

**STEAB Meeting, Berkeley CA**  
**August 14, 2007**

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# **Advanced Building Technologies**

## **Toward a New Generation of Net-Zero Energy, Carbon-Neutral Buildings**

**Stephen Selkowitz**

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Lawrence Berkeley National Laboratory**

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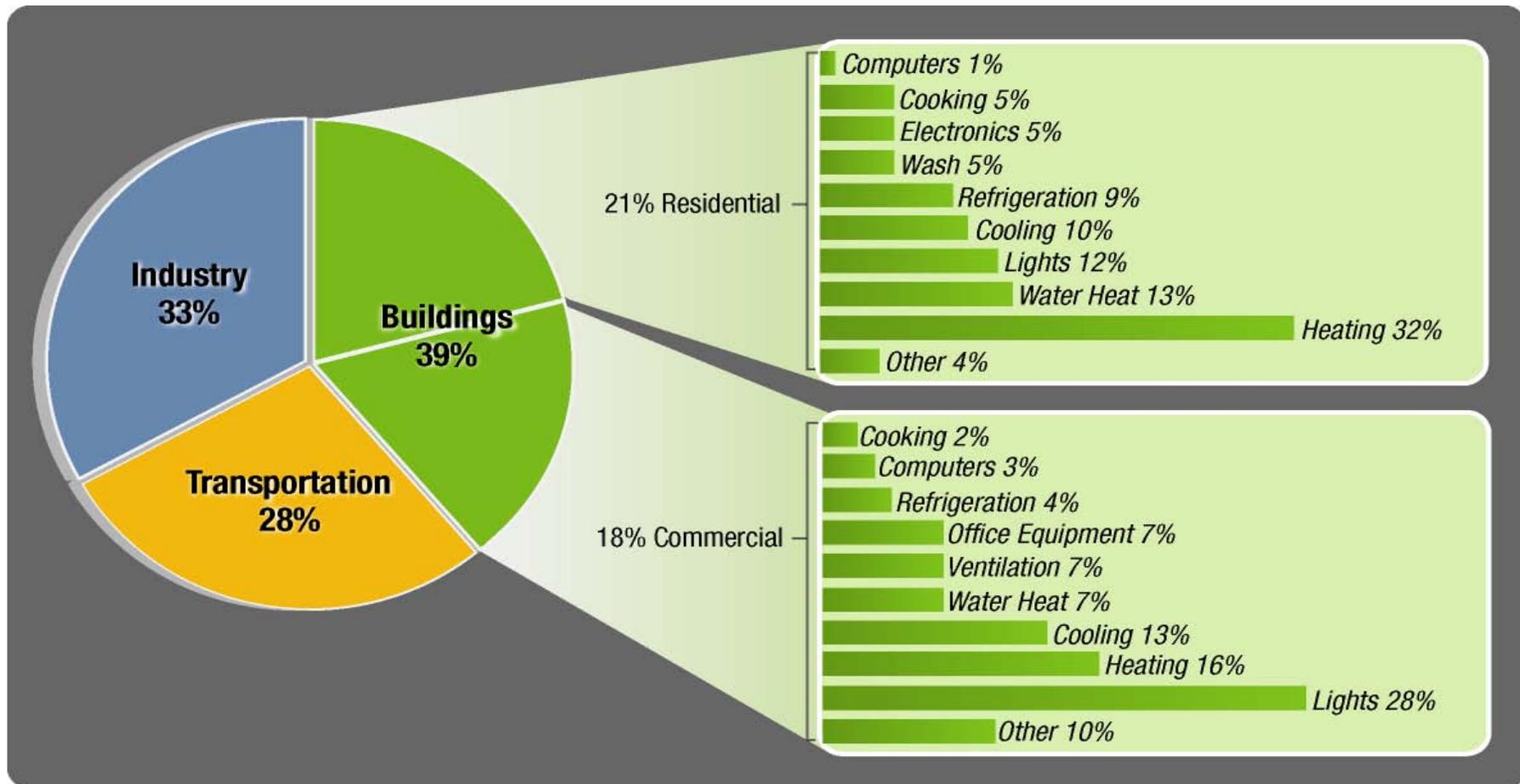
**510/486-5064**

# Building Energy Demand Challenge: End Use Energy Consumption



**Buildings consume 39% of total U.S. energy**

- 71% of electricity and 54% of natural gas



# Reducing Energy/Carbon Impacts of Buildings

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- Buildings are a big part of the problem, **and thus the solution**
  - 40% of energy use
  - 70% of electricity use; (driving carbon emissions due to coal)
- We are not going to dig or drill our way out of this
- Existing market forces are largely ineffective
- It is critically important to ***rapidly and drastically*** reduce energy/carbon impacts of buildings
- **Can We Make a Difference?**
- **How Do We Reinvent Our Future?**

# Defining a Pathway to the Future

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**“If I had asked people what they wanted, they would have said faster horses.”**

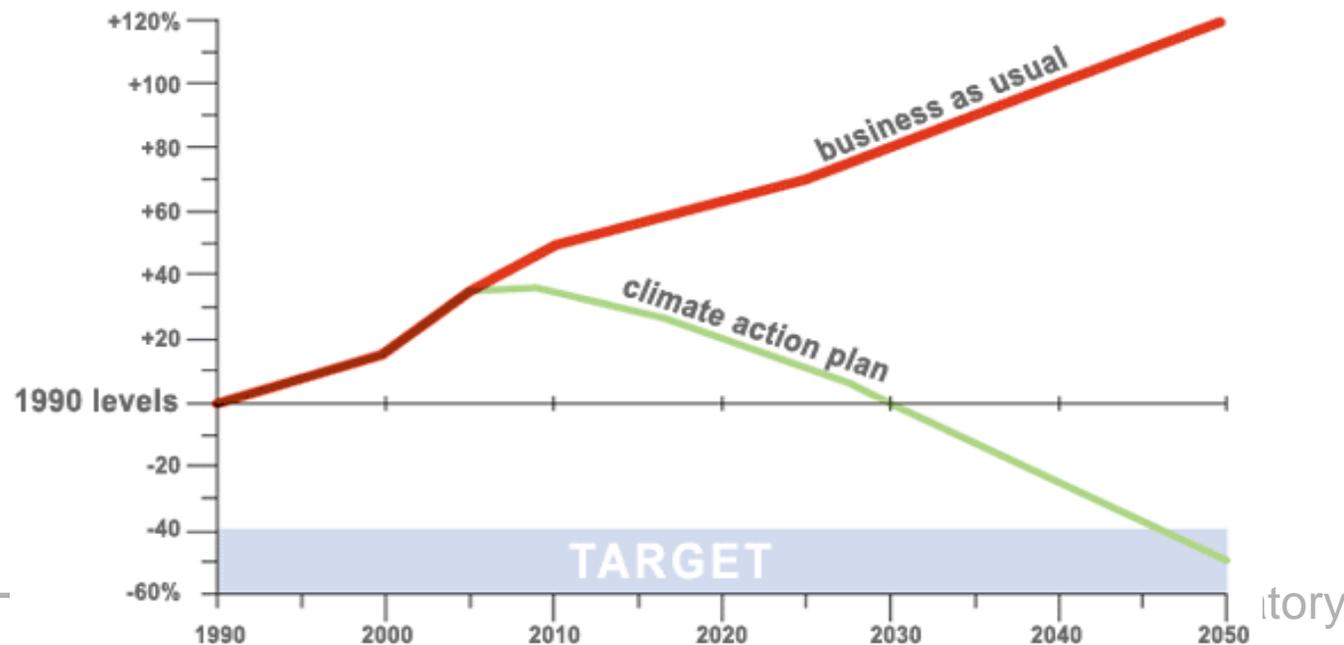
Henry Ford



# American Institute of Architects (AIA) 2030 Challenge



- That all new buildings and major renovations be designed to meet a fossil fuel, greenhouse gas (GHG) emitting, energy consumption performance standard of 50% of the regional average for that building type.
- An equal amount of existing building area be renovated annually to meet a fossil-fuel, energy-consumption performance standard of 50% of the regional average
- That the fossil fuel reduction standard for all new buildings be increased to Carbon-neutral by 2030 (using no fossil-fuel GHG-emitting energy to operate)



# Commercial Buildings Background and Context



- **Non-Res Sector Technical Potentials are very large**
  - Fragmented, risk averse industry, Real progress has been slow
  - Must address existing stock as well as new
- **Historic focus on “widgets”; now shift to “systems”**
  - Integrated systems, plug and play,..
  - New design tools, new construction processes
  - Workforce skills and training will be an issue
- **Can’t reach aggressive goals with prescriptive-only approach**
- **Need Continuum of activities - deployment alone insufficient**
  - Standards - Deploy - Demonstrate - Research
- **Need a “building sector” strategy**
  - Replicable, extensible
  - Size matters vs numbers; 5% = 50% of floor space
  - Portfolio approach : % savings vs # of buildings....
- **Need a regional, climate sensitive focus**
  - Opportunities, problem areas

# Background and Context - 2



- **Leverage New Market Drivers, Business trends**
  - Green, sustainable design
    - Health, comfort, safety, productivity
  - Intelligent buildings
  - Distributed generation, on-site power, CHP
  - Demand response, load shedding
  - Chem-bio response
  - AIA Integrated Practice initiative
  - Asset Management, Design Build, Outsourcing,...
  - Financing, valuation
- **Leverage National Activities, e.g.**
  - AIA 2030 Challenge - “carbon neutral by 2030”
  - National Building Information Model (BIM) Standard

# Background and Context - 3



- **Take the long(er) view**
  - Little real progress is made in 3 year increment only
- **Define aggressive vision even though you won't get there in 3 or 6 years**
  - Visualize what it takes to get 70% savings in 15 years
  - Plan what it takes to get 50% in 5 years
  - Action to Capture the first 20-30% now
- **Make performance visible and understandable**
  - “Can’t manage what you can’t measure”
  - More focus on how buildings actually operate
- **Assess and Evaluate**
  - What works --> Promulgate, deploy
  - What doesn't --> Fix and Deploy
- **Take the facility owner/operator perspective**
  - Drive decision making, investments and manufacturers offerings

# How (NOT) to Engage Owners in the Business of Energy Efficiency and DR



- Owners swamped by yet another “program” approach to building energy improvements; ask them to launch numerous major discrete (overlapping) programs:
  - Audit programs
  - Rebate programs
  - Benchmark programs
  - Commissioning programs
  - Retrofit programs
  - Load Management programs
  - DR programs
  - Renewables programs
  - LEED programs
  - EPCAT Tax Credit programs
  - Title 24: Codes and standards
  - ....
  - (+ Life safety, earthquake, disabled access, ....)

# A Different Approach: Two “Owner”-Targeted programs

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- For New Buildings:
  - The *“determine performance goals, use integrated design approach with state-of-the-art smart systems, construct and commission, operate to meet targets”* Program
- For Existing Buildings:
  - The *“benchmark your energy use and set goals, actively monitor end use and indoor environmental quality, diagnose and fix problems as they arise -> take operational and/or investment actions to meet goals, and actively monitor feedback, re-evaluate benchmarks in light of costs...”* Program
- Build these programs around a single shared “life-cycle” Building Information Model (BIM)

# Elements of Commercial Program



- Define Performance Benchmarks at building system level
  - Metrics: energy, demand, cost, carbon.... Stock vs Code....
- Develop a range of design strategies and costs to meet benchmarks
  - by building type and climate
- Create key climate-sensitive, integrated building systems solutions
  - Envelope cooling load control, Daylighting, Low Energy Cooling HVAC,...
  - On-site power generation and integration
  - Provide training, tools, support for “integrated systems”
- Demonstrate strategies and solutions that work
- Create construction, commissioning, operations processes to achieve goals
- Provide Real-time feedback, performance monitoring to assure continued compliance with operating goals
- Make building performance visible to occupants, public
  - Energy Performance of Buildings Directive in Europe

# Bad News <--> Good News



- **Not trivial to make this work**
  - If it was simple we wouldn't be here
  - But existing models - Auto, Aircraft, Big Box Retail
  - Solid case studies: challenge - one of a kind --> standard practice
- **Build on existing market interest**
  - Growing “willing partner” base
  - Build on existing interest in “green” agenda
    - Broader than energy but overlapping
- **Leverage new commercial market trends**
  - BIM - Life cycle data
  - Intelligent buildings - fire/life safety, telecom,...
  - Valuation of Energy savings, Green design
- **Partner Nationally for the Long Term ( Think Globally, Act Locally)**
  - Link to national efforts - most markets are national
  - Position short term programs to build on longer term ZEB efforts

# Zero-Energy Commercial Buildings Initiative

*Creating an Action Plan*



World Business Council for  
Sustainable Development



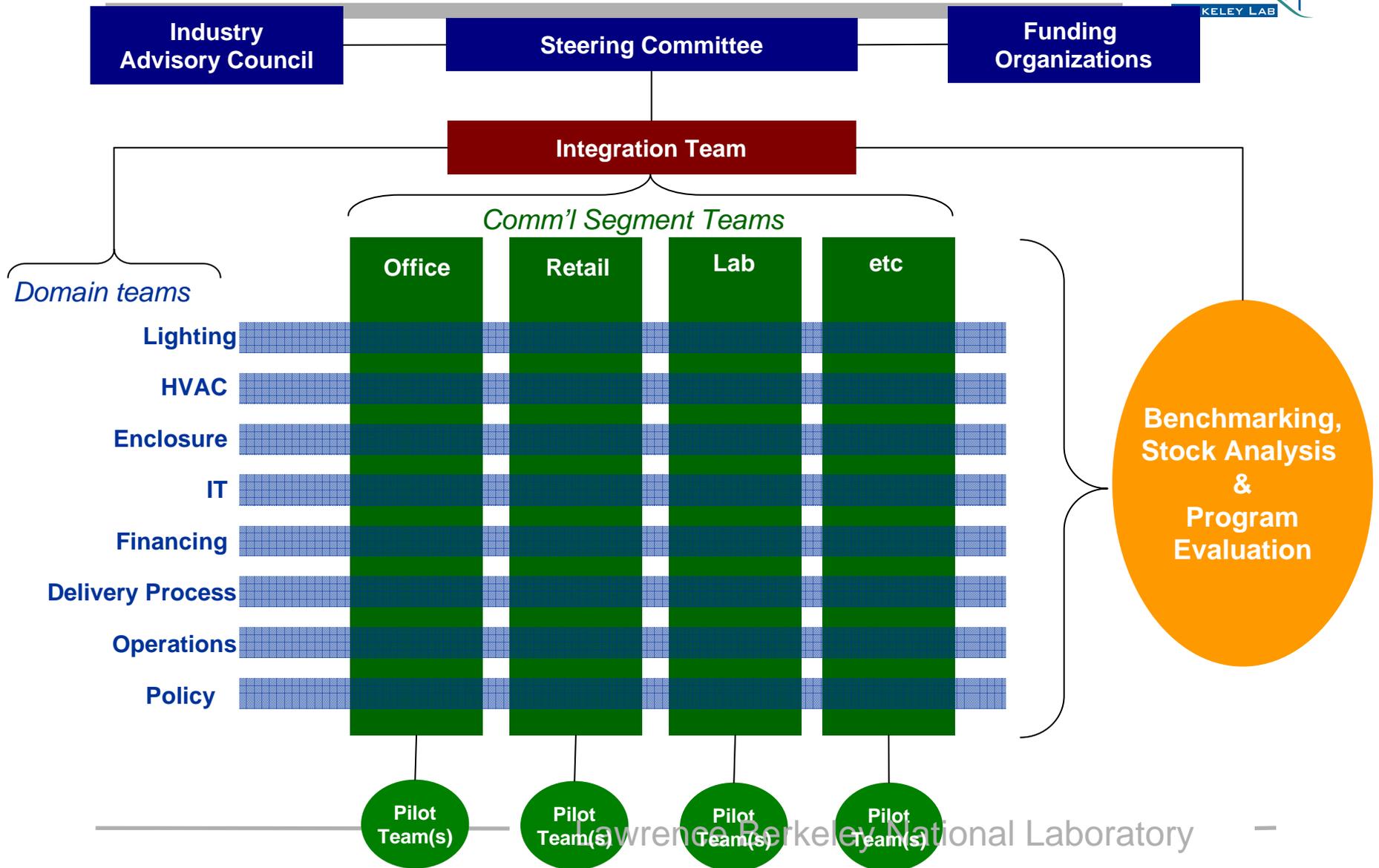
# Key Program Elements

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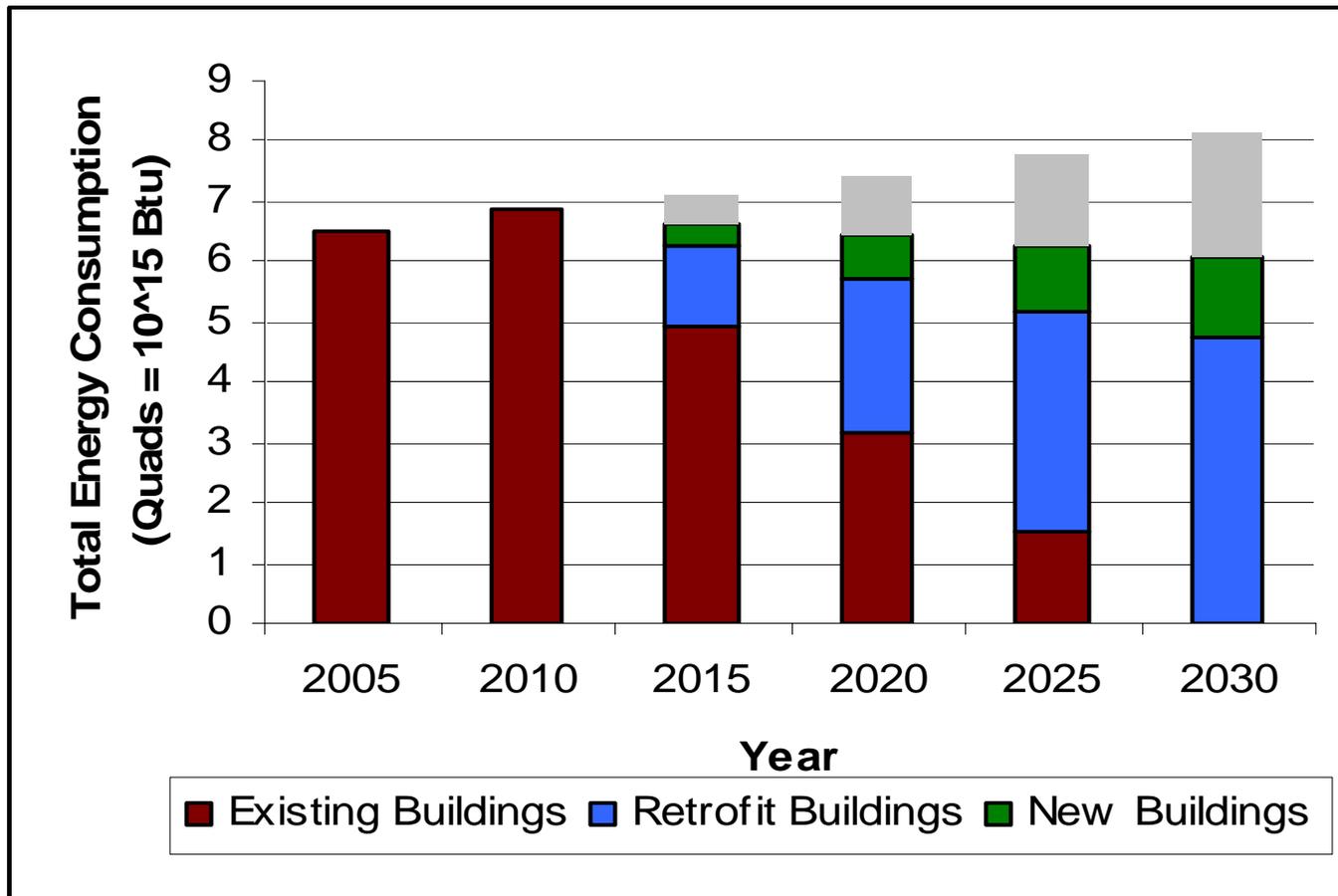
- **Deployment** - facilitates widespread implementation of known, proven and deployable practices, technologies and building systems
- **Demonstration** - feed the deployment pipelines, providing reliable performance data for new systems and solutions that exist but are not yet widely known or utilized.
- **Innovation** - achieving the very aggressive goals of carbon neutral buildings will require research- based innovation to solve known and emerging problems with technology, systems integration, performance prediction, etc
- **Investment/Decision support** - tools and information management at all levels to drive optimal investment of resources and effort

# Planning Team Structure





# Scenario 2: New Buildings Save 50% plus 20% Retrofit Savings by 2030



# “Greening the Capitol”

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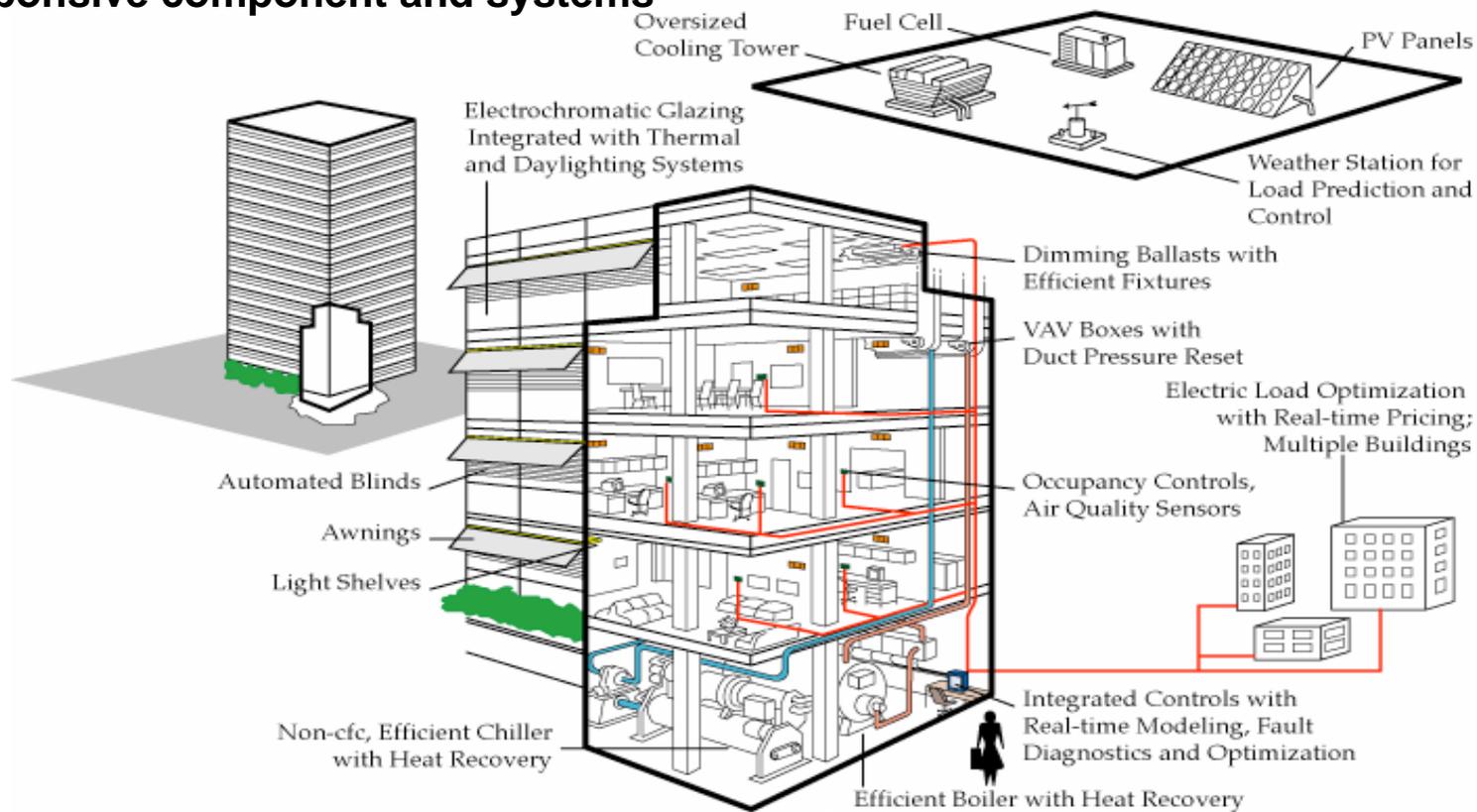


**Goal: Reduce the impact of operations of the Capitol complex to “carbon neutral”**

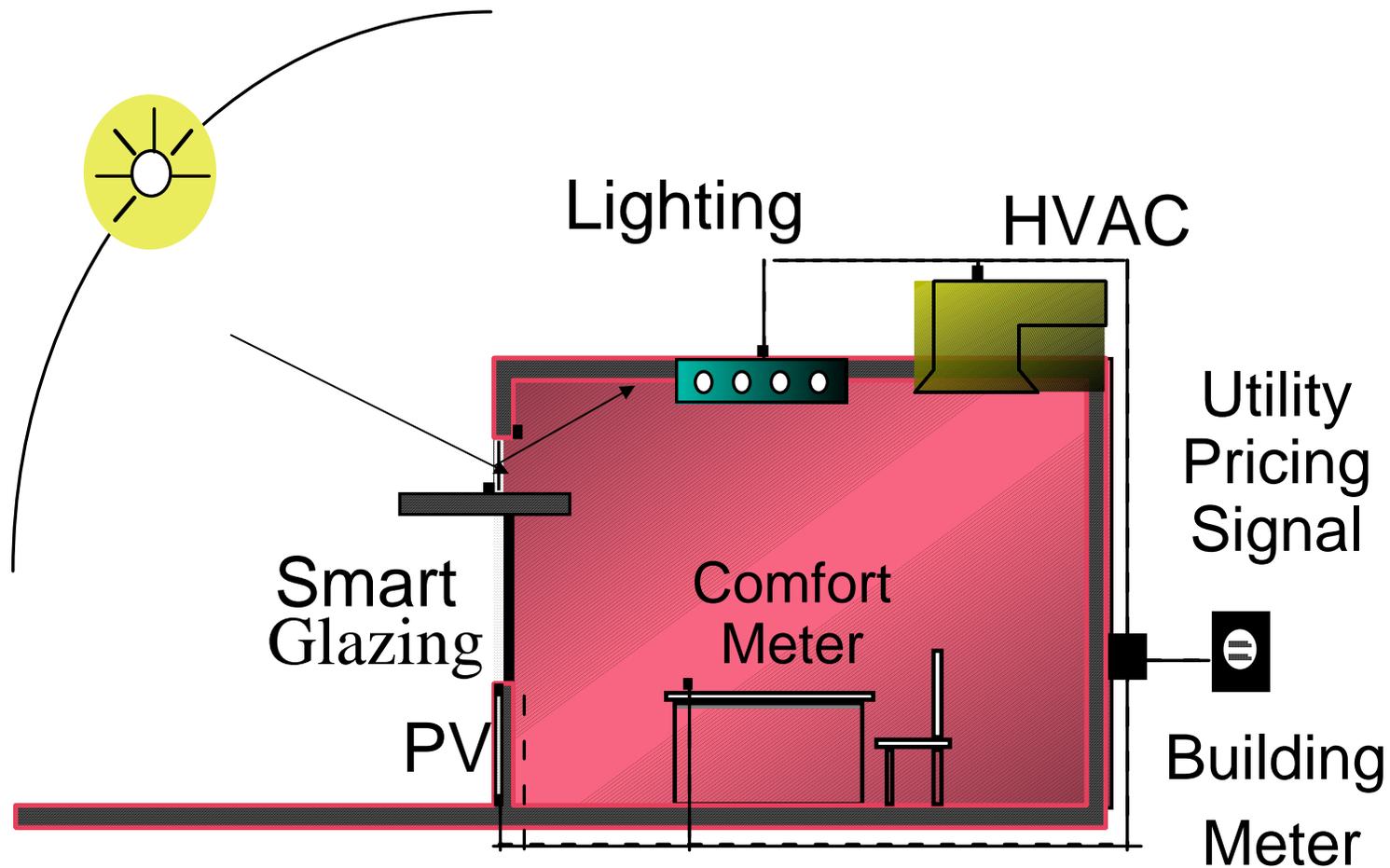
# Building Systems Integration Opportunities



- Underlying Building Information Model
- Smart Integrated Design
- Intelligent, Adaptive Controls for Occupant <-> Facility Manager
- Efficient technologies
- Smart, responsive component and systems



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



# 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

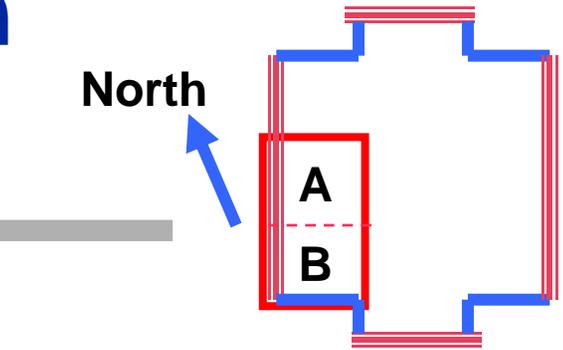
## Challenge:

- **How to develop a workable integrated hardware/software solution**
- **How to “guarantee” that such a solution will work in practice**
  
- 1,600,000 sq.ft.
- Full glass facade
- Occupancy in 2007
  
- Public/Private Partnership:
  - NYSERDA, DOE, CEC



# Approach: Test Performance in a Full-Scale Mockup

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



# Win-Win Partnership



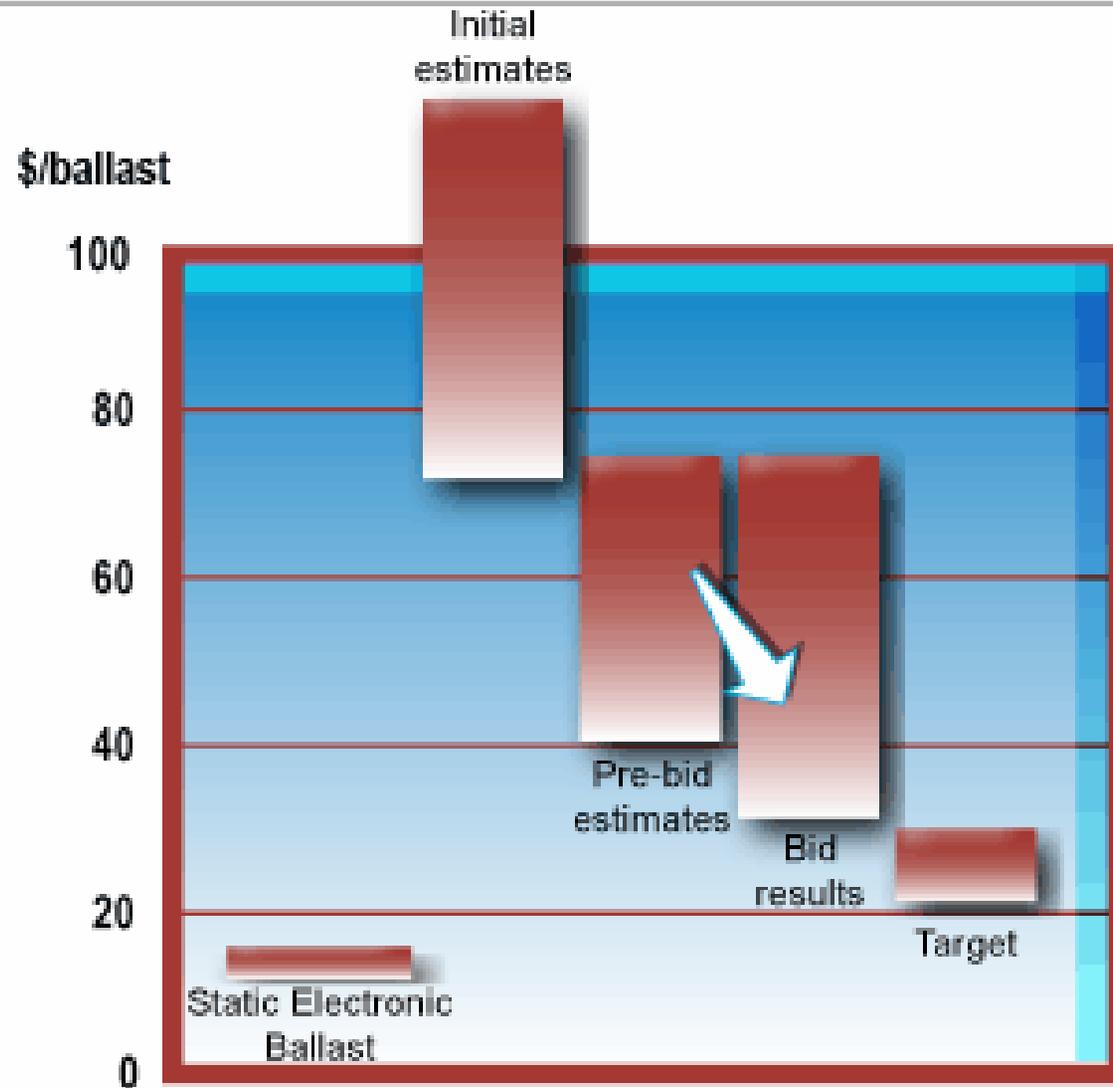
**Public Sector**  
**Energy Efficiency :**  
Commitment to goals  
Resources

**Research Lab:**  
Technical Facilitator  
Owner's Agent  
Problem solver  
Objective Arbitrator

**OwnerTeam:**  
Justify investment  
Resolve technical uncertainties  
Qualitative assessments  
Reduce Risk- Reduce cost

**Manufacturers:**  
Solve integration issues  
Understand user response issues  
Reduce Risk - Reduce Cost

# Progress Toward Cost Effective Dimming Electronic Ballast





# Shade Control Components

# The New York Times Headquarters: Shade Commissioning Tool being Tested



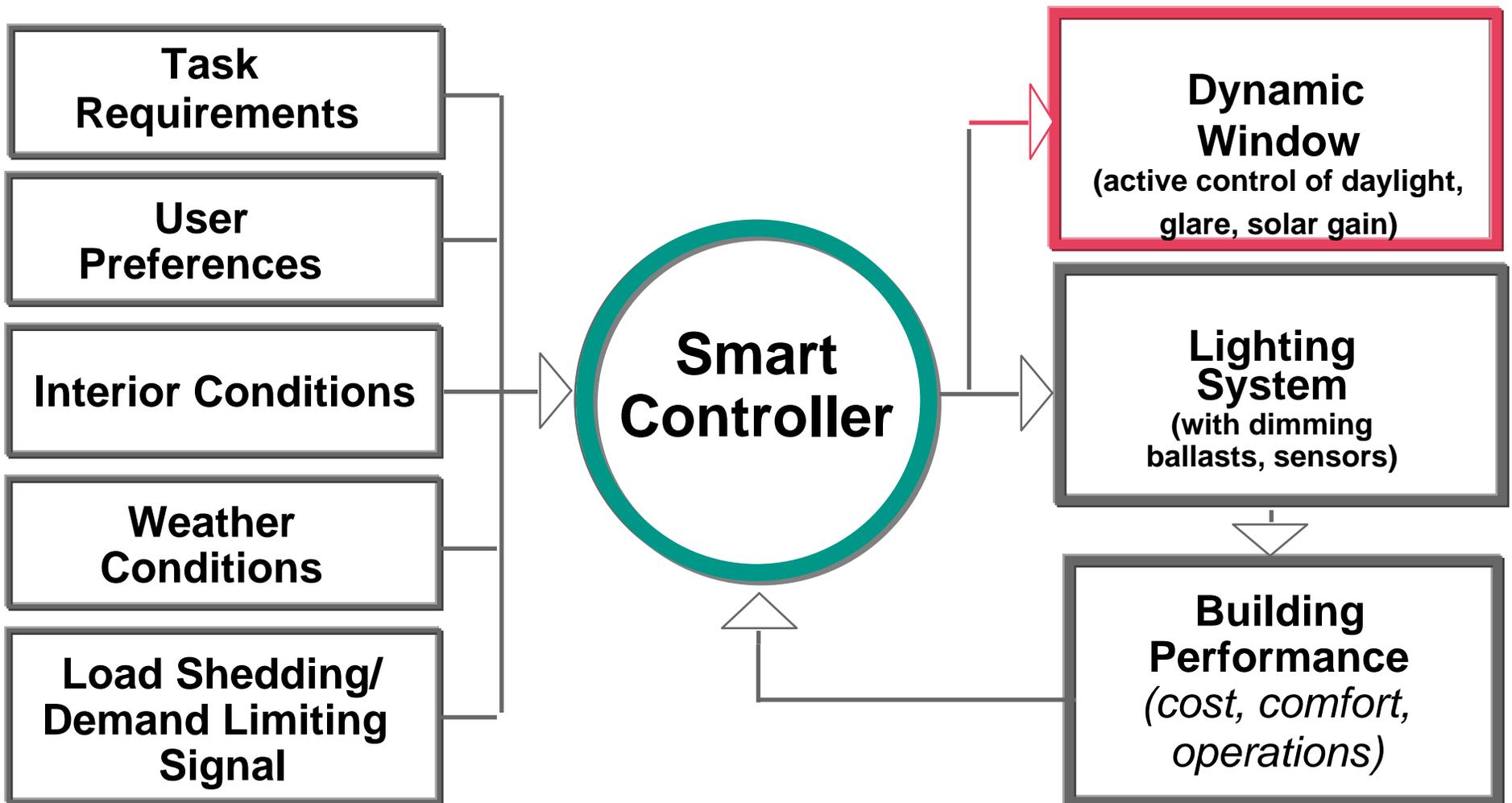
# New York Times HQ Occupancy 2007



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



# Intelligent Control of Dynamic Systems



# LBNL Façade Test Facility



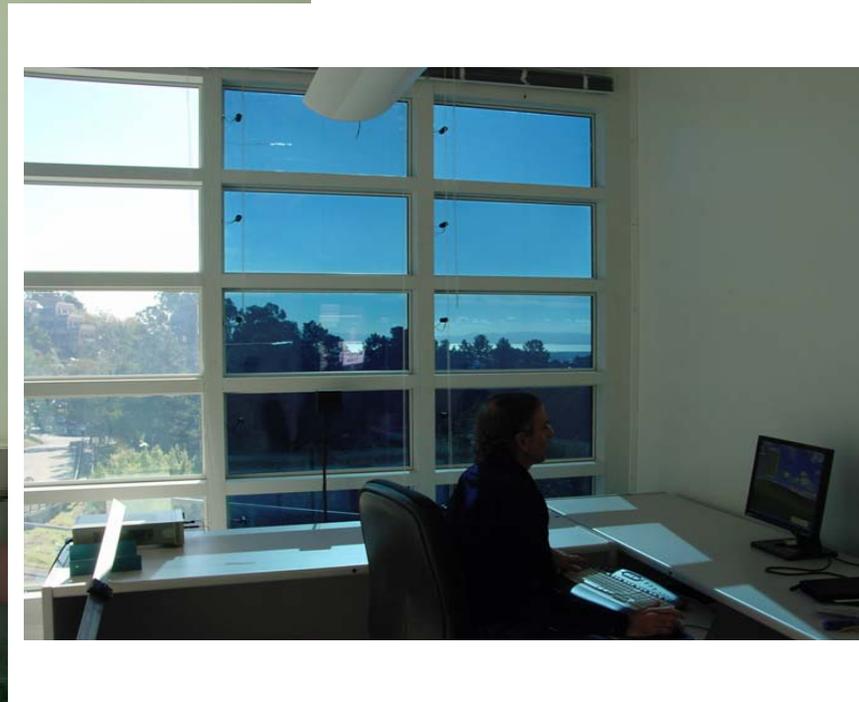
EC windows  
Blinds\*, no blinds  
Daylight or glare  
Control mode

EC windows  
Blinds\*, no blinds  
Daylight or glare  
 $T_v=0.56-0.02$   
 $SHGC=0.42-0.09$

Spectrally selective low-E  
Blinds\*, no blinds  
 $T_v=0.41$   
 $SHGC=0.23$

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

# Switchable Electrochromic Windows:



- LBNL full-scale windows field test facility

# Technology: Low-E Windows



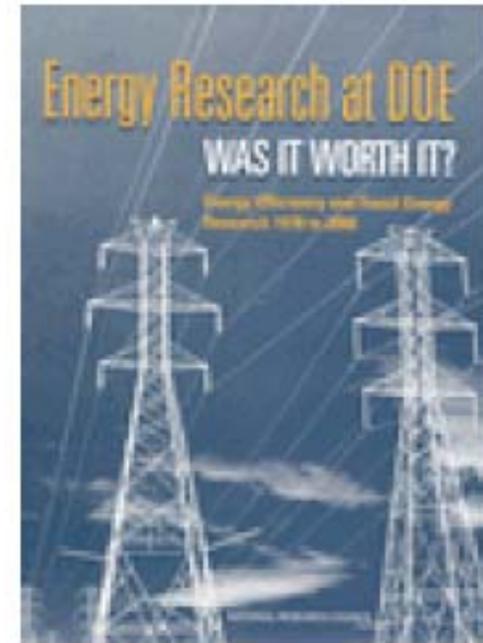
- Challenge: Double glazed windows cost U.S. consumers \$20+Billion per year in unneeded energy costs
- Triple glazed windows, too heavy, costly
- **Solution: Low-Emissivity Coating and gas fill**
- **R&D and Market Issues:**
  - Coating design
  - Window Thermal Performance optimization
  - Manufacturing technology
  - Durability
  - Cost
  - Integration into a complete window
  - Rating and labeling performance
  - Field test to verify performance vs Climate, application



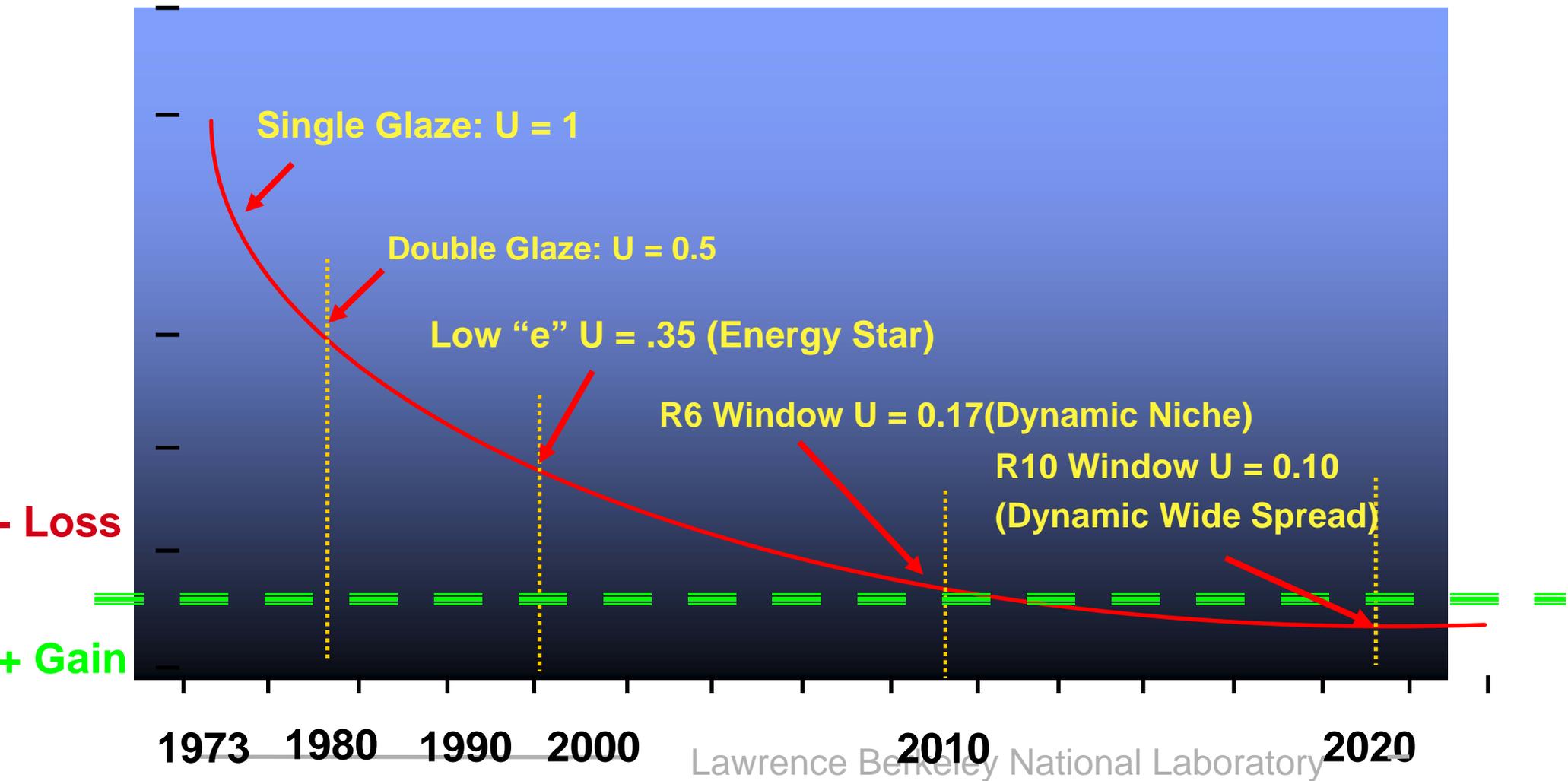
# Low-E Windows: Impacts



- R&D Action
  - DOE R&D program
  - Industry R&D investments --> investments in production
- Impacts:
  - Low-E Glazing Market growth
    - 1980: 0
    - 1990: 120M sf
    - 2003: 800M sf
- **National Academy study**
  - R&D investment vs Energy Saved and Net Economic Return
  - Effective R&D has huge ROI:
    - \$ millions invested; \$billions returned
- **Lessons learned**
  - Long lead time from Lab R&D to widespread market application
  - Widgets vs industry infrastructure- e.g. coating --> window
  - Public - private partnerships can be effective



# Advanced Windows Can Become Energy Producers



# Next Generation Prototype “Zero Energy” Window



- Current Prototype

- Dynamic Glazing; SHGC (0.04 – 0.34)
  - Electrochromic glazing
- Highly Insulating; U Value 0.18, R 5.6

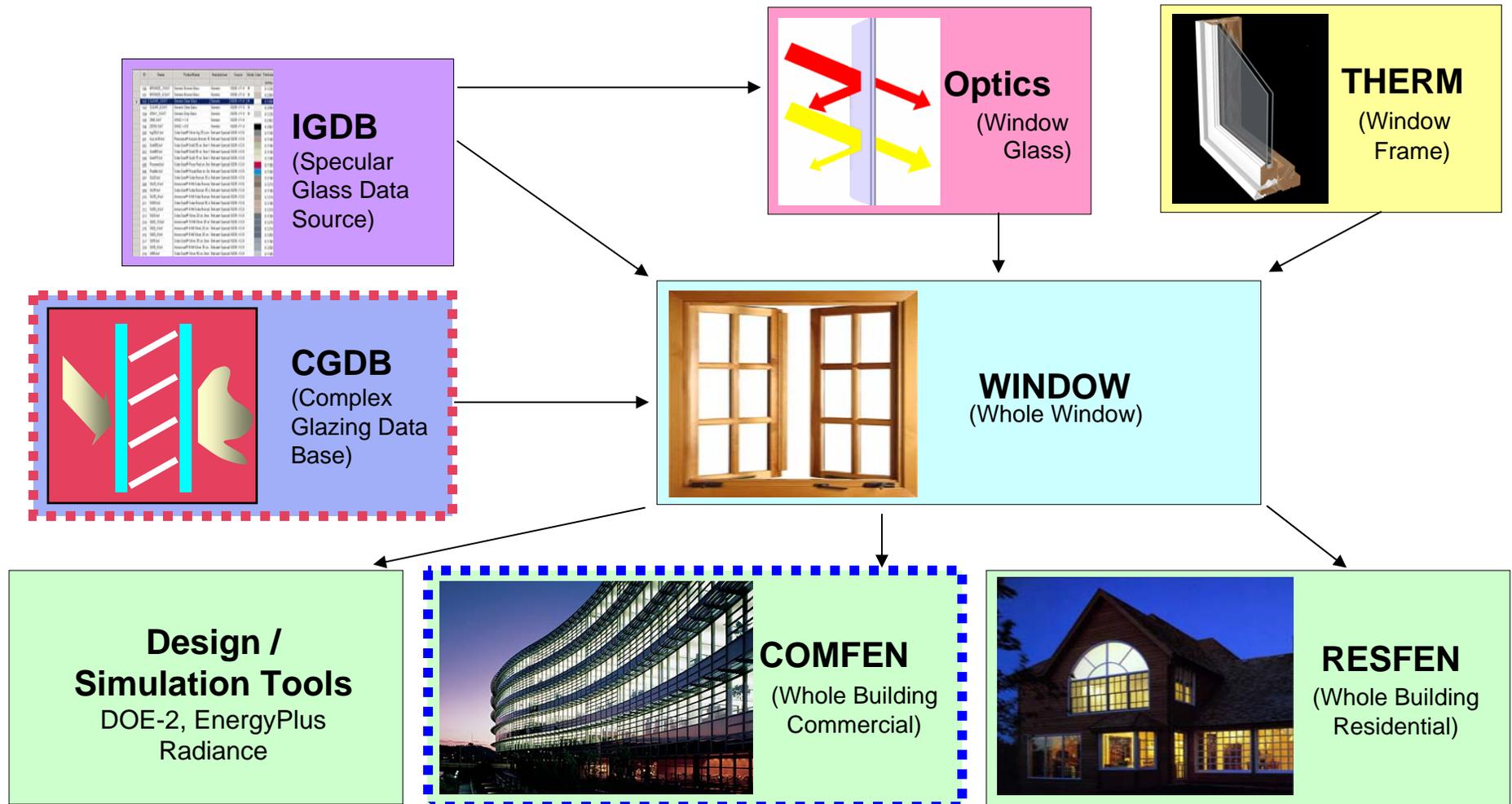
- Ongoing R&D

- Increased dynamic range
- Cost-effective production
- Frame heat transfer R&D (50% of heat lost through 20% of area)
- Systems benefits:
  - Better comfort
  - No perimeter ducts
  - No central heating system??



# WINDOW+ Suite of Tools

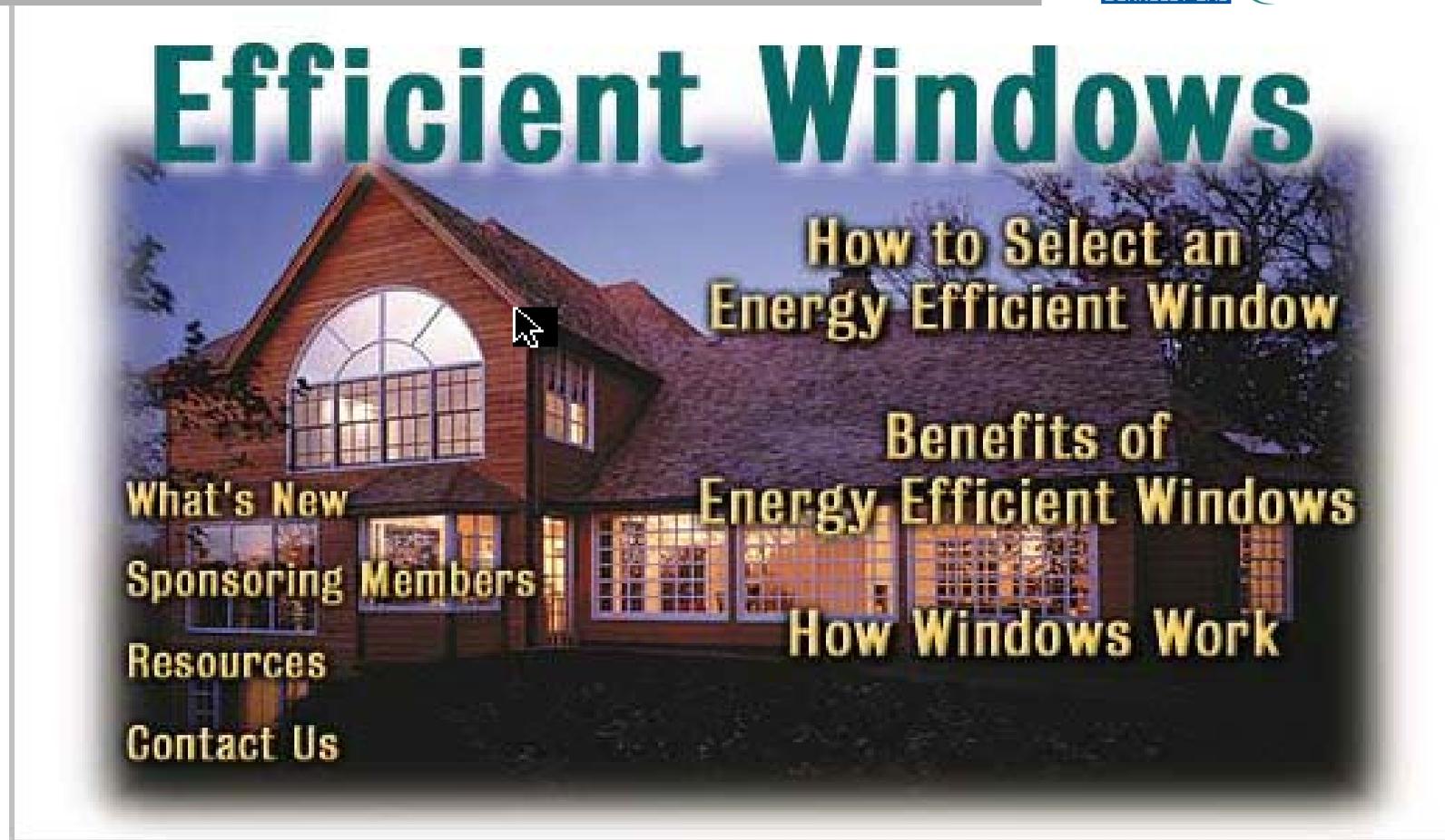
New: WINDOW6!



# [www.efficientwindows.org](http://www.efficientwindows.org) (Efficient Window Collaborative)



- Promotion, Education, Training, ...
- Alliance to Save Energy Partnership: with LBNL, U Minn,....
- Website, books, design guides,....





# Efficient Windows Collaborative

YOUR GATEWAY TO INFORMATION ON HOW TO CHOOSE ENERGY-EFFICIENT WINDOWS

<a href="#">Home</a>	<a href="#">Membership</a>	<a href="#">Codes</a>	<a href="#">Resources</a>	<a href="#">Publications</a>	<a href="#">Toolkits</a>	<a href="#">FAQ</a>	<a href="#">Contact Us</a>	<a href="#">Search</a>
<b>WINDOW SELECTION TOOL</b>			<b>WINDOW TECHNOLOGIES</b>			<b>BENEFITS</b>		

**Efficient Windows Collaborative (EWC) members have made a commitment to manufacture and promote energy-efficient windows. This site provides unbiased information on the benefits of energy-efficient windows, descriptions of how they work, and recommendations for their selection and use. Take a look to learn more!**

- The third edition of *Residential Windows: A Guide to New Technologies and Energy Performance* is now available and provides updated and expanded information on window properties and technologies, as well as new sections on such key topics as window installation, energy efficiency, and building codes. [More information»](#)
- The EWC has developed toolkits for manufacturers, designers, and builders who seek to provide their customers with low energy costs and comfort through efficient windows. [See toolkits»](#)
- **Claim a tax credit for installing energy efficient windows in your home.** On February 21, 2006, the Internal Revenue Service released a guideline detailing how the tax credit works. [Learn more»](#)
- Let utilities help you finance more energy-efficient windows for your home. Download an overview of [Utility Programs that Offer Incentives and Rebates for Energy-Efficient Windows»](#)
- Decision makers in the low-income housing sector can find options for financing energy efficiency measures through this web portal presented by the EWC. [Download "Improving Energy Performance in Low-Income Housing"](#)
- The Efficient Windows Collaborative is excited to announce the launch of a new database of efficiency initiatives including tax incentives, building code changes and legislative initiatives. [See what's going on in your state»](#)



This site is sponsored by the EWC with support from the U.S. Department of Energy's Windows and Glazings Program and the participation of industry members.

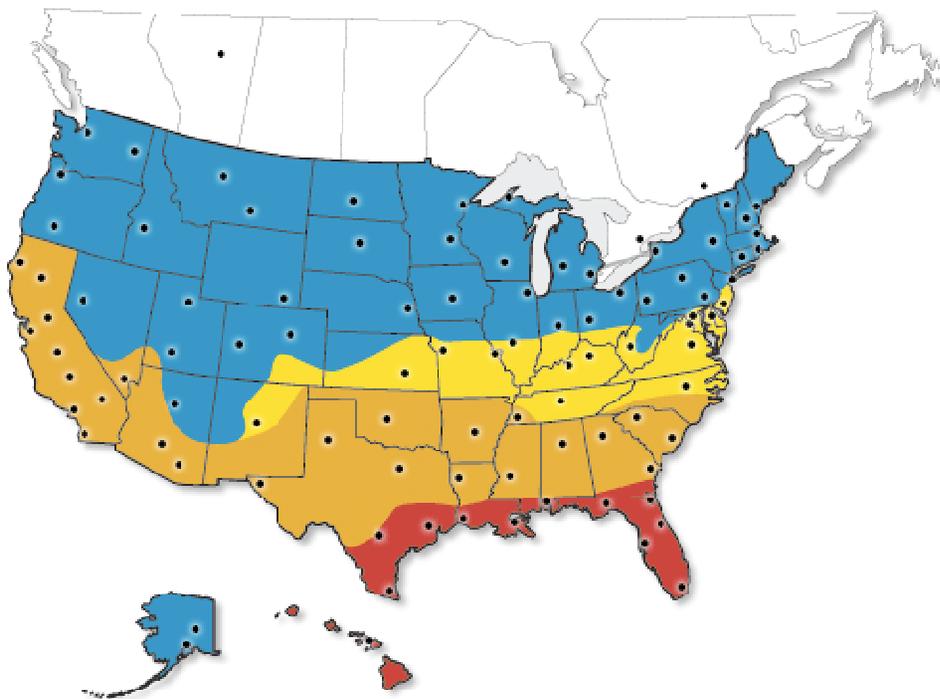
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[Window Selection Tool](#) | [Window Technologies](#) | [Benefits](#)



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## Window Selection Tool

Compare costs for a typical house by selecting a condition, window type, and a city. The annual energy use from computer simulations for a typical house in your city can be compared for different window options.



### Select a condition:

- New Construction
- Existing Construction

### Select a type:

- Windows
- Skylights

### Select a city:

AK Anchorage

[Compare Costs](#)

### When selecting windows or skylights:

- » Look for properties on the [NFRC Label](#).
- » Look for the [ENERGY STAR®](#).
- » Perform simulations using [RESFEN](#).

### Design Variations:

- » [Glazing Area](#)
- » [Shading](#)
- » [Orientation](#)

### American Architectural Manufacturers Association (AAMA):

[AAMA](#) is the source for performance standards, product certification, and educational programs. The [AAMA online Certified Products Directory](#) is the best resource available for locating products to achieve air, water, structural and forced entry resistance code compliance.



### Window & Door Manufacturers Association (WDMA):

[WDMA](#) is a trade association representing approximately 145 U.S. and Canadian manufacturers and suppliers of windows and doors for the domestic and export markets. WDMA members manufacture high performance products designed and built to performance-based standards.





# Efficient Windows Collaborative

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WINDOW SELECTION TOOL			WINDOW TECHNOLOGIES			BENEFITS		

## Denver, Colorado

### ENERGY STAR® Properties:

U-Factor ≤ .35

### Energy Costs

Natural Gas: \$0.992/therm

Electricity: \$0.120/kWh



[Colorado Factsheet](#)

[State Code Information](#)

### Window Search

Select Glass:

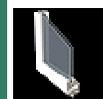
Select Frame:

ENERGY STAR®: Yes

Construction Type: New  Existing

Product Type: Windows  Skylights

### Window Types



**Window33**  
[Triple-glazed with Moderate-Solar-Gain Low-E, Argon/Krypton Gas Insulated Vinyl](#) or [Fiberglass](#)

### Properties

U = .18  
 SHGC = .40  
 VT = .50

### Annual Energy Use

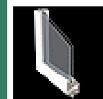


ENERGY STAR® Qualified

### Manufacturer Information

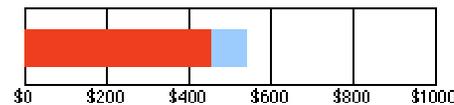


[Products](#)

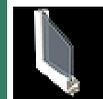


**Window30**  
[Double-glazed with High-Solar-Gain Low-E, Argon/Krypton Gas Insulated Vinyl](#) or [Fiberglass](#)

U = .29  
 SHGC = .56  
 VT = .58



[Products](#)

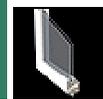


**Window34**  
[Triple-glazed with Low-Solar-Gain Low-E, Argon/Krypton Gas Insulated Vinyl](#) or [Fiberglass](#)

U = .18  
 SHGC = .26  
 VT = .43

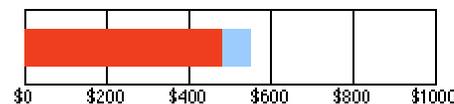


[Products](#)



**Window31**  
[Double-glazed with Moderate-Solar-Gain Low-E, Argon/Krypton Gas Insulated Vinyl](#) or [Fiberglass](#)

U = .27  
 SHGC = .46  
 VT = .60



[Products](#)



Efficient Windows

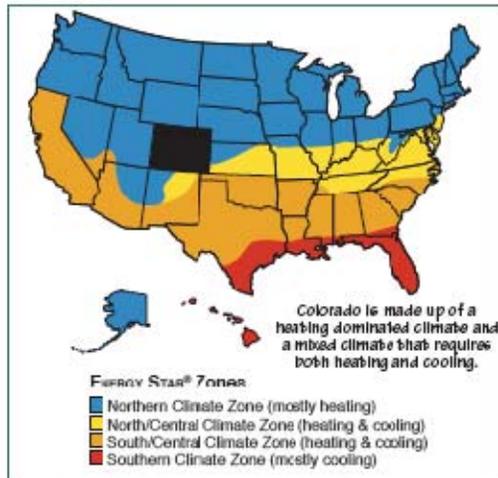


Collaborative

# Fact Sheet: Selecting Energy Efficient Windows in Colorado

[www.efficientwindows.org](http://www.efficientwindows.org)

March 2006



## Benefits of High Performance Windows

### Cooling and Heating Season Savings

Low-E coatings, gas-fills, and insulating spacers and frames can significantly reduce winter heat loss and summer heat gain.

### Improved Daylight and View

New glazings with low-solar-gain low-E coatings can reduce solar heat gain significantly with a minimal loss of visible light (compared to older tints and films).

### Improved Comfort

In summer and winter occupant comfort is increased; window temperatures are more moderate and there are fewer cold drafts. Discomfort from strong summer sunlight is reduced.

### Reduced Condensation

Frame and glazing materials that resist heat conduction do not become cold and this results in less condensation.

### Reduced Fading

Coatings on glass or plastic films within the window assembly can significantly reduce the ultraviolet (UV) and other solar radiation which causes fading of fabrics and furnishings.

### Lower Mechanical Equipment Costs

Using windows that significantly reduce solar heat gain means that cooling equipment costs may be reduced.

## 1. Look for the ENERGY STAR®

The Department of Energy (DOE) and the Environmental Protection Agency (EPA) have developed an ENERGY STAR ([www.energystar.gov](http://www.energystar.gov)) designation for products meeting certain energy performance criteria. Since performance of windows and skylights vary by climate, product recommendations are given for the four ENERGY STAR climate zones. To distinguish between ENERGY STAR products, go to Step 2.



## 2. Look for Efficient Window Properties on the NFRC Label

The National Fenestration Rating Council NFRC ([www.nfrc.org](http://www.nfrc.org)) has developed a window rating system based on whole window product performance. The NFRC label provides the only reliable way to determine the energy efficient properties and to compare products. The NFRC label appears on all fenestration products which are part of the ENERGY STAR program. See Page 2 for the recommended properties for this climate. For typical cost savings from efficient windows in a specific location, go to Step 3.

ENERGY PERFORMANCE RATING	
U-Factor (BTU/hr-ft²-F)	0.35
Solar Heat Gain Coefficient (SHGC)	0.32
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance (VT)	0.51
Light Transmittance (LT)	0.2

## 3. Compare Annual Energy Costs for a Typical House

Computer simulations for a typical 2000 square-foot house are used to compare the annual energy performance of different window types. A comparison of the energy performance of a set of windows for this climate begins on Page 3.



## 4. Customize Energy Use Calculations for a Specific House

A computer simulation program, such as RESFEN ([windows.lbl.gov/](http://windows.lbl.gov/))



# Design Guides/Information Sources



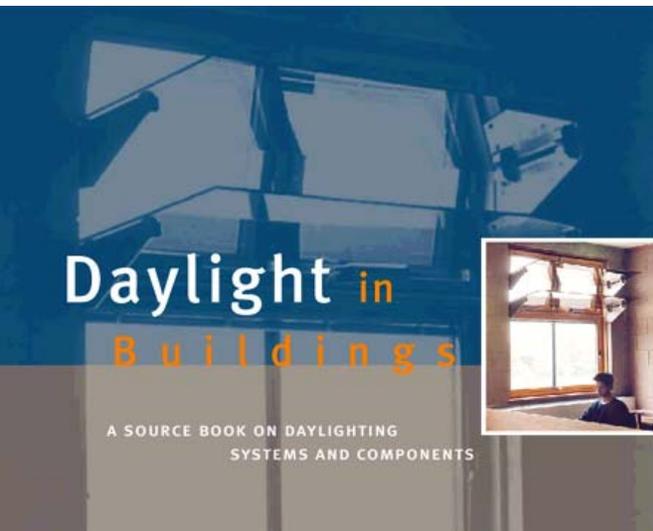
Tips for Daylighting Guide: <http://windows.lbl.gov>  
 Selective Glazings Application Guide: <http://windows.lbl.gov>  
 IEA Daylight in Buildings Source Book:  
<http://gaia.lbl.gov/iea21>  
 High Performance Building Facades: <http://gaia.lbl.gov/hpbf>



**Window Systems for High Performance Buildings:**  
 Norton Press 2004



## TIPS FOR DAYLIGHTING



**Federal Technology Alert**

A publication series designed to speed the adoption of energy-efficient and renewable technologies in the Federal sector

Prepared by the New Technology Demonstration Program

DOE/EE-0173

**Spectrally Selective Glazings**

*A wall proven window technology to reduce energy costs while enhancing daylight and view*

Spectrally selective glazing is window glass that permits some portions of the solar spectrum to enter a building while blocking others. This high-performance glazing admits as much daylight as possible while preventing transmission of as much solar heat as possible. By controlling solar heat gains in summer, preventing loss of interior heat in winter, and allowing occupants to reduce electric lighting use by making maximum use of daylight, spectrally selective glazing significantly reduces building energy consumption and peak demand. Because new spectrally selective glazings can have a virtually clear appearance, they admit more daylight and permit much brighter, more open views to the outside while still providing the solar control of the dark, reflective energy-efficient glass of the past.

Because of its solar heat transmission properties, spectrally selective glazing benefits both buildings in warm climates where solar heat gain can be a problem and buildings in colder climates where solar heat gains in summer and interior heat loss in winter are both of concern. In other words, these glazings are appropriate for residential and commercial buildings throughout the United States. The energy efficiency of spectrally selective glazing means that architects who use it can incorporate more glazing area than was possible in the past within the limitations of codes and standards specifying minimum energy performance. When spectrally selective glazing is



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## Window Design Decisions

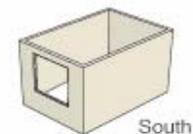
At this time only a limited set of conditions are available for offices in Chicago and Houston. Additional cities, building types and conditions will be added. More information on the [decision-making process](#)».



**Location:**  
IL Chicago

**Building Type:**  
Office

**Orientation:**  
South



<b>Window Area</b> [All]	<b>Daylight Controls</b> [All]	<b>Shading</b> [All]	<b>Light Redirection</b> [None]	<b>Window</b> [All]	Search
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# “Design” or “Analyze” Mode

Commercial Windows

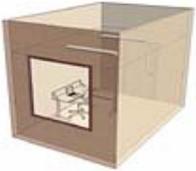
http://www.develop.csbr.umn.edu/doe/commweb2/chicago/facade30nonegall.html

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## Facade Maker: Design Your Facade



**Orientation:** South

**Window Area:** WWR=0.30

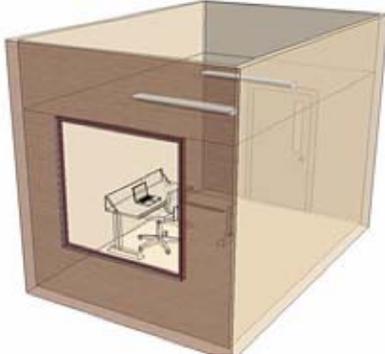
**Daylight Controls:** Yes

**Shading:** None

**Window:** Low-E Clear (2)

Clear New Search

Attribute	Performance	Data
Energy		108.2 kBtu/sf-yr
Peak Demand		4.1 W/sf
Daylight		219.9 Footcandles
Glare		7.6 Glare Index
View		4.6 View Index
Thermal Comfort		14.8 PPD



# More Info

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