LBNL Windows and Daylighting RDD&D DOE MYPP Overview

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Windows and Daylighting Program

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Building Technology and Urban Systems Department

Windows Overview

- **Context**
  - Windows are a ~5Q/yr, ~ $50B/yr cost and opportunity
  - **Vision: change windows from net loss to net supply**
  - Highly "visible" component- window selection is "complex"
  - Long-Lived Component- one chance to make the right decision!

Window-Related Energy Consumption
(Quads)

	Residential	**Commercial**
Heating	1.65	0.96
Cooling	1.02	0.52
Total	*2.67*	*1.48*

Daylight: +1 Q

- **Scope, Scale, Impact**
  - Comprehensive program: spans materials science to specific product R&D to systems integration
  - Research – Development – Demonstration – Deployment
  - All Climates, All Building Types, New and Retrofit
  - Significant Industry Collaboration and Cost Share
  - Measurable impact on technology, products, energy savings

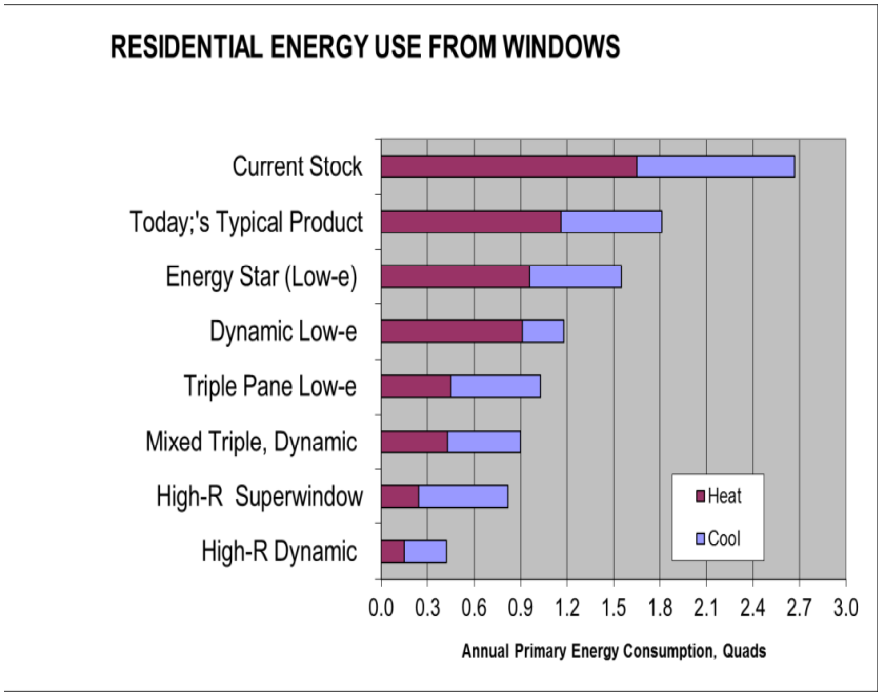
Vision: "Zero-Energy Window"

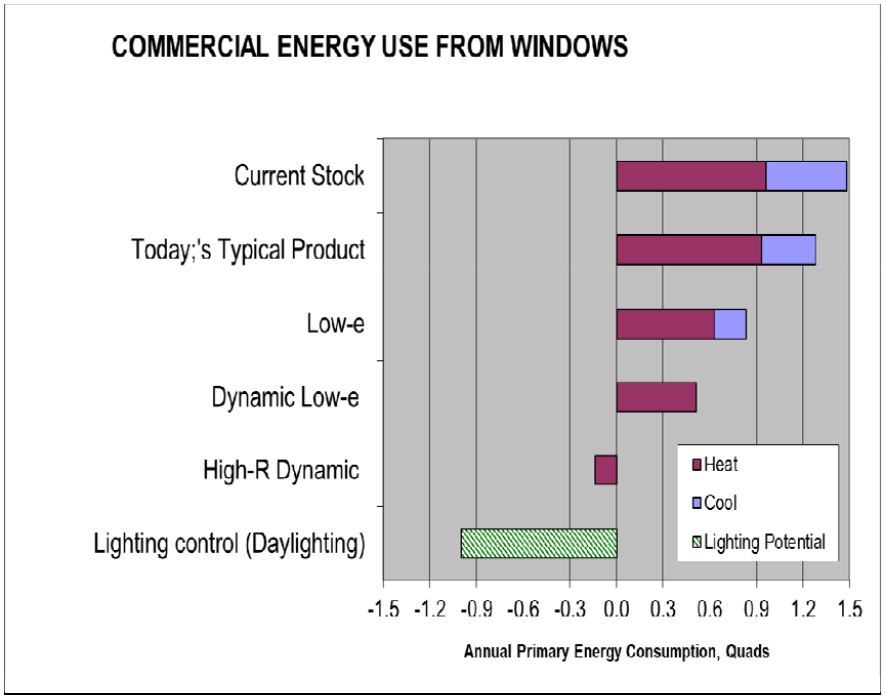
Energy Losers --> Neutral --> Net Suppliers

- 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

Examine End Use by Sector and Climate, New/Retrofit

- Overall market opportunity: Residential - 2.7 quads; Commercial – 1.5 quads (2.5 quads with lighting savings from daylighting controls)
- Short term goals: Increase savings with better use of existing product lines or tweaks to existing products (e.g., low-e blinds)
- Longer term goals: New cost effective, enhanced product options





Current Energy Use Based on US Energy Information Administration, BTP Data

Major DOE Project Areas and Staff

- Dynamic Glazing Materials – Andre Anders
- Highly Insulating Window Systems – Charlie Curcija
- Attachments and Retrofits – Charlie Curcija
- Daylighting and Facades – Eleanor Lee
- Enabling Tools – Christian Kohler

- Cost shared funding from 9 other public and private partners
  - CEC, GSA, DOD, Utilities, other state energy agencies, private companies

Dynamic Glazings

- **Multi-year Goals**:
  - develop energy-efficient dynamic windows of the future in collaboration with industry partners
  - improve performance and cost effectiveness of the most advanced concepts of dynamic windows
  - provide market viable solutions for advanced materials, and coatings and device fabrication processes

- **FY12 Objectives**
  1. through CRADA, work with Soladigm Inc. to bring energy-efficient, affordable electrochromic windows to market.
  2. using ARRA funding, support efforts by Applied Materials to develop deposition tools and "recipes" for low-cost, high performance electrochromics.
  3. Develop low-cost, high-performing transparent conducting materials that could be applied to large area EC windows

Coating Characterization

Support Industry's Electrochromic Stack Development by providing unique materials characterization

- Using the Rutherford Backscattering Spectrometry (RBS) and Nuclear Reaction Analysis (NRA), provide depth profiling of elemental composition of the electrochromic layer stack; RBS / NRA technique is not widely available: requires a sophisticated machine and skilled experts running it
- Delivered internal reports to industry partners on a regular basis, with emphasis on lithium profiling

5 MeV RBS-system in Bldg. 53, jointly operated with the Materials Research Division

AZO: FY12 Accomplishments

- **High Rate Deposition of Indium-Free Transparent Conducting Oxide (TCO) Films**
  - Indium containing TCO cannot be scaled to 10^8 m^2 needed to satisfy EC window and other markets
  - as EC windows get larger (> 1 m^2), good conductivity becomes very important, otherwise slowing of switching, non-uniformity ("irising")

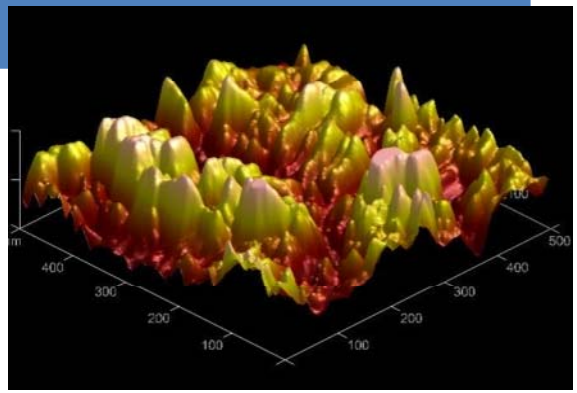
  → we pursue both sputtering and filtered arc approach of AZO
    - AZO = aluminum doped zinc oxide, abundant, cheap materials
    - sputtering is easier to scale; we work on low-energy-assisted processes as well as on filtered arc deposition
  - Results:
    1. sputtering: observed and explained the ionization localization in high power pulsed magnetron sputtering
    2. demonstrated superior material by filtered arc technology, (patent pending)
    3. started to work on scalable, high rate process involving liquid metal cathodes

Low-cost transparent conductor: AZO

Mendelsberg, et al., J. Phys D: 44, 232003 (2011).

Highlighted in

- "Europhysics News" and
- "Journal of Physics D" Highlights of the Year 2011



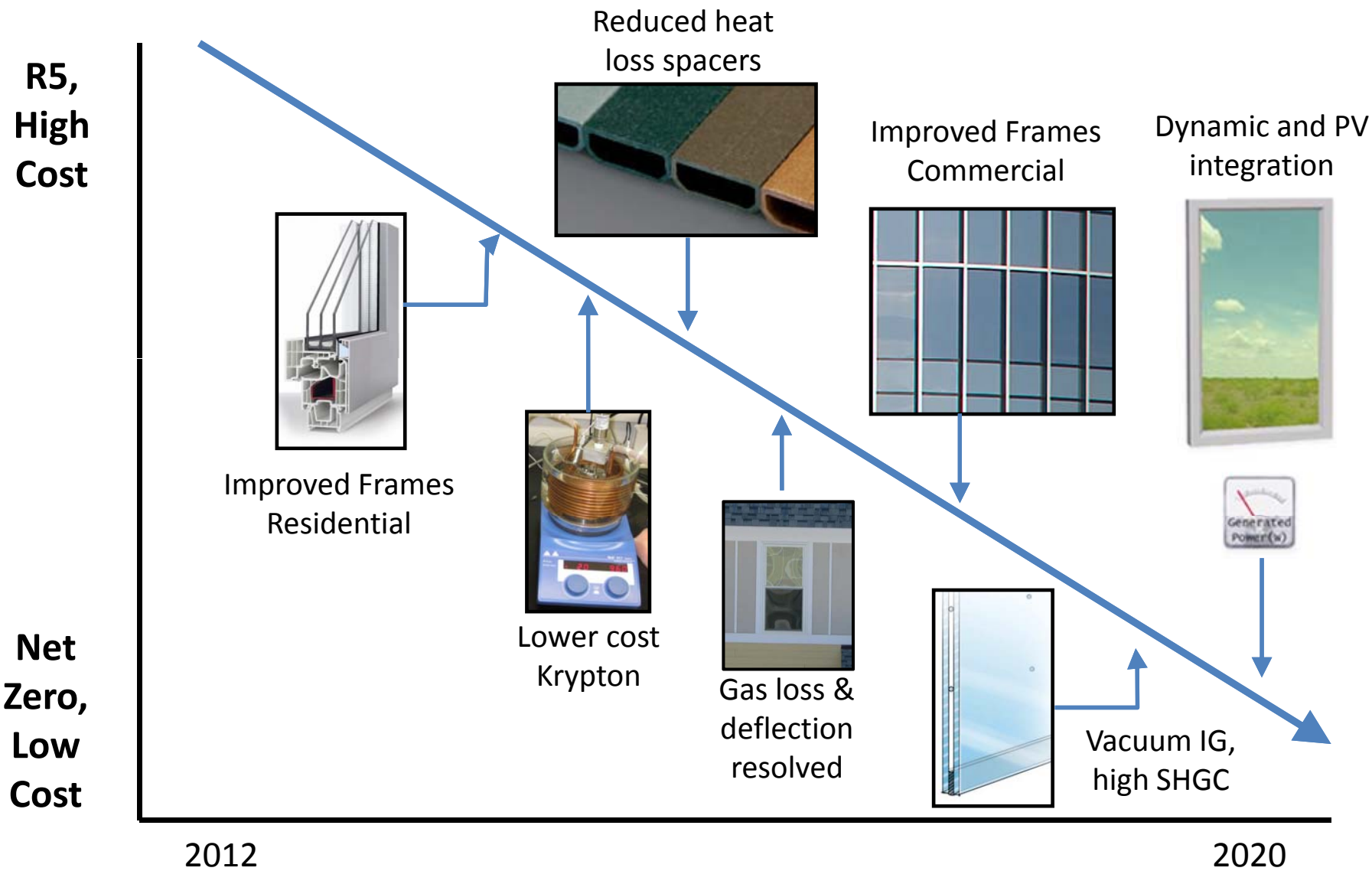
Substrate Temperature	425° C
O-Plasma Power	0 W
Thickness	505 ± 15 nm
Growth Rate	**253 ± 8 nm/min**
Sheet Resistance	6.8 ± 0.3 Ω/□
Resistivity	(3.4 ± 0.3) x 10^{-4} Ωcm
Mobility	**55 ± 3 cm^2/Vs**
Carrier Concentration	(3.8 ± 0.3) x 10^{20}
Mean VIS Transmission	96%
RMS Roughness	3.7 nm

wavelength (nm)

Highly Insulating Windows: Summary

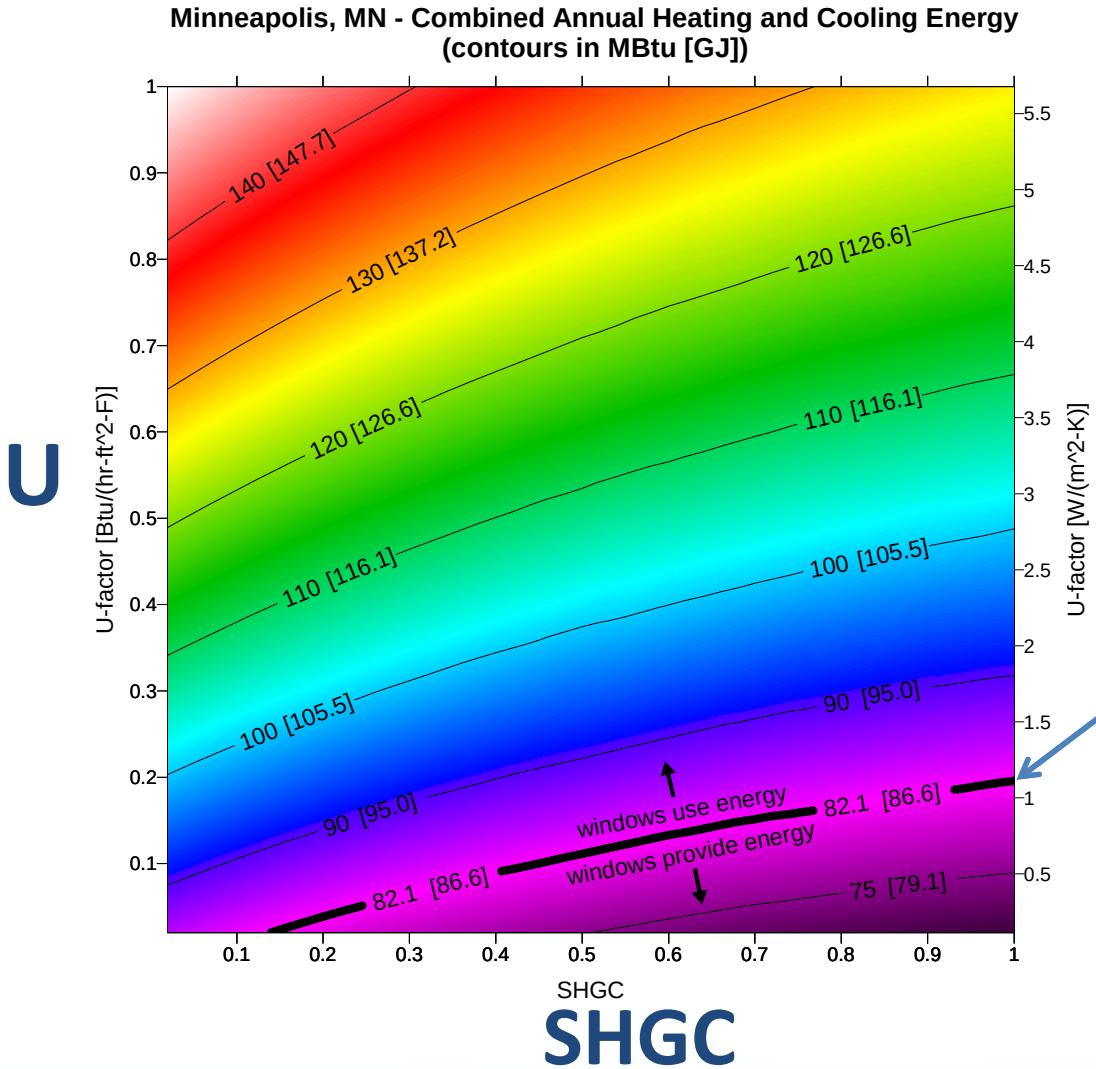
- **Glazing Systems**:
  - Incremental: Multiple Glazings, Coatings, Gas fills, maintain/develop high SHGC option - can be scaled quickly
  - Disruptive: Vacuum, aerogel – longer term, higher risk
- **Frame and Edge Systems:**
  - Existing Materials: New Thermal Designs
  - New Materials, New Designs
- **Special Systems – e.g. Translucent**
- **Applications Focus: Residential, Commercial**
- **Other Performance Issues – infiltration, hardware**
- **Measured Lab and Field Performance**
- **Business Case and Market Drivers**
  - Links to integrated building systems, e.g. eliminate perimeter heating
  - Energy Star, Codes and Standards, Tax Credits

Hi-R Technology Track: FY12-20 Timeline



Minneapolis: Heating Climate

Annual energy use vs. window properties



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

Specific windows plotted on map of iso-energy use

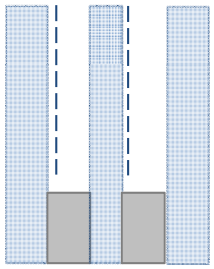
House with no windows uses 82MBTU

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

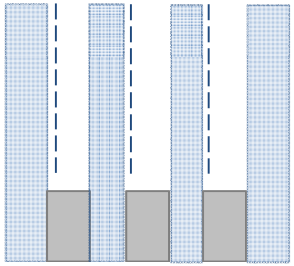
Average performance for a house – would shift for different orientations

Glazing Options

Market Today



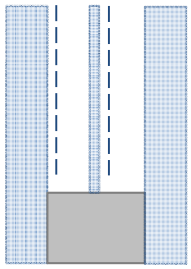
Two low-e



Three low-e

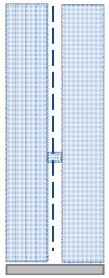
Note: low-E coated polyester film can be alternative middle glazing.

FY12-FY15

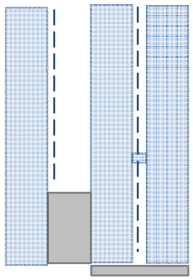


Two low-e
Thin glass
single seal
Krypton

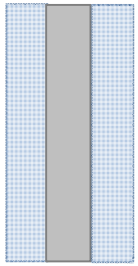
FY15-FY20



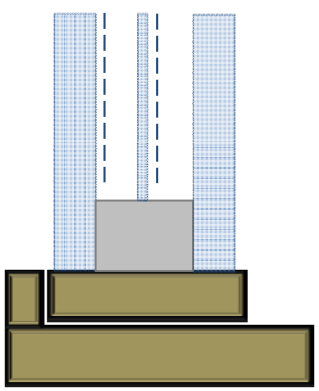
One low-e
Vacuum

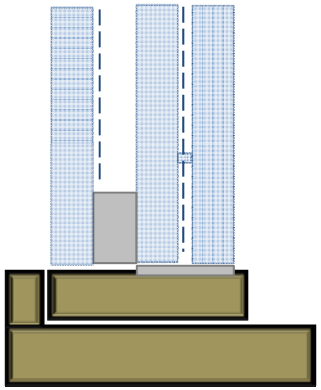


Two low-e
Vacuum Hybrid



Aerogel

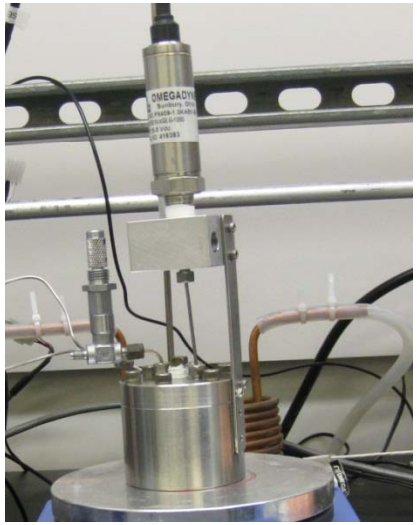


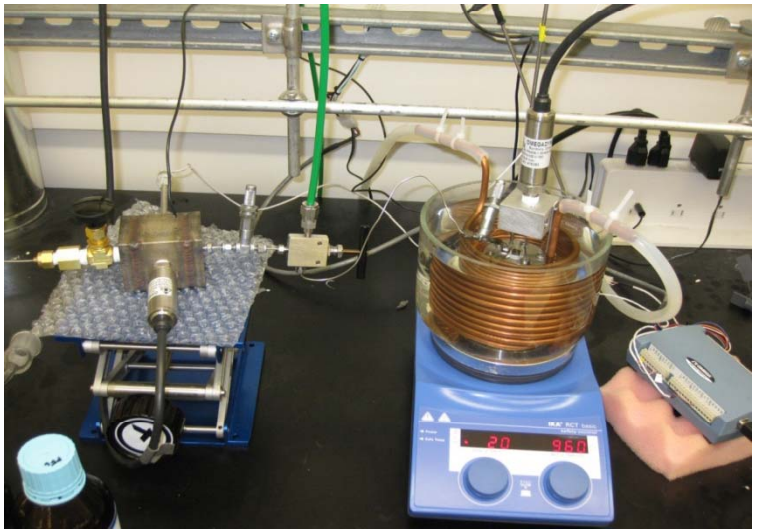


Super-insulating frame with highly insulated glazing

Low Cost Krypton Distillation

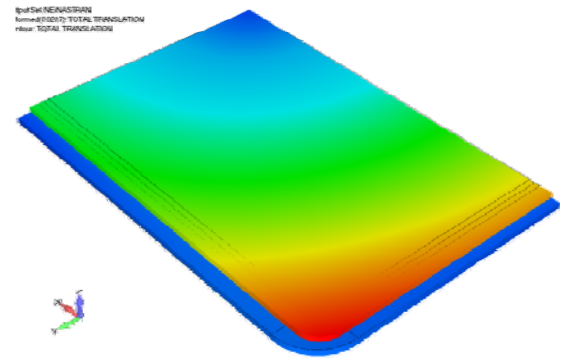
- **Background**
  - Low conductance gas needed for narrow air gaps; Krypton is "too expensive" (10 times more expensive than Argon)
- **Goal:**
  - Reduce cost and energy intensity of Kr production
- **Plan:**
  - Investigate if ionic liquids (solvents) can have increased Kr selectivity; minimal data in literature
  - Simulations show potential for x5 Kr Selectivity
  - Build specialized apparatuses for measurements
  - If promising, build lab scale process
- **Accomplishments:**
  - Selection of ionic liquids with better selectivity for Krypton as well as Xenon, which appears as by product. Xenon can make process very attractive
- **Future work:**
  - Complete measurements with selected ionic liquid
  - Process-design study and economics
  - Produce lab-scale process

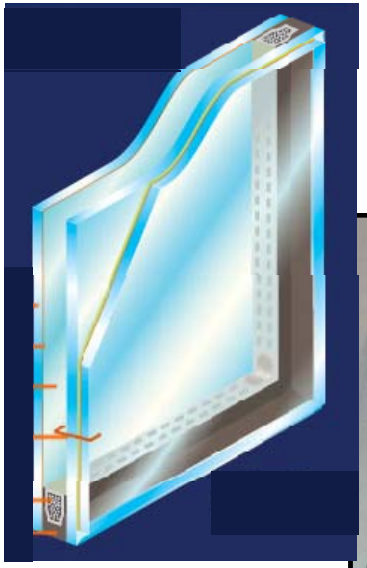




Vacuum Insulated Glazing (VIG)

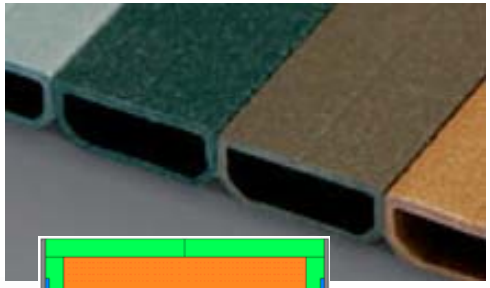
- **Goal:**
  - Work with technology developers to accomplish higher insulation values with lower failure rates
- **Plan:**
  - Model thermal impacts of support pillars and edges
  - Testing to validate new THERM/WINDOW modeling procedure
  - Explore vacuum edge seal options for use in traditional insulated glazing units
  - Explore hybrid triple-VIG configuration for increased insulation and decreased stresses
  - Continue Industry collaboration through CRADA and other forms of collaboration
- **Accomplishments:**
  - New analytical model for vacuum glazing
  - New version of WINDOW/THERM with VIG modeling capability

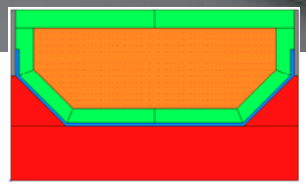


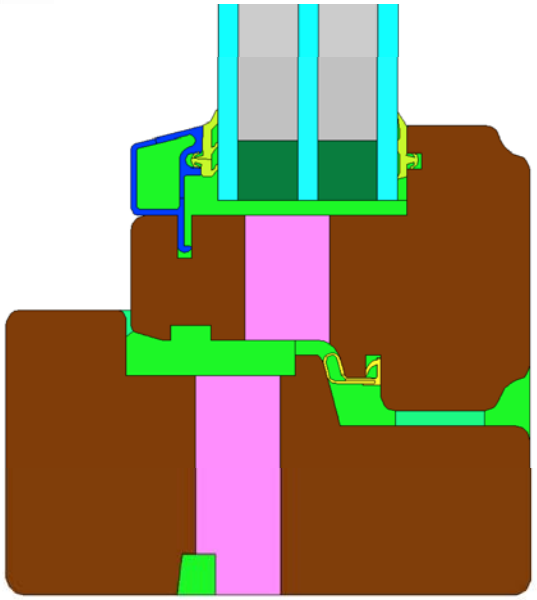


Highly Insulating Residential Frames

- **Background**
  - Frames are the weak thermal links in windows; historically structural and other concerns drove design
- **Goal**:
  - Stimulate industry R&D by defining materials performance (thermal conductivity) targets for alternative R10+ frame designs
- **Plan:**
  - Parametric simulations on five generic R5 frames
- **Accomplishments:**
  - Identification of major drivers:
    - Spacers have key importance
    - Low-e surfaces for hollow (fiberglass, vinyl) important
    - Optimal conductivity for thermal break is function of frame design
  - Published Paper to engage broader industry interest
- **Future work:**
  - Innovative materials R&D
  - Improve modeling and measurement tools
  - Industry collaborations

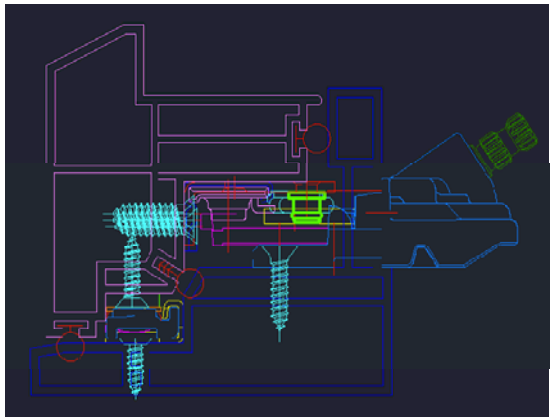


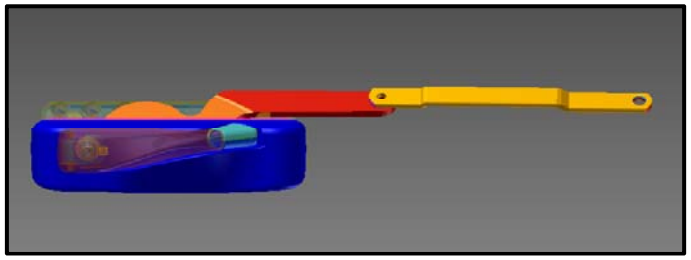




Thermal Impacts of Hardware

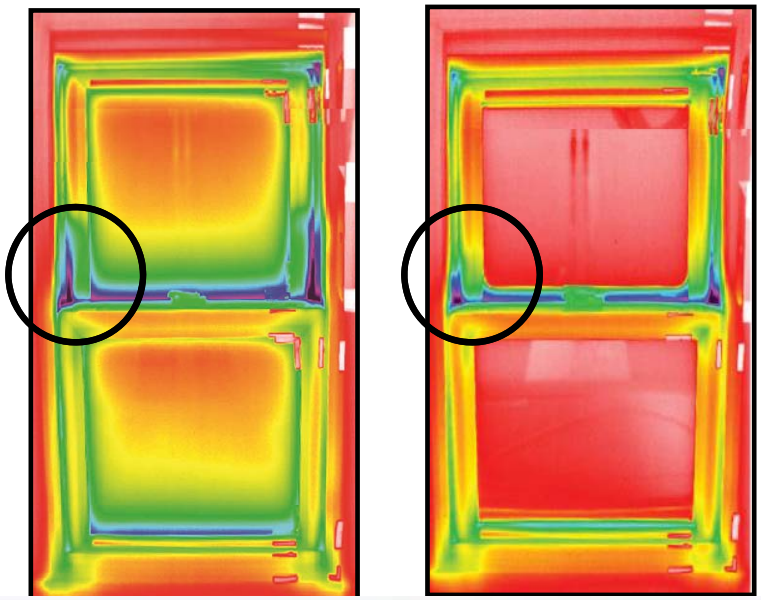
- **Goal:**
  - Ensure highly insulating (R5+) frames realize claimed performance. Small effects ignored in 1990s can be significant now.
- **Plan:**
  - Determine the impacts of non-continuous hardware on performance.
  - Analyze thermal impacts with 3-D CHT modeling programs and hot box testing.
- **Accomplishments:**
  - Completed 3-D computer modeling
- **Future work:**
  - Develop technical procedure for incorporating hardware effects into product development and thermal rating methods.
  - Develop set of recommendations for better hardware design





Measurement Facilities

- **Goal**:
  - Provide research class IR thermography and calorimetric measurements instruments to aid industry in developing high-R products
  - industry needs these facilities for direct feedback on product performance and we need for tool validation
- **Plan:**
  - Support LBNL's R&D efforts to develop Hi-R technologies
  - Support industry development of new underlying insulated glazing and frame technologies.
  - Understand and document technological options which will reduce heat transfer through windows.
  - Validate simulation methods
- **Accomplishments:**
  - Upgrade of IR Thermography apparatus is underway
  - Refurbishing of MoWiTT is underway
- **Future work:**
  - Continued collaborations with industry (CRADAs)
  - Commissioning of MoWiTT



Daylighting and Advanced Facades

- **Strategic Goal:**
  - Identify, develop, and promote innovative solar control and daylighting technologies that reduce annual energy use by 30-50% in perimeter zones of commercial buildings at an acceptable cost of conserved energy

- **Rapid Prototyping**
  - "We need ability to determine annual energy use and comfort impacts of a prototype design in less than 30 minutes."
- **Mitigating cost and risk of RD&D**
  - "We need to quickly identify major technical and market barriers before we invest more money in an idea."
  - "We need to be able to pilot test all aspects of the technology *early* in the stage-gate process to identify critical rocks in the road."

Assembling an Integrated RDD&D Program

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:

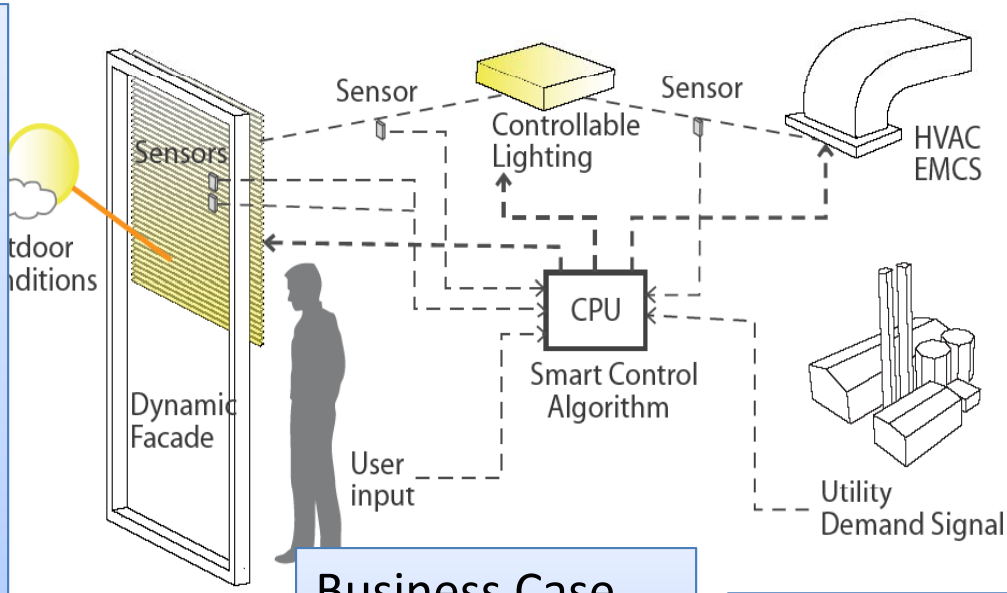
All climates
All Building types
New-Replacement-Retrofit

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,



Human Factors:

Thermal comfort
Visual comfort
Satisfaction
Performance

Business Case

Manufacturing
Installation
Commissioning
Reliability
Cost

Decision Tools

Books, Guides
Websites
Simulation Tools
Testbeds

Partners

Manufacturers
Owners
Architects
Engineers
Specifiers
Code officials
Contractors
Utilities

High-Performance Facades Research Portfolio

	Technology Innovation	Simulation Tools	Systems Integration Optimization	Market Engagement Feedback
Deployment (5-20% savings)	Low-E, Shading, Daylight control	Commercial Fenestration Design Tool (COMFEN)	Industry Partnerships	Codes and Standards, Rebates/ Incentives
Emerging Tech (20-50% savings)	Non-selective filters Angular-selective filters Super-insulating Windows Daylight-redirecting systems Intelligent facades	Complex Fenestration (CFS) Modeling Tools IGDB/ CFS Database Window 6-7 CFS/ Radiance CFS/ EnergyPlus	Bench-scale Tests: IR Chamber, Material Science Lab, Lighting Lab Windows Testbed Facility Energy Use/ Peak Demand/ HVAC Downsizing Human comfort, acceptance, satisfaction Systems Engineering: Improve, optimize Specifications, Commissioning	NFRC Rating and Labeling, CMA Tools Design Assistance/ Design Guides Utiliities DOE Commercial Buildings Initiative: National Accounts, GSA, DOD Monitored Studies and Post-Occupancy Evaluations
R&D Breakthrough (50-80% savings)	Whole-building intelligent facades	iFACade: Virtual Testbed Façade-Lighting-HVAC Controls	Systems Testbeds National User Facilities	San Francisco Federal Building New York Times Headquarters

Trial by fire: Moving from concept to pilots *ASAP*

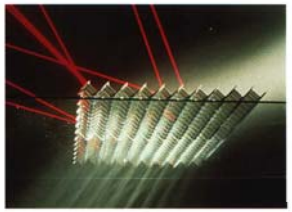
Unique capabilities of LBNL

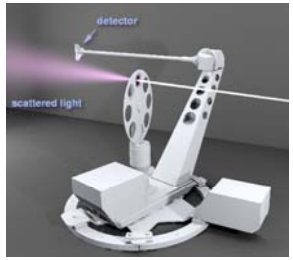
From concept →

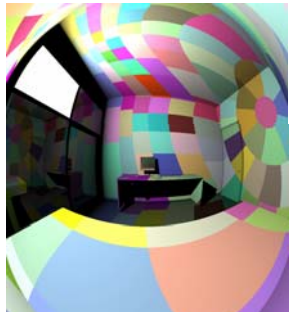
← Back to concepts stage

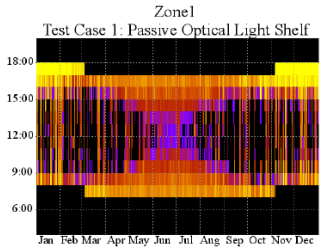
→ To product roll-out

Modeling

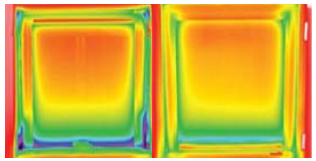


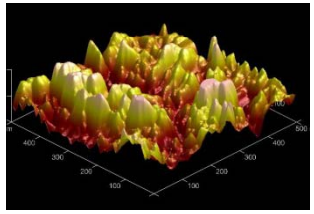


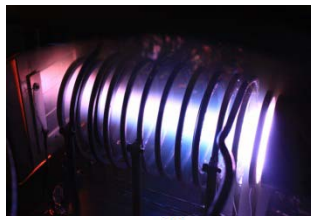


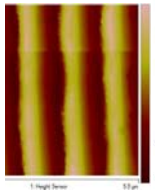


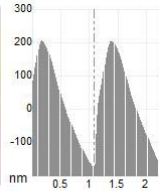
Lab Testing



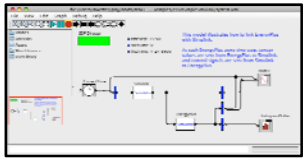


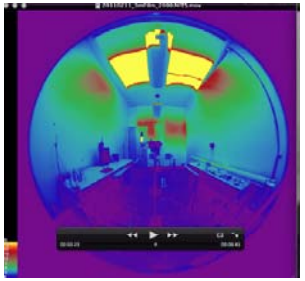




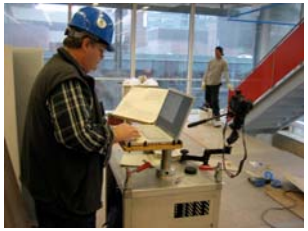


Field Testing





Demonstrations



Pathways to Increase Energy Savings

- **Increase Rate of Adoption of Existing/Emerging Technologies**.
  - Operational improvements
  - Better Design and Selection Guidance
  - New Market channels
  - New Voluntary and Mandatory Programs
  - Education: best use for a particular application (climate, orientation, etc.)
- **New Technology Options:**
  - **Incremental improvements** to technology available today
    - Performance enhancements
    - Cost reductions
    - New features
  - **Breakthrough R&D**
    - Innovation- new products, new applications
  - **Components → Integrated Systems**

Path to Rapid Prototyping

2010-2013 → 3-year collaborative R&D with CEC PIER program

2010

Develop rapid prototyping tools

(Radiance, BCVTB, Modelica, EnergyPlus)

2011

Validate tools and conduct pilot test of tools

2012

Apply tools in collaboration with industry

Disseminate tools to industry

Improve & design new prototypes

Introduce innovative technologies to the market

Goniophotometer

CGDB

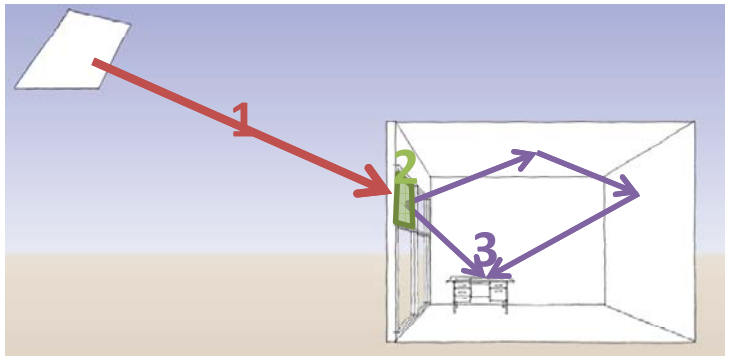
Window 6

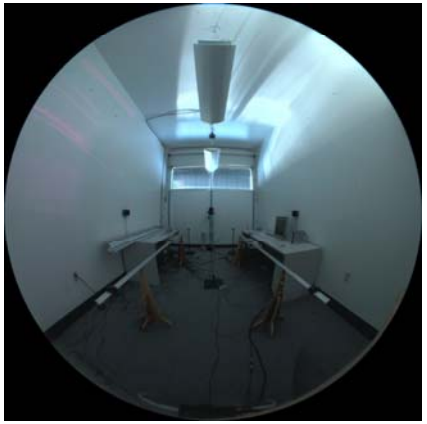
Rapid Prototyping of CFS

- 2009: Daylighting ray-tracing tools to assess annual energy use of optically complex fenestration systems (CFS) are slow and inaccurate (*3-6 month* computation time for 1-year analysis; assumed material properties)

- 2010: New Radiance tools developed to assess daylighting of CFS (Radiance *rtcontrib*, *genBSDF*)

- 2011: Validate tools against empirical data from field test; tools are now being used in design of new products

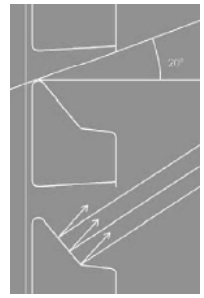




[1] McNeil, A., Lee, E.S. 2012. A validation of the Radiance three-phase simulation method for modeling annual daylight performance of optically complex fenestration systems. *Journal of Building Performance Simulation* 2012: 1-14.

Rapid Prototyping of Angle Selective Glazing

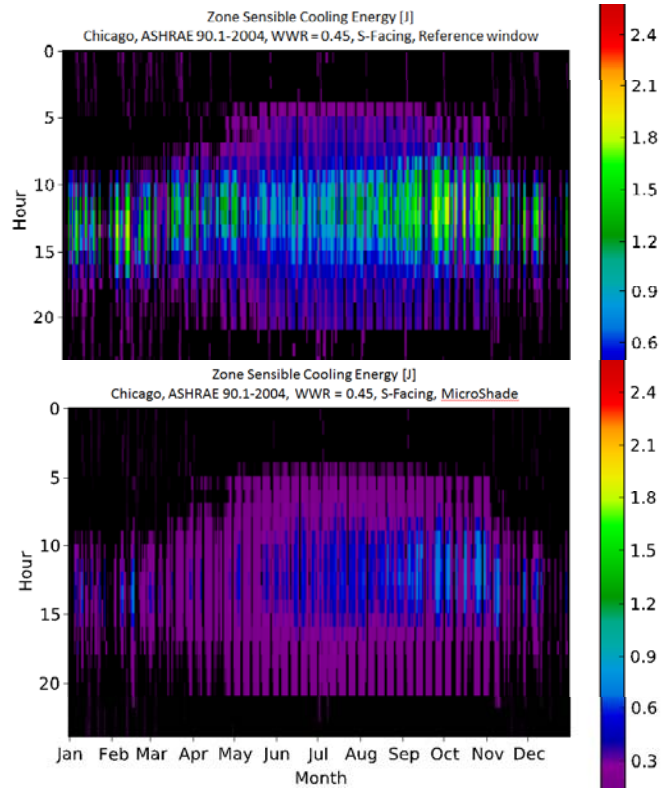
- Commercial: Angular selective shading systems

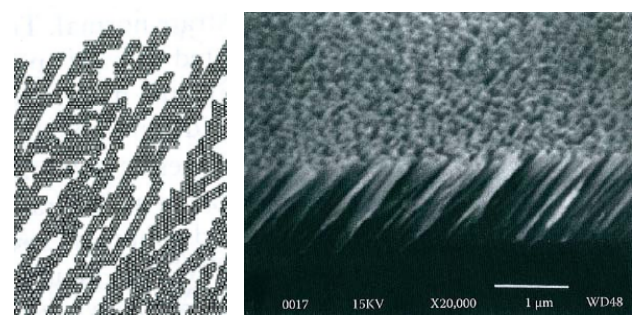


- FY12 Goal:
  - Develop shading systems that block direct beam sunlight and enable useful daylighting and views without glare
  - Perimeter zone energy use reductions of 50% compared to ASHRAE 90.1-2004

- Assess technical potential of commercial products:
  - 5 companies products
  - Large-area windows with daylighting meet EUI goals (Houston-Chicago, south-facing):
    - R5+interior shade: 28-37% for WWR=0.45
    - Angle shade/ IGU: 38-46% with WWR=0.45

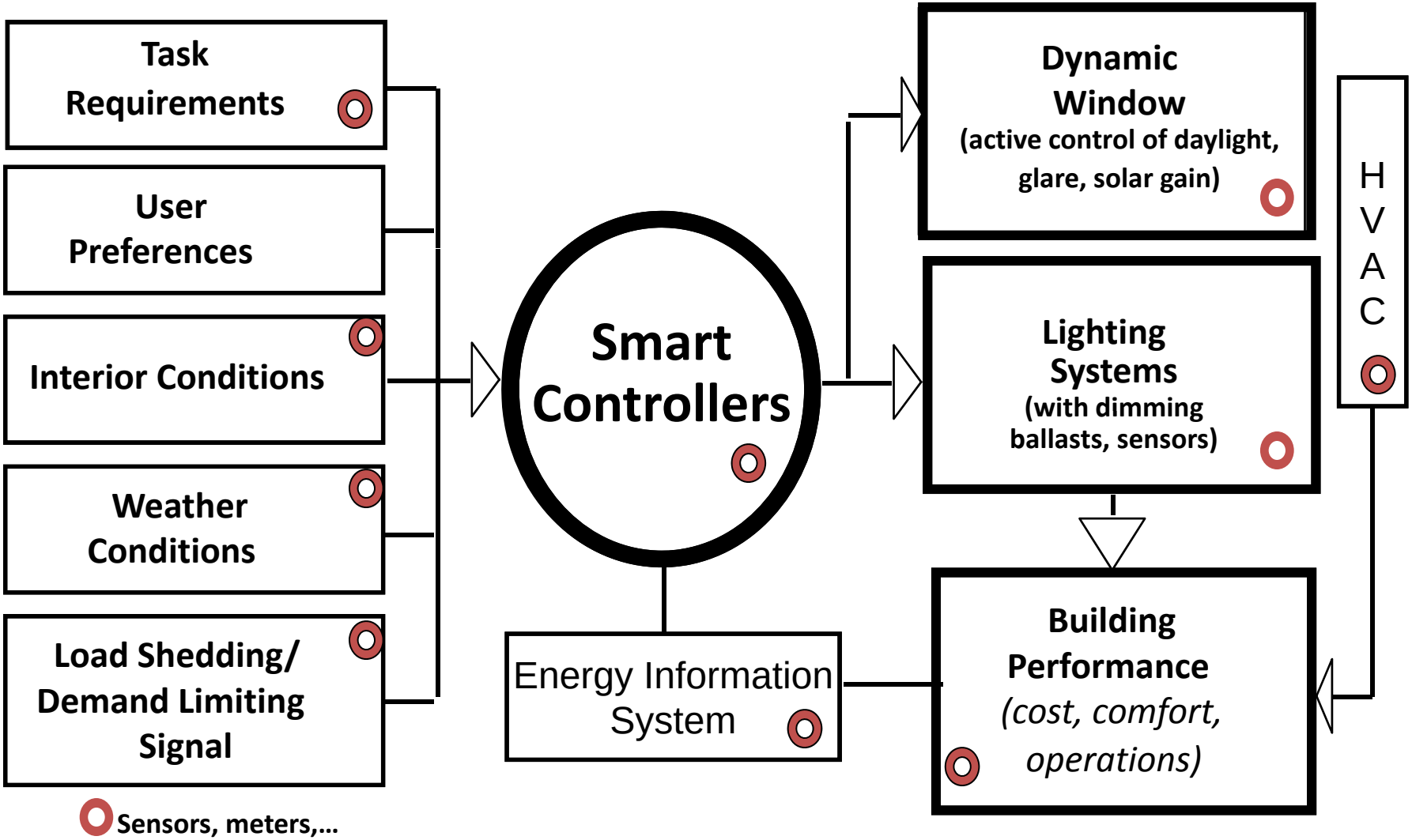
- Underway → Develop prototypes to minimize HVAC cooling/ heating loads





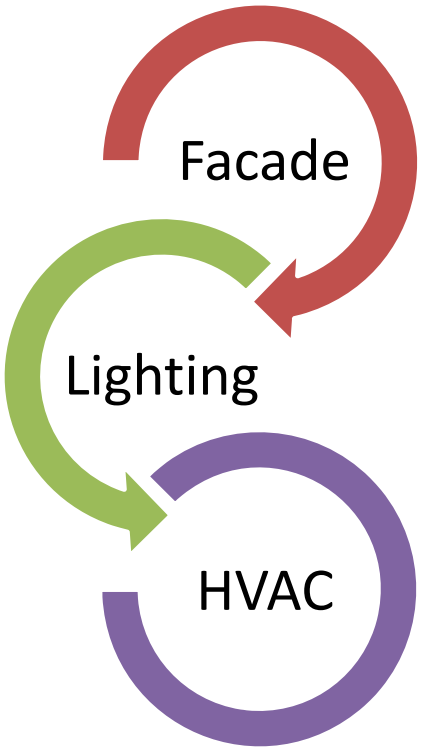
Inclined columnar nanostructures (MJ. Brett, *J.Mater.Sci* 24(1989); GW Mbise et al. *J.Phys.D: Appl. Phys.* 30(1997))

Exploring Intelligent Control Systems



Rapid Prototyping of Dynamic Integrated Systems

- Heuristic control algorithms achieve modest energy savings and are best defined for component measures.
  - Electrochromic field tests (2009)
  - Exterior & interior motorized attachments (2010)
- Testing and evaluation of empirically derived models for daylight and solar controls is too slow: 6-12 months.
- Model predictive controls (MPC) + sensors enable greater savings by enabling more optimal control between synergistic systems (façade → lighting and HVAC).



MPC is used extensively in transportation and aerospace industries.

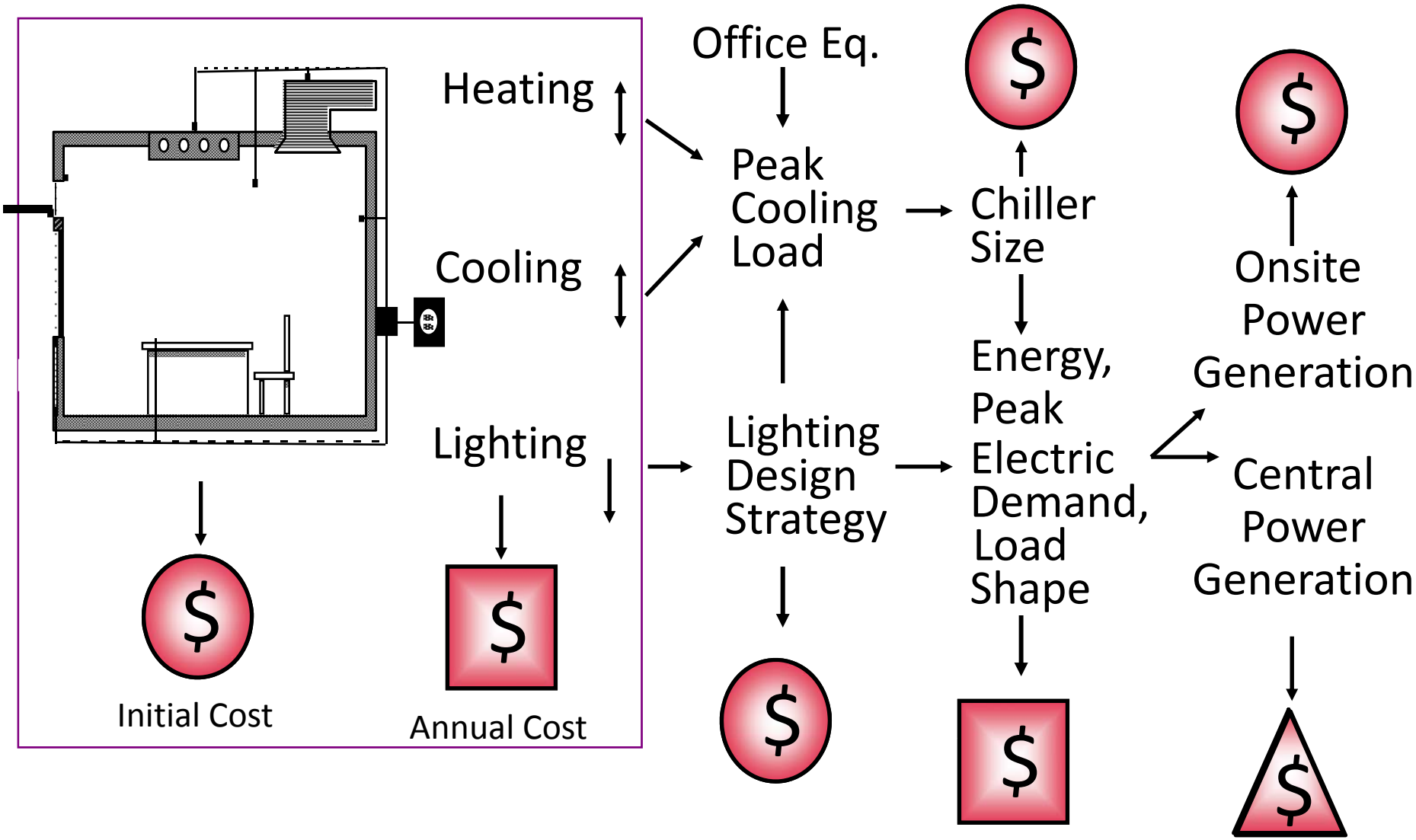
Rapid Prototyping of Dynamic Integrated Systems

- **Goal: Develop rapid prototyping tools for integrated façade-lighting-HVAC control systems**
- 2011 Trial by fire → Proof-of-concept:
  - Real-time control using Radiance + BCVTB in Windows Testbed Facility
    - 2-zone motorized exterior venetian blind – glare versus daylighting
    - Motorized awning – Direct sun versus daylighting
  - Industry feedback and field test trials:
    - 4 manufacturers

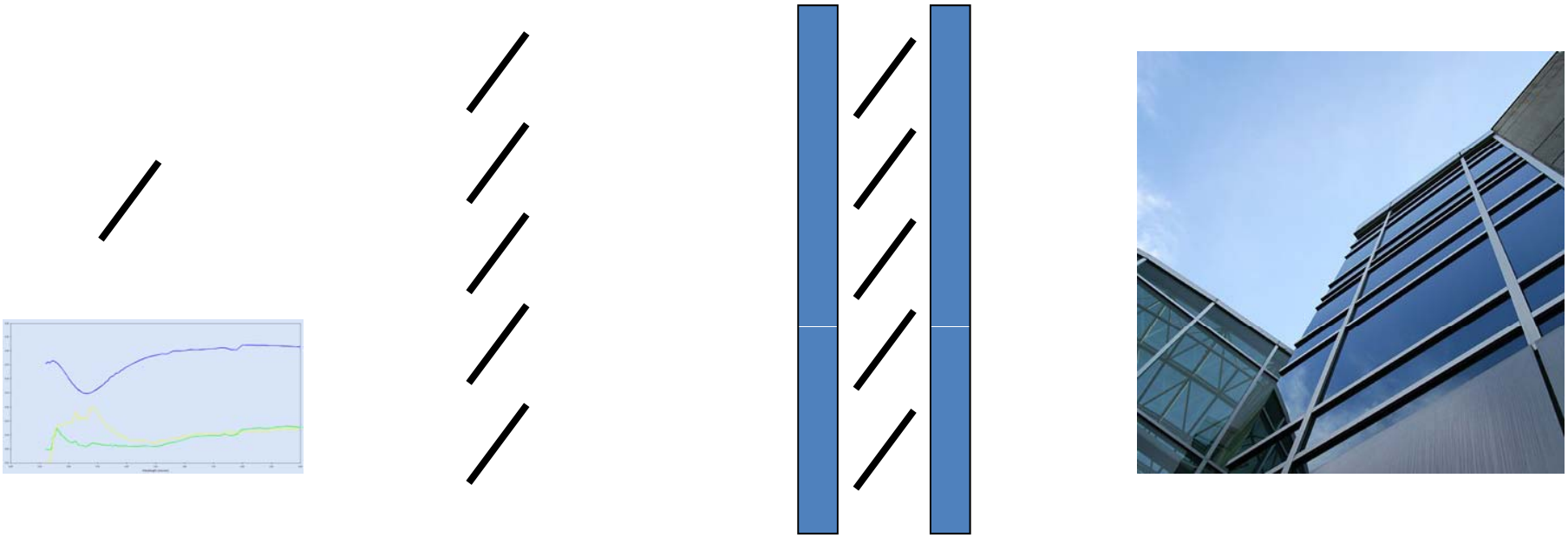
Library additions:

- BCVTB socket connection to Radiance
- Remote access/ control via http:// interface to 71T
- Modelica/ Window 6 tarcog model developed and validated with field test data

System Integration: Cost tradeoffs



FROM COMPONENTS TO SYSTEMS



Material Layer System Building

We take this modular approach since there are millions of variants and billions of window/attachment combinations

DEFINTION OF BSDF (BTDF, BRDF)

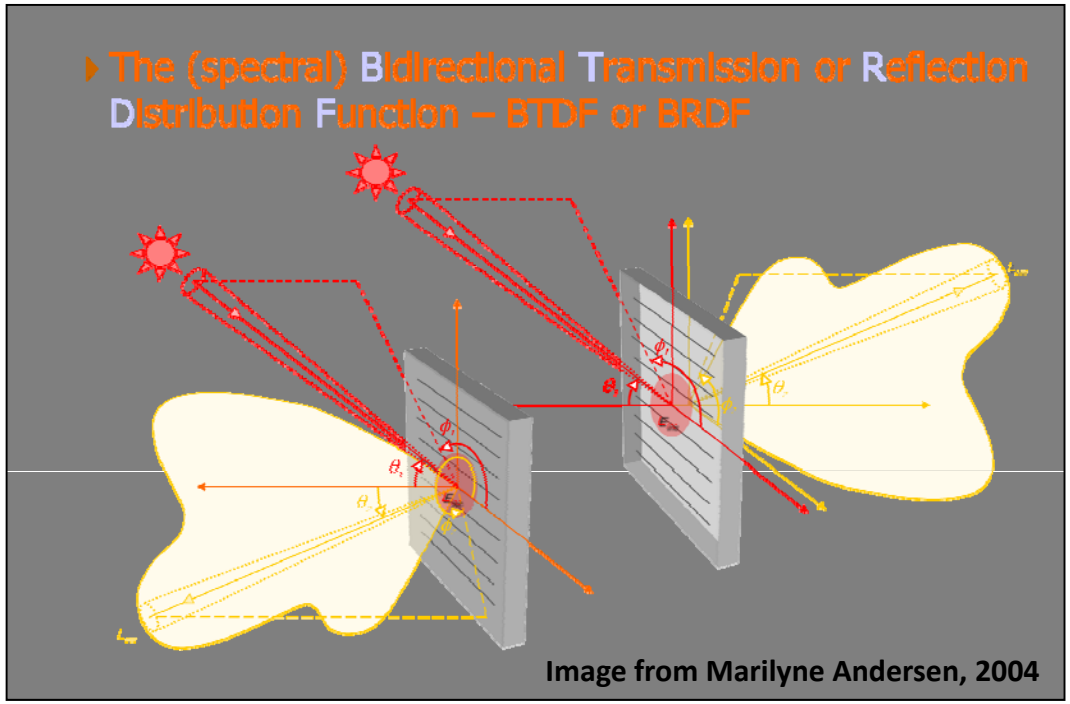
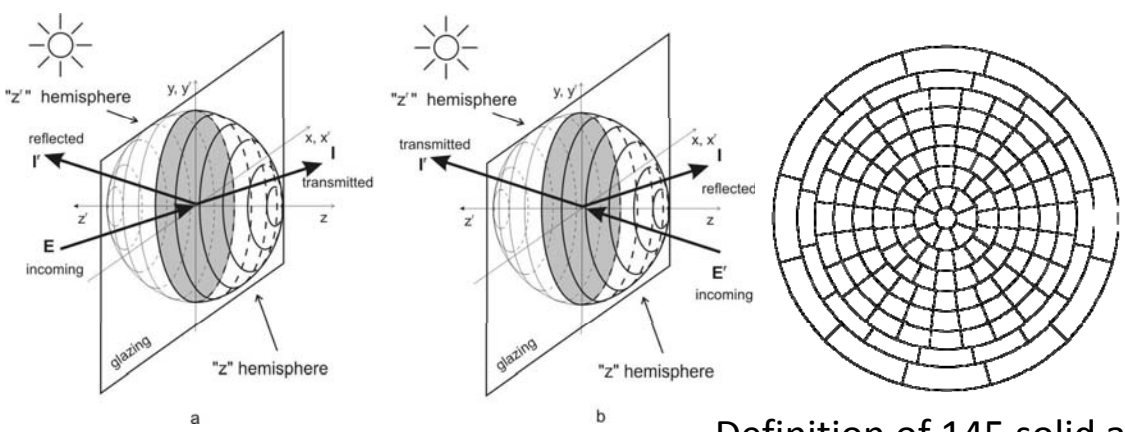


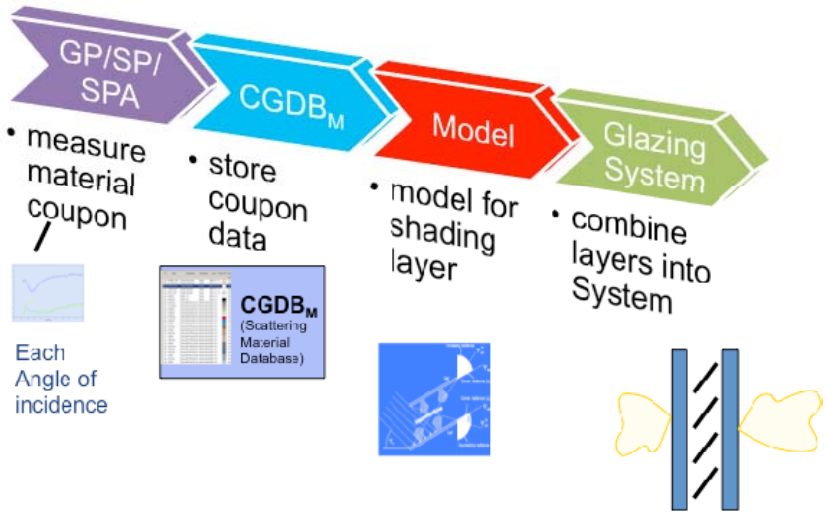
Image from Marilyne Andersen, 2004

- Bi-Directional Distribution Function (BSDF) consists of two BTDF and 2 BRDF (front and back)
- BSDF fully describes optical performance of an arbitrary scattering system regardless of the type of shading device or complex glazing
- Complex glazing model in WINDOW utilizes layer BSDF to calculate BSDF of the complete system.
- Window system BSDF allows for calculation of rating indices such as U-Factor, SHGC and VT, while still providing detailed information for building energy simulation tools, such as EnergyPlus and COMFEN/RESFEN.
- Developed standardized XML schema for publishing layer and window system BSDF for use by industry and energy simulation tools

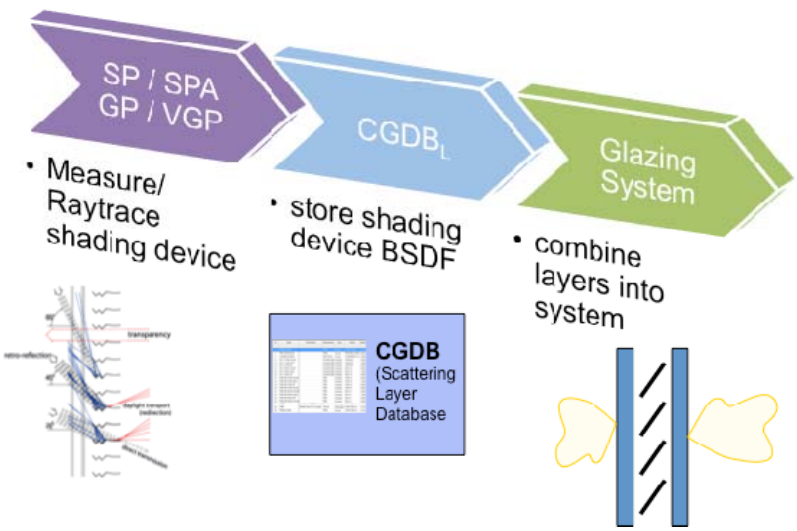


Definition of 145 solid angles

COMPLEX GLAZING DATABASE-CGDB

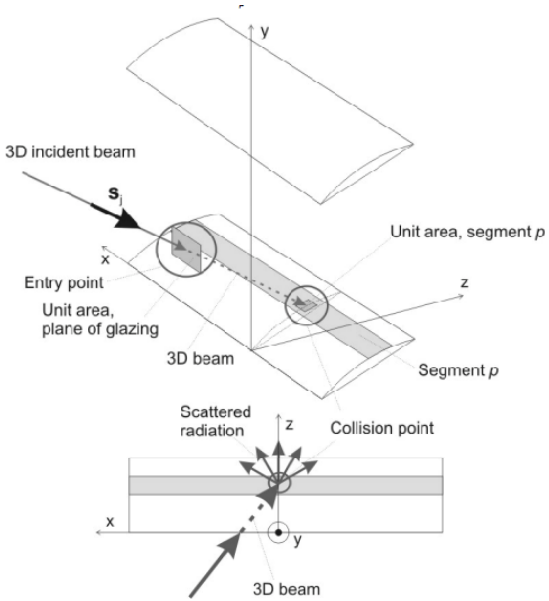


Process Flow for Systems for which there are analytical models and measurement data for material coupons

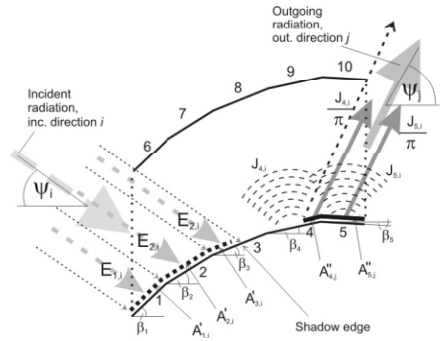


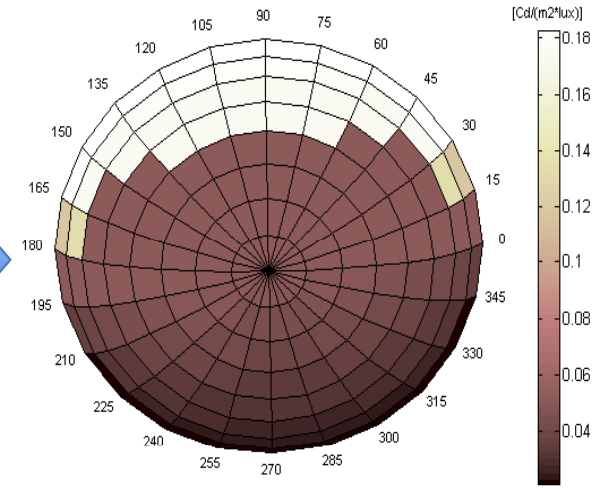
Process Flow for Systems for which there are no analytical models; direct system measurement required

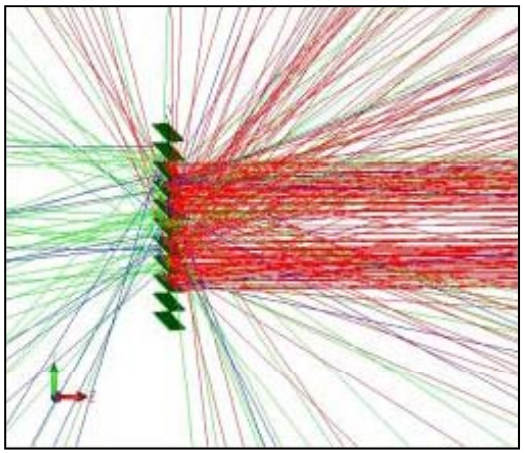
VENETIAN BLINDS

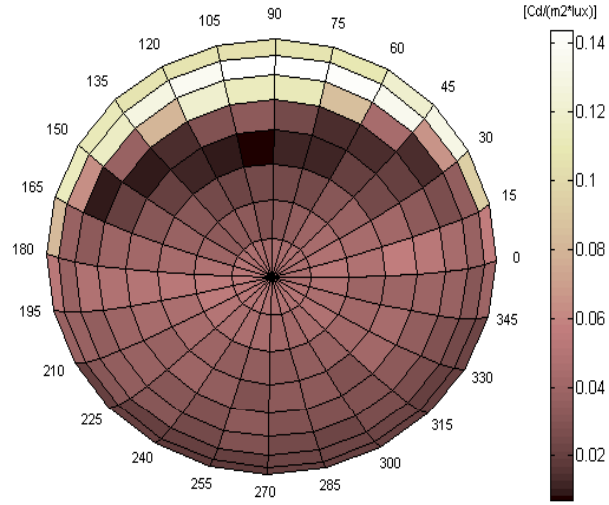


Analytical Model (WINDOW)









Full Ray-Tracing Model

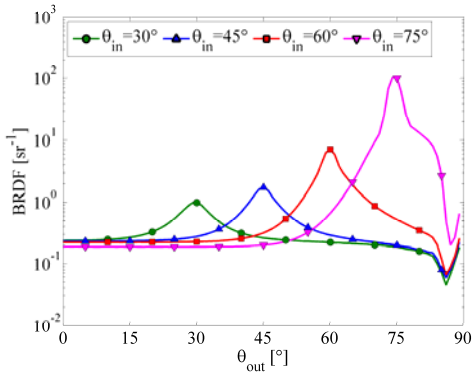
STATE OF TECHNICAL PROCEDURES

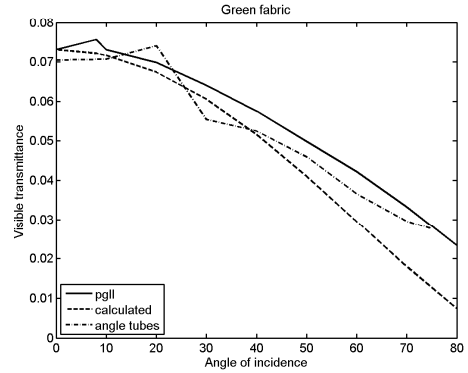
There is a need for a multiyear approach to build tools and ratings

Product	Test Procedure			Simulate in WINDOW/THERM			NFRC Approved WINDOW/THERM		
	IN	OUT	BG	IN	OUT	BG	IN	OUT	BG
Cellular Type			✓						
Slat Type			✓	✓	✓	✓			✓
Sheer Type			✓						
Shutter Type			✓	✓	✓	✓			
Pleated Type			✓						
Roller Type			✓	✓	✓	✓	✓		
Roman Shade			✓						
Drape			✓						
Flat panel non glazed			✓	✓	✓	✓	✓		
Flat glazed panel	✓	✓	✓	✓	✓	✓	✓	✓	✓
Surface applied films	✓	✓	✓	✓	✓	✓	✓	✓	✓
Awnings									

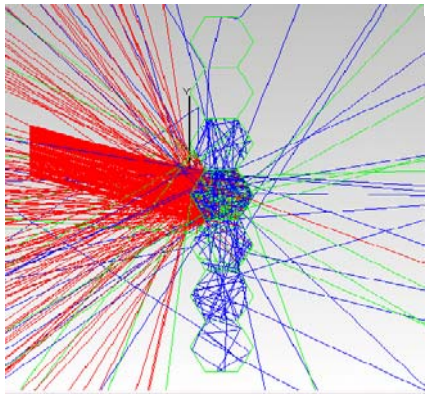
Notes: **IN**: indoor mounted attachment; **OUT**: outdoor mounted attachment; **BG**: Between-glazing mounted attachment

HONEYCOMB SHADES - OPTICAL





Measure Coupon of Fabric → **Process Measurement Data and Construct BSDF**



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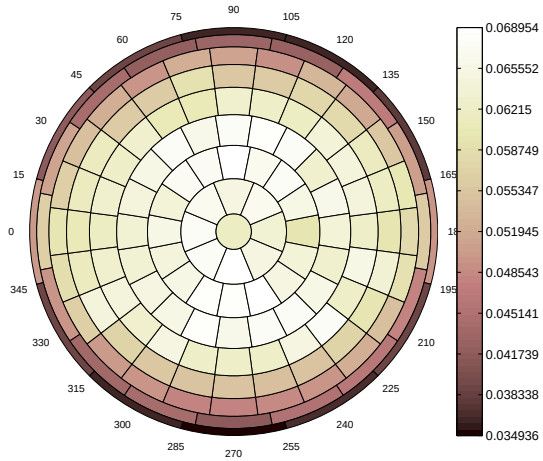

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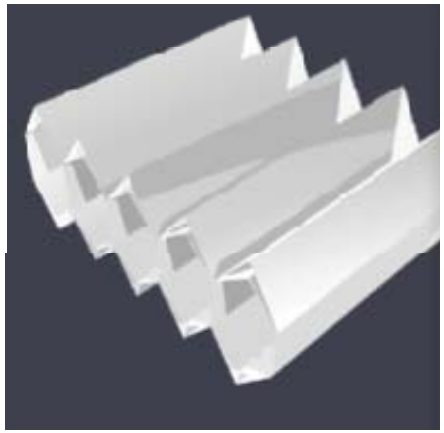
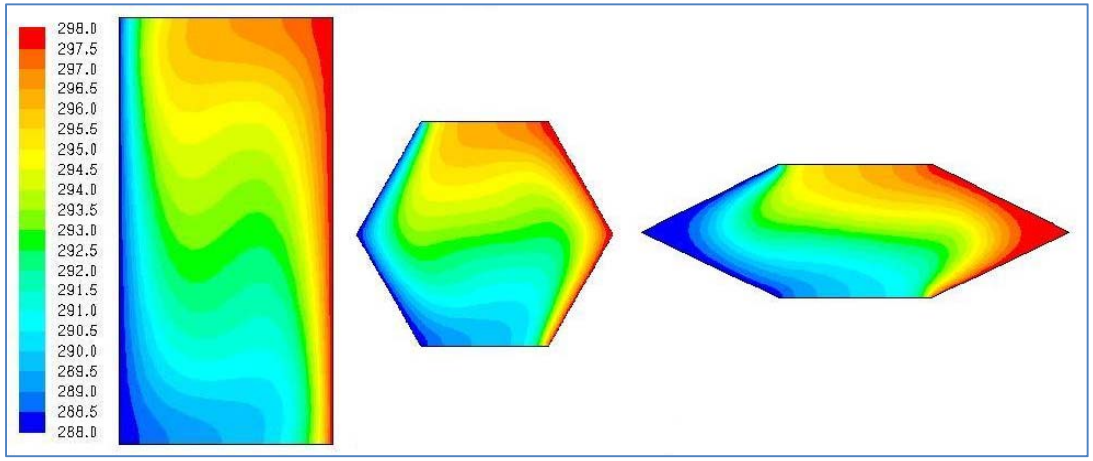
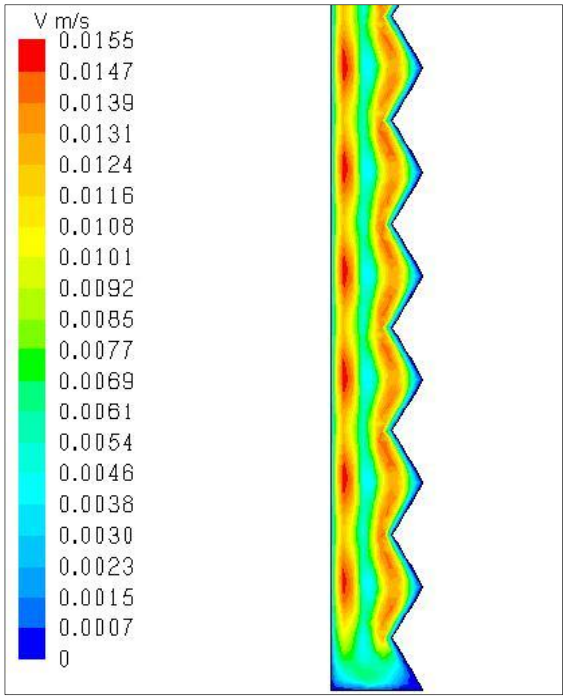
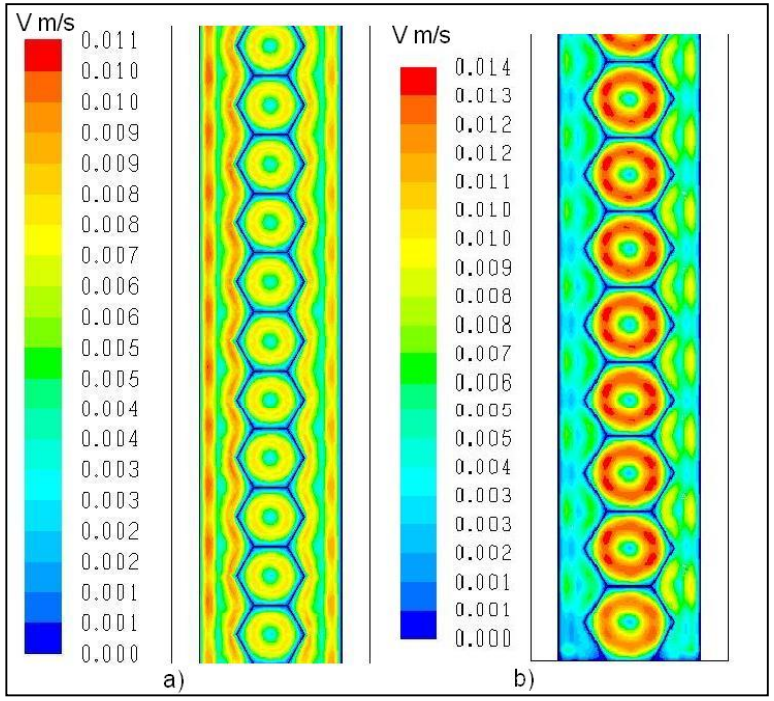


Perform Ray-Tracing Using New genHoney Module of WINDOW

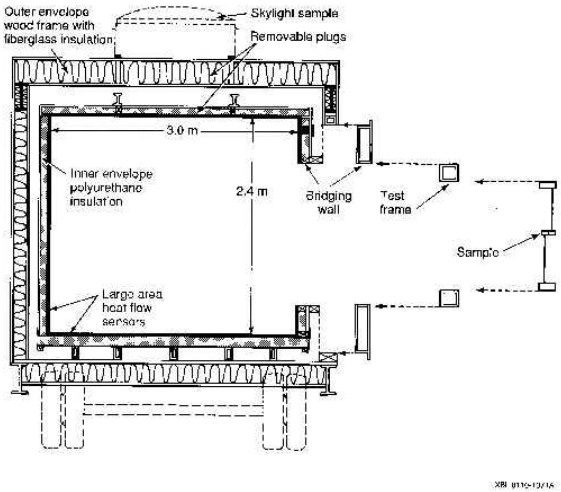
HONEYCOMB SHADES - THERMAL

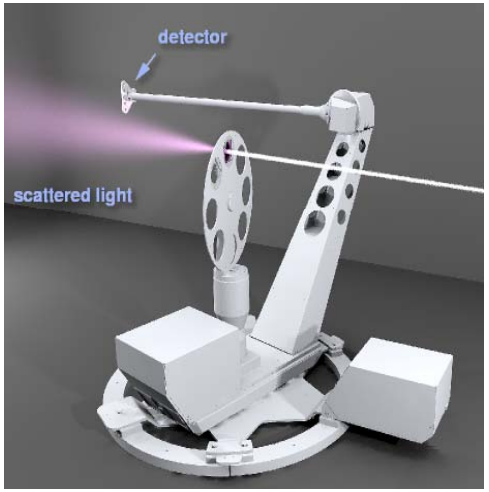




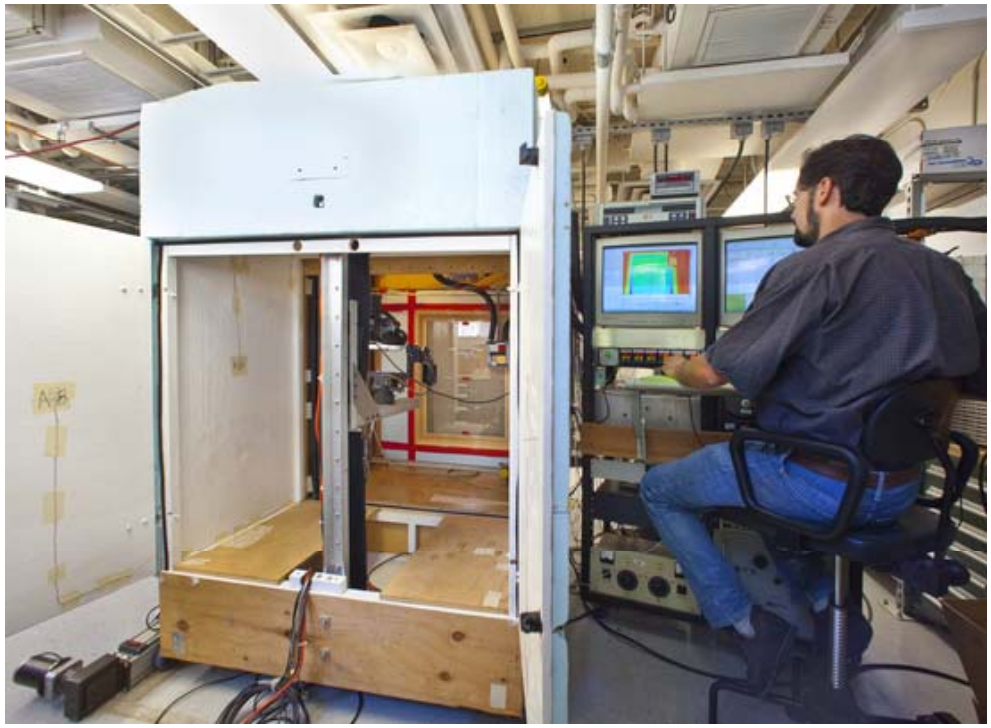


VALIDATION THROUGH TESTING

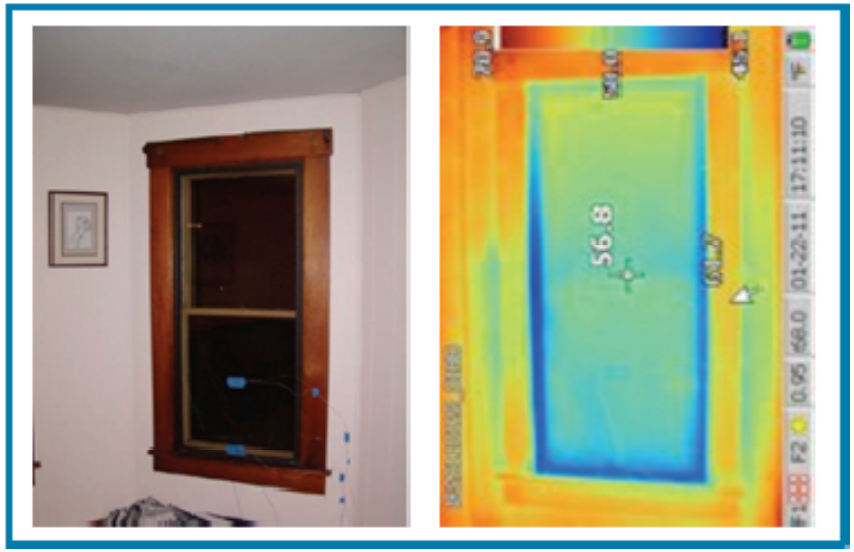


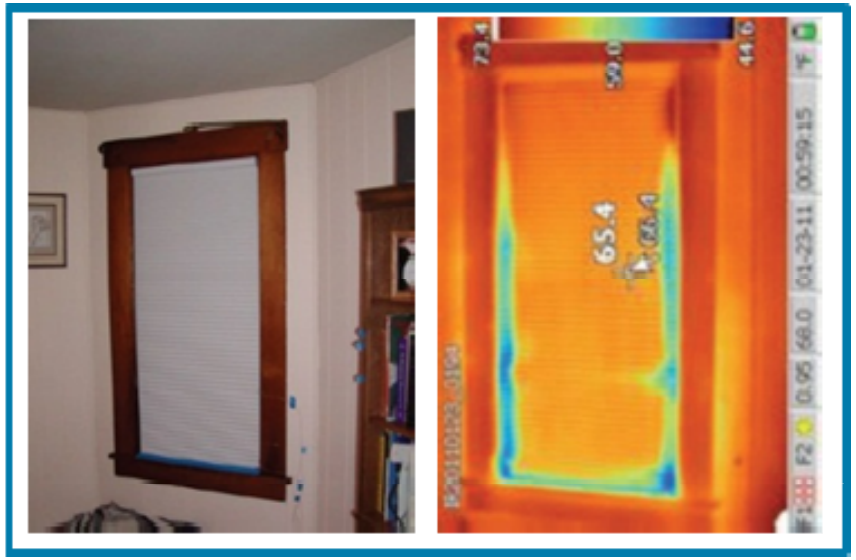


IR TESTING OF ATTACHMENTS



Laboratory IR Thermography





Field IR Thermography

PRODUCT OPTIONS & FEATURES

LEGEND
- ● "Greatest benefit"
- ◑ "Moderate benefit"
- ○ "Neutral or average"
- ⊙ "Potential detriment or weak point"

Retrofit Option	Thermal							Visual				Economics			Other				
	Insulation	Airtightness	Solar Heat Control	Winter Comfort	Summer Comfort	Condensation Resistance	Ventilation	Maintains View	Daylighting	Glare Control	Privacy	Low Product Cost	Low Installation Cost[9]	Durability/Service Life[10]	Adjustability	Protection for Window	Noise Control	Egress	Security
Exterior Attachments																			
Low-e storms windows	●	◑	○[1]	●	○[1]	◑	●	●	◑	○	○	○	○	●	◑	●	◑	○	◑
Awnings	○	○	●	○	●	○	●	◑[2]	◑	●	○	○	⊙[3]	◑	◑[4]	◑	○	●	○
Roller shades	○	○	●	○	●	○	◑	○	○	◑	●	◑	◑	○	◑	◑	○	○	○
Roller shutters	◑	○	●	○	●	○	○	⊙	⊙	●	●	⊙	⊙	●	◑	●	◑	○	●
Interior Attachments																			
Conventional roller shades	○	○	◑	◑	◑	○	○	○	◑	◑	●	●	●	○	◑	○	○	○	○
Conventional drapes	○	○	◑[5]	◑	◑	○	○	○	○	◑	●	●	●	○	◑	○	○	○	○
Louvered blinds	○	○	◑	○	◑	○	◑	◑	●	●	●	●	●	○	●	○	○	○	○
Fixed window panels	◑[6]	◑	○[1]	◑	○[1]	◑	⊙	●	◑	○	○	◑[7]	●	○	⊙	○	◑	⊙	◑
Insulated cellular shades[8]	●	◑	◑	●	◑	⊙	○	○	◑	◑	●	○	◑	◑	●	○	◑	○	○
Window quilts	●	◑	◑	●	◑	⊙	⊙	⊙	⊙	○	●	○	⊙	○	◑	○	◑	○	○
Surface-applied films	○	○	◑	○	◑	○	○	◑	◑	◑	◑	◑	◑	○	○	○	◑	●	◑
Other																			
Existing window rehab	○	◑	○	◑	○	○	●	●	◑	○	○	●	⊙	◑	●	◑	◑	◑	○
Solar Screens	○	○	●	○	◑	○	◑	⊙	⊙	◑	○	◑	●	◑	⊙	○	○	○	○
Seasonal single-use film kits	◑	●	○	◑	○	●	⊙	◑	◑	○	○	●	●	⊙	⊙	○	○	○	○

Footnotes:

1. Current low-e, *high* solar heat gain exterior storm windows and interior window panels will soon be joined by low-e, *low* solar heat gain options.
2. Fixed awnings may partially block view.
3. Fixed awnings are much less expensive than motorized retractable awnings.
4. Assumes awning is retractable.
5. Assumes drape with light-colored exterior.
6. Low-e glass and double-layer plastic panels have greatest insulation benefits.
7. Plastic fixed panels are the most affordable.
8. Assumes cellular shade is top-down/bottom-up type.
9. Many attachments can be DIY installations; only full solid circles assume DIY in this table.
10. Assumes that warranty serves as a proxy for service life/ durability and that the individual values mean that a warranty corresponding to the value is available for that window attachment.

Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

Enabling Tools for Window Design and Selection

Windows and Daylighting Program

Windows and Envelope Materials Group

Building Technology and Urban Systems Department

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building Technologies Program

Workflow: From Building Science Foundation to Ratings to Market-Based Programs

DOE Programs
Codes, Residential and Commercial Integration, FEMP
Other Federal Agencies: GSA, DOD
State, Regional Agencies; Utilities

Programs
Energy Star
Utility Rebates
Energy Codes
Tax Incentives

Ratings
U, SHGC, VT, CR, EP

Technical Standards
ASTM C1199, E1423, E908, C518
ISO 15099, 12567, 9050, 18292

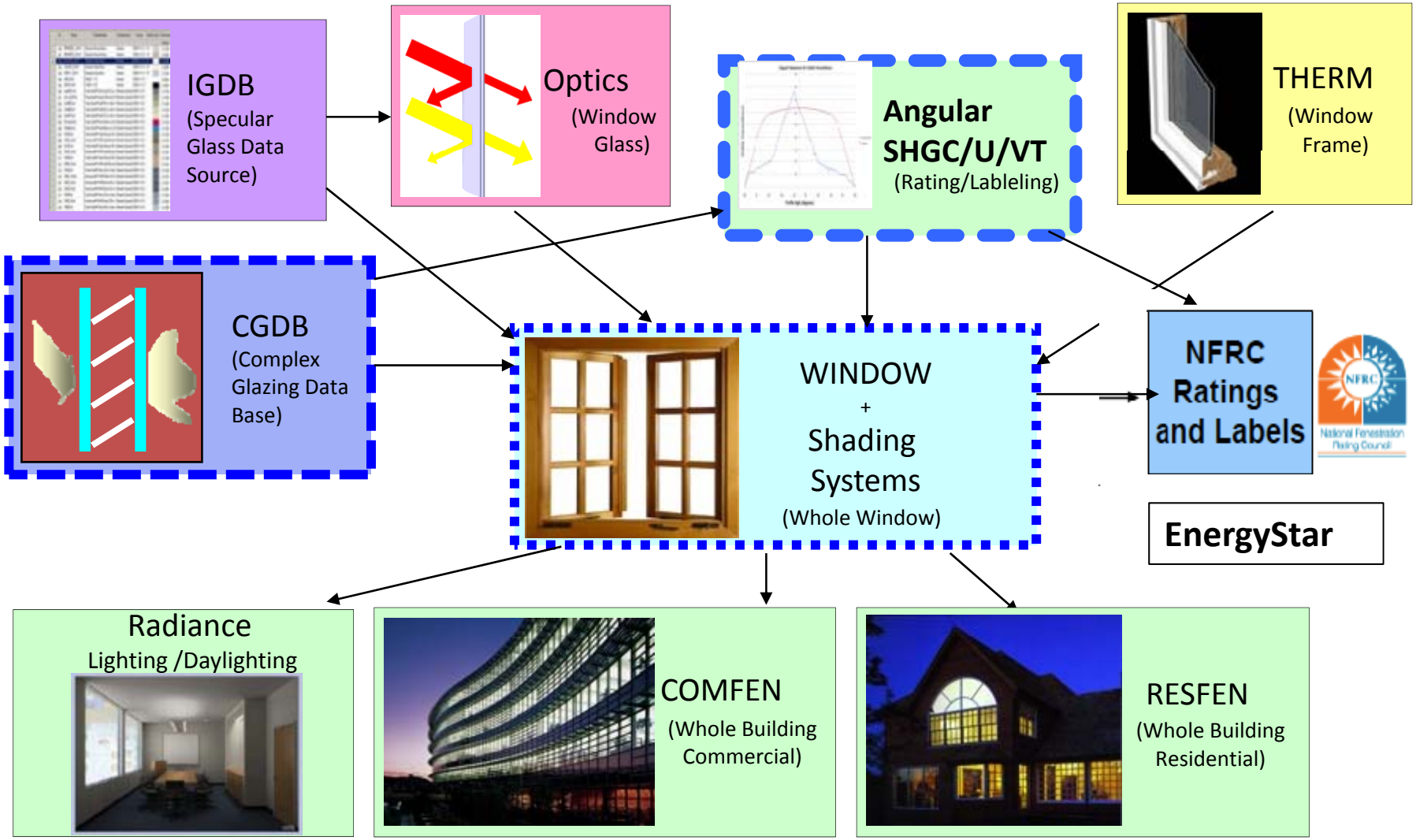
Tools for Assessment
WINDOW, THERM, OPTICS
Hot Box, Solar Calorimeter

Enabling Building Science
Simulation and Measurement Infrastructure
Field Studies, Validation Data base

Industry Collaborations
Technology Development -- Technology Applications
Incremental, Breakthrough
Engagement Mechanisms- e.g. WFO, CRADA,..
Companies, Partnerships, Alliances, Trade Associations...

Enabling Tools: Glazing and Façade Decision Support Tools

Download http://windows.lbl.gov/software/ FY11 ~ 40,000 Downloads

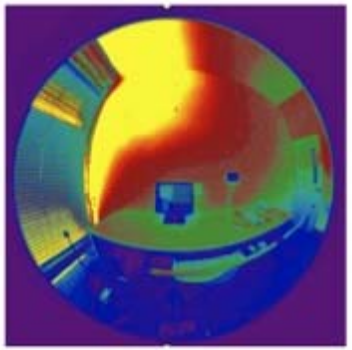


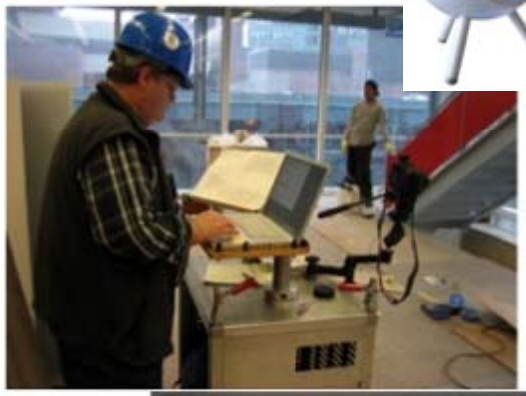
Commercial Windows Website Efficient Windows Website

Design /Simulation Tools

Tools for Glazing/Shading/Daylighting Measurement + Validation

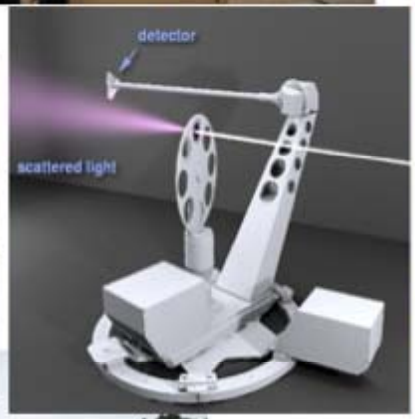
Environmental Energy Technologies Division

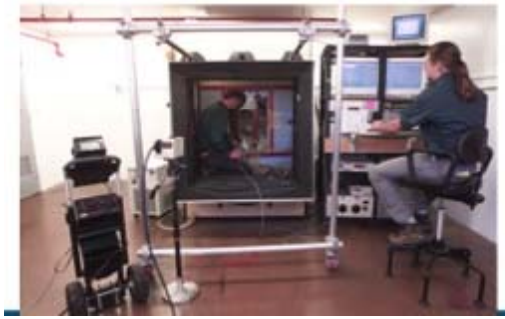




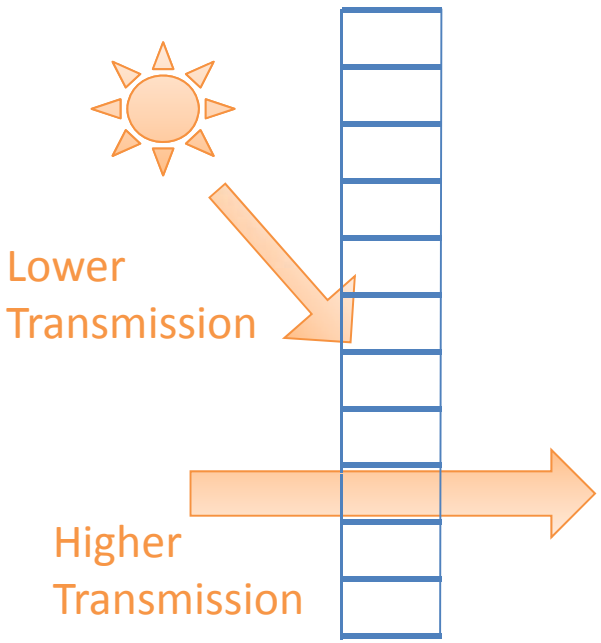
Façade/daylighting test facility
Integrated Systems testbeds
Mobile Thermal Test Facility
IR Thermography chamber

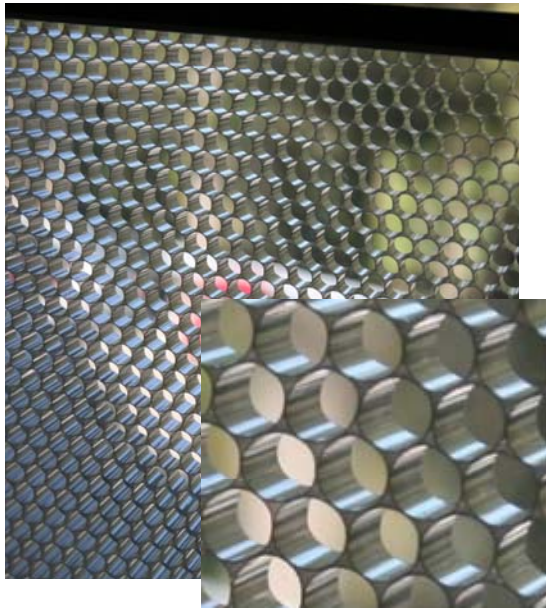
Large integrating sphere
- Optics laboratory
- **Scanning Goniophotometer**
- HDR Imaging
- Field Data Collection systems
- Commissioning systems
- Virtual Building Controls Testbed
- Daylighting controls laboratory



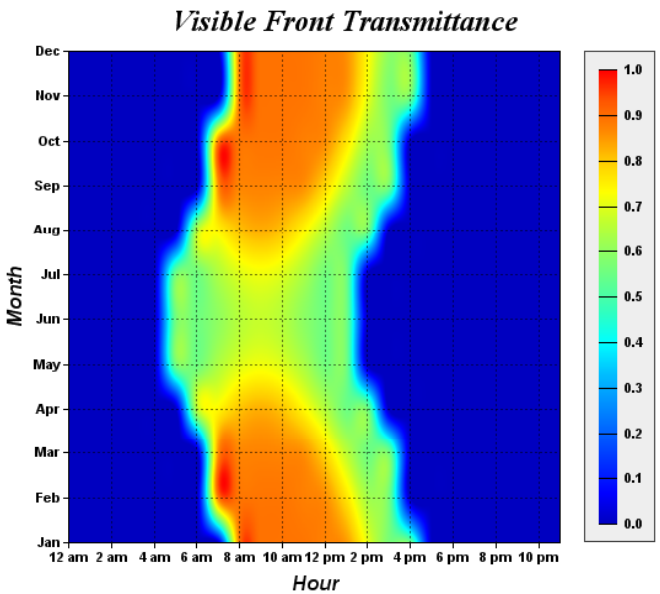


Annual Performance





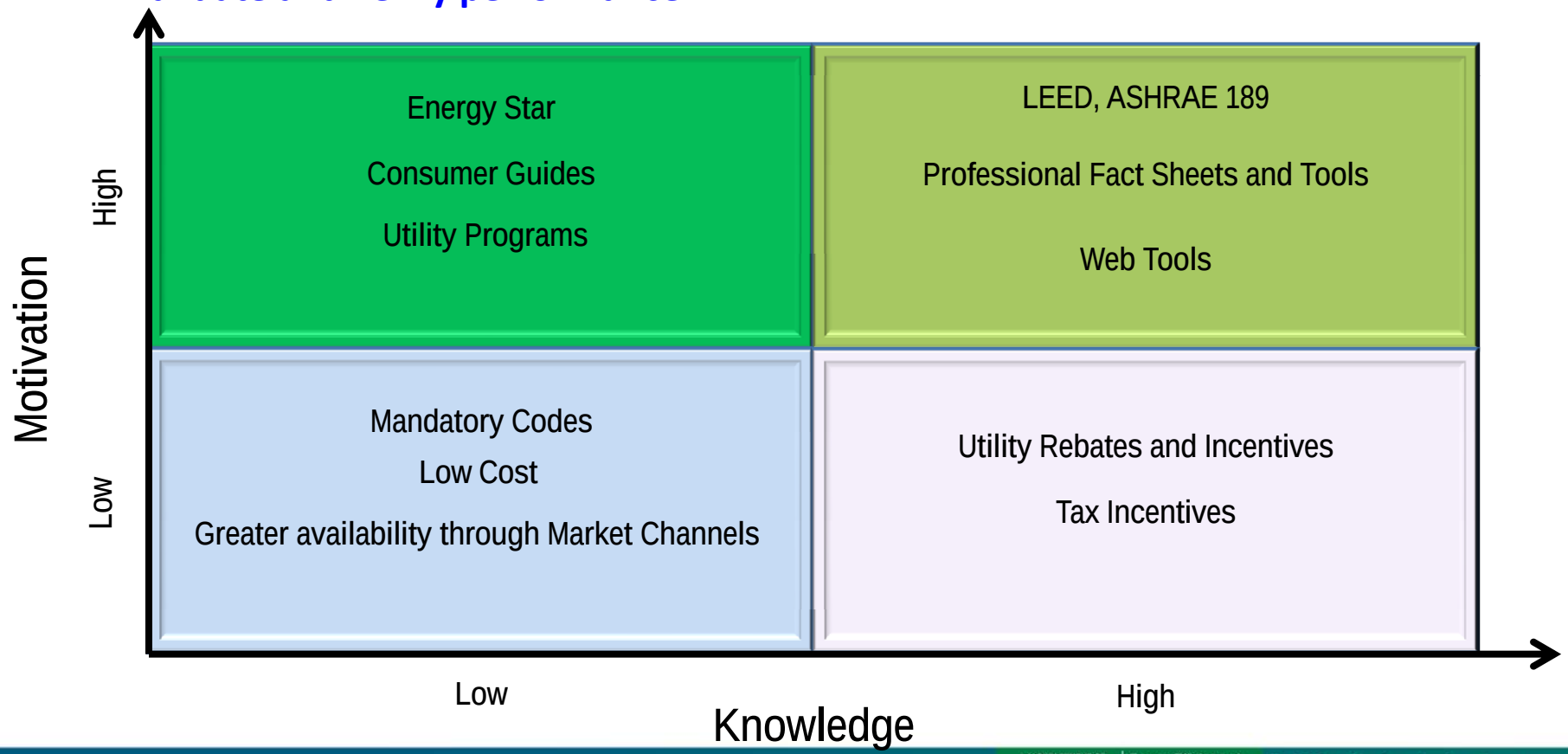
A perpendicular columnar structure admits more light at normal incidence than at off angles



Annual plot in WINDOW shows Visible Transmittance for sun positions throughout the year

Portfolio of Targeted Strategies to Increase Energy Savings

- ***Goal:*** **Multiple Targeted Strategies to Push/Pull more efficient windows into marketplace**
- ***Strategy:*** **Optimal strategy depends on audience and partner interests. Organize by 1) level of motivation to adopt efficient products, and 2) level of knowledge to implement decision making.**
- ***Role of R&D and Emerging Technologies: (keep the innovation pipeline full!)***
  - **Reduce cost and risk of technology solutions**
  - **Create new, higher performing, more cost effective solutions**
  - **Validate and verify performance**

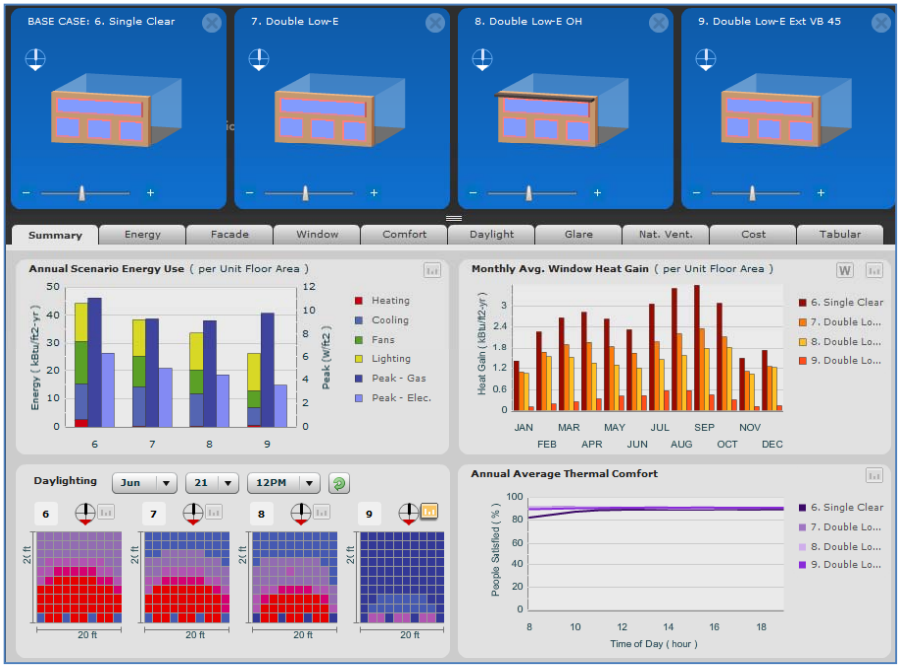


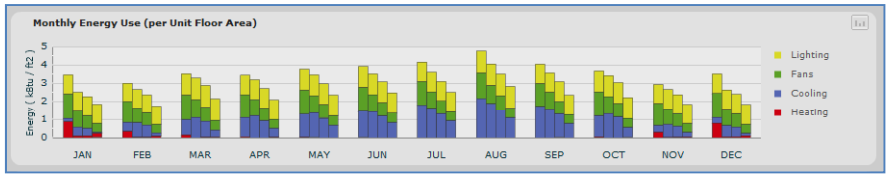
COMFEN: Energy Impact of Window Selection

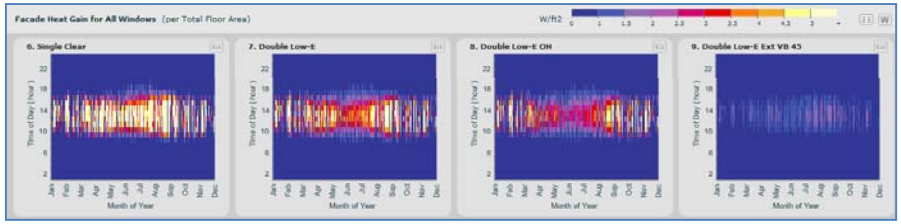
Early Design Scenario comparisons

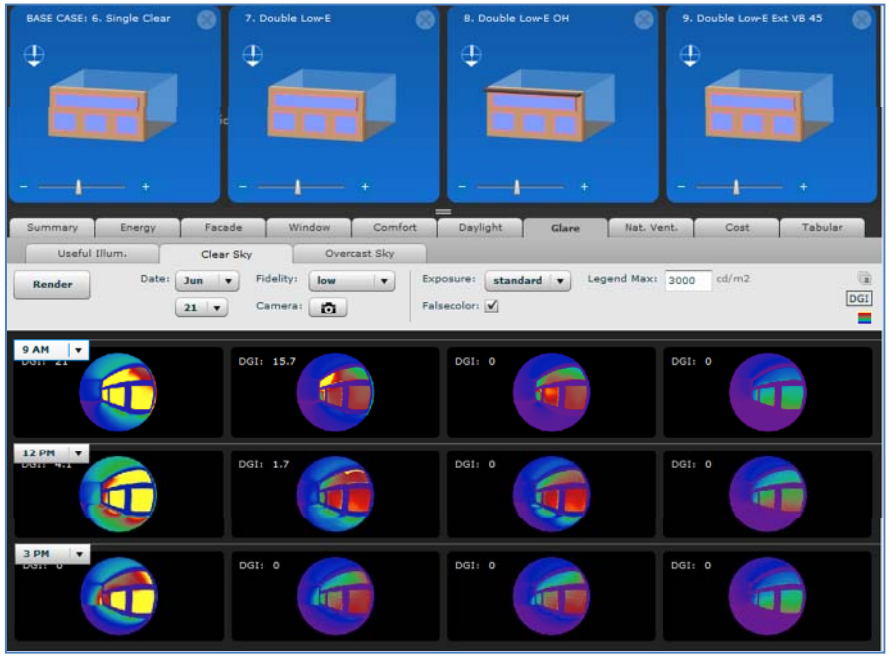
- Rapid analysis of façade options in early design development
- Easy to learn, easy to use
- Powerful tools under the hood (E+, Radiance, WINDOW 6)

Strong positive response from early adopters (architects / engineers)





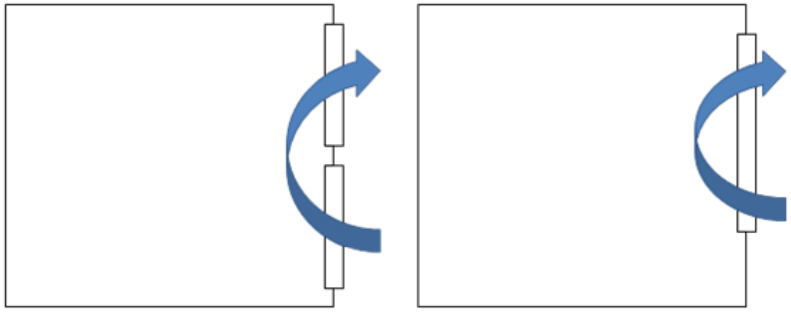


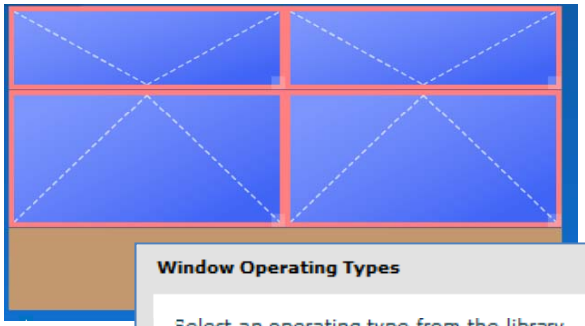


COMFEN: Accomplishments 2012 (to date)

Natural Ventilation Model Added

Single sided ventilation



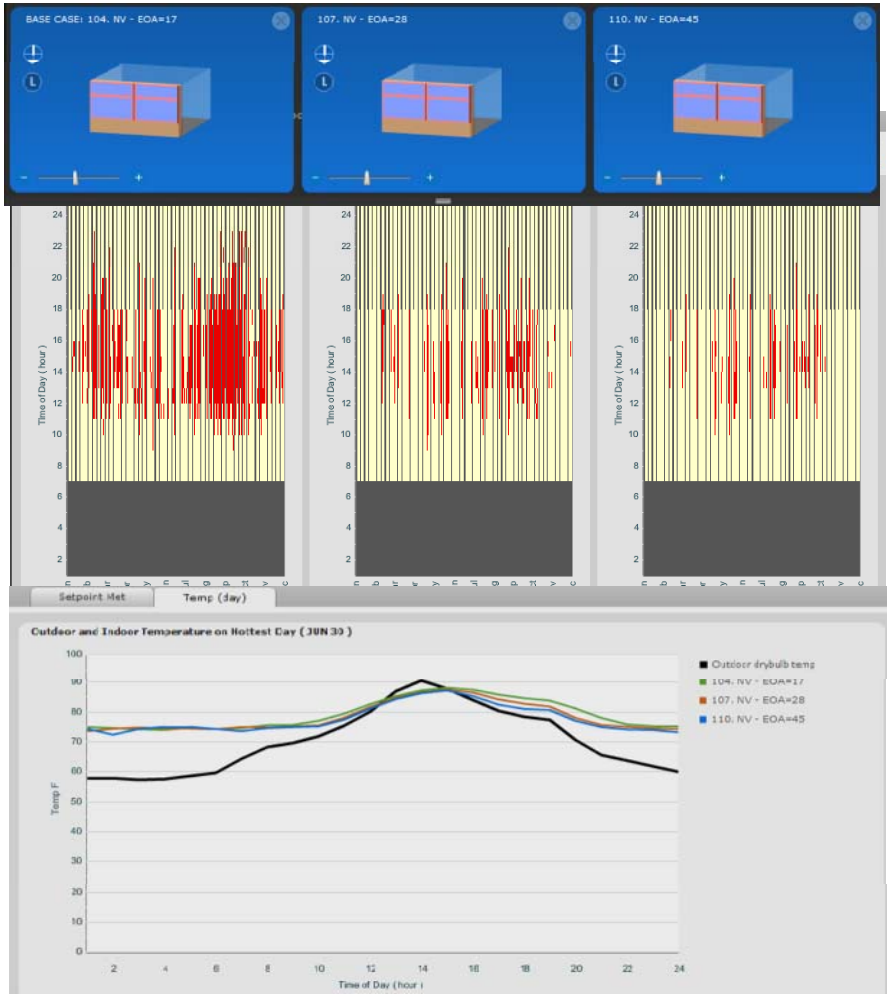


Window Operating Types

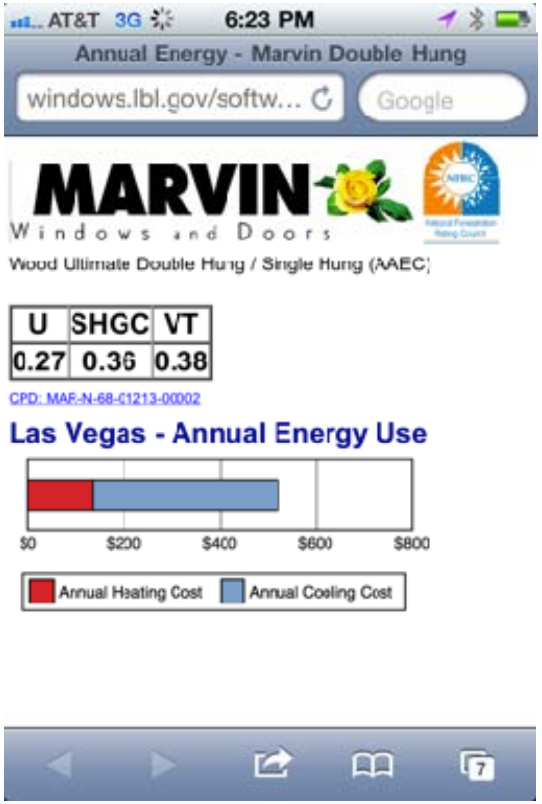
Select an operating type from the library

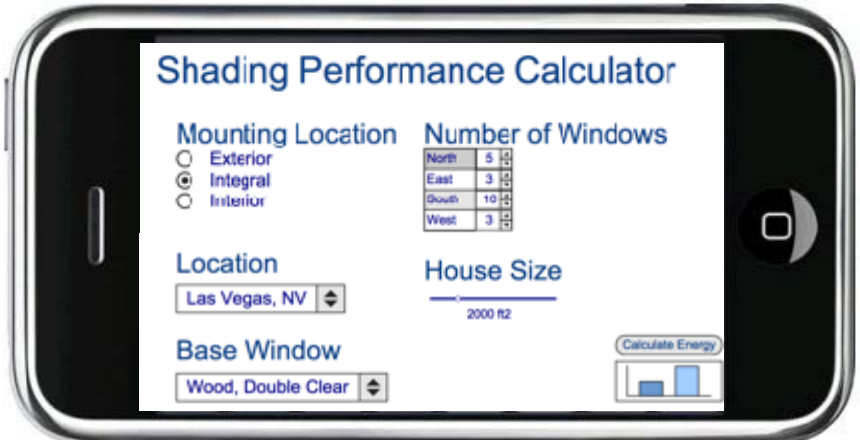
ID	Name	Default effective open area (%)
1	Awning	75
2	Casement	90
3	Hopper	45
6	Single-hung	45
7	Horizontal Slider	45

Zone Temperature Information



SMART LABELS – Product Selection with Smart Phone Apps
Select Optimized Windows in your Local Building Supply Center





New FLEXLAB Testbed Facility –

Facility for **L**ow **E**nergy E**x**periments in Buildings

Operational in 2013

TEST BED
Exploded Axonometric Diagram

Components:

1 **ARMATURE**
- 1.1 Concrete Foundation
- 1.2 Underslab Insulation
- 1.3 Concrete Slab
- 1.4 Structural Steel Frame
- 1.5 Adiabatic Walls
- 1.6 Concrete Slab at Roof

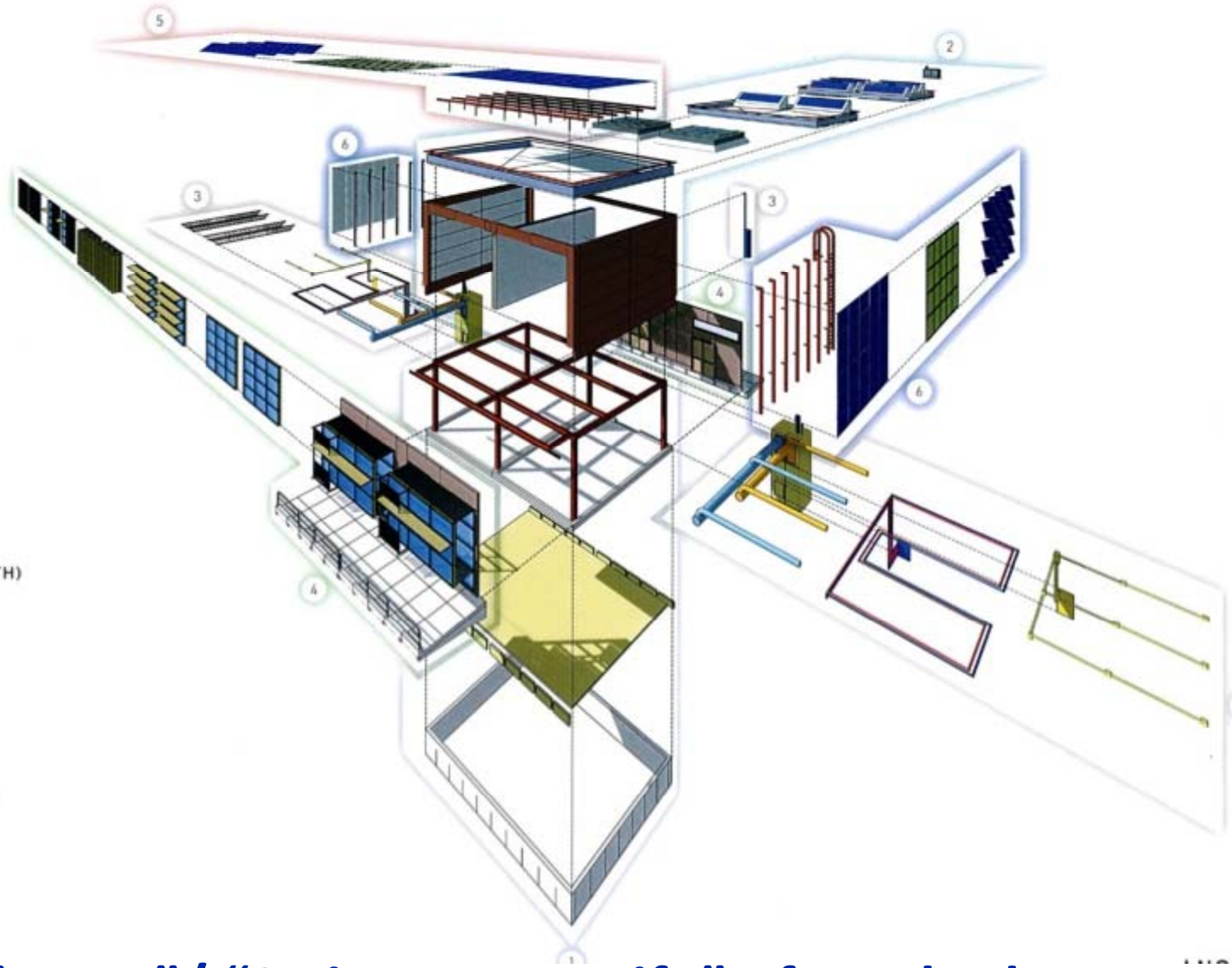
2 **ENCLOSURE**
- 2.1 Panelized Cladding System
- 2.2 Testing Surface at Roof
- 2.3 Skylights
- 2.4 Clerestory at North
- 2.5 Light Monitors

3 **INFRASTRUCTURE**
- 3.1 Vertically Oriented Hub
- 3.2 Horizontal Air Supply and Return
- 3.3 Heated/Chilled Water Loops
- 3.4 Ceiling Mounted Electrical Grid/Drops
- 3.5 Underfloor Utility Access at Foundation
- 3.6 Rainwater Retention System

4 **TESTING SURFACE A (NORTH/SOUTH)**
- 4.1 Modular Reconfigurable facade
- 4.2 Exterior Work Area
- 4.3 Gantry Above
- 4.4 Utilities Provided Adjacent

5 **TESTING SURFACE B (ROOF)**
- 5.1 Raised Test Grid
- 5.2 Modular UV Screens (PV, Green, Etc.)
- 5.3 Access Ladder
- 5.4 Utilities Provided Adjacent
- 5.5 Alternate Roof Systems (See Enclosure)

6 **TESTING SURFACE C (EAST/WEST)**
- 6.1 Raised Test Grid
- 6.2 Modular UV Screens (PV, Green, Etc.)
- 6.3 Utilities Provided Adjacent



"Kit of Parts"/ "Swiss Army Knife" of Testbeds

LBNL National User Testbed Facility

Integrated Systems Test-Beds

Core Facilities

- New Construction Test Beds
  - Focus on Integrated Systems
  - 7000SF
  - Outside B90
- Controls & Visualization
  - Virtual Design
  - Modeling
  - Controls Interoperability
  - ~1000SF inside B90
- Lighting & Plug Load
  - ~3000SF inside B90
  - Span Full width of B90
  - Fully Occupied