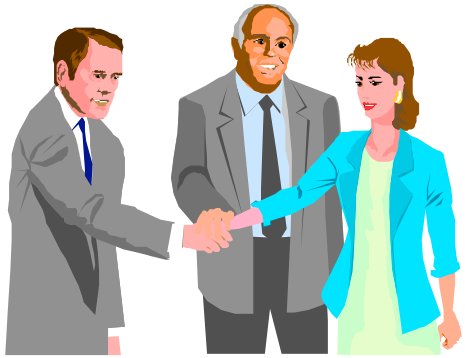
- **"Advanced":**
  - Improved, high performance technology
  - Dynamic response to changing external, internal conditions
- **"Interactive, Intelligent"**
  - Mode
    - Manual vs automatic
    - Intelligent, Adaptive
  - Occupant
    - Personal control
    - Comfort, Satisfaction, Productivity
  - Facility Operator
    - Energy, demand
    - Life safety
- **"Facades"**
  - Glazing, Shading, Framing,
  - Lighting -Daylighting- HVAC functions



Glazing Benefits to Occupants?

Suggestive, but not yet definitive, studies, show glazing impacts on people re: preference, performance, health

- View
- Connection to outdoors
- Daylight
  - Spectrum
  - Variability
  - Directionality
  - Intensity



Energy Costs in Perspective

Cost / Sq. Ft. Floor -Year

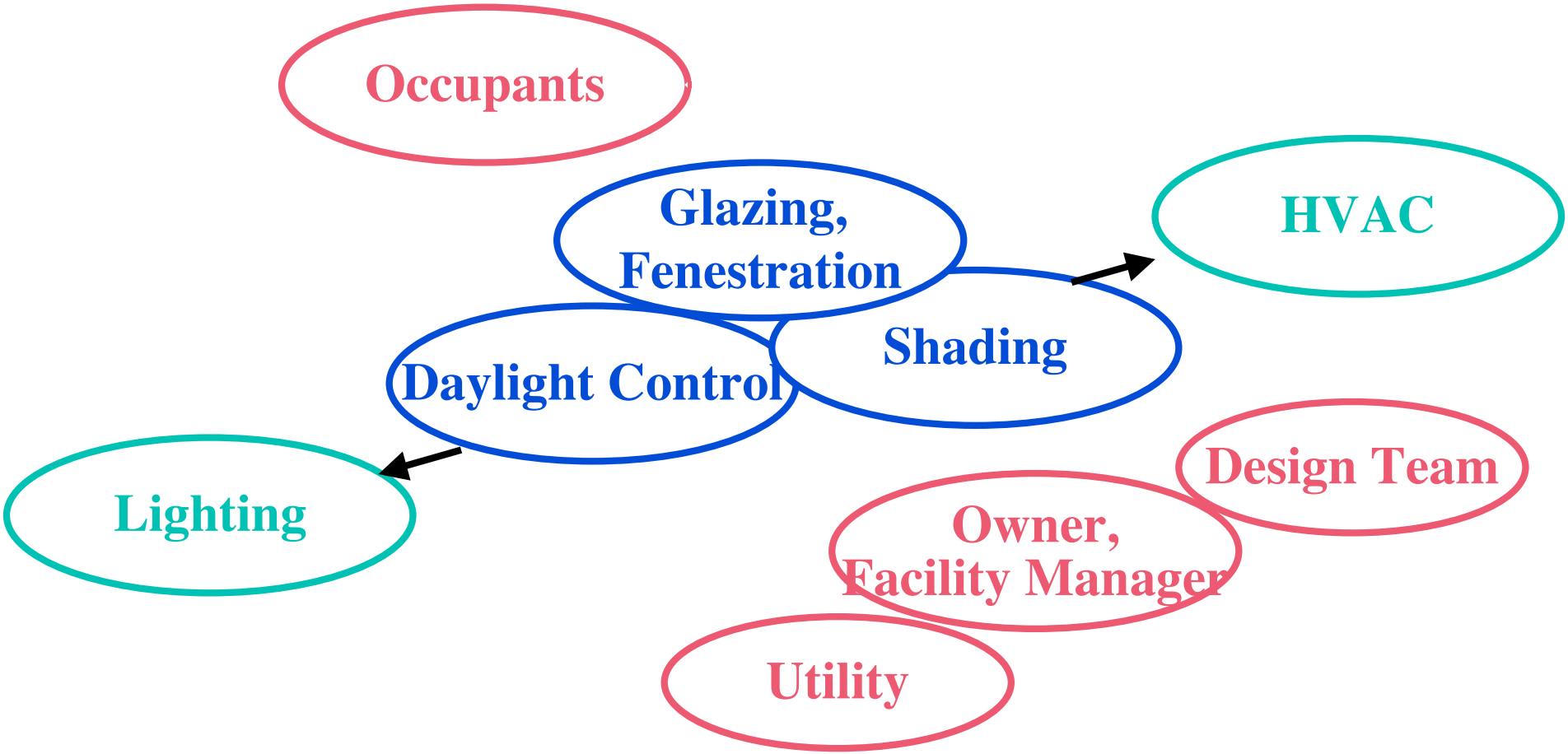
- Energy Cost: $2.00
- Maintenance: $3.00
- Taxes: $3.00
- Rent: $30.00
- "Productivity" $300.00

Owner Issues: High Performance Glazing

- Energy
- Comfort
- View/Privacy
- Security
- Acoustic
- Structure

- Daylight
- Aesthetic
- Weatherproof
- Cleaning
- Maintenance

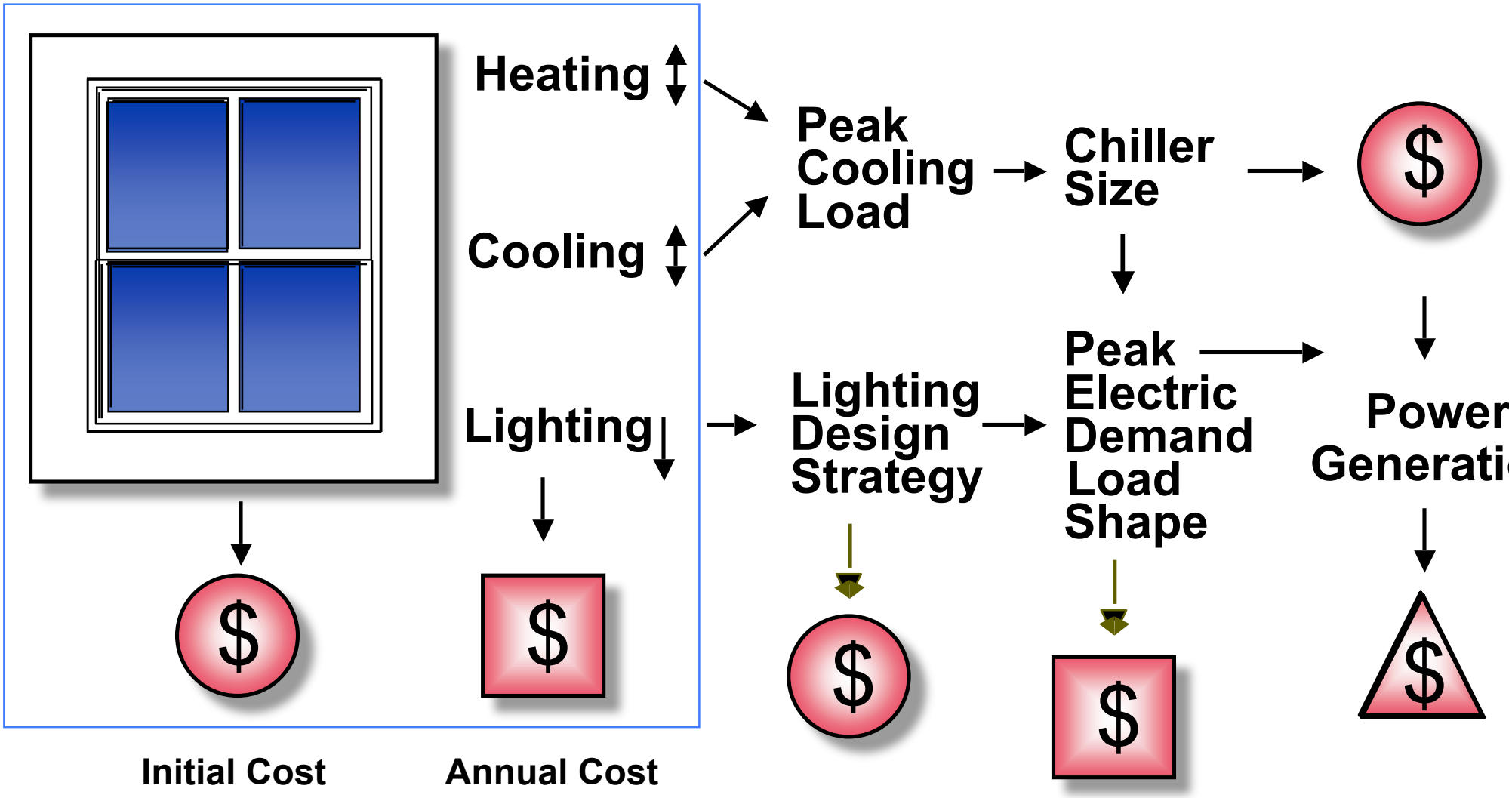
Intelligent Facade Systems: w/ Building interconnections



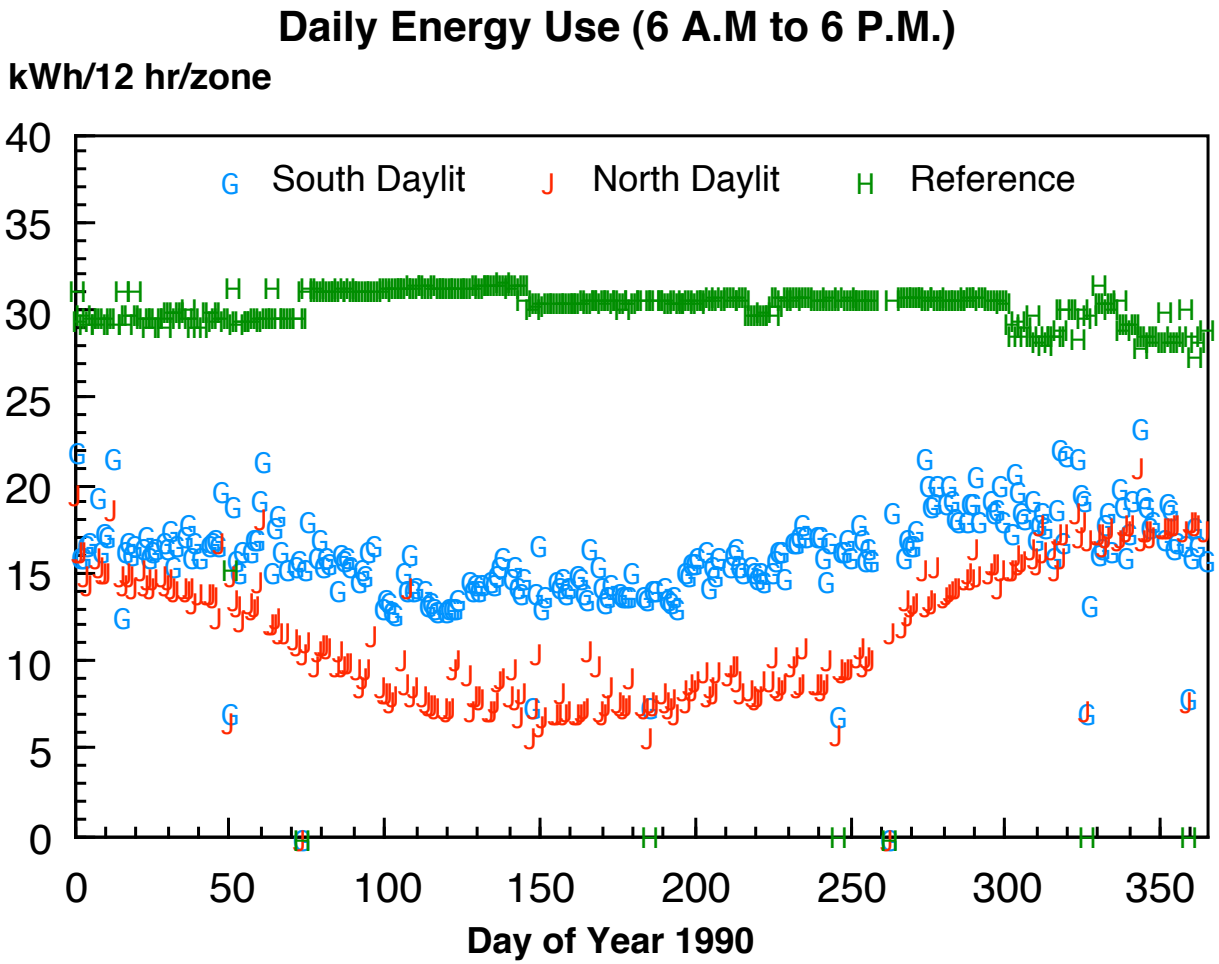
Integrated Design Process:

Prog - SD- DD- CD- Construction

System integration Cost tradeoffs



Good Lighting Controls Work
(but too much light can be a problem)

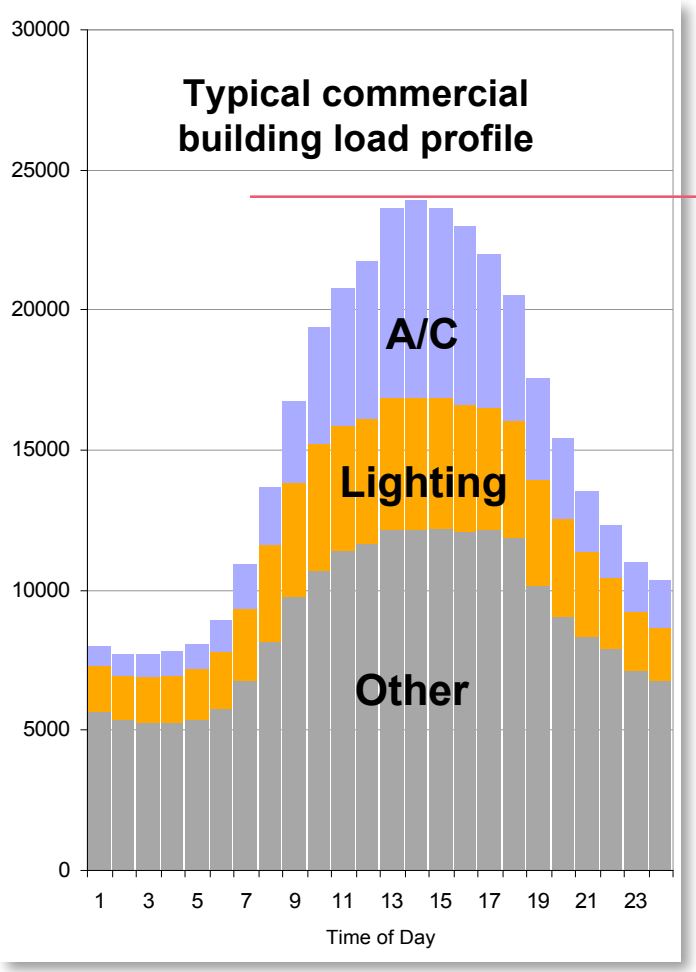


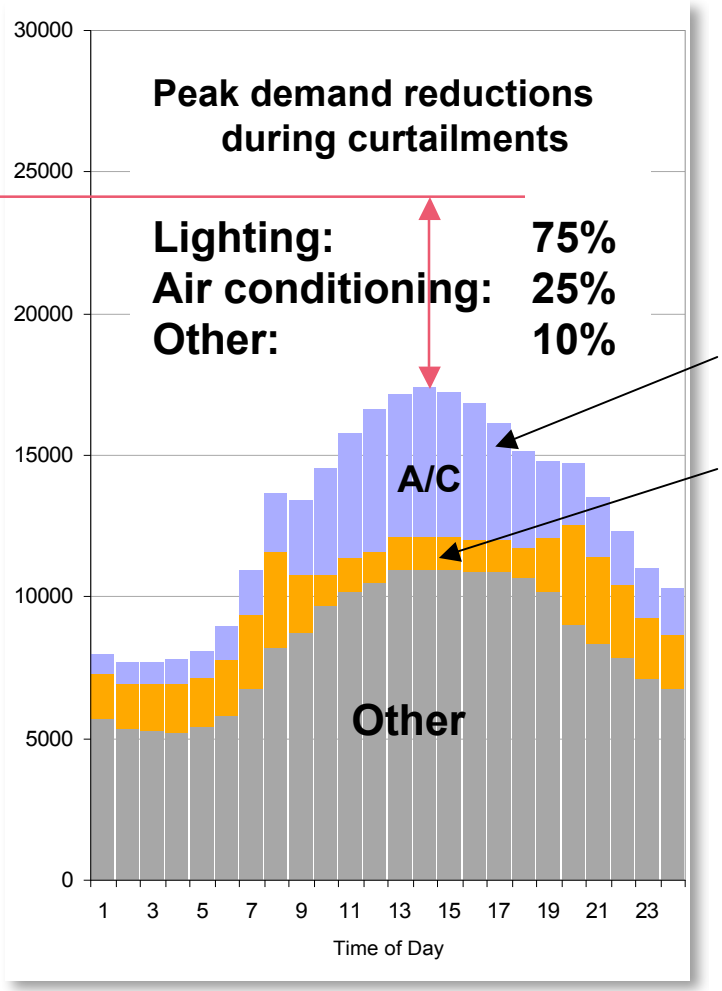
Data from advanced lighting controls demonstration in Emeryville, CA (1990)

Lessons:
Its not just the lighting controls…
Need smart shades

Energy/Demand Management with Active Façades+ Daylighting Controls

Electric Demand

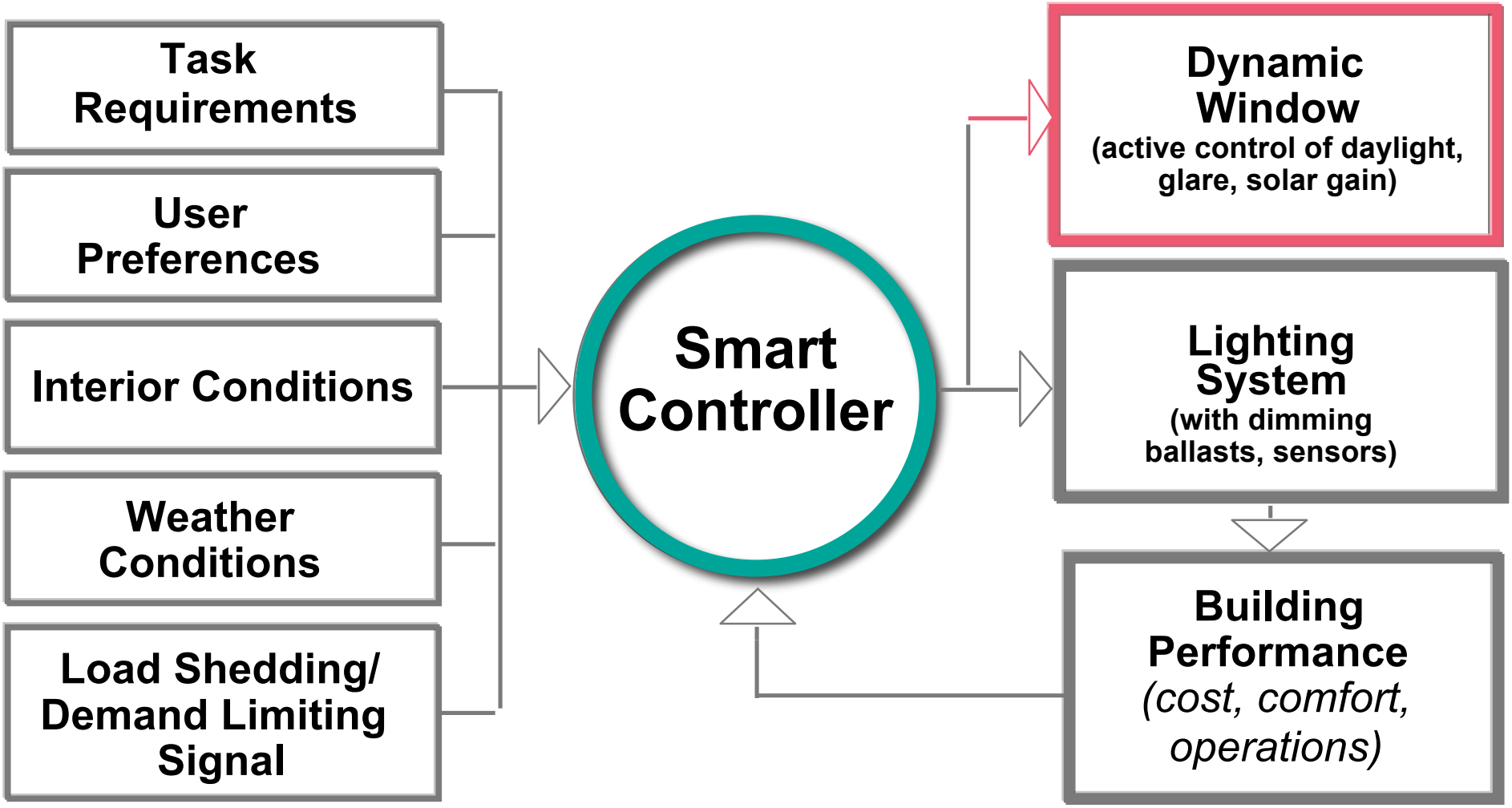




Reduced Solar Gain

Dimmed Lighting

Intelligent Control Systems



Vision for Daylighting and Dynamic Facade Systems

- Integrated façade systems composed of dynamic, smart materials/components…
  - Glazing
  - Framing
  - Sun Shading
  - Daylight and glare control
  - Electric lighting control
- …serve occupant, owner and societal needs…
  - Energy, demand, carbon
- …for performance and sustainability across the building life cycle.

- Owner Challenges
- Business Challenges
- R&D Challenges

NY Times HQ Project

Three Examples of Building Systems Integration R&D

- **Test room level - research lab context**
  - More info: http://windows.lbl.gov/comm_perf/electrochromic

- **Full size mockup of a building;**
  - 500 sq.M section of floor plate
  - New York Times HQ project includes specifications, commissioning, etc
  - More info: http://windows.lbl.gov/comm_perf/newyorktimes.htm

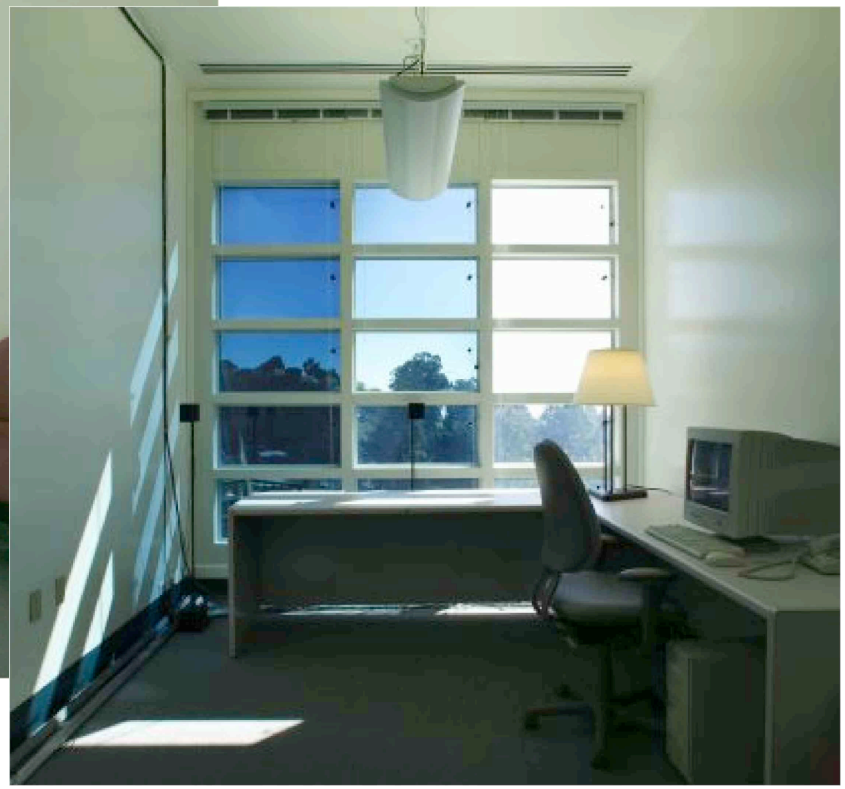
- **Full building /Virtual Building**
  - San Francisco Federal Building
  - Natural ventilation
  - Design optimization with advanced tools
  - Virtual controls testbed to optimize control strategies before occupancy

LBNL Façade Test Facility

Blinds*, no blinds Daylight or glare Control mode	Blinds*, no blinds Daylight or glare Tv=0.56-0.02 SHGC=0.42-0.09	Blinds*, no blinds Tv=0.41 SHGC=0.23

- *Venetian blinds fully down, 45 deg angle
  Glare control: When direct sun, Tv of EC=0.05.

Switchable Electrochromic Windows:



- LBNL full-scale windows field test facility

The New York Times HQ Building

Owners program:

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

Need/Goal:

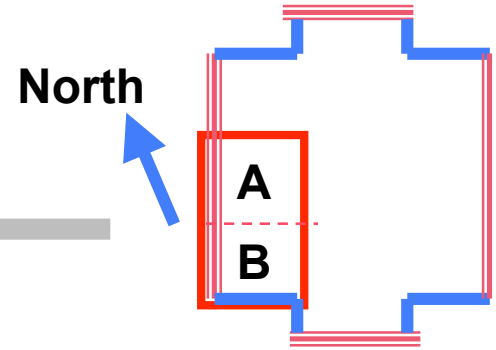
- Develop integrated , automated shading and dimmable lighting system
  - Affordable, reliable and robust
- Transform the market- push these solutions toward widespread use

Challenge:

- How to develop a workable integrated hardware/software solution
- How to “guarantee” that such a solution will work in practice

- 160,000 sq.M
- Full glass facade
- Occupancy in 2007

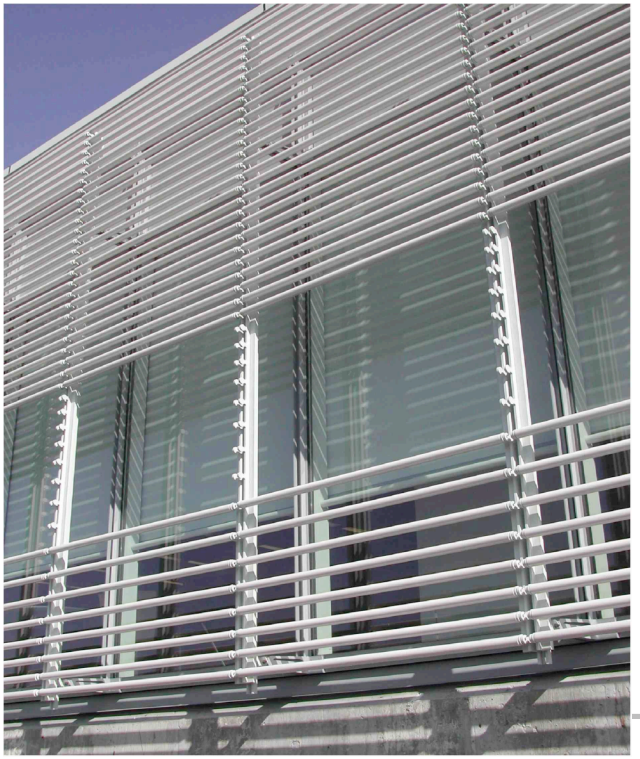
Approach: Test Performance in a Full-Scale Mockup



- Shading, daylighting, employee feedback and constructability: ~450 sq M 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

New York Times HQ, Occupancy 2007

- Major construction complete
- Commissioning underway
- Occupancy 2007
- Extensive monitoring planned



"Natural Ventilation Cooling System" New GSA SF Federal Building

Morphosis/Arup design/GSA Owner

Outcome: "Class A" office building;

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

Status: Occupancy 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