US DOE Envelope and Windows Roadmap Workshop

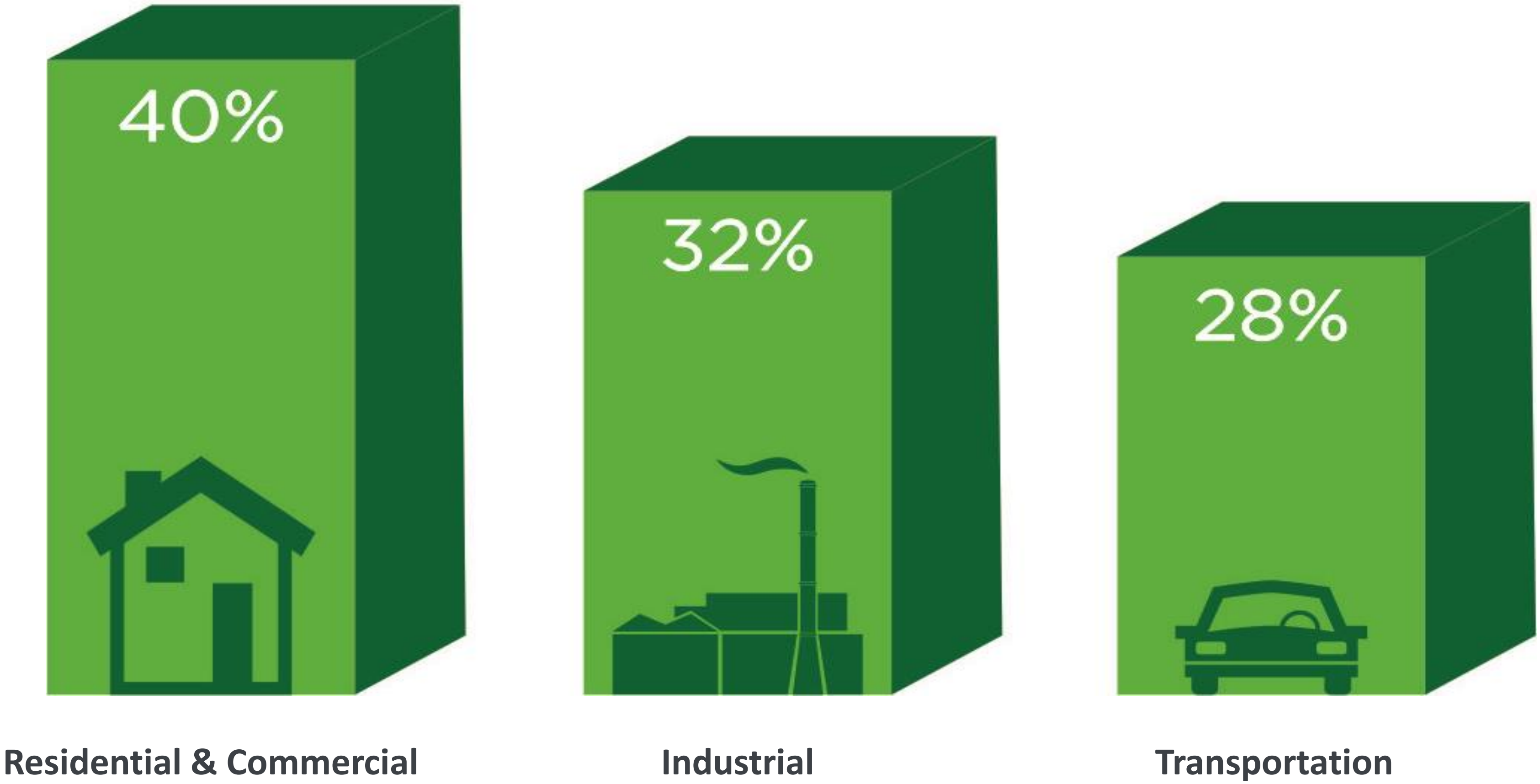
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Marc LaFrance

31 May 2017

IIT, Chicago

Buildings Largest End-use Sector for Energy Consumption



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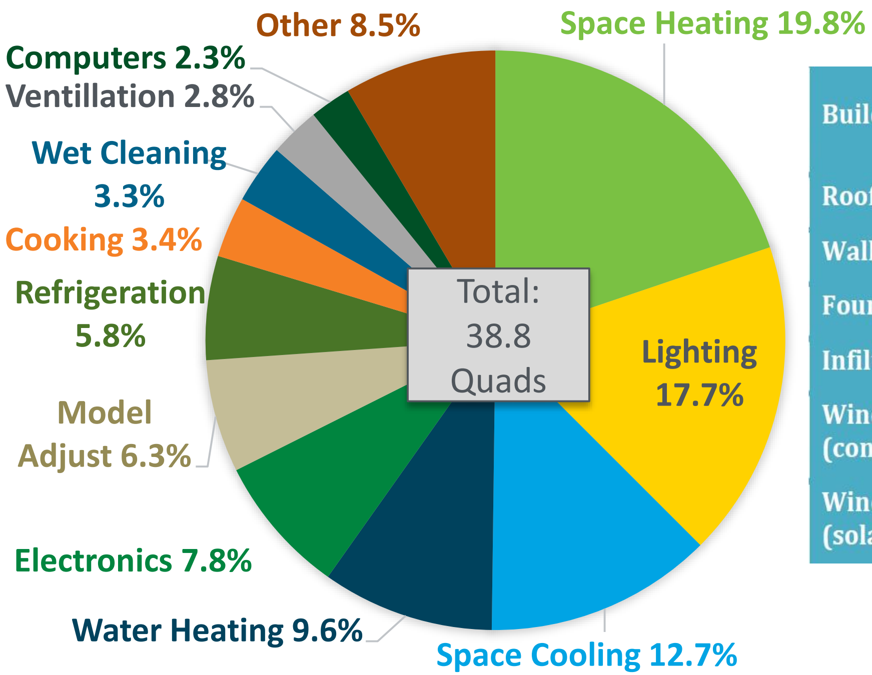
U.S. Building's Energy Consumption and Expenditures

Building Energy Use



Envelope & Windows Impact Over 50% of Loads

Building Component	Residential (quads)		Commercial (quads)	
	Heating	Cooling	Heating	Cooling
Roofs	1.00	0.49	0.88	0.05
Walls	1.54	0.34	1.48	-0.03
Foundation	1.17	-0.22	0.79	-0.21
Infiltration	2.26	0.59	1.29	-0.15
Window (conduction)	2.06	0.03	1.60	-0.30
Window (solar heat gain)	-0.66	1.14	-0.97	1.38

Buildings Natural Gas Use: 60% of U.S. total

Buildings Electricity Use: 75% of U.S. total

U.S. Building Energy Bill: $380 billion per year

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BTO 2016-2020 Multi-Year Program Plan

BTO Goal:

- **2030 goal:** Reduce average energy use per square foot of U.S. buildings by **30%** below 2010 levels
- **Long-term goal:** reduce average EUI of U.S. buildings by **50%**

National Goals:

- By 2030, double energy productivity relative to 2010
- Reduce greenhouse gas emissions 26%–28% below 2005 levels by 2025

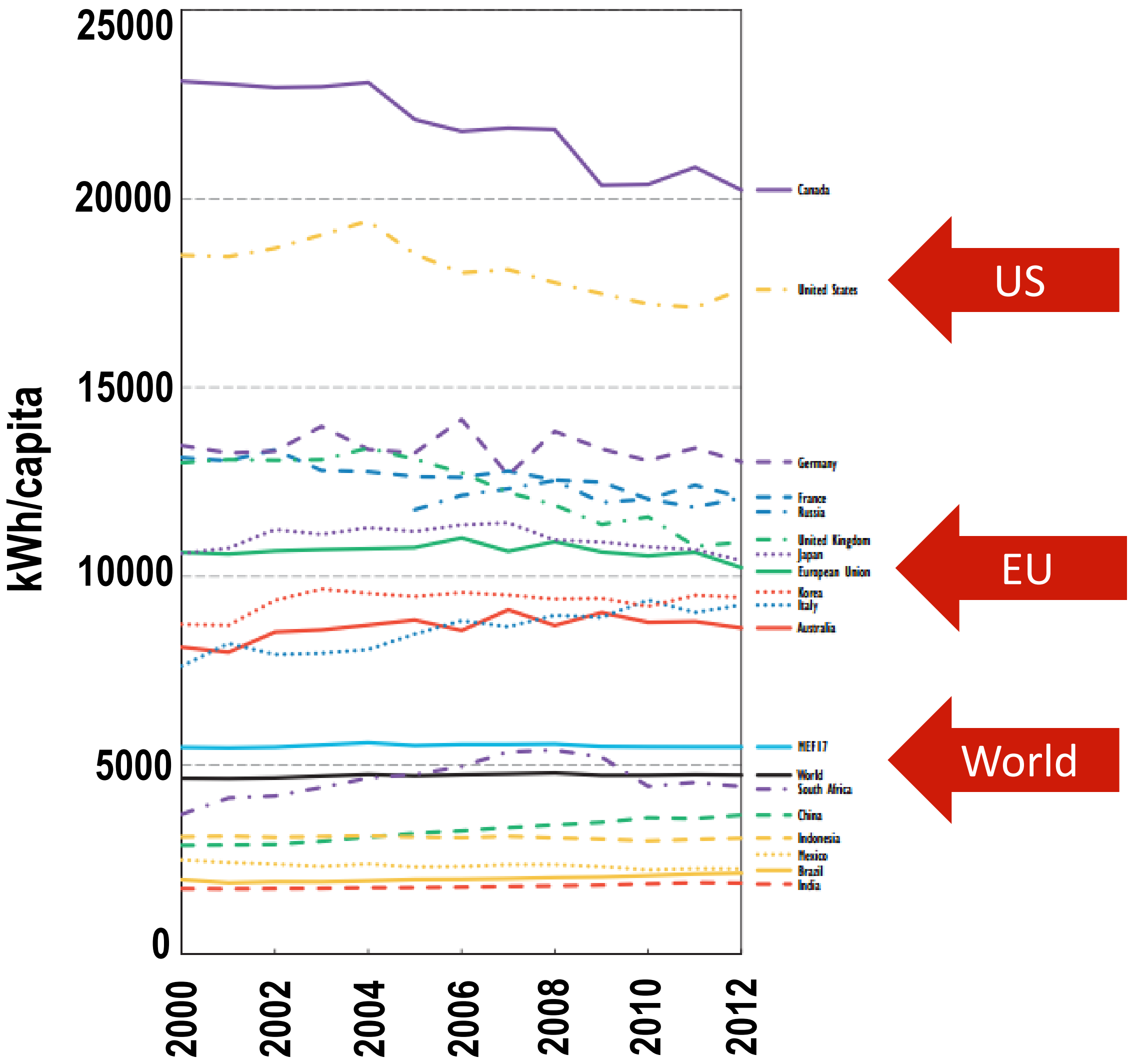
http://energy.gov/eere/buildings/downloads/multi-year-program-plan

Building Energy Consumption per Capita

- US has one of the highest building energy use per capita of the world
- UK has had one of the fastest declines
- Energy efficient materials and products, building codes and overall energy policy drive reductions

Source: IEA, Building Energy Performance Metrics Report, 2015

Figure 9 • Building energy use per capita in MEF economies, 2000-12



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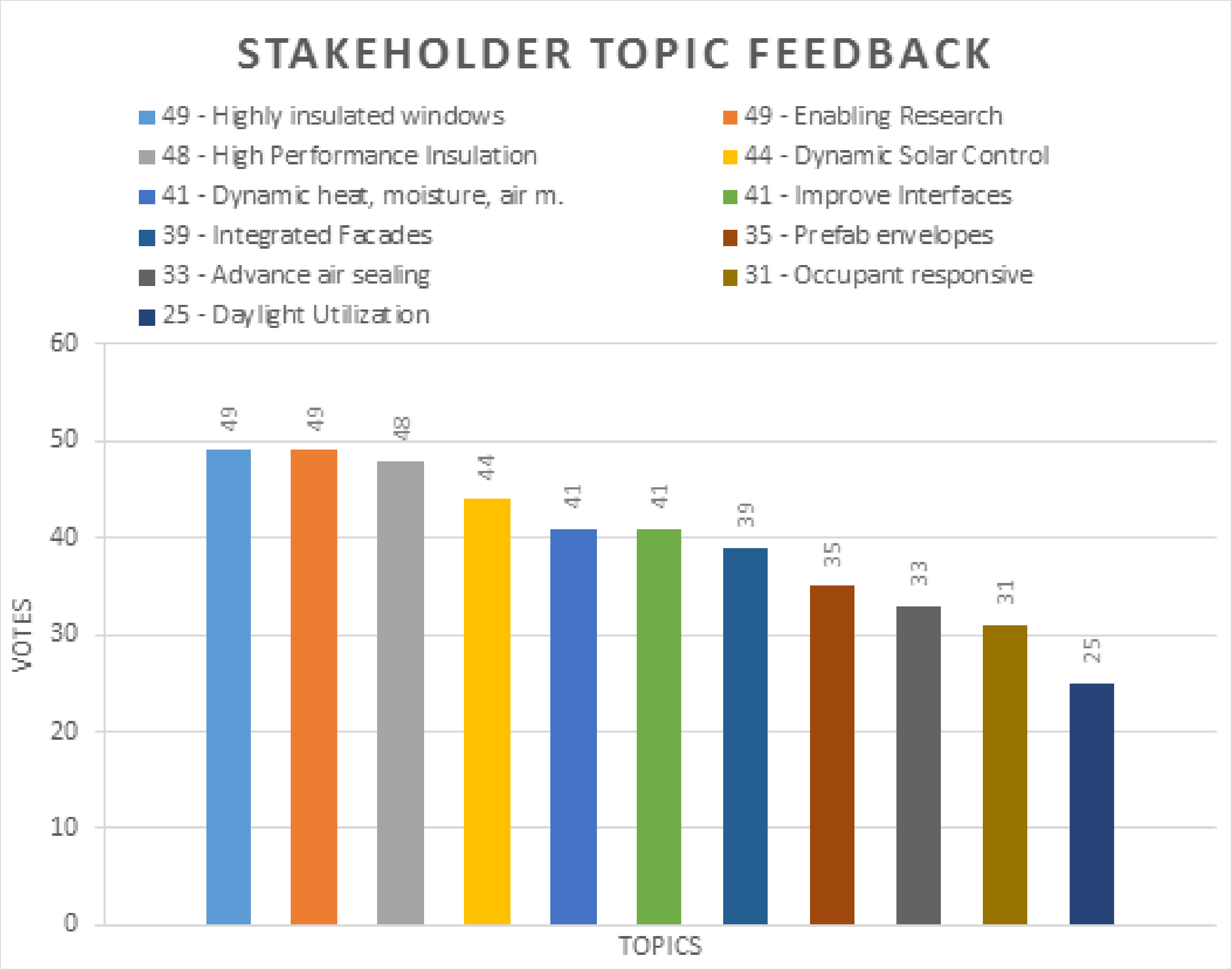
Objectives for Workshop

- Confirm critical role that Building Envelope and Windows play in achieving BTO Goals
- Seek stakeholder input that will contribute to an update to the building envelope and windows technology roadmap
- Identify goals and actions to achieve technological progress that will result in less energy consumption in the buildings sector while supporting associated benefits (e.g. peak load reduction, job creation, productivity, etc)
- Identify opportunities for DOE R&D investment, dependent upon funding and priorities
- Identify high risk scientific challenges and material development opportunities for national laboratory and academia investigations
- Identify actions with partners for implementation including approaches to overcome barriers to adoption

Participant Responses from Registration Page



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Reference Materials

- DOE Envelope and Windows Roadmap
  - Highly insulated windows, dynamic windows, and daylighting
  - Thin high performance insulation, advanced air sealing, and highly insulated roofs
- Building America Research to Market Plan
  - High performance moisture managed envelopes; optimal comfort for low-load homes; optimal ventilation and IAQ
- IEA Building Energy Efficiency Envelope Roadmap
  - Global regional assessments on high priority technology adoption and performance metrics
  - Identification of high priority technologies and actions associated by entity
  - Policy assessments
- Competitive Financial Opportunities
  - FY17 BENEFIT: Innovative, HVAC, Sensors & Control, Scale – up > up to 20M
  - FY 17 SBIR – Windows focus on highly insulating, dynamic, fundamental supporting science

Current Roadmap Goals/Targets – Review & Update Needed

Technology	2025 Installed Cost Premium Target	2025 Performance Target
Highest Priority R&D Area		
R-10 Windows	Residential: ≤ $\$6/ft^2$ Commercial: ≤ $\$3/ft^2$ over typical 2010 windows	• Residential: R-10, $V_T > 0.6$ • Commercial: R-7, $V_T > 0.4$ • Comparable weight and thickness to currently installed base
High Priority R&D Areas		
Dynamic Windows	Windows: ≤ $\$8/ft^2$ Window Films: ≤ $\$2/ft^2$ over a standard IGU	• ΔSHGC > 0.4 • V_T bleached state > 0.6 (residential) and > 0.4 (commercial)
Visible light redirection (commercial)	≤ $\$5/ft^2$ over standard window or shade including lighting and controls costs	50% reduction in lighting energy use over a 50-ft floor plate

Vision: Convert Windows to Net Zero Energy: +5Q

Strategy: Energy Losers -> Neutral -> Supply Net Energy

Performance Gaps: Defined by Climate/Energy Function

- **Heating climates**
  - Reduce heat losses so solar energy balances and exceeds loss
  - **Gap**: technologies with lower heat loss, U ~.1
- **Cooling climates**
  - Reduce cooling loads but allow daylight/view
  - **Gap**: Shift from Static properties -> dynamic control of SHGC, Tv
- **All climates – Lighting, Ventilation**
  - Replace electric lighting with daylight
  - **Gap**: extend daylight use to 30’ depth
  - Utilize natural ventilation w/ operable windows
- **Electricity supply options**
  - Photovoltaics-building skin as power source

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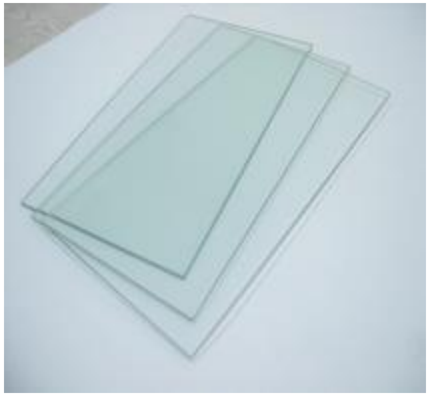
Glazing and Façade R&D Landscape

Multiple "Scales" for R&D and Innovation

Nano ⟶ Micro → Macro

"1μ" coating → "1mm" glass → "1m" Window, shading → "100m" Building

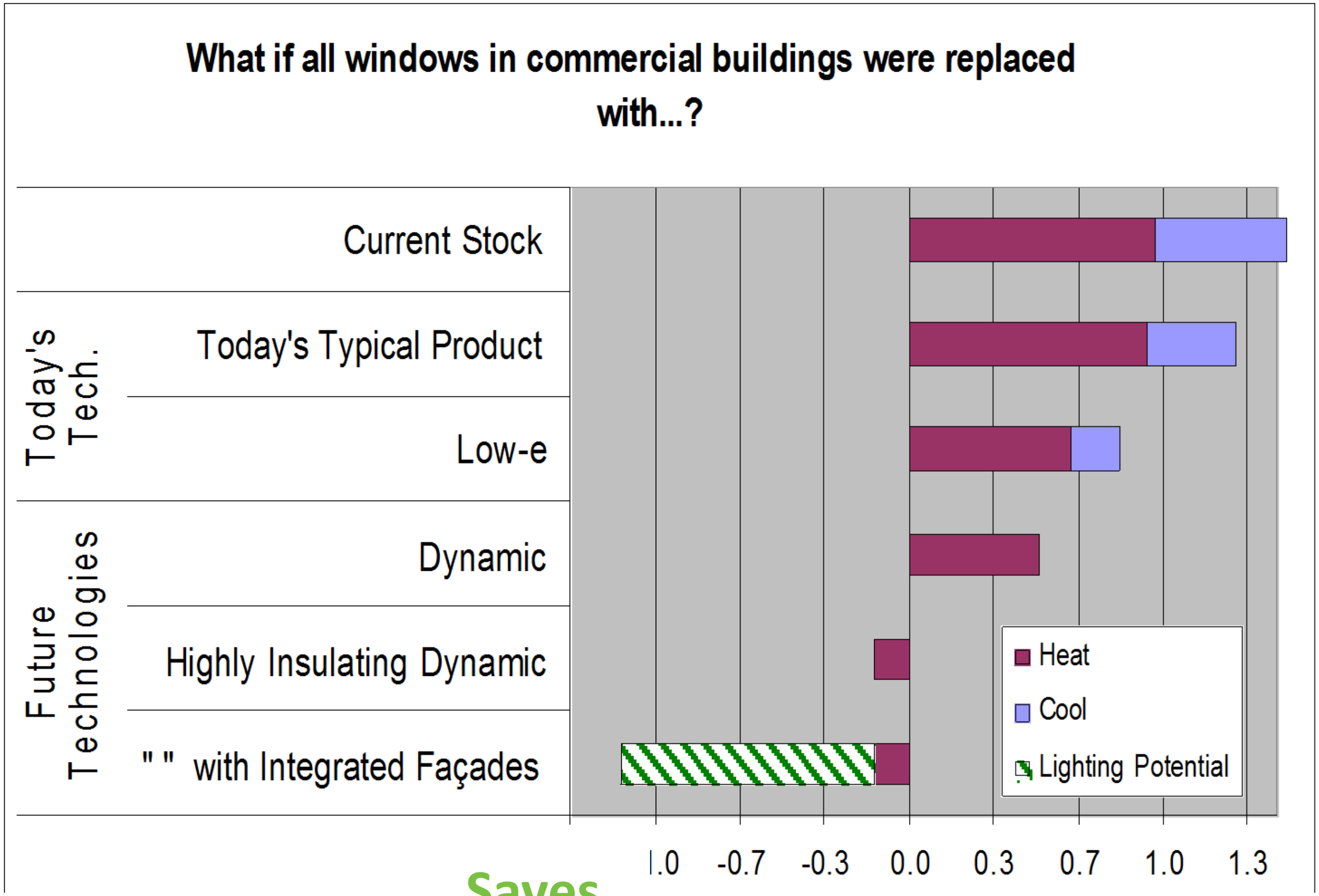


Next Generation of Windows

- Highly insulated, dynamic solar control, daylighting
  - Commercially available products in both areas but very low market penetration, and low likelihood of rapid change
  - What technology or market innovation could change that?
- Value to low energy buildings
  - Improved thermal and visual comfort, reduced noise, smaller HVAC, reduced peak loads
  - Residential: eliminate branch duct work and allow for more window area
  - Commercial: perimeter zone conditioning eliminated, lower utility rates linked to peak demand
- How to build consumer demand, industry feedback?
  - R&D innovation: more features at lower cost
  - Voluntary programs to grow market demand
  - Mandatory codes and standards, as proposed in Canada for Hi-R
  - Improve value proposition on conventional window replacements, etc

"Zero Net Energy" facades: National Impacts

Converting a $20B/yr cost to a $15B/yr Net Surplus!



Cost = $20B

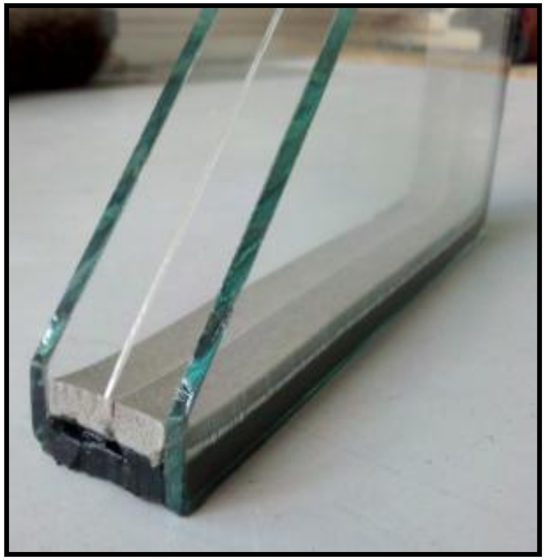
Saves $15B

Current Windows Activity

- Competitive Financial Awards
  - **WCMA:** Attachments Energy Rating Council (AERC)
  - **Arconic:** Novel Thermal Break with Simplified Manufacturing for R-7 Commercial Windows
  - **LBNL and Pella:** Highly Insulating Residential Windows Using Smart Automated Shading
- Annual Operating Plan Projects
  - **LBNL:** window suite of software tools development and maintenance, technology development, and Energy Star Most Efficient support, and five specialized laboratory facilities for development and validation
  - **NREL**: durability testing, and installed cost analysis - difficult to find an easy reduced, better consumer education needed, customer acquisition
- International Collaboration India (CBERD) and China (CERC 2), small level of effort on window activity

Stepping Stone to Next-Gen Windows: "R8 Thin Triples"

- Market "stuck" at Energy Star window, double, low-E, R3
  - No Market Pull so manufacturers won't invest in triples: now <2% sales
  - Transition to Much Lower U =~.1 - .15 would save 1+ Quad
- **Challenge:** Drop-in "R8 IGU Glazing" to replace current R4 IGU
  - **No change in IGU weight, width -> no need for expensive sash redesign**
- New R8 IGU added to existing frame will improve Window R3 -> R6
- **Technology approach**
  - Add thin (.7mm) glass layer, extra low-E, improved spacer, Krypton gas fill
  - Optimized thermal package can achieve R10
  - Other package benefits: e.g comfort, smaller HVAC
- **Benefits**
  - **Improved Comfort, Larger window size w/codes, lower HVAC, big energy savings**
  - **Primes housing market for more extensive future change**, vacuum windows, smart windows, etc
- **Status: LBNL has validated concept with proof prototypes**
  - Assembled 6 industry partners to advance to pilot line



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Key Challenges and Opportunities for Windows

- Window replacement not usually cost effective based on energy benefits unless replacing window anyway
  - reduce installed cost (new and retrofit)
- Ensuring quality, consistent installation, and transparency on what customers buy
  - replacement window vs new window
- Integrated wall/window upgrade as a system should reduce cost and add “market value” to homes
  - Is it possible to get early window replacement based on home value improvements?
- Value proposition to consumers can be increased by reducing cost and fully assessing benefits
  - all energy impacts: infiltration, comfort, thermostat settings; and non-energy benefits: reduced noise, aesthetics, resale and market value, etc

Workshop Strategy

- Gaps and Opportunities
  – What is broken, how can things be improved, what barriers are holding back greater investment into building envelopes and windows
- Technical Solutions
  – Refine and re-confirm, as appropriate, DOE existing technology strategies
  – Explore fundamental new approaches that could offer greater value proposition with significant R&D over a longer timeframe
  – Define near term solutions that can be pursued by stakeholders with specialized technical support from national laboratories
- Innovative Technology Pathways and Implementation
  – Define actions by entities on how to develop and implement technology solutions
  – Identify suggested priorities, metrics and goals

Contact Information – Residential and Emerging Technologies Teams

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DOE Envelope and Windows Workshop

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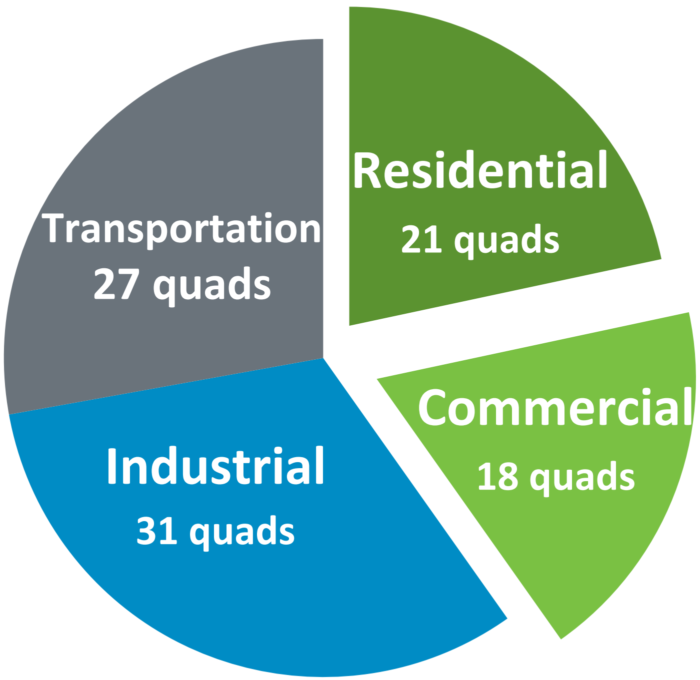
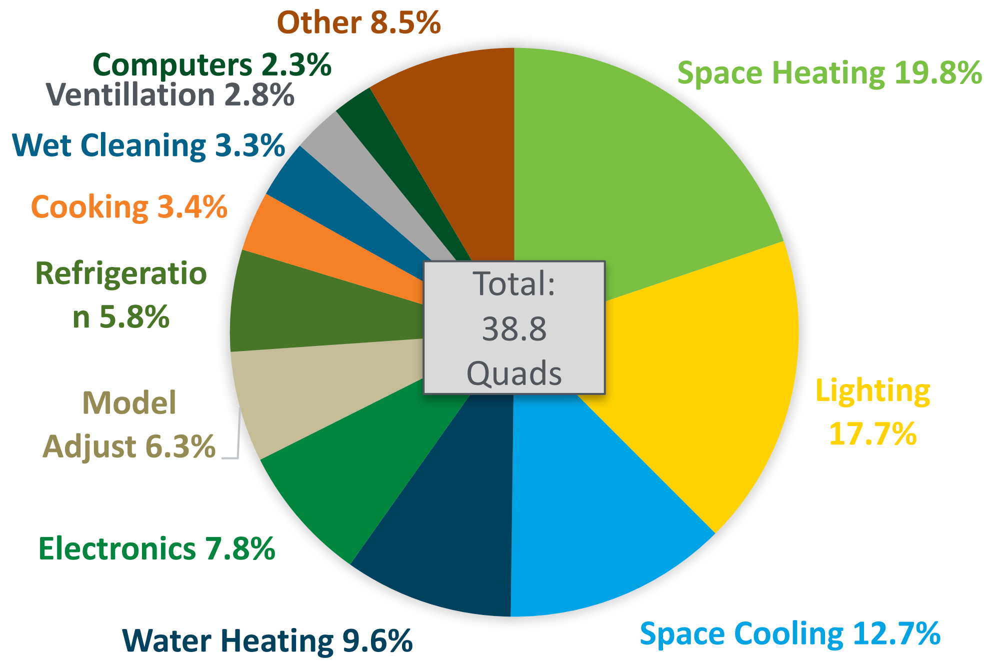
Sven Mumme
Envelope Technology Manager
May 31, 2017 | Chicago, IL

U.S. Energy and Electricity Consumption by Sector

Energy Use



Building Energy Use



Buildings Energy Use: 40% of U.S. total

Buildings Electricity Use: 75% of U.S. total

U.S. Building Energy Bill: $380 billion per year

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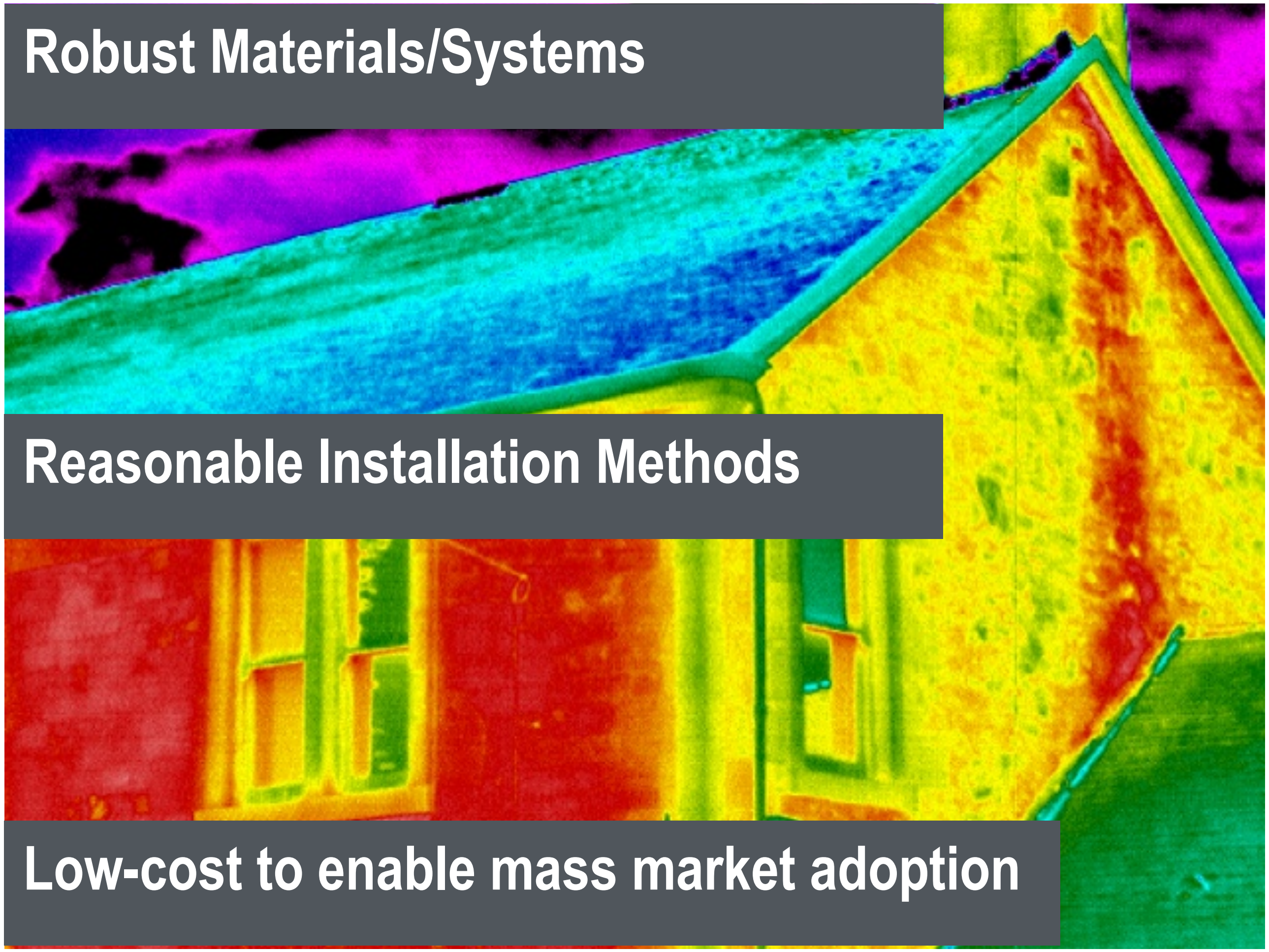
1. Make more efficient machines

Two Strategies for Reducing Energy Consumption

2. Be smarter about how we use energy



Robust Materials/Systems

Reasonable Installation Methods

Low-cost to enable mass market adoption

Energy use associated with the envelope (2010)

Opaque envelope	**7.3 quads**
Roofs	2.4 quads
Walls	3.3 quads
Foundation	1.5 quads
Air Infiltration	**4 quads**
Windows	**4.3 quads**

Windows & Building Envelope Program Goal:

25% Reduction in Energy Consumption due to Building Envelope by 2030

- Building Envelope
- Commercial & Residential Sectors
- New Buildings & Retrofits

Requires next-generation energy efficiency technologies for **mass-market adoption**

Priority areas for envelope R&D based on roadmap

Technology	2025 Installed Cost Premium Target	2025 Performance Target
Highest Priority R&D Area		
Building envelope insulation	≤ $0.25/ft^2$	• ≥ R-12/inch thermal insulation material for retrofitting walls • Meets durability requirements • Minimizes occupant disturbance
Air-sealing technologies	≤ $0.5/ft^2$ finished floor	• Residential < 1 ACH50 • Commercial: < 0.25 CFM75/ft^2 • Concurrently regulates heat, air, and moisture
High Priority R&D Areas		
Highly insulating Roofs	≤$1//ft^2$	• An energy use reduction equivalent to doubling current ASHRAE R-values

Metrics and targets for 2020 and 2025

Metrics, Statuses, and Targets: Building Envelope				
Project Area	**Metric**	**Status**	**2020 Target**	**2025 Target**
Building Envelope Material for Retrofit Applications	R/in	R-6/in	R-8/in	R-12/in
	Installed cost premium ($/sq. ft.)	$1.1	$0.35	$0.25
Air-Sealing System: Residential	ACH50	7	3	1
	Installed cost premium ($/sq. ft. finished floor area) Incl. mechanical ventilation	$1.4	$0.5	$0.5
Air-Sealing System: Commercial	CFM75 per 5-sided envelope;	1.38	0.25	0.25
	Installed cost premium ($/sq. ft. 5-sided envelope) incl. mechanical ventilation	$1.40	$0.60	$0.50
Highly Insulating Roof: Commercial	R-value (climate zones 2; 6);	R-17	R-35; R-45	R-50; R-60
	Installed cost premium over today's roofs ($/sq. ft.)	$4.4	$3	$1

Building Envelope Needs

- Quick and easy building envelope retrofit solutions that reduce cost and complexity
- "Seamless" interfaces/transitions between functional areas (e.g., roof-walls, walls-windows, walls-foundation)
- Novel approaches for measuring envelope infiltration
- Cost-effective air-sealing technologies that are well-suited to retrofit applications (remediate flaws and infiltration points)

Building Envelope R&D Areas of Interest to BTO

New Materials for Building Efficiency

Ultra-low Thermal Conductivity Materials

Multi-functional Materials

Advanced Thermal, Moisture and Air Management: A Dynamic System Approach

At the end of the our two days together…..

- Input to Roadmap update
- Topic areas for possible inclusion in R&D portfolio
  - Idea/technology solution/gap addressed
  - Technology impact/benefit
  - Technology pathway to success
  - Key metrics & targets
- Relevant cross-cutting perspectives
  - Residential & Commercial
  - Retrofit & New Construction

Contact Information

Thank you!

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Building Envelope Systems Research

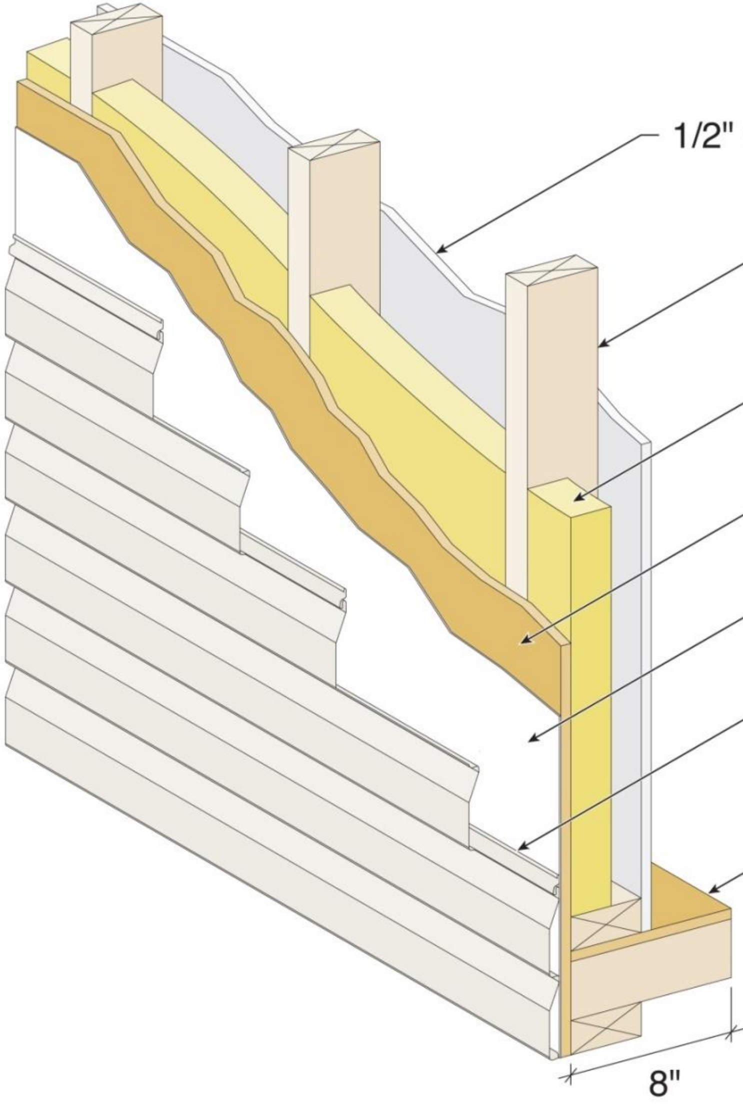
Presented by:

Roderick Jackson, Ph.D.
Group Leader,
Building Envelope Systems Research

Presented to:

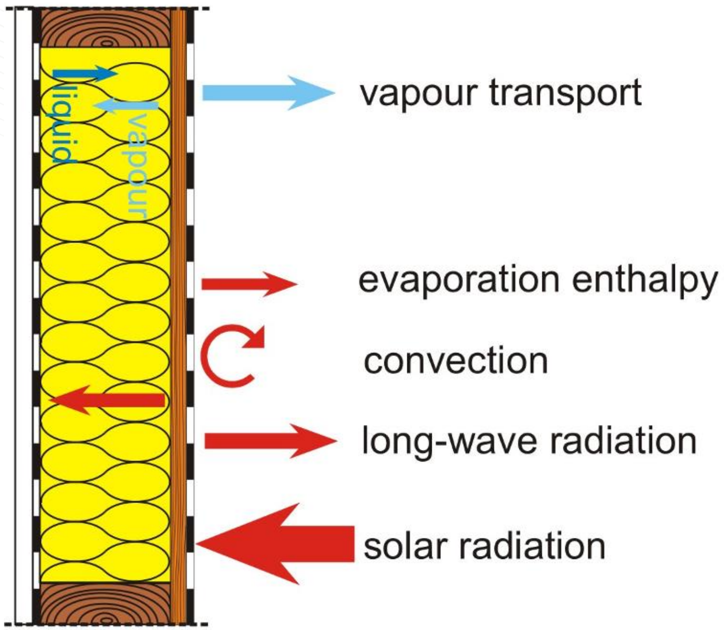
DOE Building Envelope and Windows Workshop

The Building Envelope is a COMPLEX and INTEGRATED SYSTEM

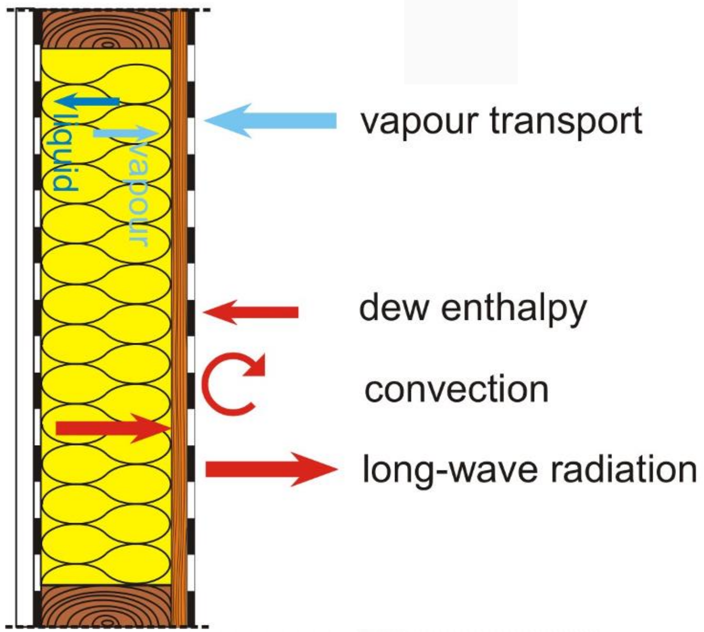


A Complex System with Complex Processes

During the day…..



At night…..



A COMPLEX SYSTEM in a COMPLEX ENVIRONMENT

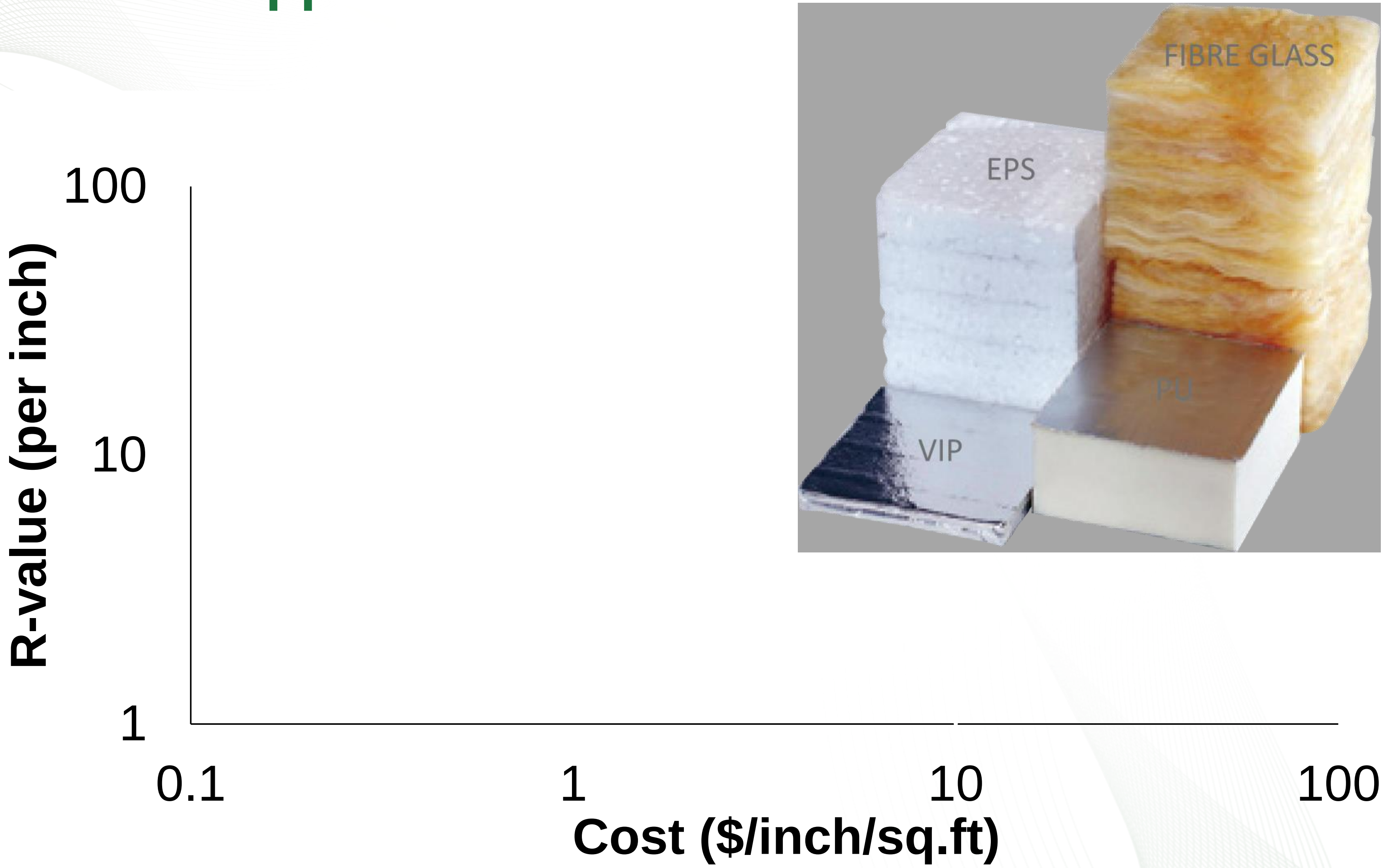
commons.wikimedia.org

Building Component Requirements

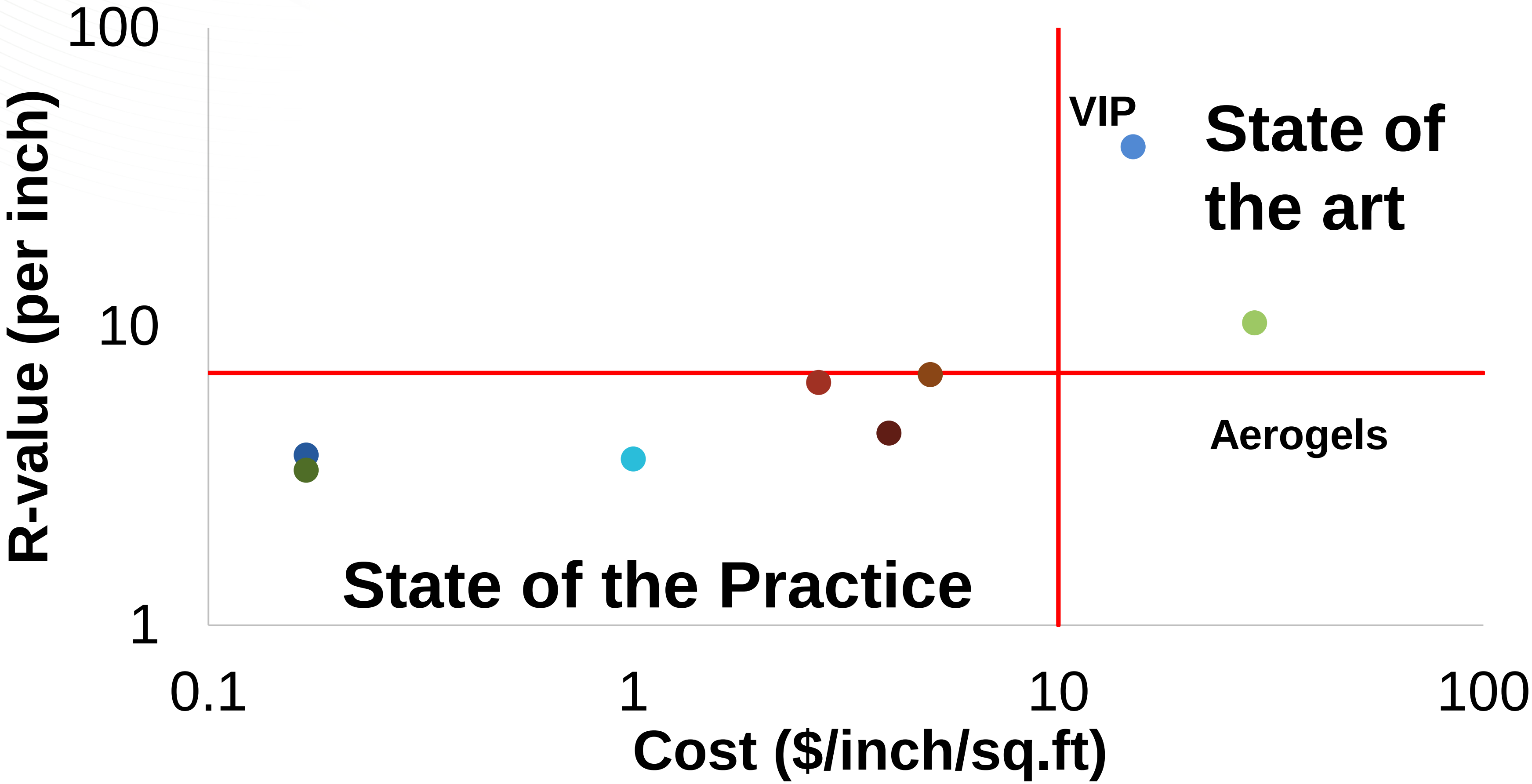
- Many Climates and Extremes
  - Temperature, UV, Wind, Freeze/ Thaw, Moisture, Mold, Fire, Structure, Toxicity, Human Safety
- New vs Retrofit
- Many Building Types
  - Many different designs (parameter mixes)
- Strong Interactions
- Highly Cost Sensitive

Technical Challenges and Current Research

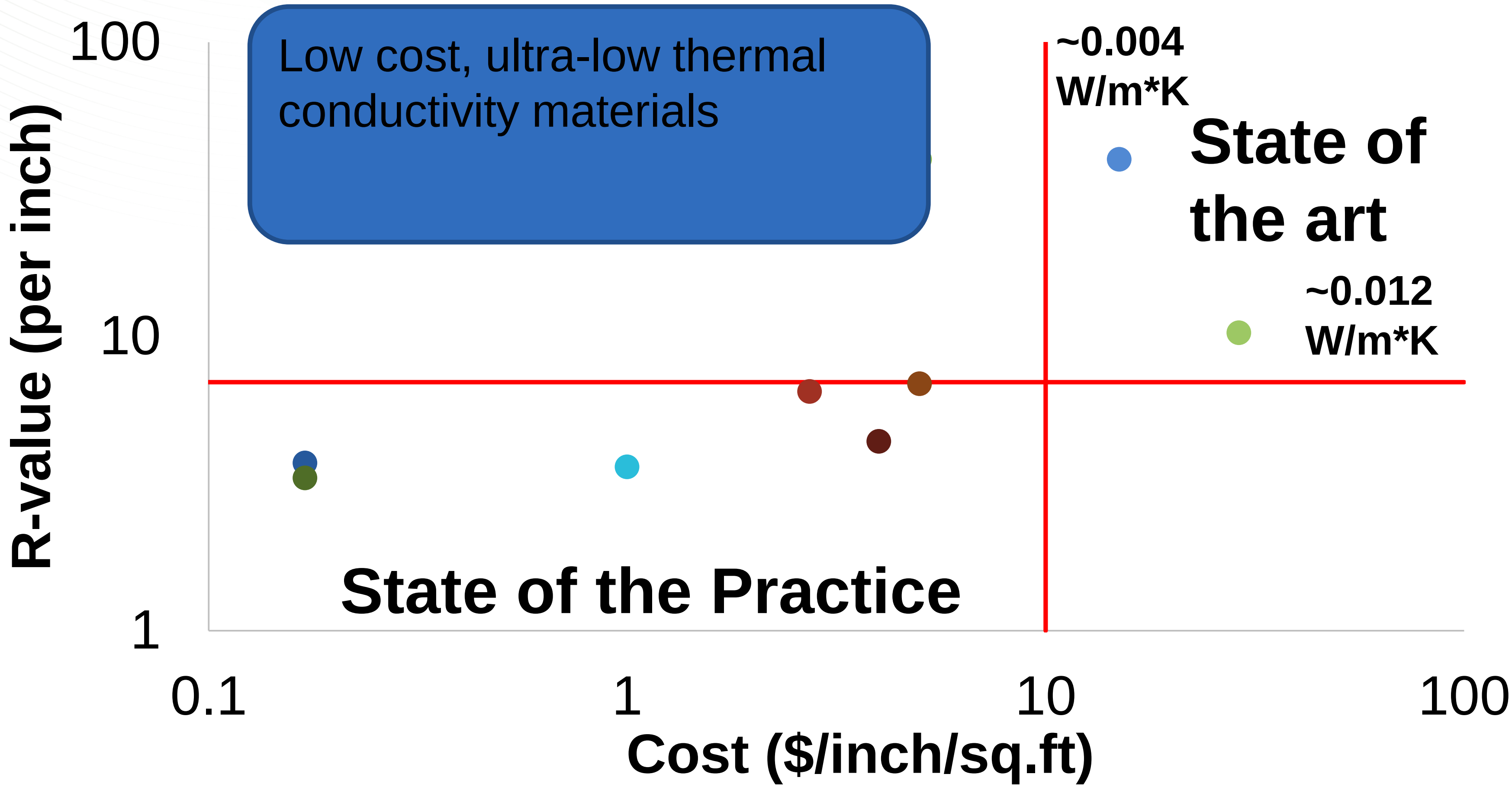
Insulation materials for building envelopes – Innovation opportunities



Insulation materials for building envelopes – Innovation opportunities



Insulation materials for building envelopes – Innovation opportunities



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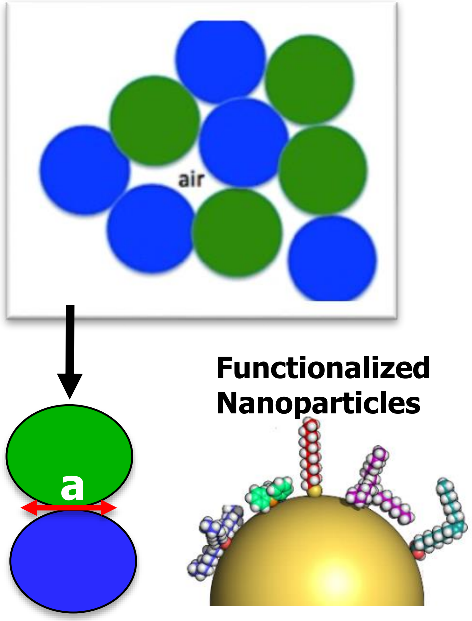
Robust Super Insulation at a Competitive Price

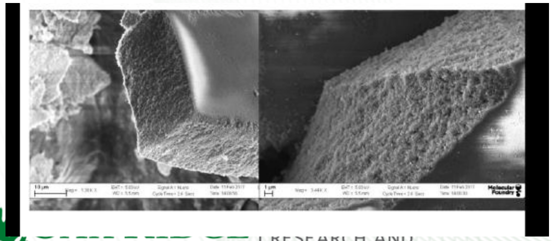
Technology Summary

LBNL is developing a novel insulation using nanoscale phonon engineering to optimize surface energy, particle size, and acoustic property mismatch to achieve R-12/inch.

- R/inch value at least 2 – 4 times higher than conventional insulation
- Almost an order-of-magnitude lower cost vs. aerogel and VIPs
- Increased mechanical robustness and flexibility vs. aerogel and VIPs

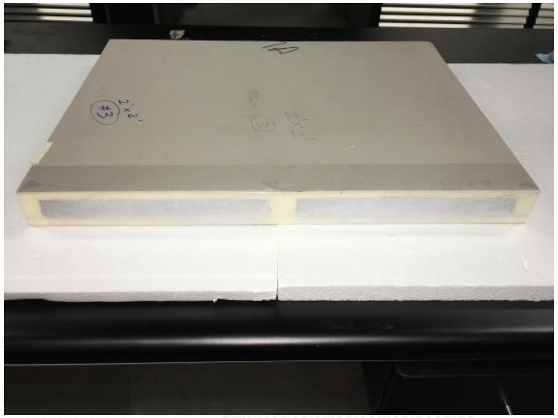


- Particle-particle constriction limits inter-particle phonon transport
- Reduced surface energy and mismatched vibrational spectra further reduce phonon transmission



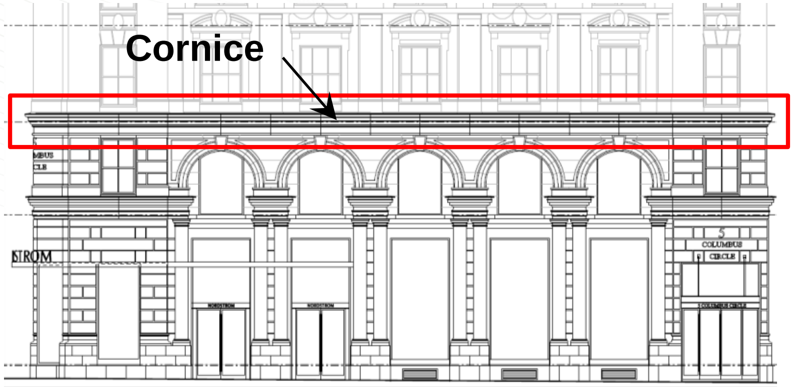
Modified Atmosphere Insulation Composite Boards

- ORNL/NanoPore/Firestone collaboration: new composite foam-MAI insulation board
- Combination of Modified Atmosphere Insulation (MAI) panels, a low-cost alternative to vacuum insulation, and polyisocyanurate
- Two applications: wall sheathing and commercial roof retrofits
- Second prototype achieved R11.4-R11.9/inch (goal is R-12/inch)
- Energy savings potential of 1,319 TBtu

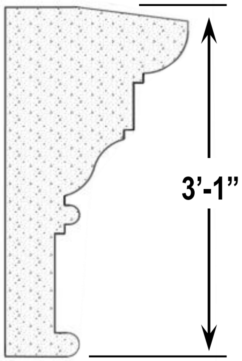


New concretes, composites, and processes for next generation precast envelopes

Building Elevation



Cornice Cross Section



Current Assembly Process

Can We Manage the Heat Differently?

- **The building envelope is not spatially and temporally invariant.**
- **Why do we manage heat that way?**

Thermal Management Using Anisotropy

Reducing Unwanted Heat Flows Through Building Envelopes

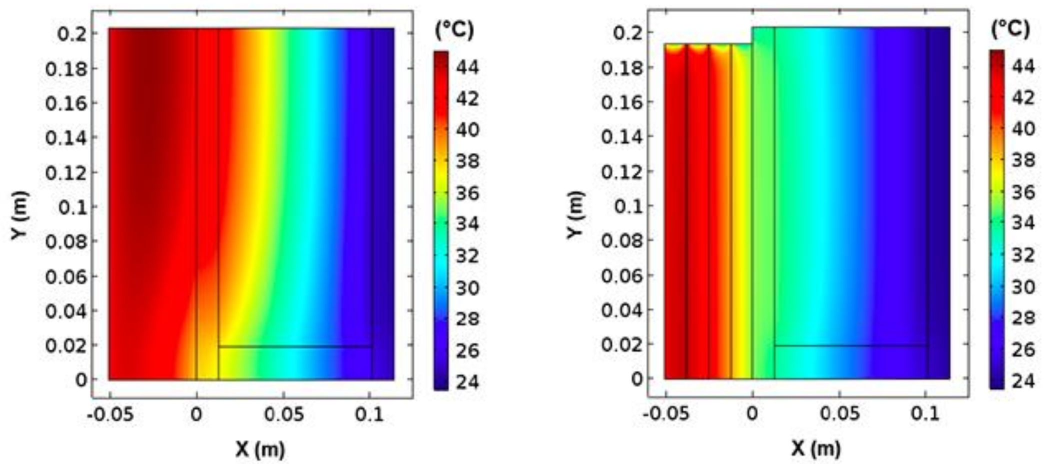
ORNL is investigating directional heat dissipation using anisotropy for reducing unwanted heat flows through the building envelope.

Anisotropic Materials and Composites

Anisotropic composites can be created by alternate layering of isotropic materials, with differing overall thermal conductivities (k) along different axes.

Simulations Show Potential for Reducing Unwanted Heat Gains

Calculations showed annual reductions of 9-69% in internal heat gains through a west-facing wall compared to the isotropic exterior insulation case



Calculated temperature distribution in the wall section with exterior insulation (left) vs. anisotropic composite and heat sink (right)

Envisioning a truly integrated dynamic system

Can Multifunctional Materials Enable New Integrated Solutions?

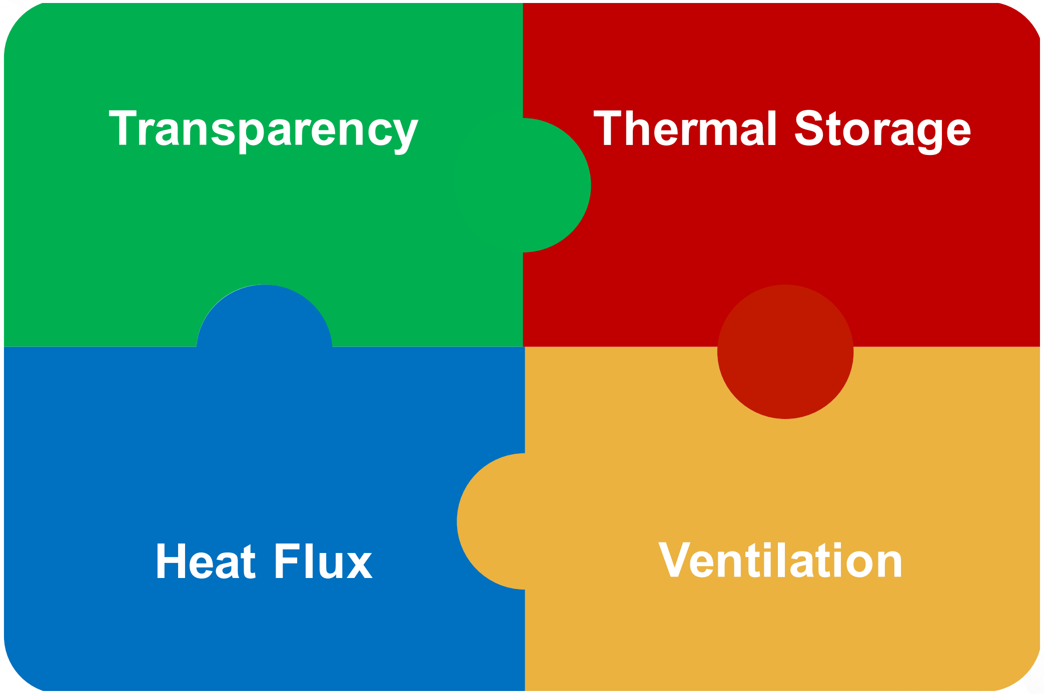


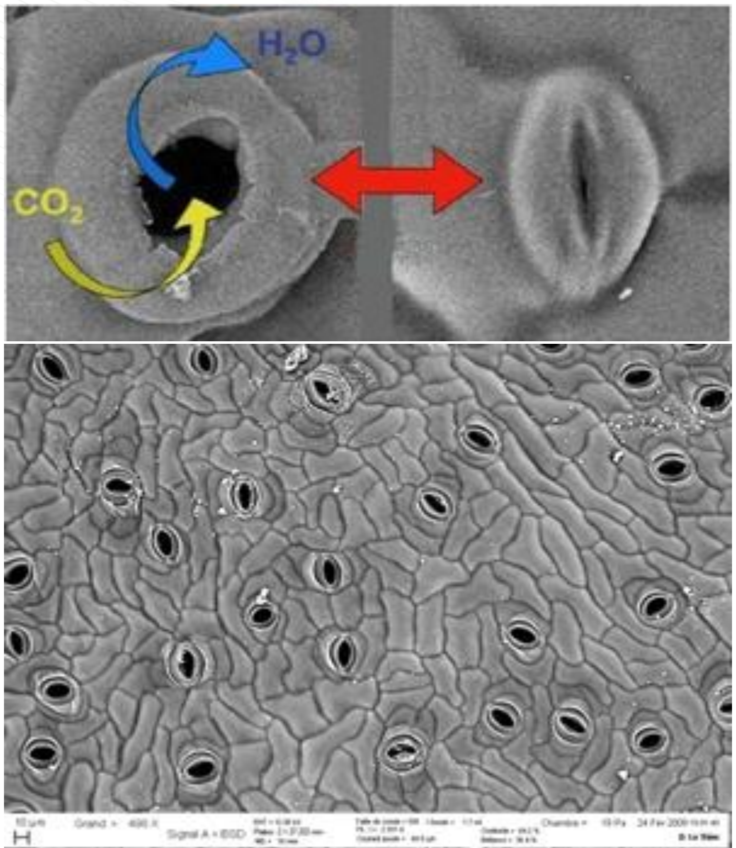
Image source: Fadl Saadi, “Smarter Structures: Synchronizing Building Envelope Technologies”

Multifunctional Materials Development

A multifunctional material requires a new design methodology in which **system-level performance is emphasized over the optimization of individual functions.**

Optimizing system-level performance involves optimization **methodologies that are not commonly used in materials science.**

The Original Multifunctional Materials…Evolved…



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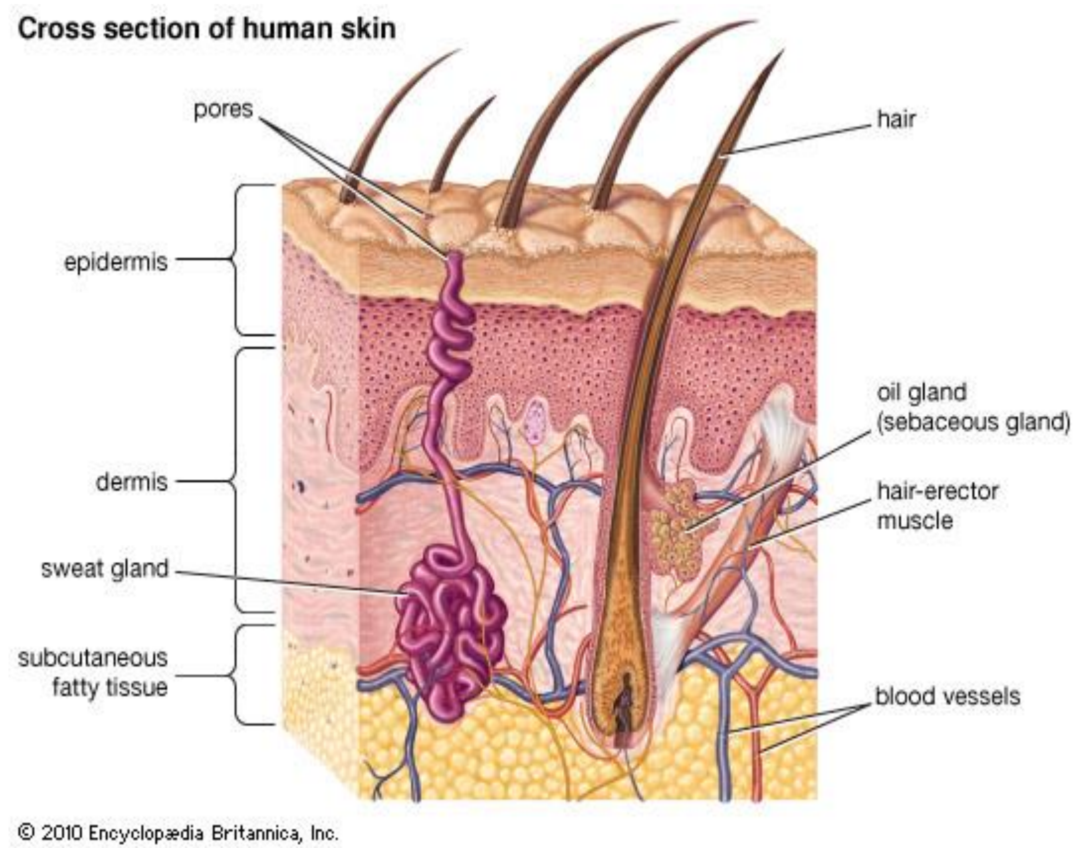
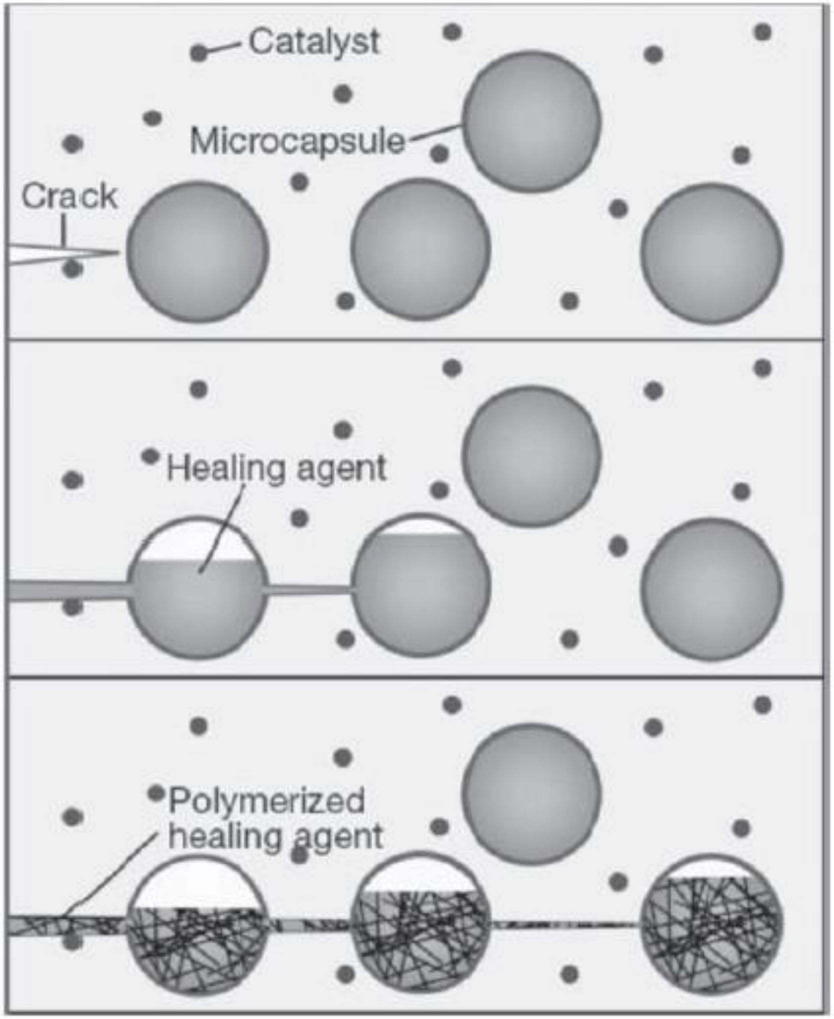


Self Healing Materials



Adv. Mater. 2010, 22, 5424–5430

Responsive to damage/failure event.

Anticipated that the original functionality can be restored.

Metals, ceramics, concrete, and polymers.

Thank You

Roderick Jackson, PhD
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@Dr_rkjackson

Future of Envelopes

(a couple of thoughts)

Leonard Sciarra, AIA, LEED ap+, ASHRAE

Gensler

We used to build light or massive



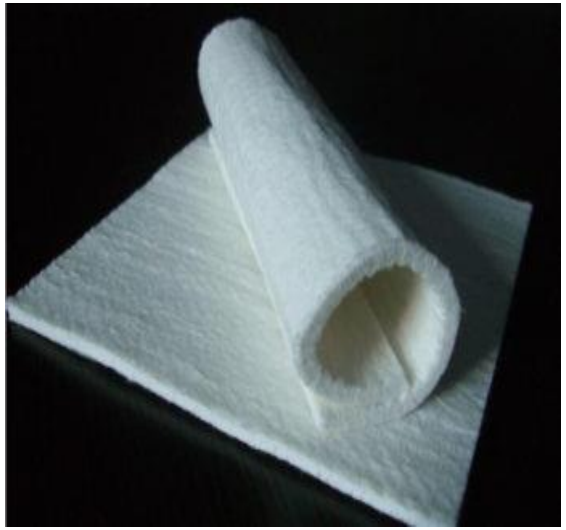

20 years
CENTRIFUGAL
Refrigeration
Carrier

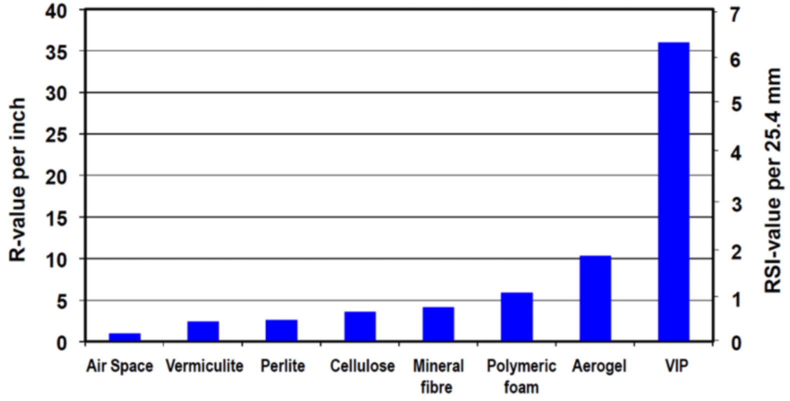

7 10:08

So What is the future…..

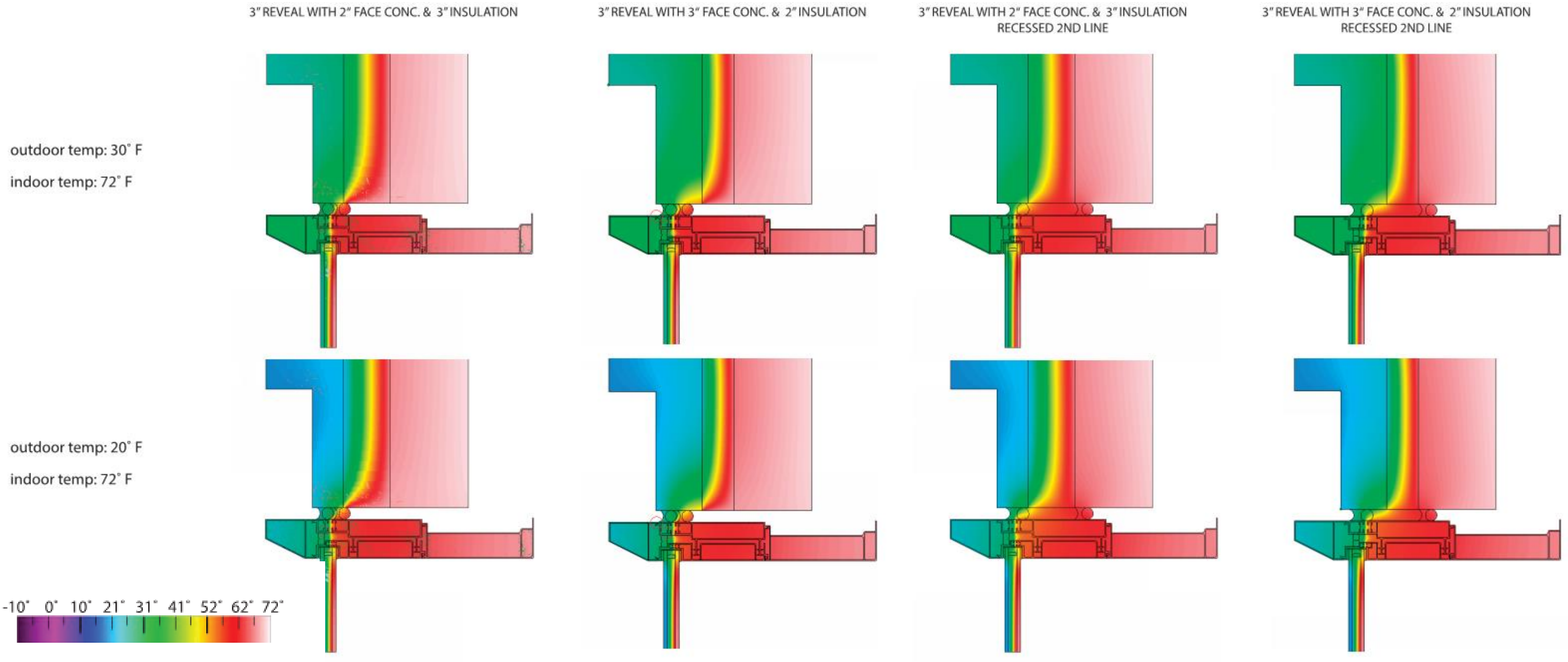
Integrate the benefits of mass and light frame construction

Insulate more with thinner insulation





Better thermally broken curtain wall



Lower SHGC

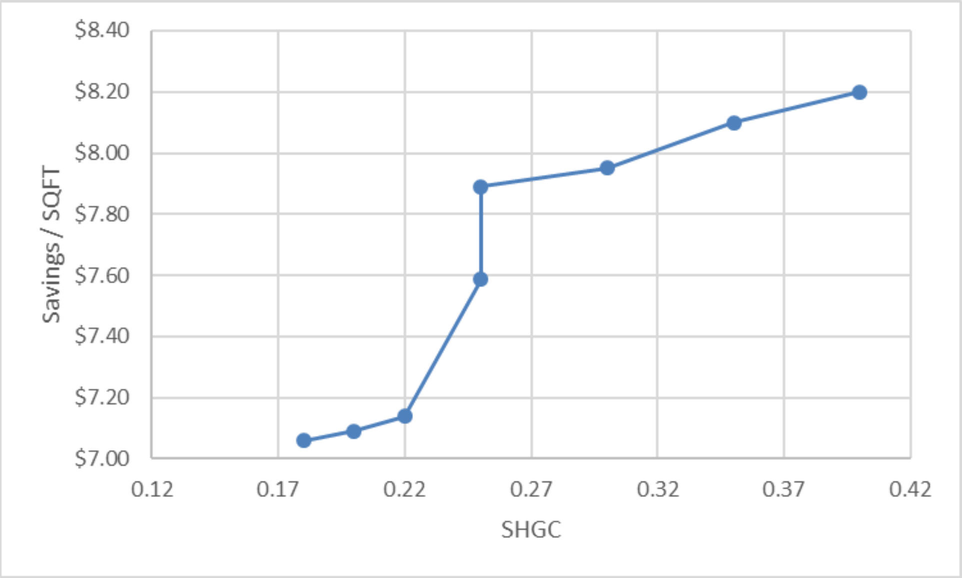
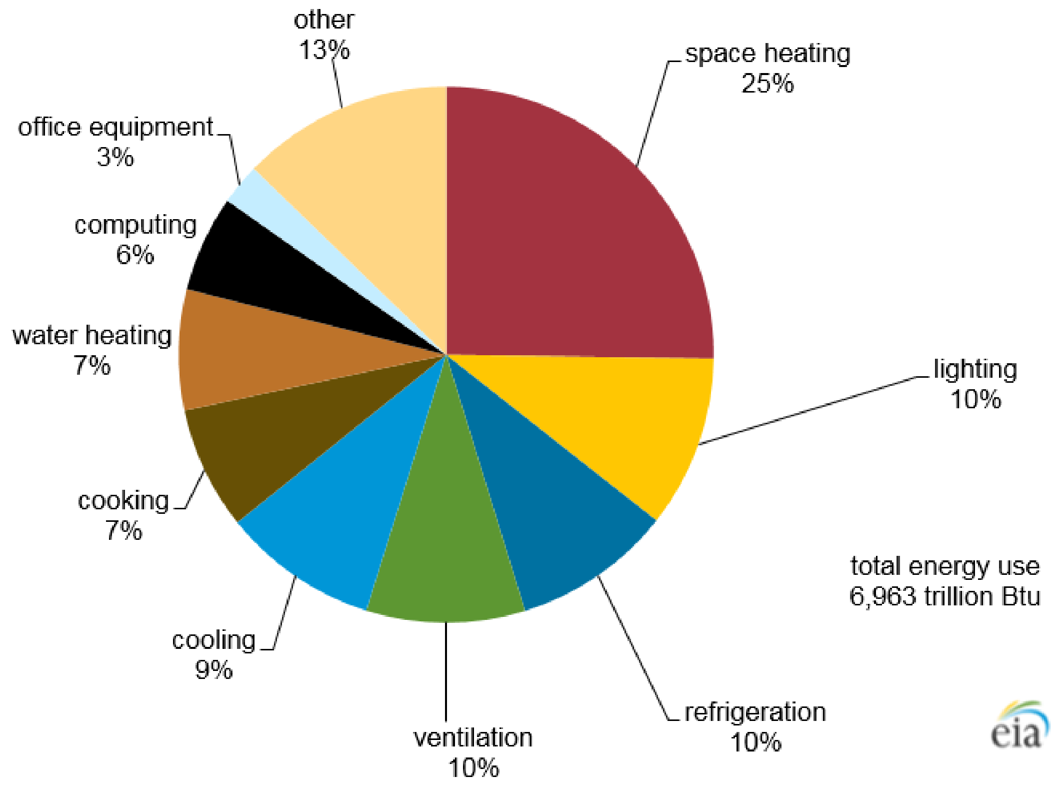
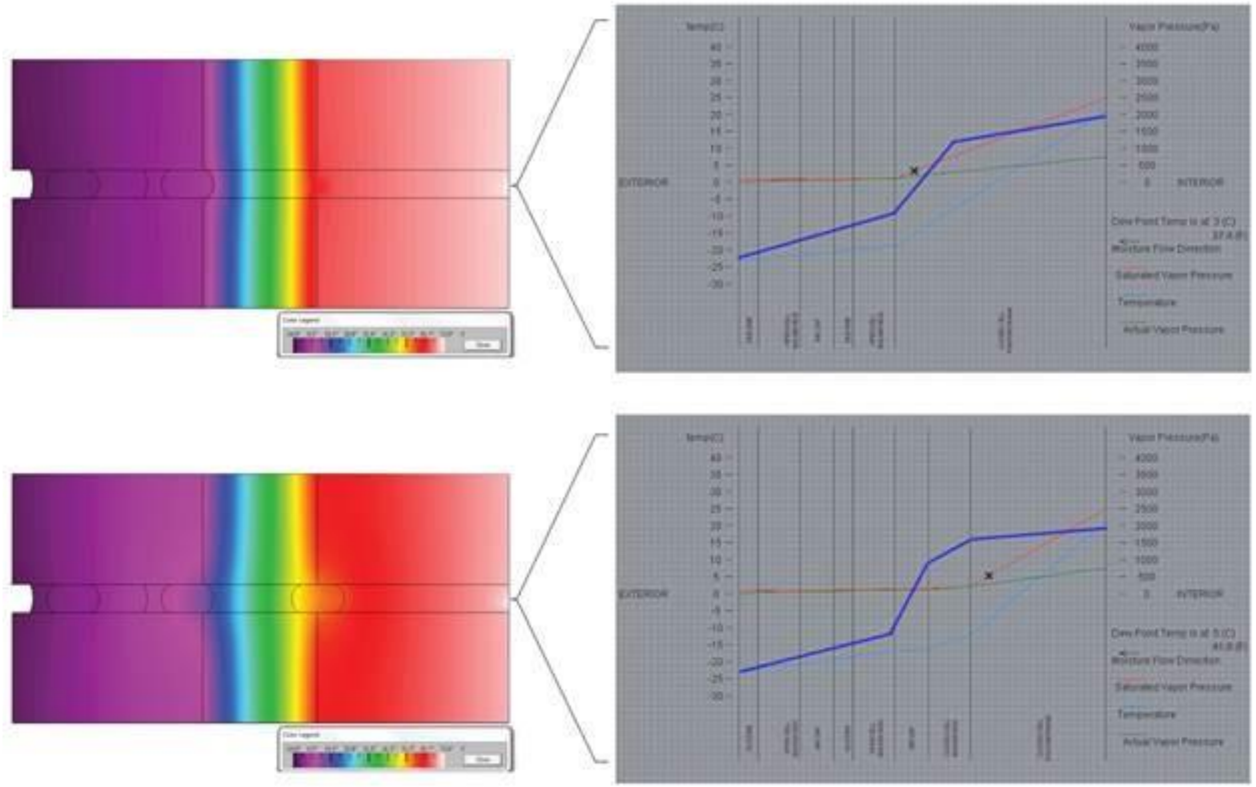


Figure 5. Space heating demanded the most overall energy use in commercial buildings in 2012, followed by other uses



Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey.

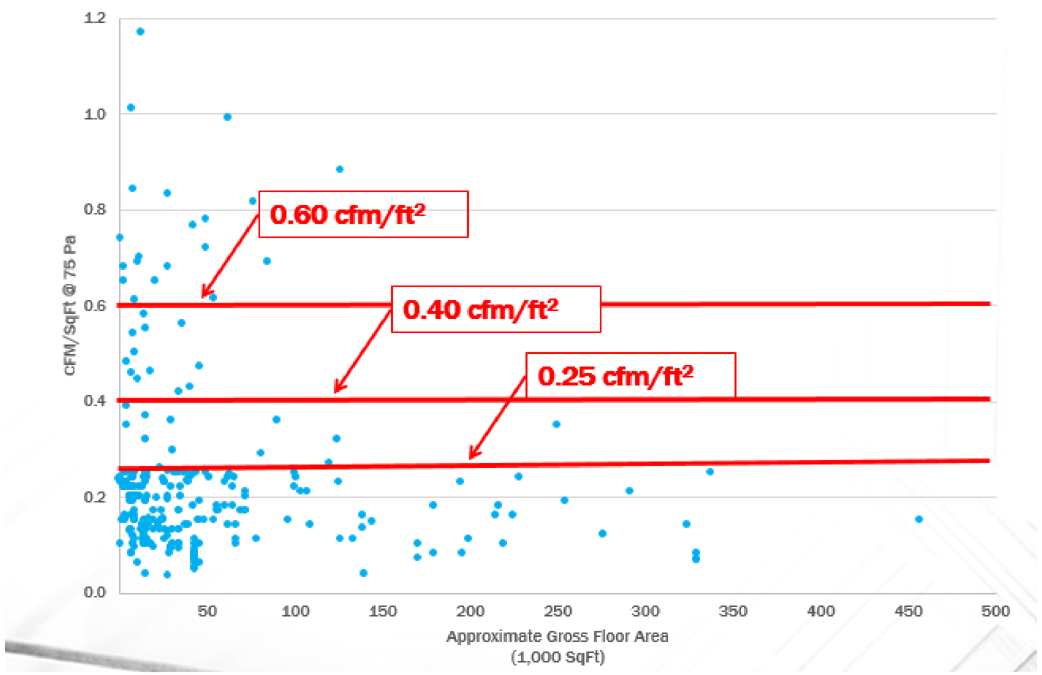
Redundant water management



Air Leakage

- Addendum I – 90.1-2016

Specific Leakage



STANDARD

ANSI/ASHRAE/IES Standard 90.1-2016
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2013)
Includes ANSI/ASHRAE/IES addenda listed in Appendix H

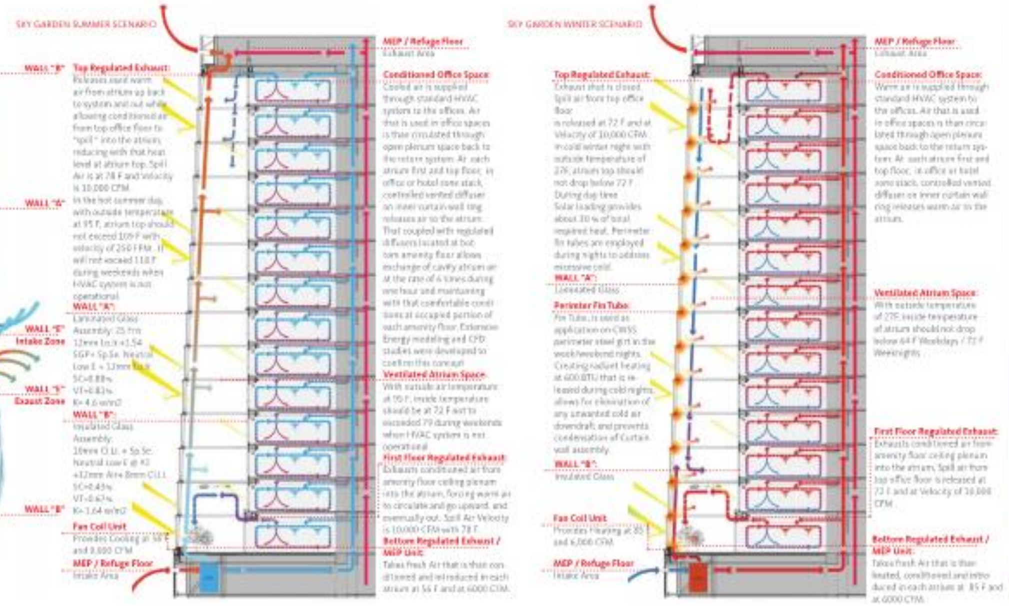
Energy Standard for Buildings Except Low-Rise Residential Buildings

5.4.3.1.3 Testing, Acceptable Materials, and Assemblies

The *building* shall comply with whole-*building* pressurization testing in accordance with Section 5.4.3.1.3(a) or with the *continuous air barrier* requirements in Section 5.4.3.1.3(b) or 5.4.3.1.3(c).

a. Whole-*building* pressurization testing shall be conducted in accordance with ASTM E779 or ASTM E1827 by an independent third party. The measured air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft^2 under a pressure differential of 0.3 in. of water, with this air leakage rate normalized by the sum of the above and below-*grade building envelope* areas of the *conditioned* and *semiheated space*.

But Breathable



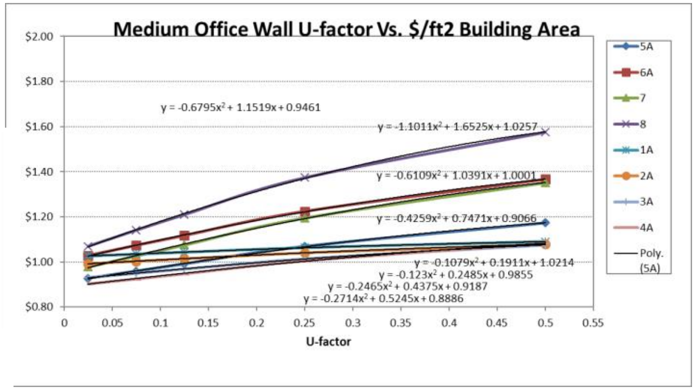
Thermal Bridging

- Ongong addendum

STANDARD

ANSI/ASHRAE/IES Standard 90.1-2016
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2013)
Includes ANSI/ASHRAE/IES addenda listed in Appendix H

Energy Standard for Buildings Except Low-Rise Residential Buildings



The Implementation of 1365-RP into Standard 90.1

Why Implement 1365-RP into Standard 90.1?

Standard 90.1 provides guidance on determining thermal transmittance through in envelope systems with distributed thermal bridges for a few limited cases. It does not address major thermal bridges such as slab edges, shelf angles, parapets, flashings at window perimeters, etc. In practice, these details are largely overlooked. However, using the information provided by 1365-RP, it is clear that a significant portion of the heat flow through opaque envelope a… that are ign… discrepanc… into wall as… details.

SSPC 901 ENV Thermal Bridge Task Group, Sub-Group Findings

Jonathan Humble
Chair - 901-ENV-TB Task Group
16 October 2014

5.5.5 Thermal Bridges. Thermal bridges shall comply with Sections 5.5.5.1 through 5.5.5.3.

Exceptions:
1. Buildings located in Climate Zone 1 through 3.
2. Semi-heated buildings located in Climate Zones 1 through 6.
3. Alternative practices shall be permitted where such practices comply with normative Appendix A, Section A10.

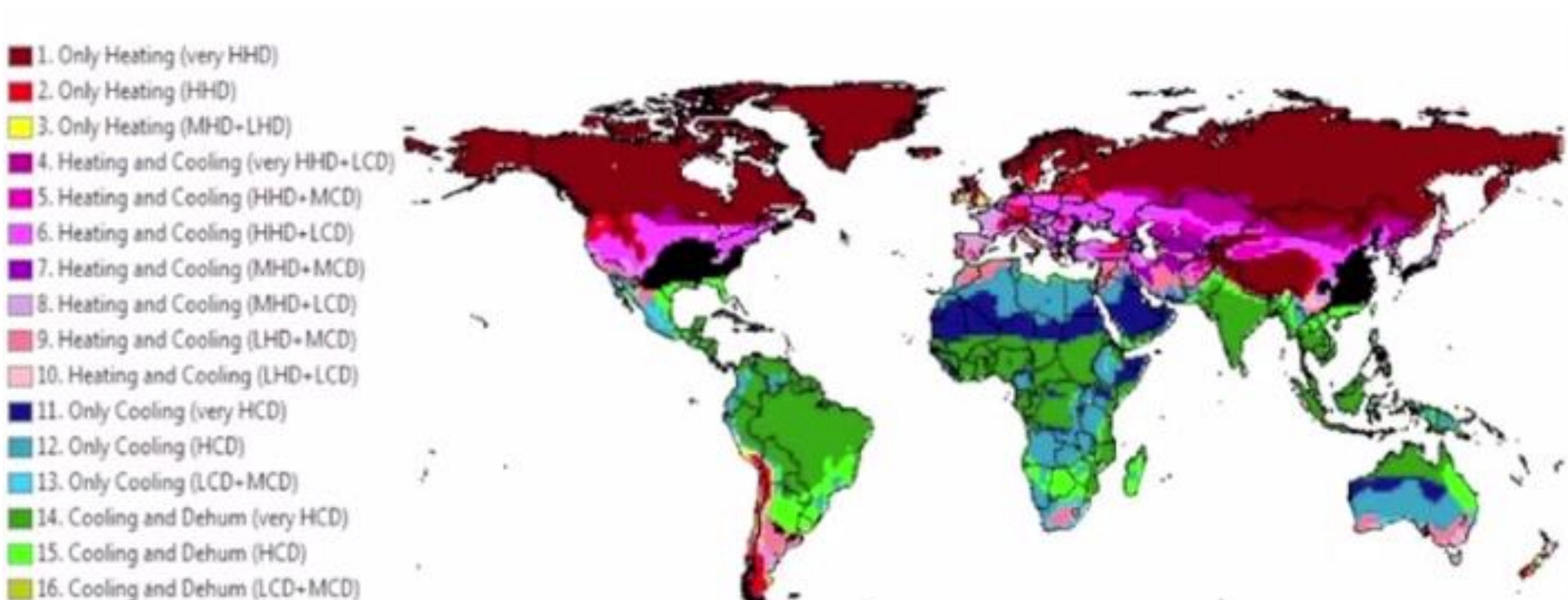
Building Integrated Power Generation

The Future is now…..

PASSIVE BUILDING TRENDS

Second and Delaware, Kansas City, MO

PHIUS+2015:
CLIMATE SPECIFIC DESIGN



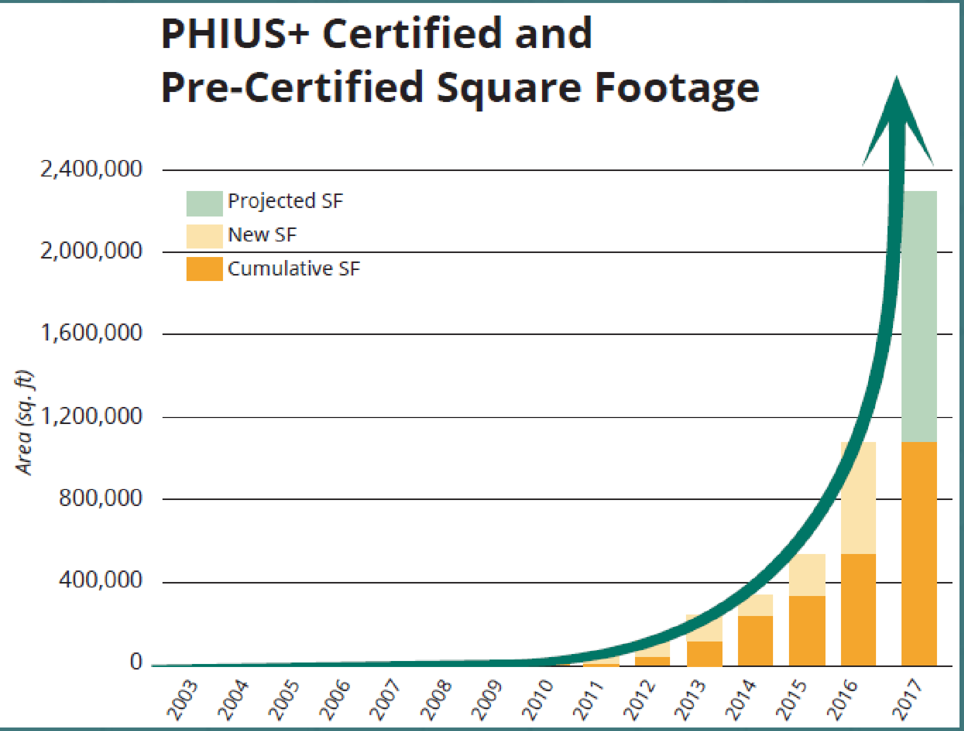
Graph Courtesy of Global Buildings Performance Network

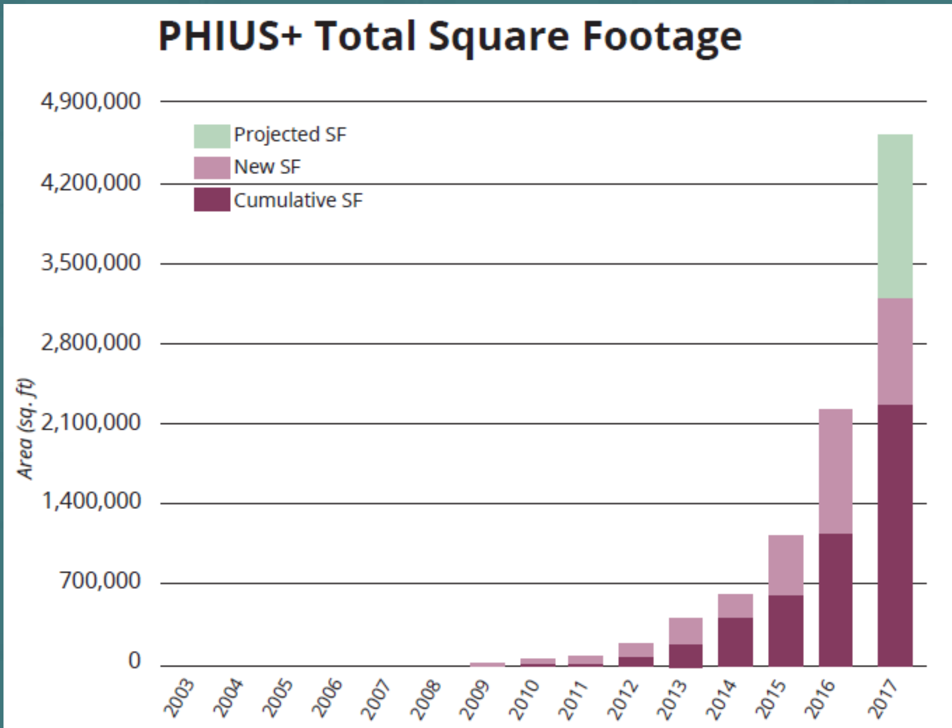
DOE PERFORMANCE STAIRCASE

IECC 2009	IECC 2012	ENERGY STAR v3	ENERGY STAR v3.1	ZERH	PHIUS+	PHIUS+ SourceZero
						Source Zero Renew-able Energy System
					Balanced Ventilation HRV/ERV	Balanced Ventilation HRV/ERV
				SOLAR READY Depends on climate	SOLAR READY ALWAYS	SOLAR READY ALWAYS
				Eff. Comps. & H2O Distrib	Eff. Comps. & H_2O Distrib	Eff. Comps. & H_2O Distrib
				EPA Indoor Air Pacakge	EPA Indoor Air Pacakge	EPA Indoor Air Pacakge
				Ducts in Condit. Space	Ducts in Condit. Space	Ducts in Condit. Space
		HVAC QI w/WHV	HVAC QI w/WHV	HVAC QI w/WHV	Micro-load HVAC QI	Micro-load HVAC QI
		Water Management	Water Management	Water Management	Water Management	Water Management
		Independent Verification	Independent Verification	Independent Verification	Independent Verification	Independent Verification
IECC 2009 Enclosure	IECC 2012 Enclosure	IECC 2009 Enclosure	IECC 2012 Enclosure	IECC 2012/15 Encl./ES Win.	Ultra-Efficient Enclosure	Ultra-Efficient Enclosure
HERS 85-90	HERS 70-80	HERS 65-75	HERS 55-65	HERS 48-55	HERS 35-45	HERS < 0

PHIUS+ TRENDS FOR 2017

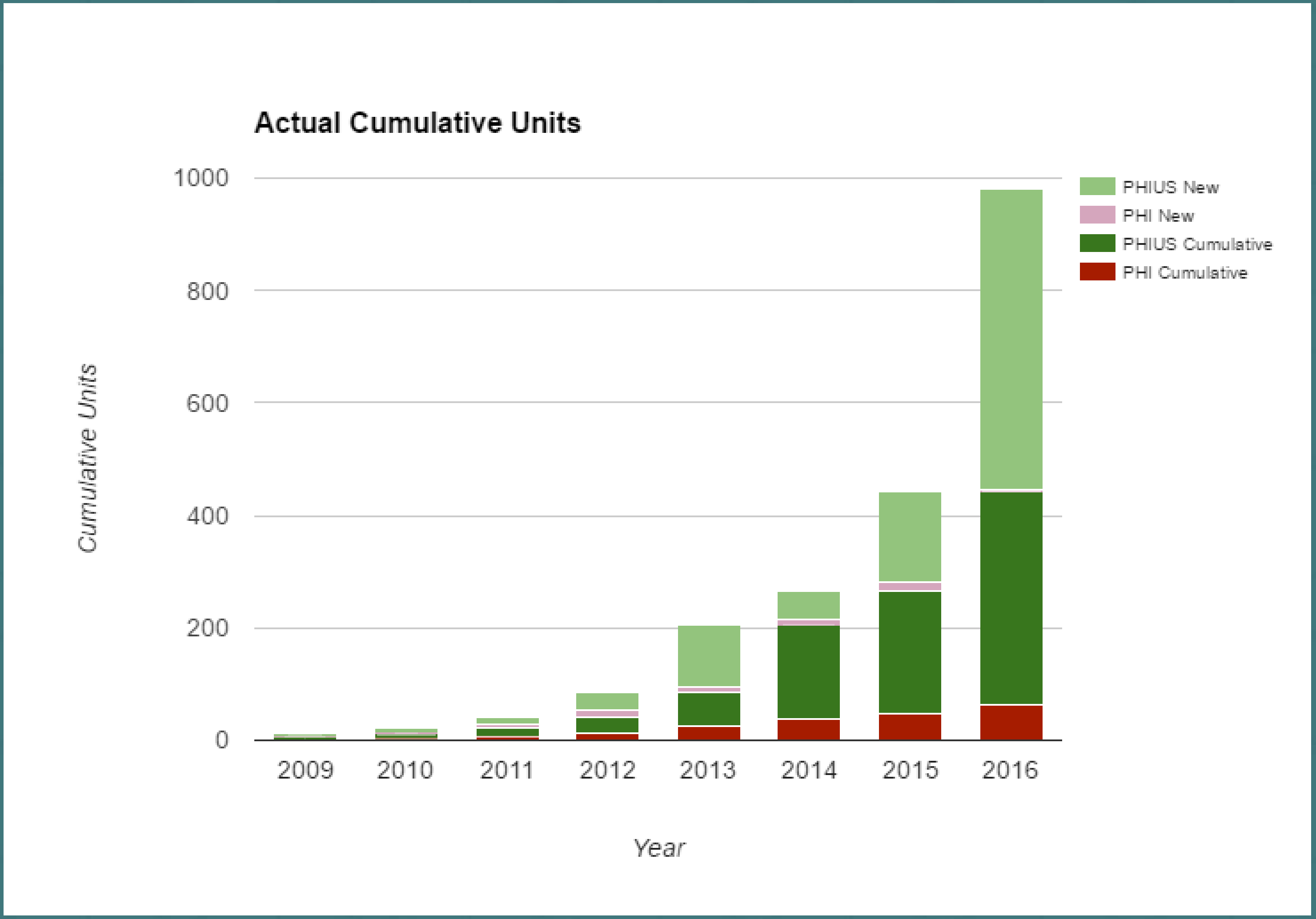
Source: www.phius.org





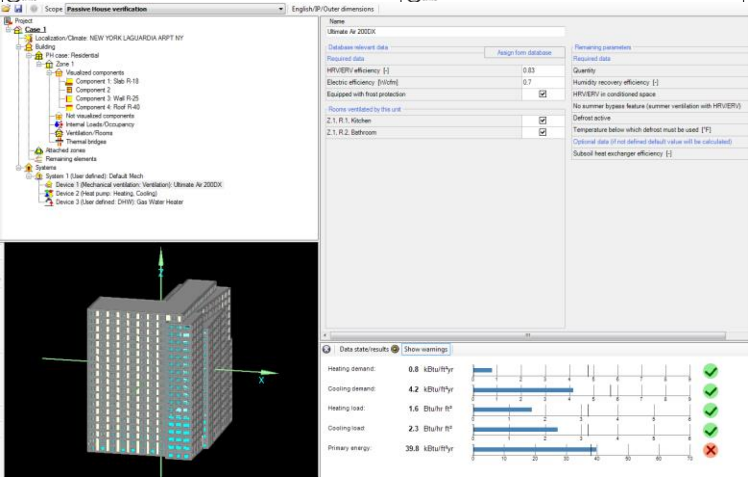
95% of total certified and pre-certified passive building construction (SQFT) in NA

PHIUS+ AND PHI TRENDS IN NA:
CERTIFICATIONS BY END OF 2016



Source: Pembina Institute

MULTIFAMILY/COMMERCIAL HAS BETTER **SURFACE TO VOLUME** RATIO THAN SMALLER STRUCTURES



SF Home Specs 5A:

- R-50 WALLS
- R-90 ROOF
- R-50 SLAB
- R-8 WINDOWS

Large MF Specs 5A:

- R-32 WALLS
- R-50 ROOF
- R-20 SLAB
- R-5 WINDOWS

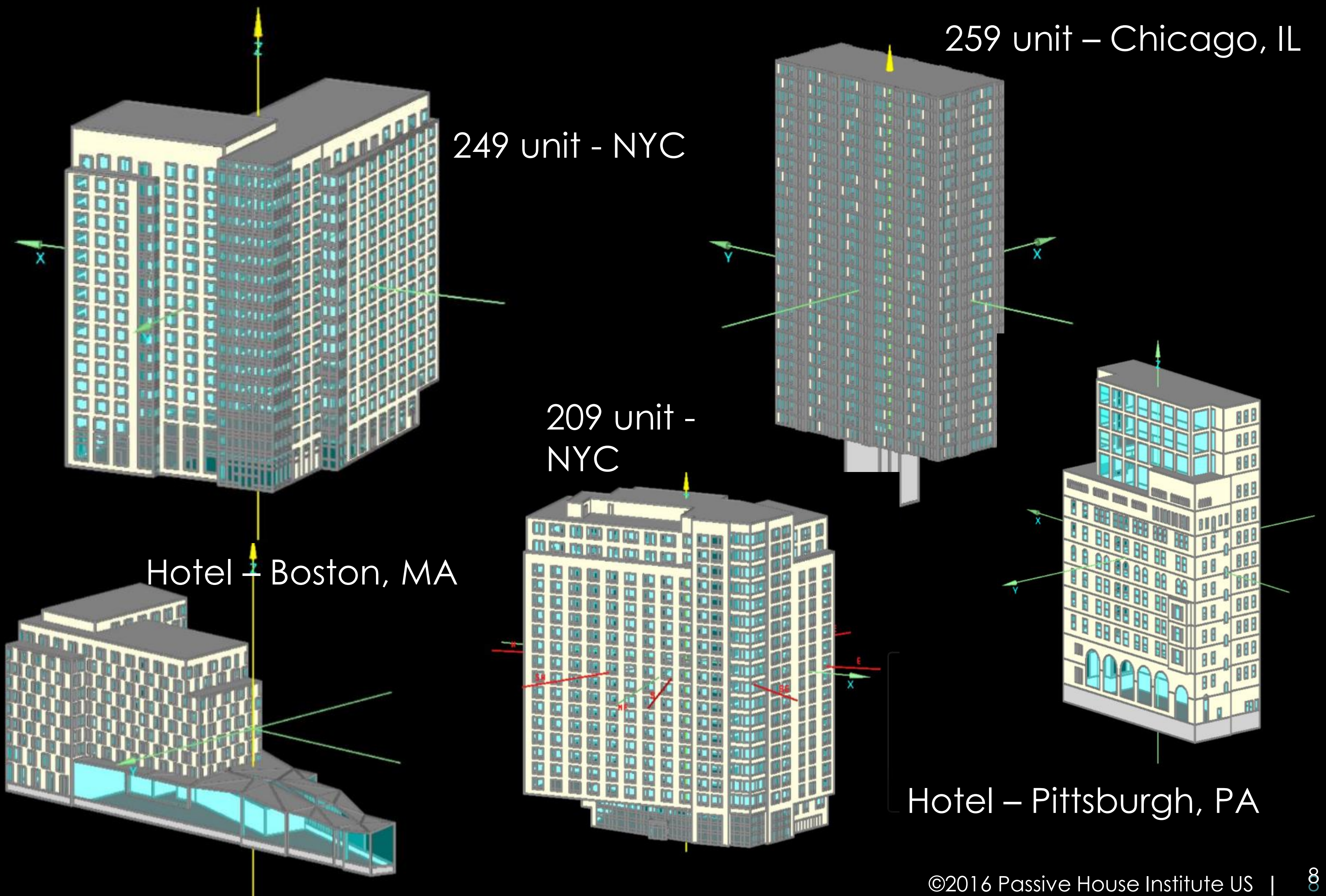
350+ PHIUS PROJECTS NATIONWIDE

70+ MULTIFAMILY SUBMITTED, PRE-CERTIFIED, CERTIFIED

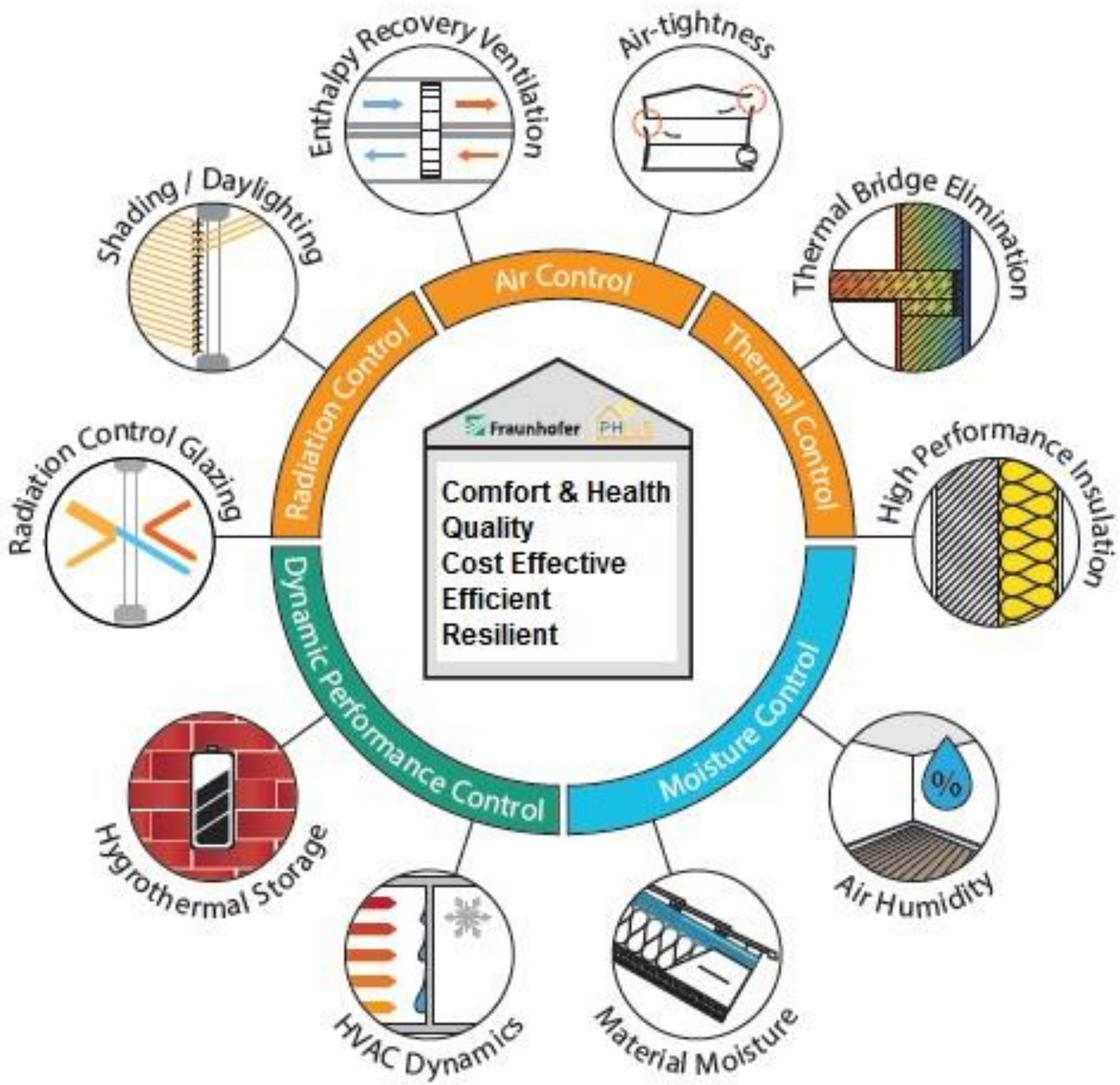
SITE EUIs OF 10-25 kBTU/ft².yr

~20-50% better than DOE's Zero Energy Home Program

FEASIBILITY STUDIES



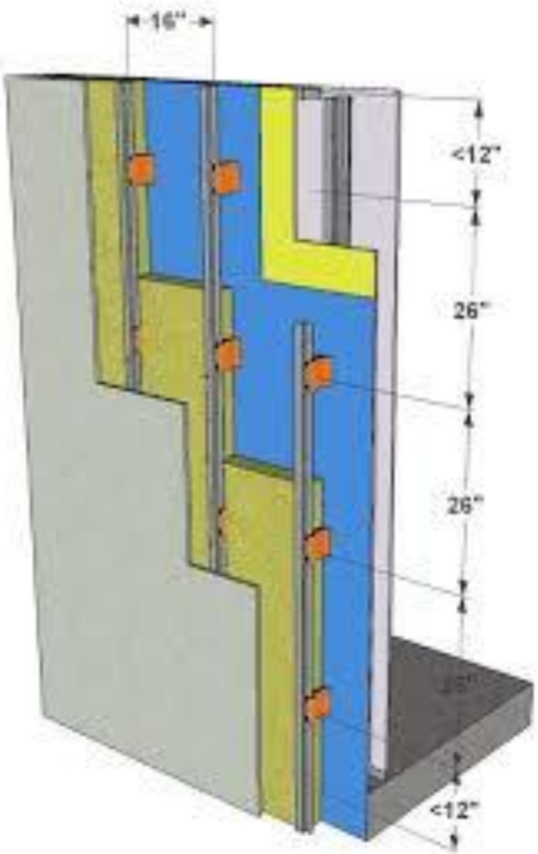
PASSIVE BUILDING PRINCIPLES



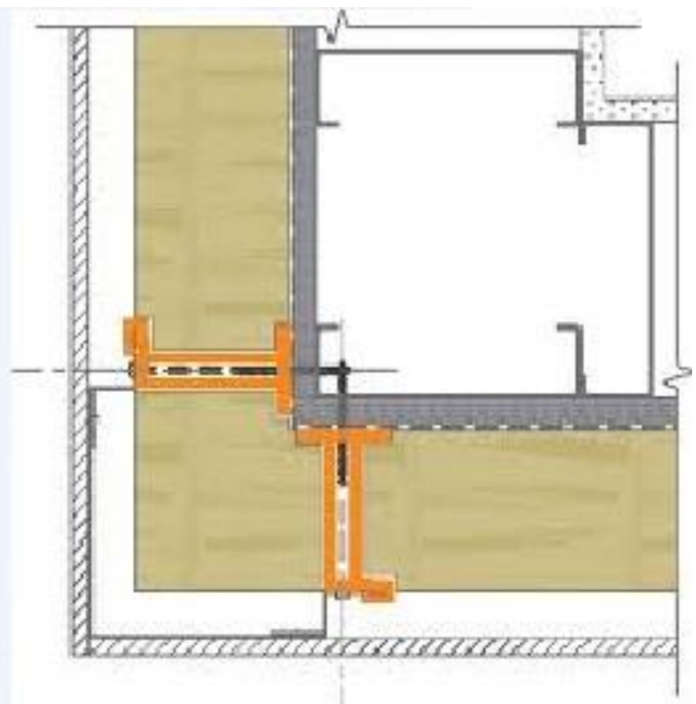
CONTINUOUS INSULATION

INSULATED CONCRETE FORMS

THERMAL BREAKS



Cascadia Clip® system



MINIMIZE POINT TB LOSS

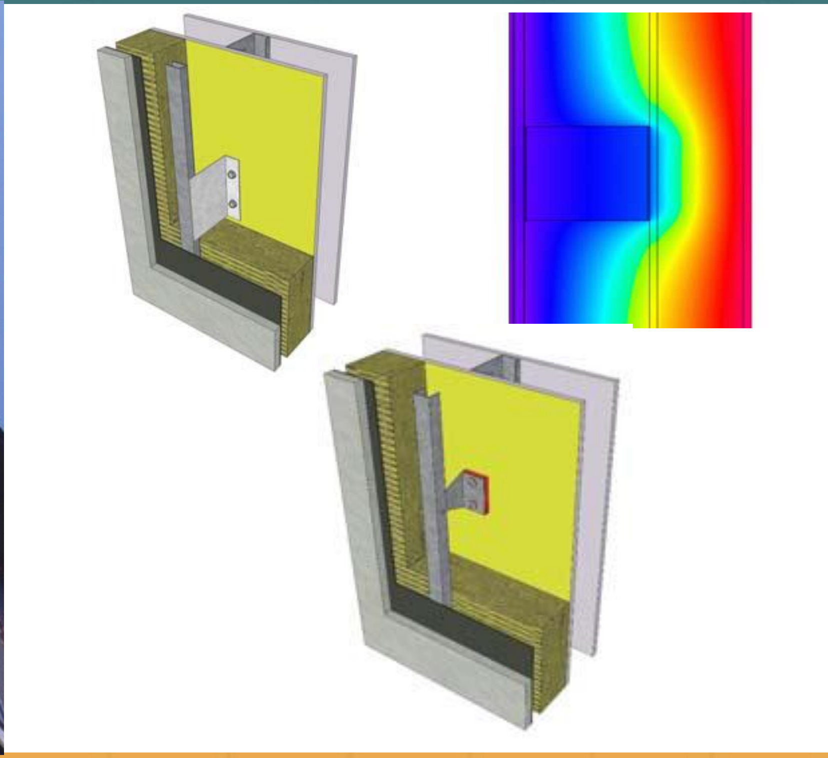


Photo courtesy Jesse Thompson

Illustrations by RDH, Shawn Colin, NAPHC 2014

STRUCTURAL THERMAL BRIDGING CAUSED BY CLADDING SYSTEMS ATTACHMENT – RED SPACER BEHIND STAND-OFF=THERMAL BREAK

UPTOWN LOFTS STRUCTURAL THERMAL BRIDGE ISSUE: SEPARATION TO UNCONDITIONED PARKING DECK

Mechanical Properties

Tensile Strength	PSI	ASTM D638	9,400
Flexural Strength	PSI	ASTM D790	22,300
Compressive Strength	PSI	ASTM D695	38,900
Compressive Modulus	PSI	ASTM D695	1,450,377
Shear Strength	PSI	ASTM D732	13,400
Thickness	in	-	1/4", 1/2", 1"

Flame Resistance

Oxygen Index	%O_2	ASTM D2863	21.8

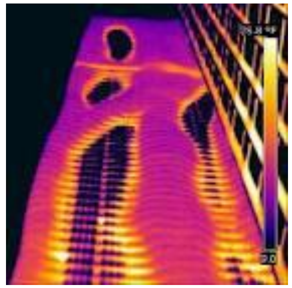
Thermal Properties

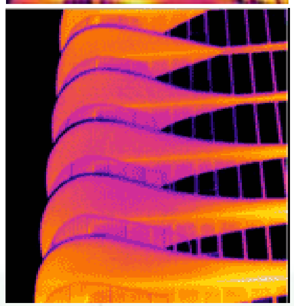
Coefficient of Thermal Expansion	in/in/°Cx10^{-5}	ASTM D696	2.2
Thermal Conductivity	BTU/Hr/ft²/in/°F W/m*K	ASTM C177	1.8** 0.259
** Reference: Thermal Conductivity of Steel	BTU/Hr/ft²/in/°F W/m*K		374.5 54.0

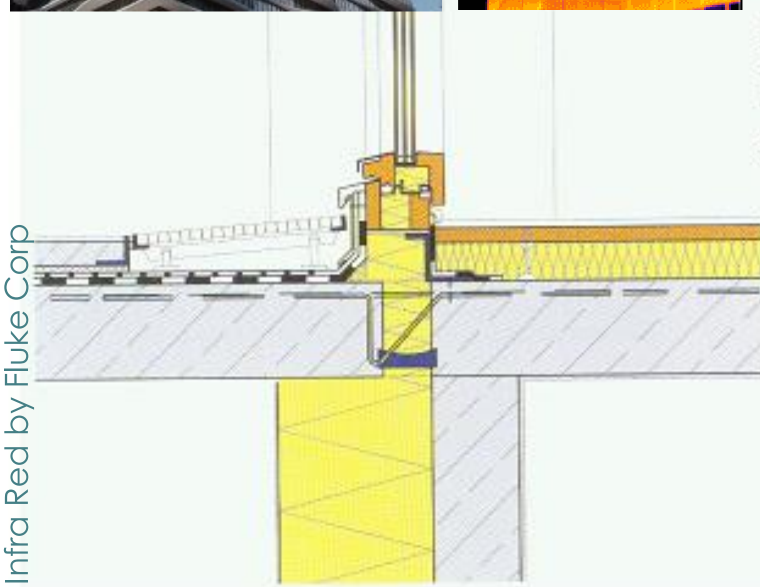
Additional Products for Building & Construction

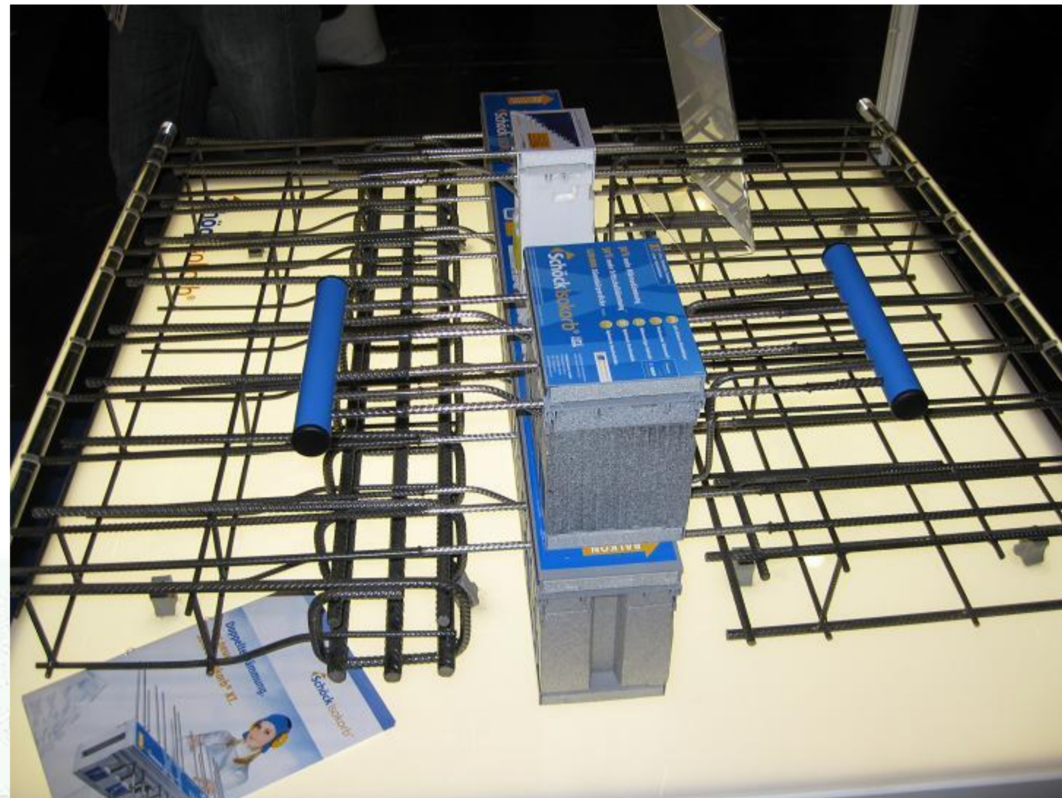
Photo: Jesse Thompson

STRUCTURAL THERMAL BREAKS



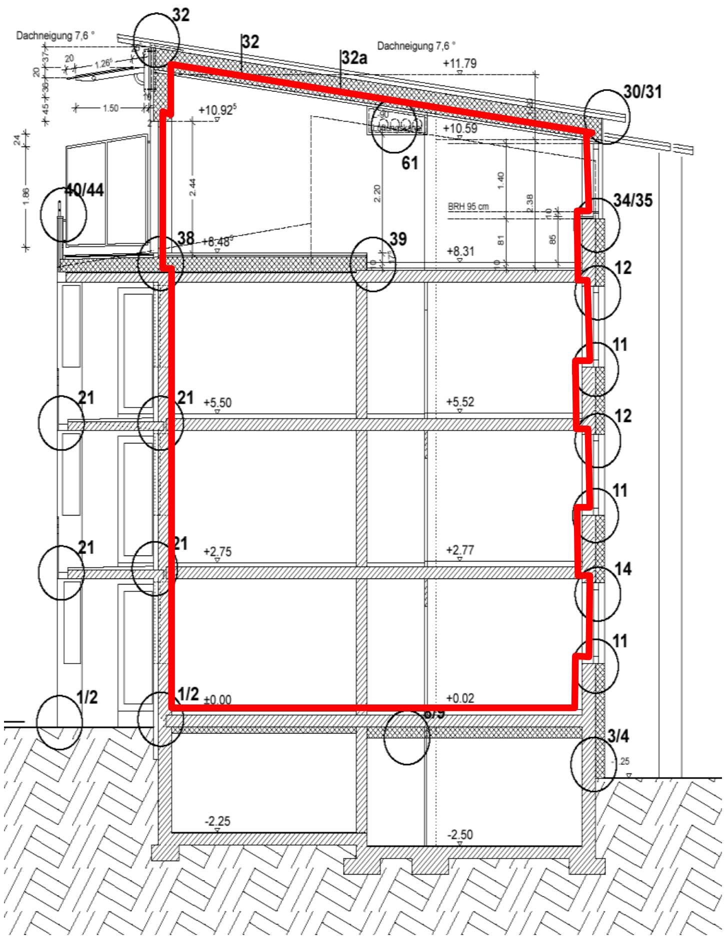






Source: Building Science Corporation Newsletter #49: Aqua Tower and Infra Red by Fluke Corp

AIR-TIGHTNESS **BENEFITS**



Energy benefits:

- Minimizes energy losses in conjunction with ventilation
- Minimizes latent loads in conjunction with ventilation

Hygrothermal benefits:

- Minimizes moisture traveling into the wall through infiltration or exfiltration
- Minimizes condensation risk in components
- Increases durability of assemblies

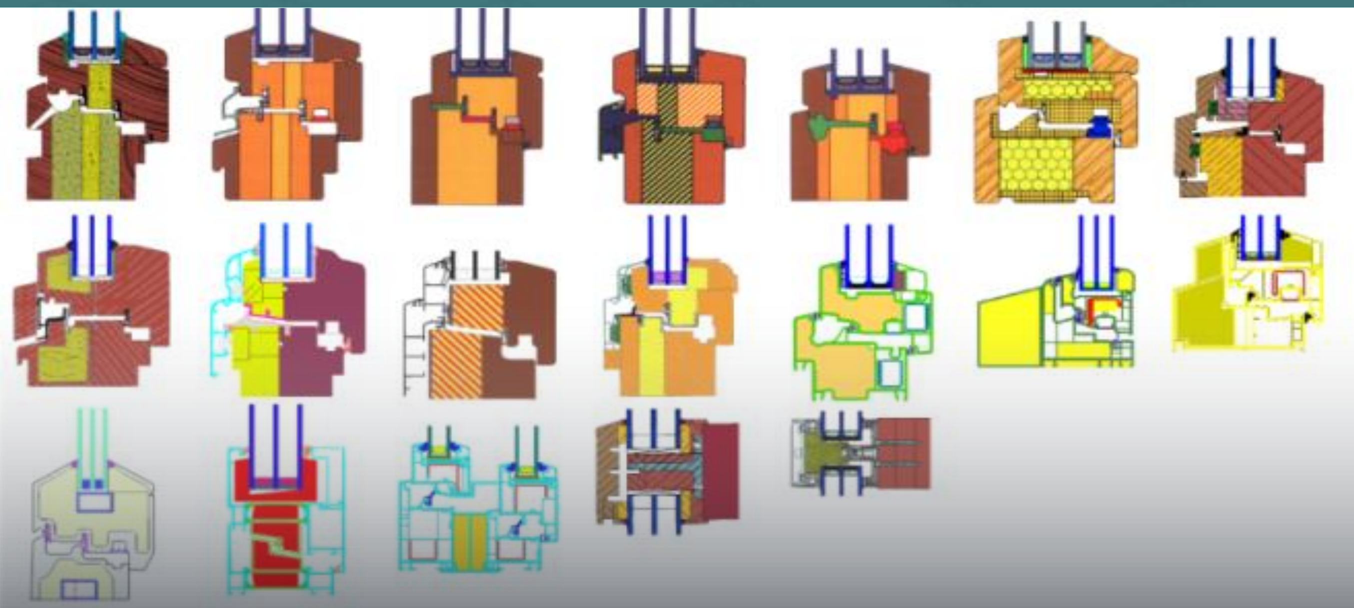
Source: www.prosoco.com/r-guard

EXTERIOR AIR BARRIERS

EASE OF CONTINUOUS APPLICATION: SPRAY-APPLIED FOR MF PROJECTS

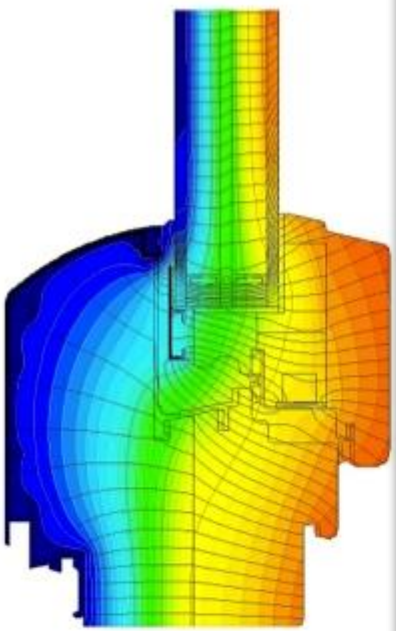
HIGH PERFORMANCE WINDOWS

FOR BETTER COMFORT



IMPROVING WINDOW PERFORMANCE MINIMIZES HEAT LOSS/GAIN, ASSURES THERMAL COMFORT,
ELIMINATES CONDENSATION

DIALING IN WINDOW PERFORMANCE BY CLIMATE



WUFI® Passive

Product name:	Alpen Casement 073				Center-of-glass properties		
ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	PHIUS Passive House Institute US		Alpen _073		
			Whole-window installed U-value			Ucog-Value	
Climate specific recommendations:			W/m2K	BTU/hr.ft2.F	SHGC	W/m2K	BTU/hr.ft2.F
8			0.82	0.14	0.469	0.478	0.084
7			0.82	0.15	0.469	0.482	0.085
6			0.83	0.15	0.469	0.489	0.086
5			0.83	0.15			
4			0.83	0.15			
Marine North			0.84	0.15			
Marine South	☑		0.84	0.15			
3	☑		0.84	0.15			
2 West			0.83	0.15			
2 East			0.83	0.15			

Alpen Casement 073	FRAME		
	Frame height		U-fra
	mm	in	W/m2K
Head	72	2.82	1.12
Sill	72	2.82	1.12
Left	72	2.82	1.12
Right	72	2.82	1.12

Valid through February 2016

Find & Compare Windows

PHIUS Certified Data for Windows : PHIUS Certified Window Data for Designers & Builders

Available manufacturers:

Alpen
Cold Chain
HH
Intus
Kolbe
Marvin
Thermotech
Veka
Wasco
Zola

Frame Material (FM)

FG - Fiberglass
VL - Vinyl
WD - Wood
PC - Unplasticized Polyvinyl Chloride (uPVC)
Al - Aluminum
AW - Aluminum Clad Wood

Psi-Opaque Grade (PO)

Frame-spacer grade is based on combining the frame heat transmission and the edge-of glass effect into a single linear heat loss coefficient. This provides a basis for comparison of frames of different widths and different frame-spacer combinations.

PO [Btu/h.ft.F]	Frame-Spacer Grade
<=0.065	A+
<=0.110	A+
<=0.155	B
<=0.200	C
>0.200	D

Downloadable datasheets (.pdf) and therm files (.zip) for each listing

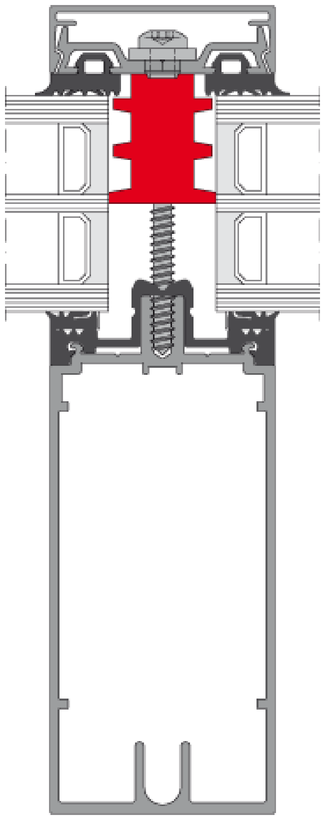
Recommendations by climate zone

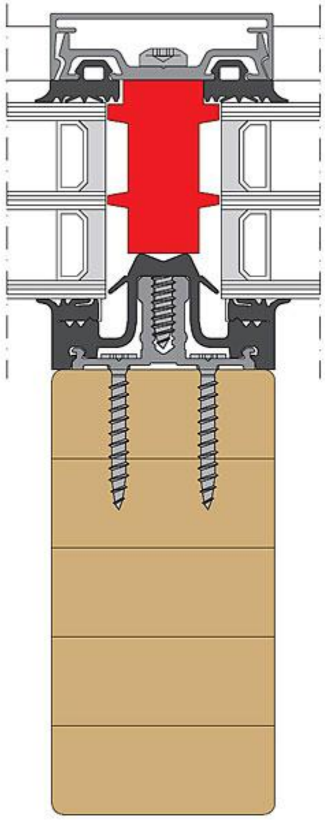
Climate zone map

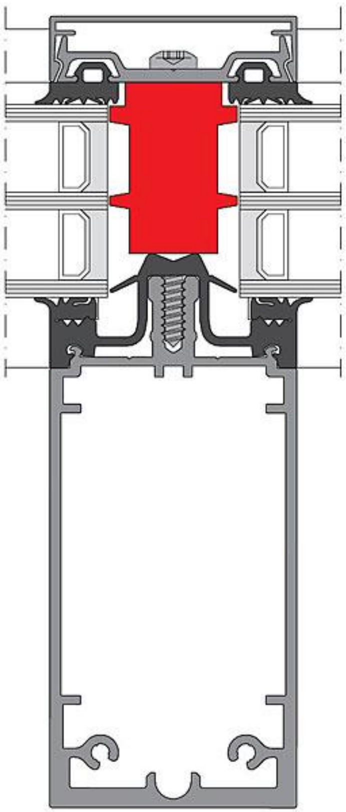
					South - Facing										North, East, West - Facing											
	Model	Glazing	FM	PO	8	7	6	5	4	4C	3C	3	2B	2A	8	7	6	5	4	4C	3C	3	2B	2A	Datasheet	thm
Alpen	525-SH Casement	108	FG	B																					datasheet	.zip
Alpen	525-S 5L Casement	200	FG	B							☑	☑													datasheet	.zip
Alpen	525-S Casement 5S-L2	17	FG	B							☑	☑	☑	☑							☑	☑	☑	☑	datasheet	.zip
Alpen	525-S Fixed HP 5S-H	108	FG	B																					datasheet	.zip
Alpen	525-S Fixed HP 5S-L	109	FG	B							☑	☑								☑					datasheet	.zip


CURTAIN WALLS &
HIGH PERFORMANCE PANELIZATION

Source: Schüco







	system width	U_f-value
THERM⁺ A-V	50 / 56 mm	**up to 0.85 W/(m²K)**
THERM⁺ S-I	50 / 56 mm	**up to 0.88 W/(m²K)**
THERM⁺ H-V	50 / 56 / 76 mm	**up to 0.87 W/(m²K)**
THERM⁺ H-I	50 / 56 / 76 mm	**up to 0.88 W/(m²K)**

U.S. DEPARTMENT OF ENERGY

Fraunhofer IBP

bsc Building Science Corporation

Rocky Mountain Institute

PASSIVE BUILDING

IS PART OF THE SOLUTION

PHIUS Passive House Institute US

Katrin Klingenberg, Executive Director
www.PHIUS.org/www.PHAUS.org

PASSIVE HOUSE ALLIANCE UNITED STATES