Pushing the Building Envelope: The Impact of Cutting-Edge Technologies

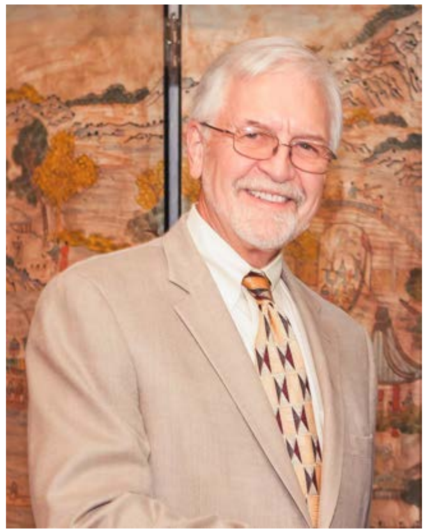
Thursday, July 11th, 2019

9:00 AM – 10:30 AM

Session Panel

Mahabir Bhandari

Oak Ridge National Laboratory (ORNL)



Wendell Brase

University of California, Irvine

Jessica Abralind

Arlington County (VA)

Cedar Blazek

DOE (Moderator)

Mahabir Bhandari

Oak Ridge National Laboratory (ORNL)

U.S. DEPARTMENT OF ENERGY

Pushing the Envelope: Cutting Edge Research

Mahabir Bhandari, PhD

Building Envelope and Urban Systems Research Group

Oak Ridge National Laboratory

Agenda Topics

- Join us! Get involved with the Better Building Building Envelope Technology Research Team (ETRT)
- Envelope Research: Emerging Technologies
- Envelope Deployment: Integration/Field Studies
- Q&A

Acknowledgement: Diana Hun, PhD, ORNL Building Envelope Subprogram Manager and other team members

Building Envelope: 5.81 Quads

The commercial **building envelope** is the **primary determinant** of the amount of **energy required** to heat, cool, and ventilate a building

Table 2. Primary Energy Consumption Attributable to Fenestration and Building Envelope Components in 2010 (Quads)[6]

Building Component	Residential		Commercial	
	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
Windows (Conduction)	2.06	0.03	1.60	-0.30
Windows (Solar Heat Gain)	-0.66	1.14	-0.97	1.38

Source: Office of Energy Efficiency and Renewable Energy 2011b; Office of Energy Efficiency and Renewable Energy 2011d; Office of Energy Efficiency and Renewable Energy 2011e; Office of Energy Efficiency and Renewable Energy 2011g

Better Buildings Alliance: Leadership to Deploy Advanced Technologies

- Commercial Real Estate
- Food Service, Retail, and Grocery
- Healthcare
- Hospitality
- Higher Education

TECHNOLOGY SOLUTIONS TEAMS

- Lighting & Electrical
- Space Conditioning
- Plug & Process Loads
- Refrigeration
- Energy Management Information Systems
- Renewables Integration
- Building Envelope

MARKET SOLUTIONS TEAMS

- Energy Efficiency Project Financing
- Leasing and Tenant Build-Out
- Energy Data Access
- High Performance Property Valuation and Mortgages

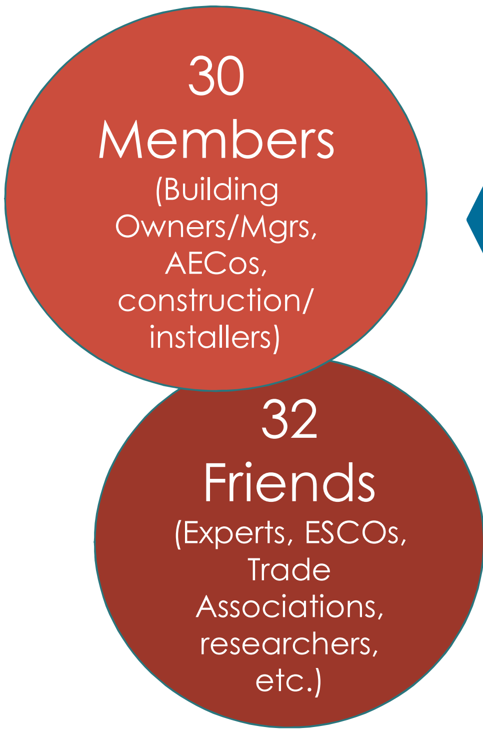
To join, contact Melissa Lapsa at lapsamv@ornl.gov

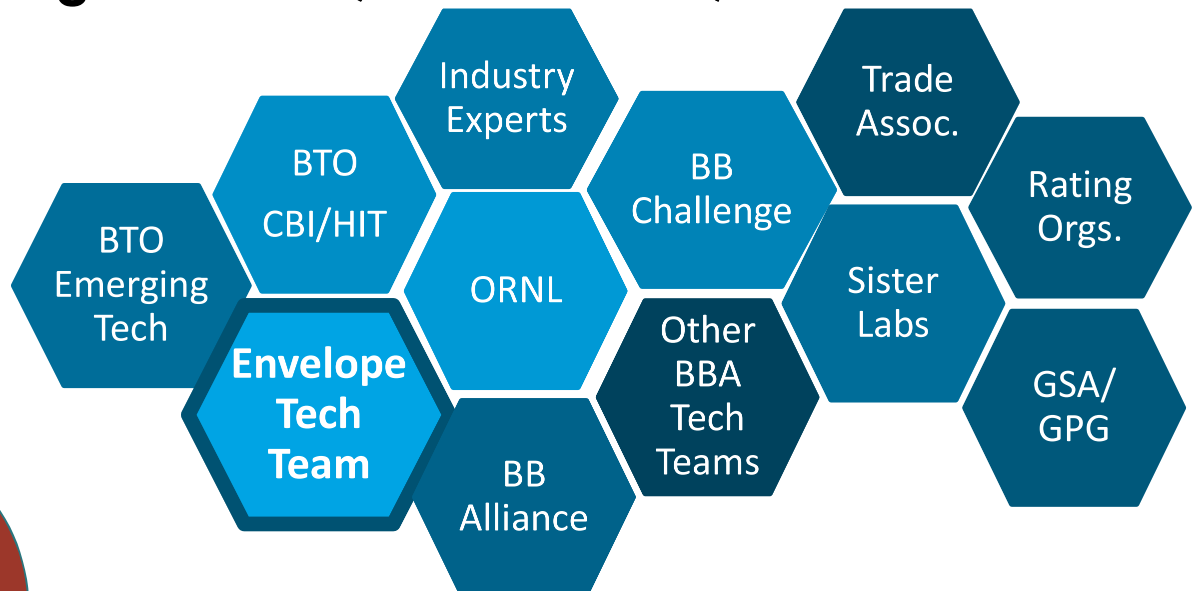
Better Buildings U.S. DEPARTMENT OF ENERGY

Oak Ridge National Laboratory | BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER

A Unique and Diverse Team…

Informing R&D Plans, Case Studies, and Demonstrations

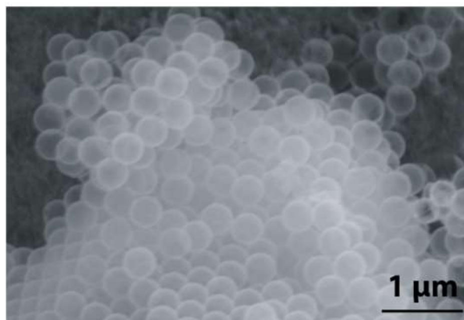


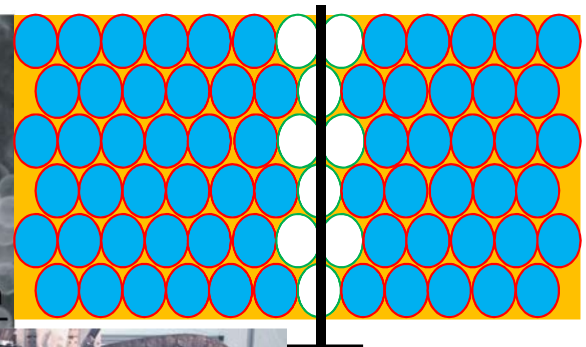


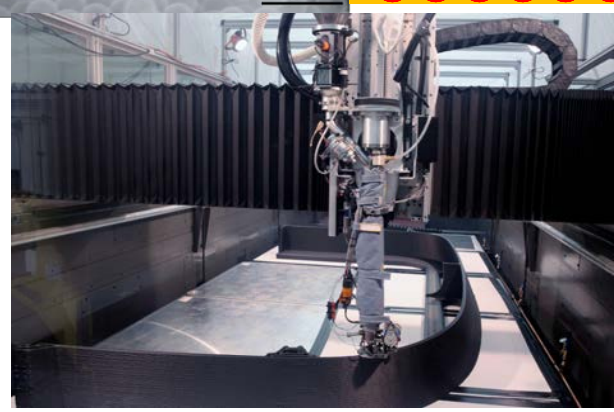
- Demonstration of high performance envelope technologies and solutions
- Comprised of Better Buildings Partners and representatives from the design community, including A&E firms

To join, email Melissa Lapsa: lapsamv@ornl.gov

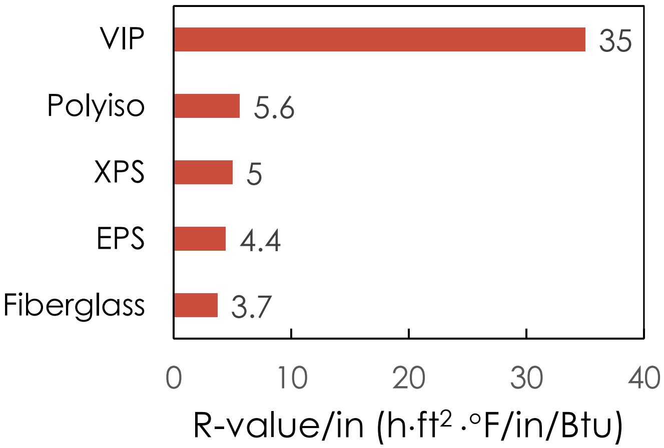
Envelope Research: Emerging Technologies



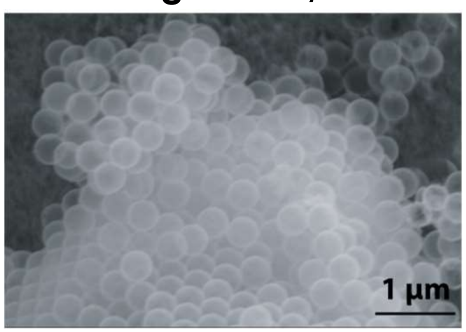




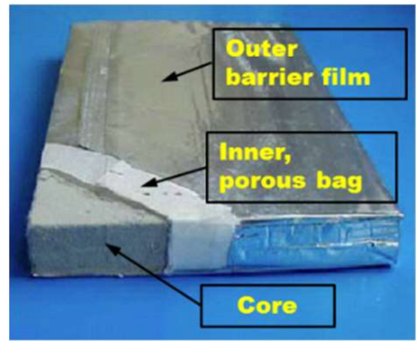
Insulation Materials with High-R/in



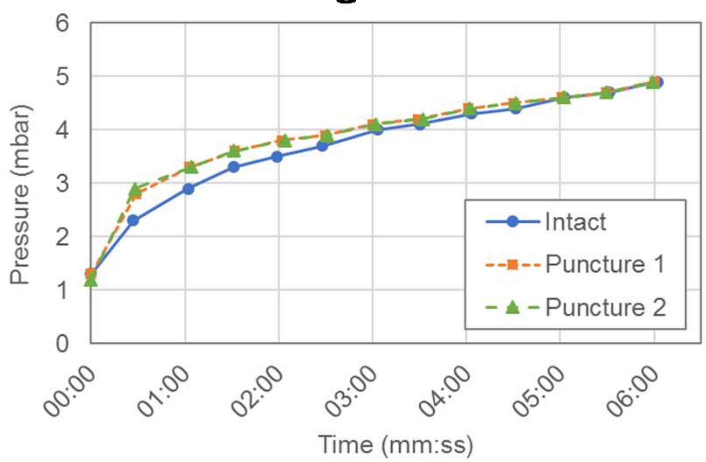
Hollow Silica Particles
Target ~R10/in



Vacuum Insulated Panels (VIPs)

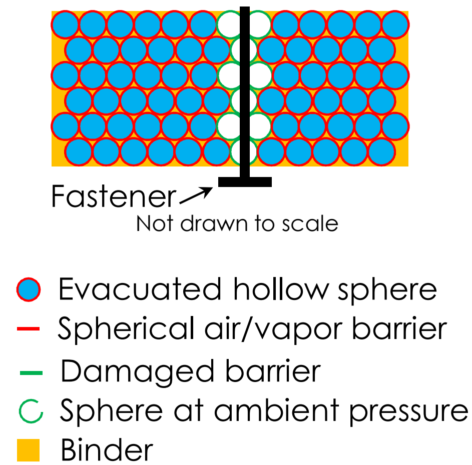


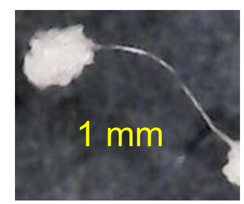
Self-Healing Film for VIPs



Evacuated Spheres

Target ≥R14/in





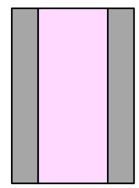
Prefab Assemblies

Vinyl Siding Insulated with VIPs ~R10

Lightweight Insulated Precast Panels

New design

1½" : 4" : 1½"



Concrete density = 100 pcf
Panel weight = 25 psf

Second trial

Photo courtesy of Gate Precast

Fiber Reinforced Polymer (FRP) Insulated Panels

Photo courtesy of Kreysler & Associates

Photo courtesy of Kreysler & Associates

Oak Ridge National Laboratory | Building Technologies Research and Integration Center

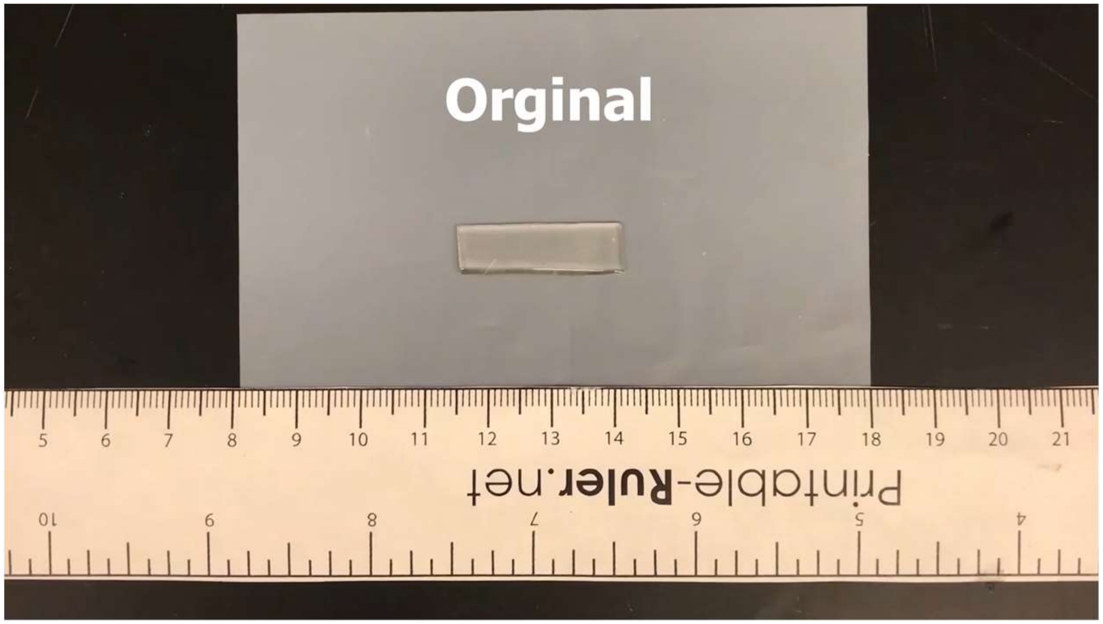
Self-Healing Sealant

Joints are among the weakest areas in the air and water barrier systems of building envelopes

Adhesion Failure

Cohesion Failure

After "self-healing" at room temperature



OAK RIDGE National Laboratory | BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER

Additive Manufacturing and Integrated Energy (AMIE)

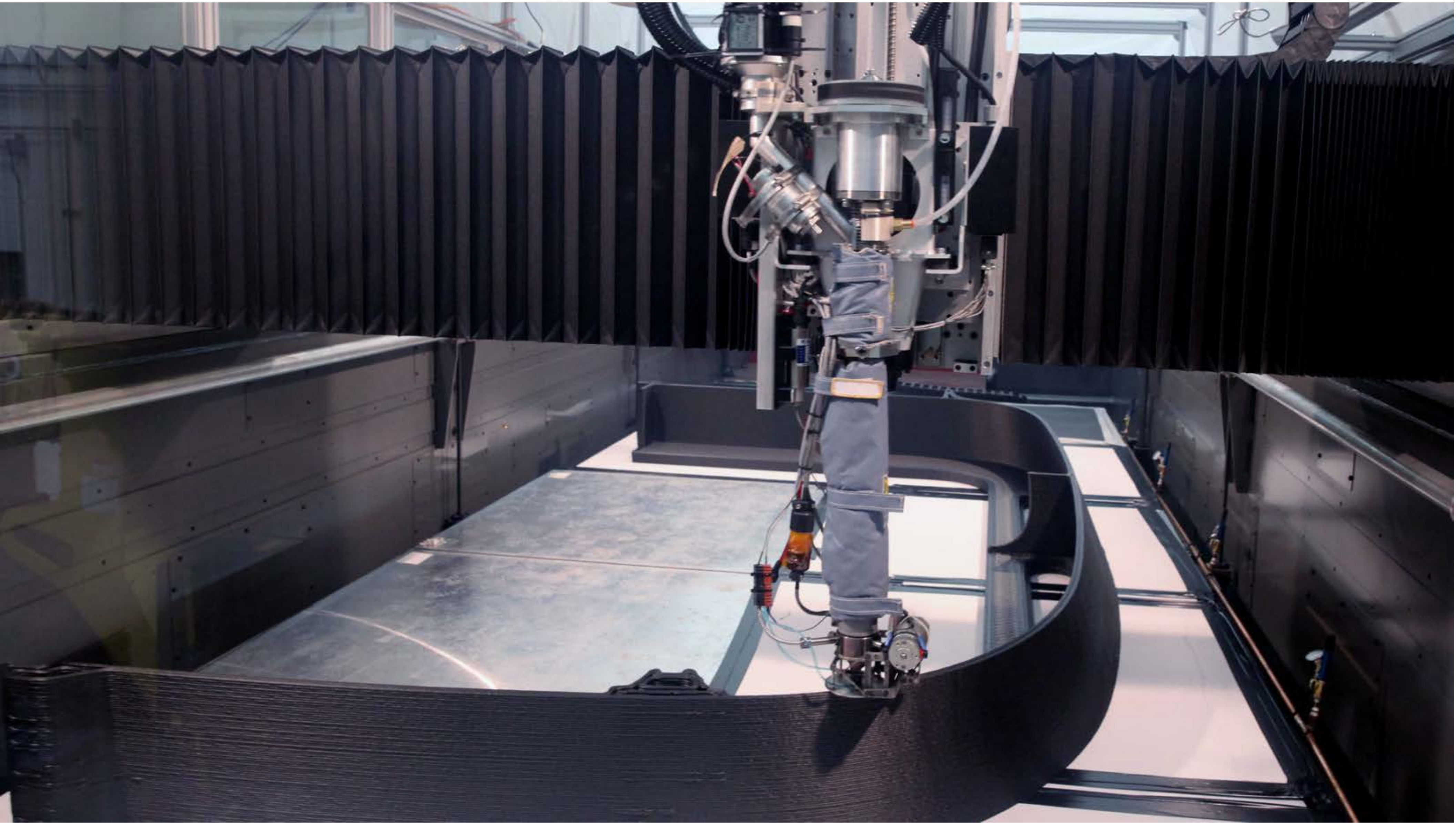
2016

GOVERNOR'S CHAIR ENERGY + URBANISM
THE UNIVERSITY OF TENNESSEE
OAK RIDGE NATIONAL LABORATORY
SKIDMORE, OWINGS & MERRILL LLP

THE UNIVERSITY of TENNESSEE UT KNOXVILLE

SOM

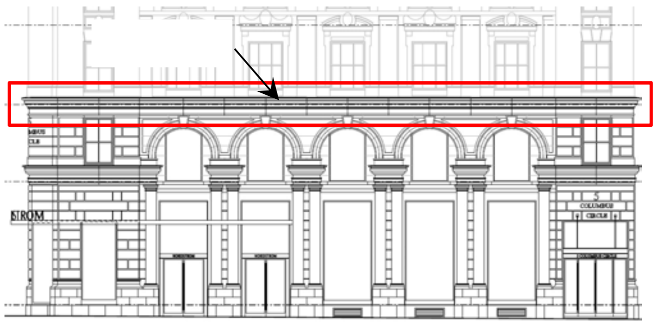
OAK RIDGE National Laboratory



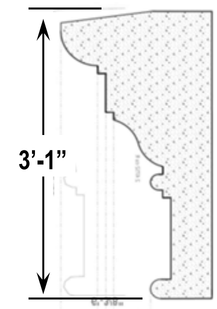
ASSEMBLY SEQUENCE

New Mold Manufacturing Process for Precast Concrete

Building Elevation



Cornice Cross Section

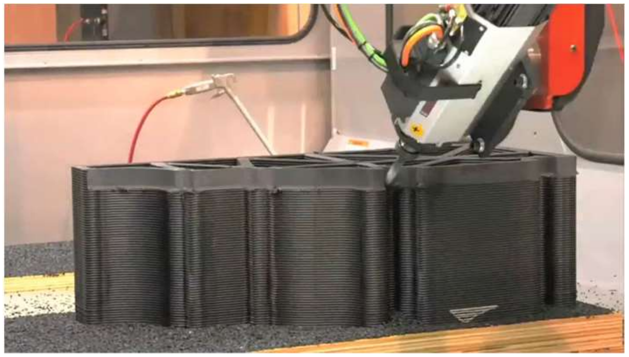


First 3D Printed Mold Prototype

Current Assembly Process

3D Printing

Machining

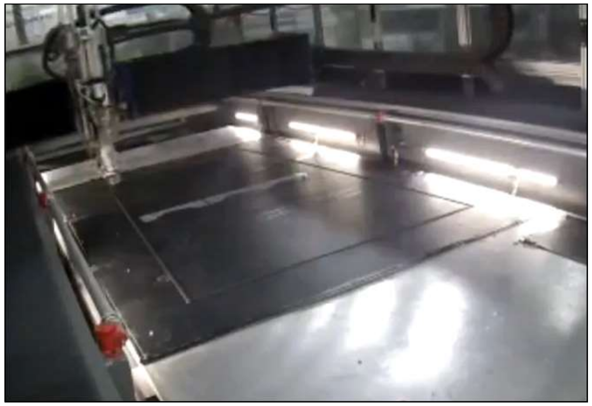


Domino Site - A Building

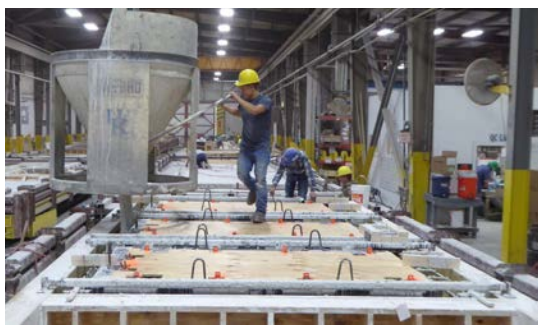
First building with precast façade made with 3D printed molds

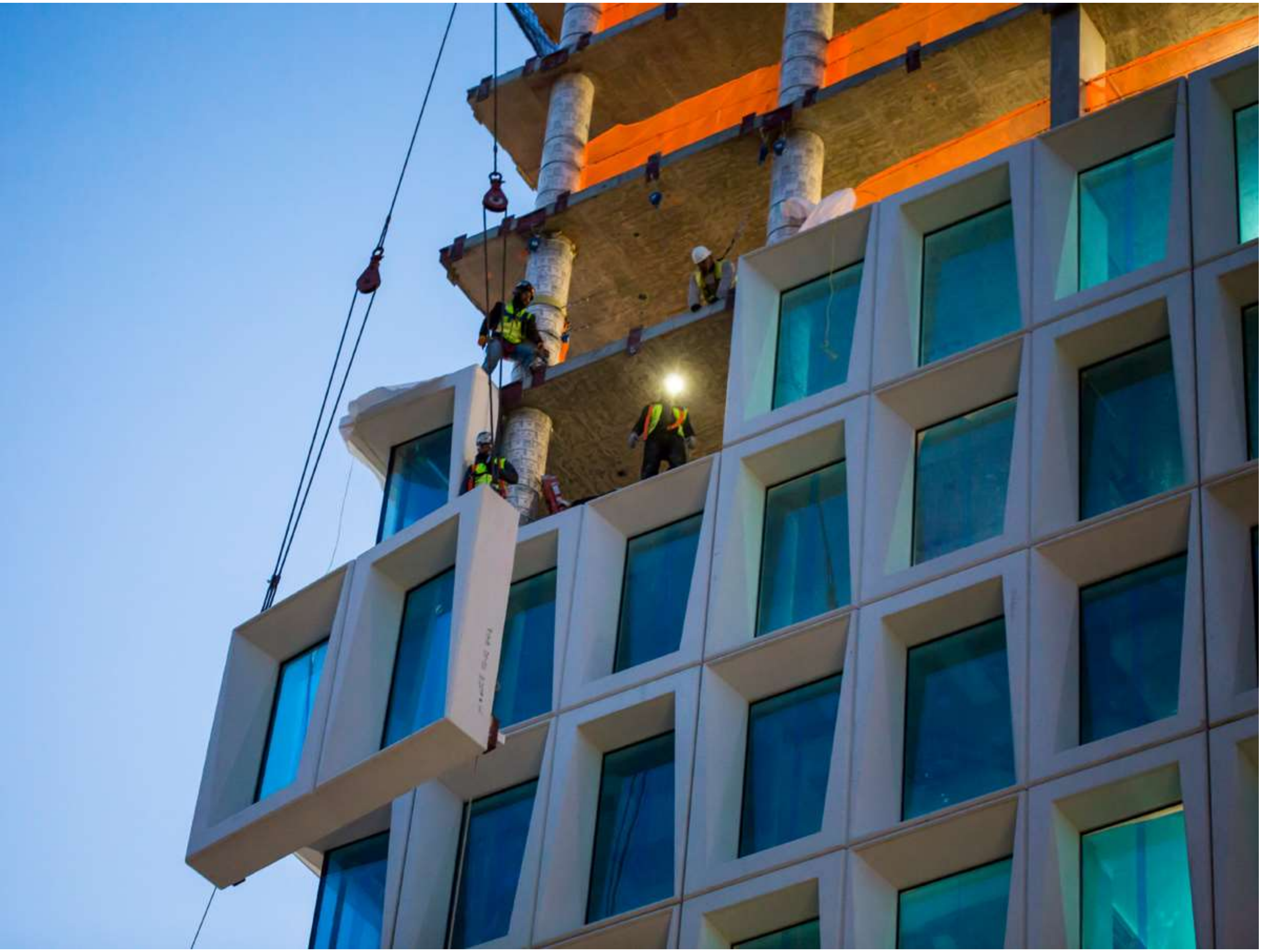
New Mold Manufacturing Process

3D Printing → **Machining** → **Mold**



Casting setup → **Concrete casting** → **Precast parts**

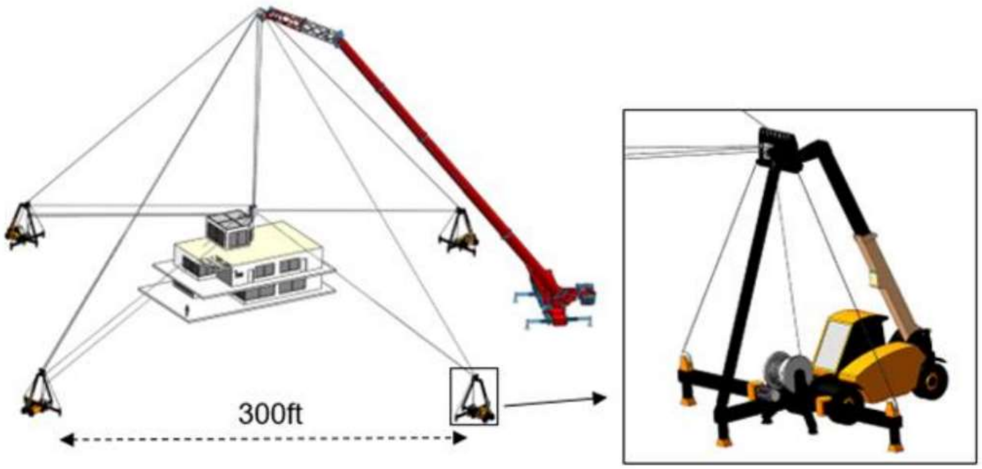




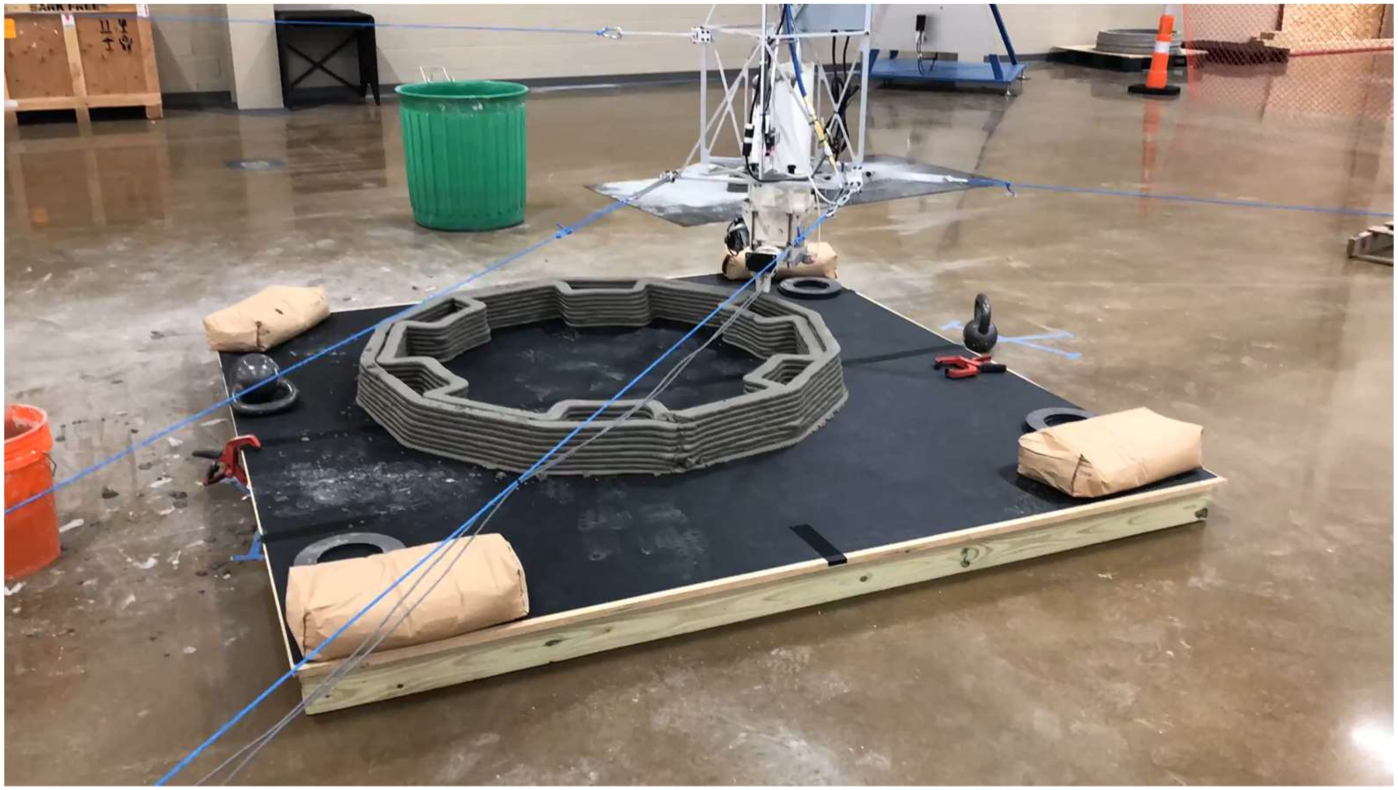

Onsite 3D Printing of Buildings

Traditional Gantry System

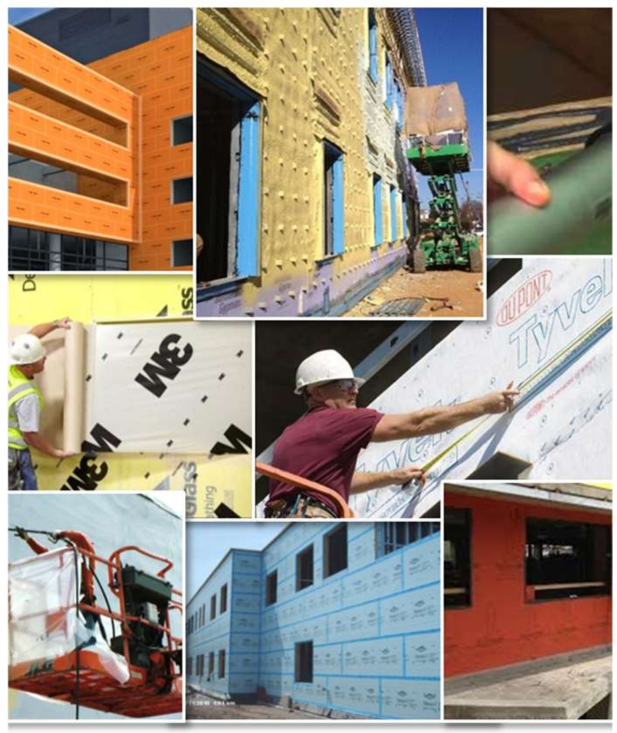
ORNL's SkyBAAM



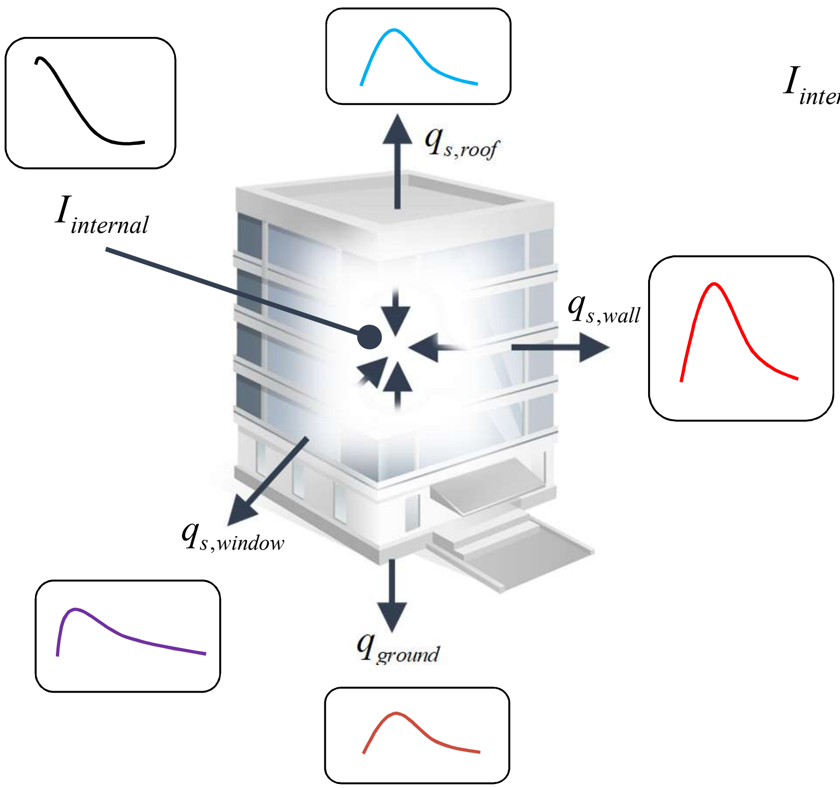
SkyBAAM



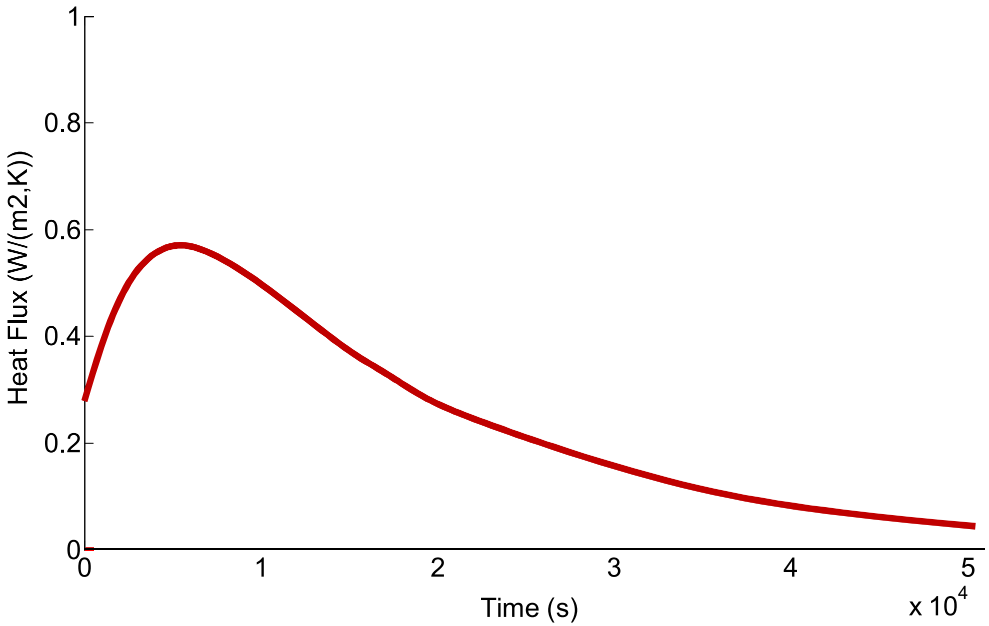
Envelope Deployment: Integration/Field Studies



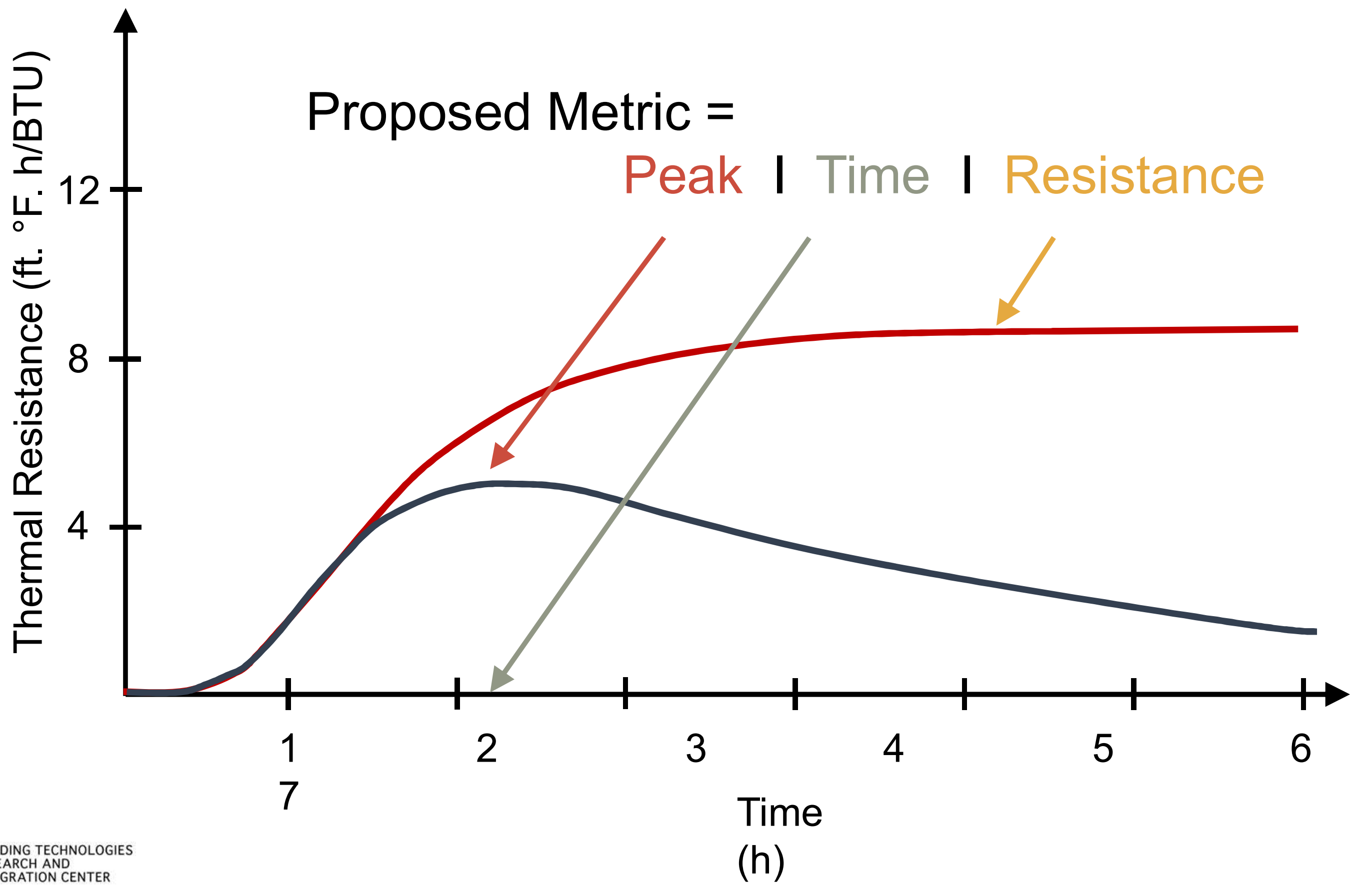
Building Envelope Performance Metric



$I_{internal}$



OAK RIDGE National Laboratory | BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER



Proposed Metric =
Peak | Time | Resistance
Thermal Resistance (ft. °F. h/BTU)
12
8
4
1
2
3
4
5
6
7
Time
(h)

Building A

42% I 2.8h I 8.5

Peak *Time* *Resistance*

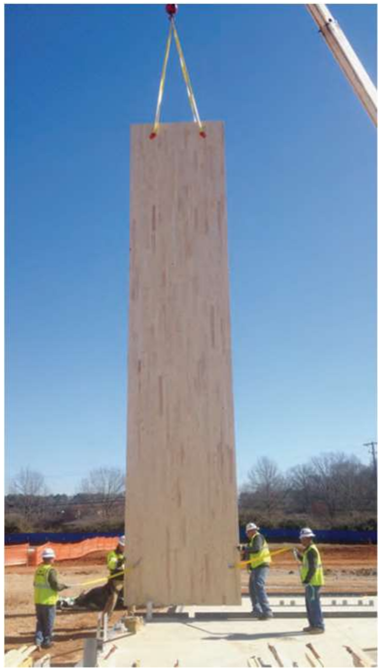
Building B

26% I 6.2h I 8.3

Peak *Time* *Resistance*

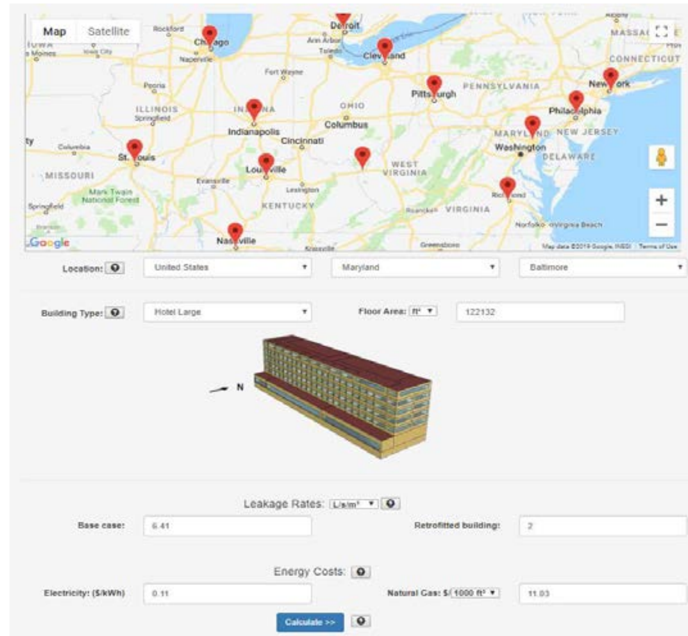
Cross-Laminated Timber

- Lendlease
  - Owner, developer, design-builder, and asset manager
  - CLT hotels
    - Redstone Arsenal, AL
    - Fort Drum, NY
    - Fort Bragg, NC
- Validation study
  - Evaluation of energy/hygrothermal performance
  - Fort Jackson, SC
  - Energy savings
  - Peak load reductions



Air Leakage Calculator

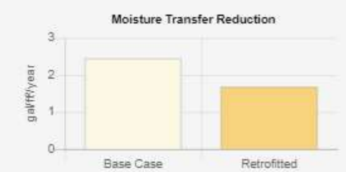
- Online tool uses simulation results from EnergyPlus and CONTAM
- Estimates from improvements in airtightness
  - Energy savings
  - Cost savings
  - Reductions in moisture transfer
- 50+ cities
- Building types
  - Standalone retail
  - Medium office
  - Mid-rise apartment
  - High-rise apartment
  - Hospital
  - Large hotel
  - Secondary school



Leakage Rate		Equivalent Leakage Area	
Base Case	Retrofitted Building	Base Case	Retrofitted Building
6.41 L/s/m² at 75 Pa	2.00 L/s/m² at 75 Pa	31.80 ft²	9.92 ft²

Predicted Savings	Electricity	Natural Gas
Energy	3,950 kWh	321,002 ft³
Cost	$ 434.50	$ 3,540.66
Total Cost Savings	$ 3,975.15	

Moisture Transfer Into the space Due to the Air Leakage	
Base Case	Retrofitted Building
2.46 gal/ft²/year	1.69 gal/ft²/year



Envelope Research Facilities

Facilities for Assembly Evaluations


Syracuse, NY


Charleston, SC


Tacoma, WA


Oak Ridge, TN

Facilities for Whole Building Evaluations


Metal building that simulates construction from the 1980s


Commercial building that simulates construction from the 1980s


Residential building

Join the Envelope Technology Research Team!

Building Managers

Architects and Engineers

Building Owners

Trade Associations

Manufacturers

Installers/ Builders

Energy Service Providers

Researchers

Upcoming ETRT Activities:

- Field testing the BEP metric
- Investigating market interest in an Envelope focused challenge and recognition campaign
- ETRT Team Meetings: Fall 2019

To join, contact Melissa Lapsa at lapsamv@ornl.gov

Thank You!

Questions/comments:

Melissa Lapsa: lapsamv@ornl.gov
Mahabir Bhandari: bhandarims@ornl.gov

Wendell Brase

University of California, Irvine

U.S. DEPARTMENT OF ENERGY

Pushing the Building Envelope: The Impact of Cutting-Edge Technologies

Wendell Brase
Associate Chancellor - Sustainability
University of California, Irvine

Better Buildings CHALLENGE
U.S. DEPARTMENT OF ENERGY

UCI University of California, Irvine

UC Irvine's Path to Better Buildings

Started in 1992, when. . .

- Buildings built prior decade met Title 24 upon ***completion***
- Premature major maintenance

UCI

First Step : Set Goals

1. Beat Title 24 by 30% for new construction
2. No major maintenance for 20 years
3. Develop a framework of life-cycle performance standards

University of California, Irvine
Construction Standards and Costs

Overall Goals and Quality Standards

Building Organization and Massing

Design Concepts that Work Synergistically for Laboratory Buildings

Structural and Foundation Systems

Building Mechanical Systems

Management of Solar Heat Gain

Roofing and Flashings

Site Development

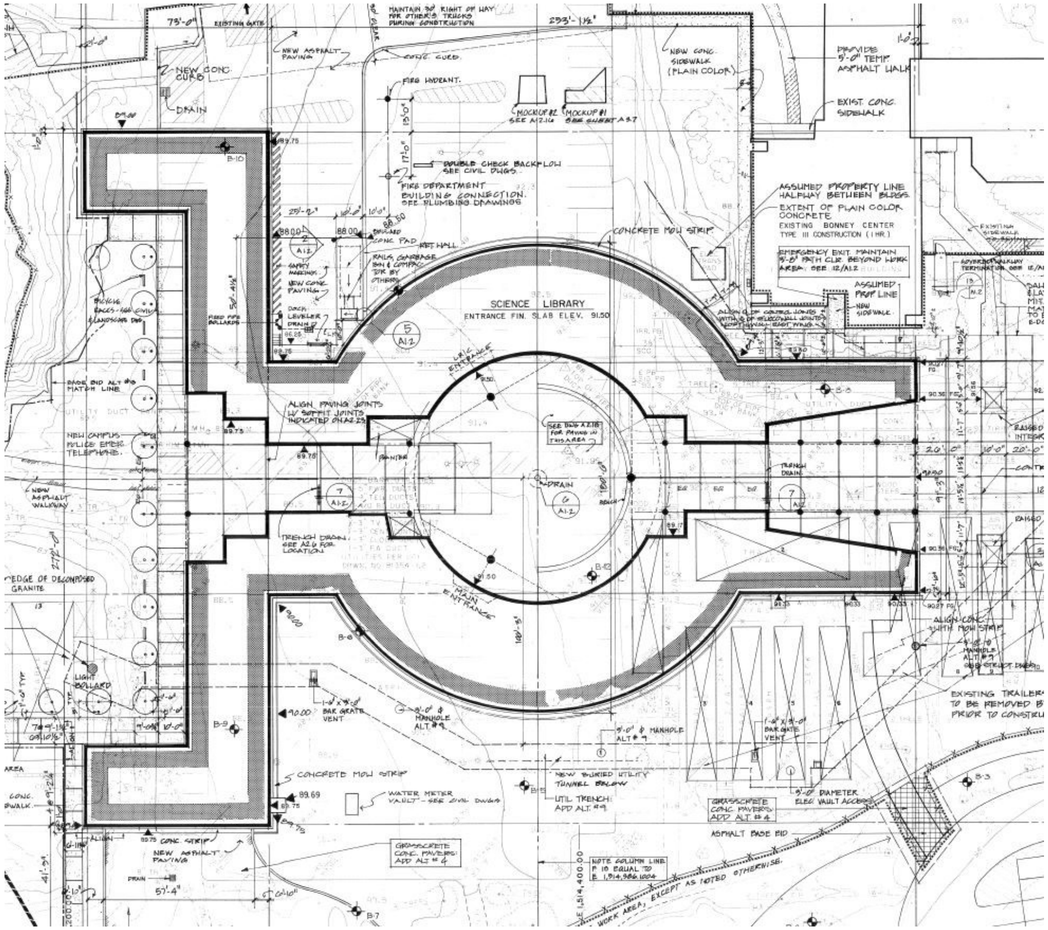
Exterior Cladding and Interior Finishes

Priorities and Trade-Offs

Benefits and Cost-Control Strategies

Results

Example of New Performance Standard : Massing



UCI

Second Step : Research (1993)

1. Premature life-cycle failures prior 20 years
2. Labs 21 (now Intl. Institute for Sustainable Laboratories)
3. LBNL study on building envelope

UCI

Step 3 : Shaped Design-Build to Incentivize Life-Cycle Design

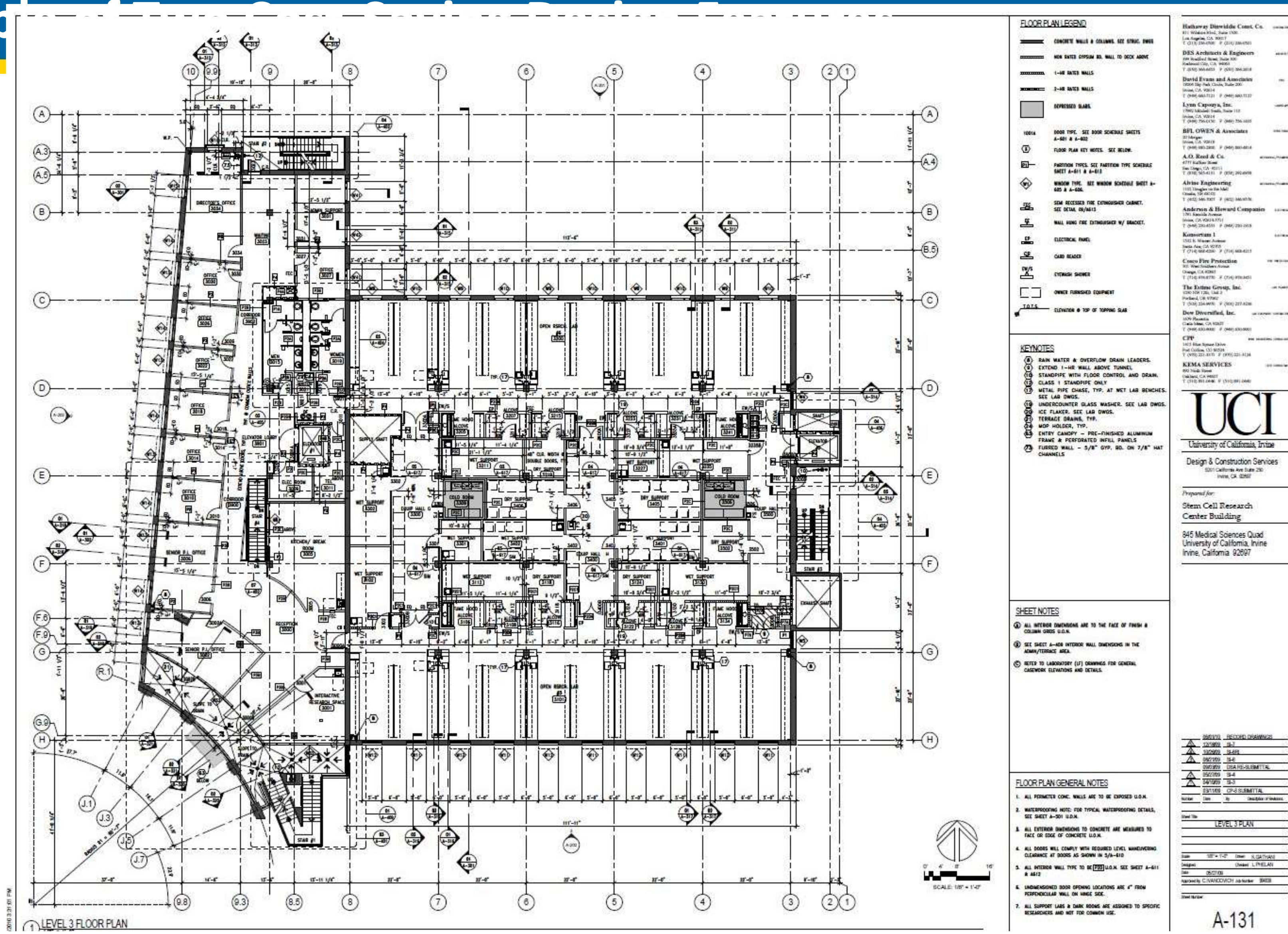
- Beat Title 24 20-30%
- No major maintenance for 20 years
- Apply framework of life-cycle performance standards
- Use design-build evaluation criteria to score requirement sufficiency and incentivize stretch goals

Mechanical System Energy Performance Requirements

Air-handler face velocity / air-speed through filtration	
Total air system pressure drop (supply+exhaust+filtration)	
Air-handler and duct sound-attenuators	
Minimum occupied lab air-changes per hour (ACH)	
Minimum unoccupied lab air-changes per hour (ACH)	
“Purge” laboratory air changes per hour (ACH)	
Exhaust stack discharge velocity (labs)	
Exhaust by-pass damper (outside air into exhaust header)	
Illumination power density	
Heat-generating equipment exhaust	
Fume hoods	

Example of Building Completed 2004

Examp


FLOOR PLAN LEGEND
KEYNOTES
SHEET NOTES
FLOOR PLAN GENERAL NOTES
UCI
University of California, Irvine
Design & Construction Services
Stem Cell Research Center Building
845 Medical Sciences Quad
University of California, Irvine
Irvine, California 92697
LEVEL 3 PLAN
A-131
LEVEL 3 FLOOR PLAN

Step 4 : 2007 Climate-Neutrality Goal Raised the Bar

UCI

2008-2019 Performance Goals for Energy

- Out-perform Title 24 by 50%
- Mechanical system performance requirements
- “Smart” HVAC controls and high efficiency lighting
- “Information layer” to ensure sustained “smart” performance
- Use design-build process to drive results.

What is a "Smart" Building?

Just enough energy, at just the right place, at just the right time!

How:

- ✓ Challenge all accepted design practices
- ✓ Use software and sensors to make building systems dynamic and "smart"

Key Components of a “Smart” Building

- Demand-controlled HVAC
- Many HVAC zones
- Right-sizing airchanges to minimize reheat
- Demand-controlled LED lighting.

UCI

Mechanical System Energy Performance Requirements

Air-handler face velocity / air-speed through filtration	300 ft. (91.4 m.) /minute maximum
Total air system pressure drop (supply+exhaust+filtration)	Labs: < 5 in. of water (1,250 pascals) Non-lab spaces: < 3.5 in. of water (875 pascals)
Air-handler and duct sound-attenuators	None
Minimum occupied lab air-changes per hour (ACH)	4 ACH with contaminant sensing (Aircuity)
Minimum unoccupied lab air-changes per hour (ACH)	2 ACH with contaminant sensing + reduced thermal inputs while building "coasts" during setback
"Purge" laboratory air changes per hour (ACH)	10-12 ACH when contaminants sensed
Exhaust stack discharge velocity (labs)	Requires wind study; design goal ~1,500 FPM; > 1,500 FPM if/when necessary to avoid re-entrainment
Exhaust by-pass damper (outside air into exhaust header)	Only activated by adverse wind conditions
Illumination power density	< 0.5 watt/SF including task lighting where needed
Heat-generating equipment exhaust	Linear exhaust grilles over equipment such as freezers
Fume hoods	Occupancy controlled, low-flow/high performance

What Next?

- ☑ Lighting efficient and demand-controlled
- ☑ HVAC efficient and demand-controlled
- ☑ Exhaust efficient and demand-controlled
- ☑ Envelope thermal mass
- ☑ Cool roof
- ☑ Windows high-performance glass
- ☐ ???
- ☐ ???

Sunlight Heat Gain

High-performance glass	75% effective
Electrochromic glass w/smart controls	90% effective
Fully shaded glass	98% effective
Combination of HP glass + 50% shading	88% effective

UCI Sunlight Management Performance Requirements

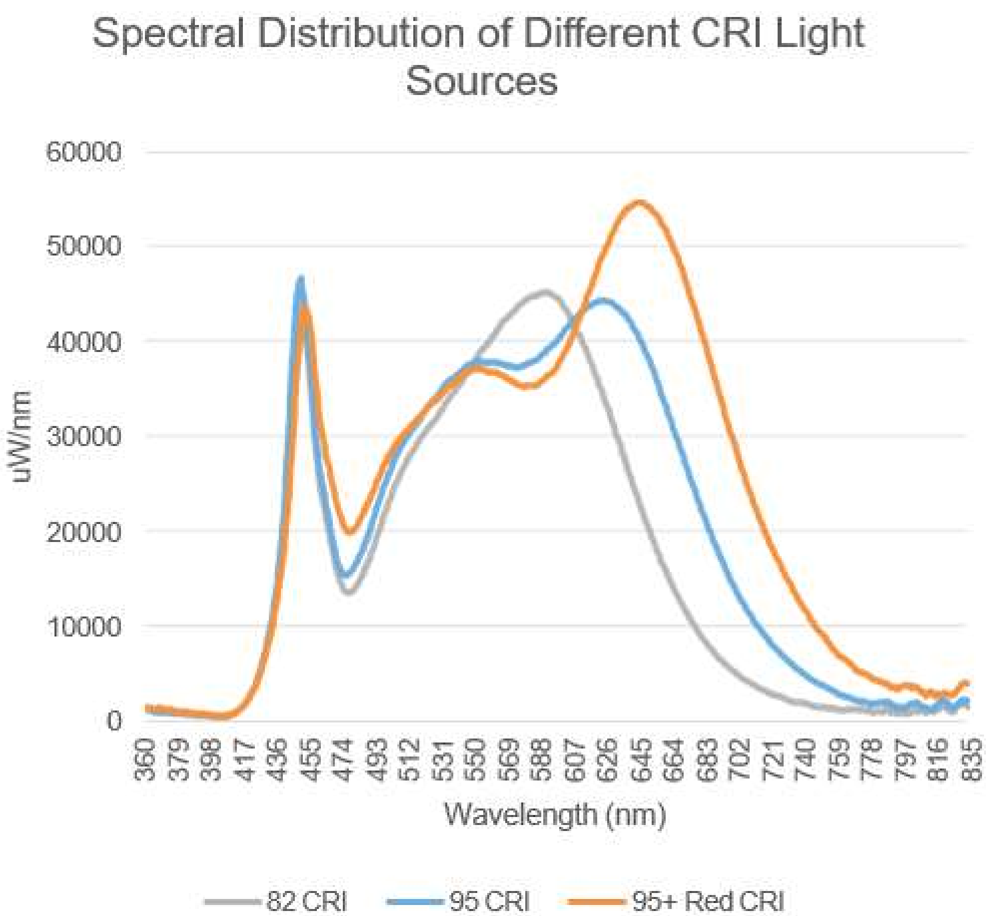
Condition	Shading Requirement	Glazing Type	Interior Window Covering / Glare Control	Comments
North, northeast, and northwest exposures	No exterior or glass shading required for facades > 30° N of E or W	Clear insulated glass	Perforated blinds or shades for glare and sun-control (except lobbies, stairwells, other public spaces)	Not tinted
N / E / W exterior sun-shading devices	Reduce 85% of annual direct sun	Clear insulated glass		Include shade from adjacent buildings, mature trees, building overhangs, recesses, and fins
N / E / W exterior sun-shading + high performance glass	Reduce 85% of annual direct sun	High performance glass		Example: 40% effective seasonal shading system with 0.25 shading coefficient would attain 85% annual performance requirement
N / E / W electrochromic glass	Reduce 85% of annual direct sun	Electrochromic (dynamic) glass	Not required, as shading coefficient of 0.10 can be achieved	Electrochromic glass with smart controls & dynamic shading coefficient

Value Priority Assigned to Daylighting

- LEED
- Other green rating systems
- An obsolete value?

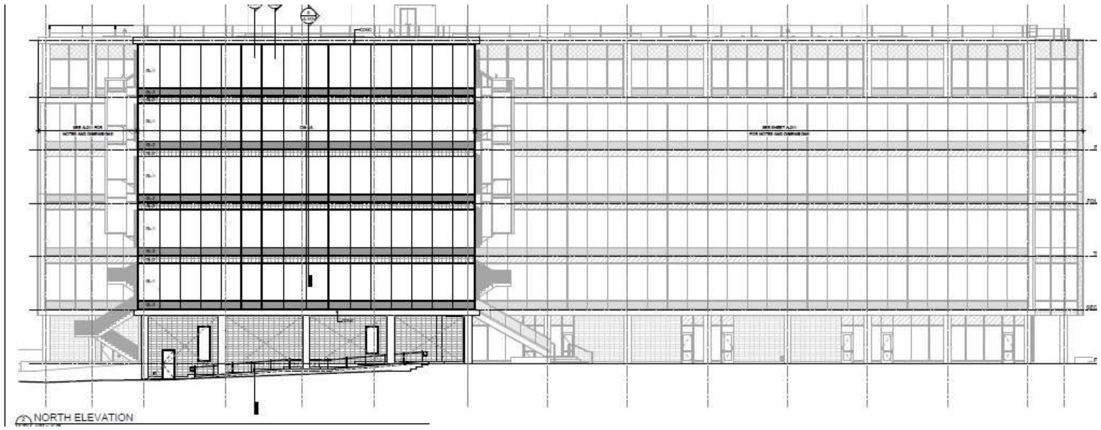
UCI

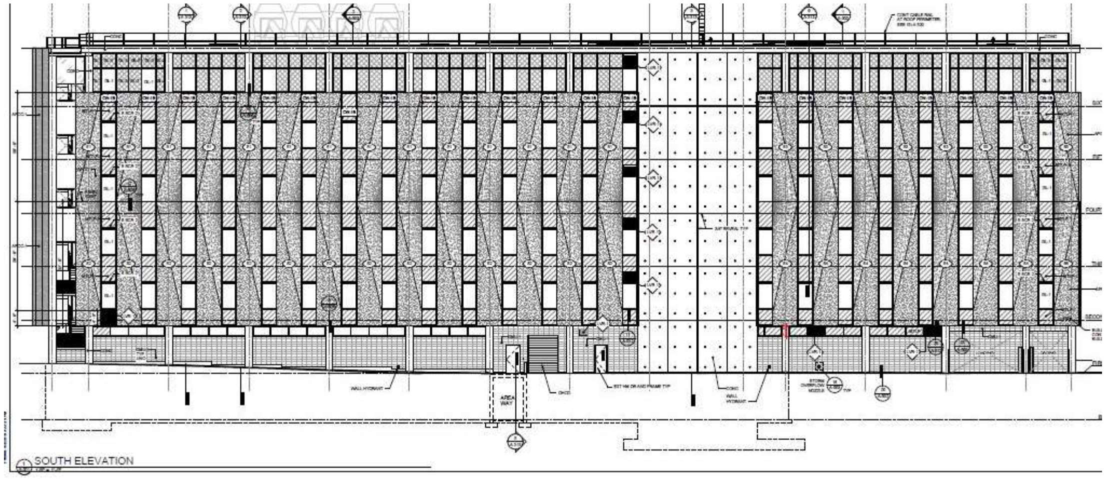
Fluorescent vs. High-CRI LED Lighting



Our Solution at UC Irvine

- CRI-95 lighting
- More selective use of glass

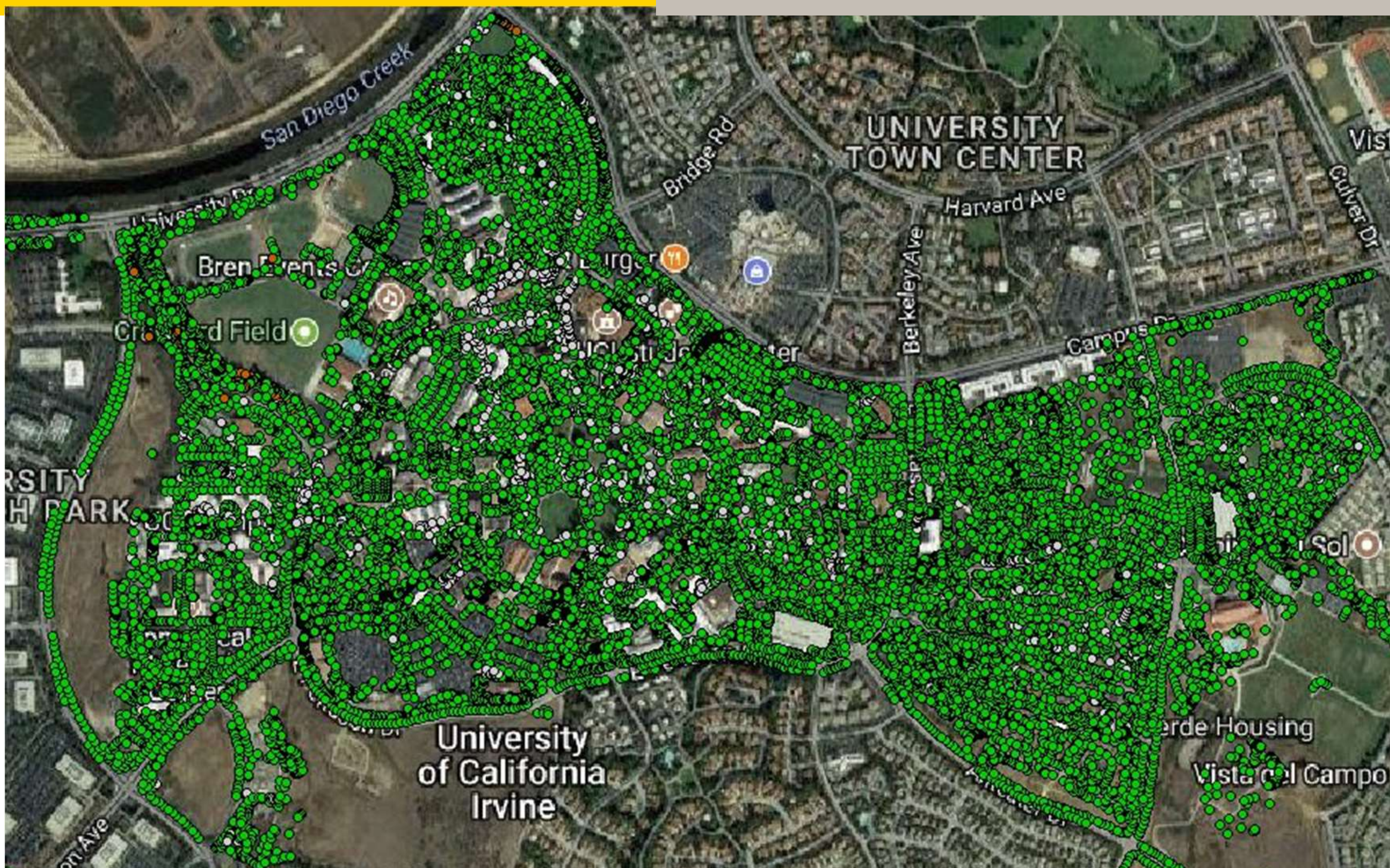




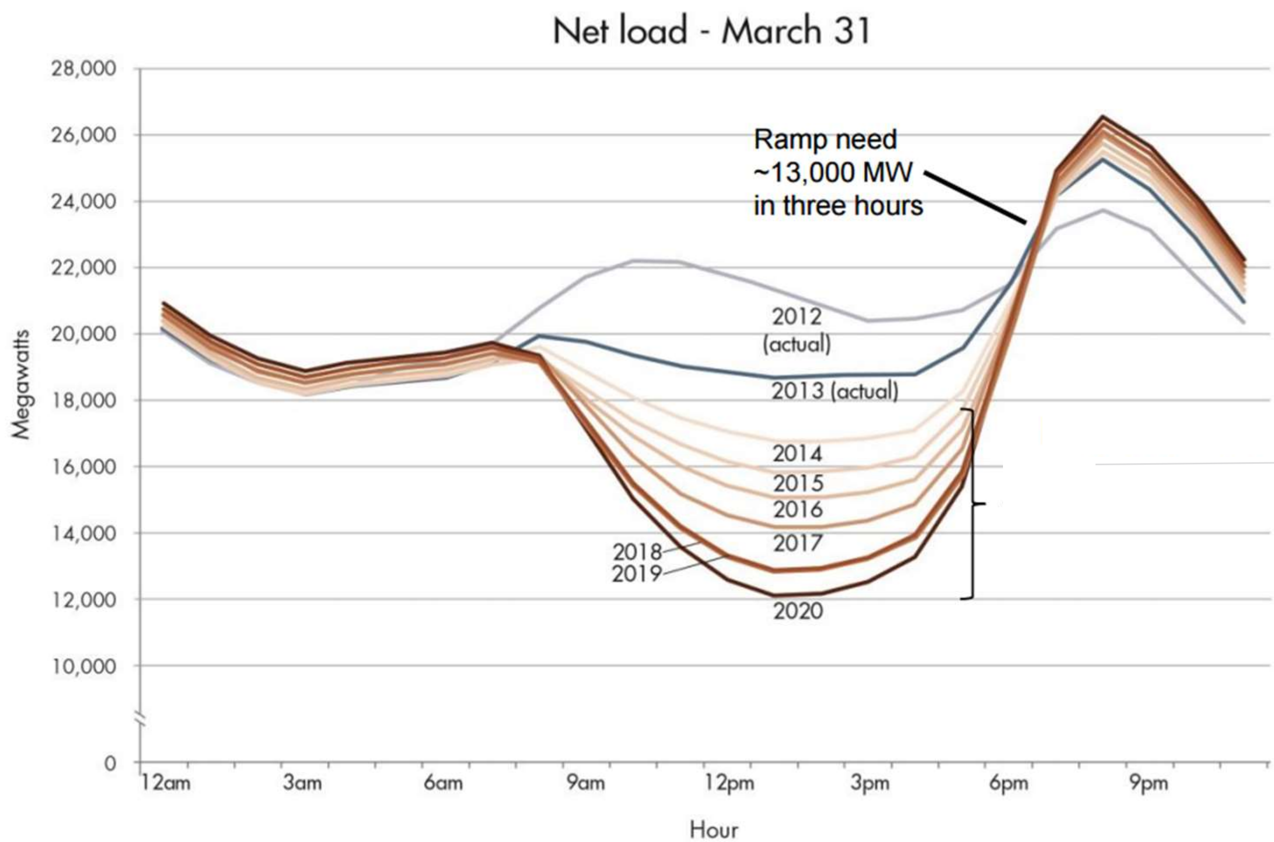
UCI

Other Ideas Being Explored

- “Fatter” buildings
- Larger trees
- Lutron pilot
- Shift energy load to low-carbon



Exploiting the “Duck Curve” to Reduce Carbon Footprint



How Do We Pay For Life-Cycle Performance?

Cost-Control & Savings Opportunities	Areas Into Which Savings are Redirected
Avoid custom-fabricated, exotic, specialized materials	High-quality teaching spaces
Conventional interior finishes	Stainless steel flashings
No floor coverings in laboratories	Durable hardware and interior finishes
Generic acoustical materials	Operable office windows (w/HVAC interlocks)
No sound absorption in partial-height partitions or walls w/doors	Quality hardscape and landscape features
Downsize HVAC due to sun shading	Sound isolation where needed (e.g., offices)
Essentially eliminate window coverings if electrochromic glass is used	Weather-protection canopy to extend life of roof-mounted equipment
Eliminate exterior wall insulation, furring, sheetrock, and paint	Sun-shading 85% overall annual effectiveness
	Exterior walls ≥ 12 in. concrete integral color, exposed both sides

UCI

Results: How Much Better After 25 Years?

	1992	2019
Energy performance	Met code, then deteriorated	30-50% better than code no deterioration
Premature major maintenance	Excessive	Zero
LEED Awards	--	18 Platinum 10 Gold
National Awards	Numerous architectural awards	DBIA Awards: 4 National Awards of Merit 3 National Awards of Excellence Excellence in Engineering Design Project of the Year

UCI

Page 1 of 9

University of California, Irvine
Construction Standards and Costs

The University of California, Irvine pursues performance goals in new construction and applies quality standards that affect the costs of capital projects. Construction costs are not "high" or "low" in the *abstract*, but rather in relation to specific quality standards and the design solutions, means, and methods used to attain these standards. Thus, evaluating whether construction costs are appropriate involves determining whether:

- Quality standards are excessive, insufficient, or appropriate;
- Resultant project costs are reasonable compared to projects with essentially the same quality parameters.

"Quality" encompasses the durability of building systems and finishes; the robustness and life-cycle performance of building systems; the aesthetics of materials, their composition, and their detailing; and the resource sustainability and efficiency of the building as an overall system.

Overall Goals and Quality Standards

UCI, in order to support distinguished research and academic programs, builds facilities of high quality. As such, UCI facilities are designed to convey the "look and feel," as well as embody the inherent construction quality, of the best facilities of other UC campuses, leading public universities, and other research institutions with whom we compete for faculty, students, sponsored research, and general reputation.

Since 1992, new buildings have been designed to achieve five broad goals:

1. New buildings must "create a place," rather than constitute stand-alone objects – forming social, aesthetic, contextually sensitive relationships with neighboring buildings and the larger campus.
2. New buildings reinforce a consistent design framework of classical contextual architecture, applied in ways that convey a feeling of permanence and quality, and interpreted in ways that meet the contemporary and changing needs of a modern research university.
3. New buildings employ materials, systems, and design features that will forestall the expense of major maintenance (defined as >1 percent of value) for at least 20 years.
4. New buildings attain exemplary sustainability performance – at least LEED Gold and outperforming California's Title 24 energy efficiency standards by as much as 50 percent.
5. Capital construction projects are designed and delivered within the approved project budget, scope, and schedule.

UCI

https://designandconstruction.uci.edu/documents/UCIConstructionStandardsandCosts_May2018rev.pdf

How Did We Do It?

1. Technology
2. Questioned status-quo design practices
3. Targeted energy waste that was built-into building systems
4. Made intentional, explicit trade-offs to fund life-cycle performance
5. Never stop improving!




Presented Monday, July 11, at the 2019 Better Buildings Summit, Arlington, VA

UCI University of California, Irvine

Jessica Abralind

Arlington County (VA)

U.S. DEPARTMENT OF ENERGY

Pushing the Building Envelope in Arlington County, VA

Jessica Abralind, Green Building Planner

Arlington County, VA

July 11, 2019

Outline

- Arlington's Facility Sustainability Policy for New Construction and Major Renovation
- Renovation example – Solid Waste and Traffic Engineering and Operations facility
- New Construction example – Lubber Run Community Center

Arlington's Facility Sustainability Policy

- **Recent update:** more focus on building enclosure, prioritize passive energy saving strategies like insulation, air sealing
- **Policy includes Earthcraft Light Commercial (ECLC) rating system as compliance path** because it fits smaller buildings better than LEED and includes a blower door test and air leakage performance standards
- **Interdepartmental working group** including facilities maintenance, facilities design and construction, Parks, Fire, Housing, Inspection Services
- **Why?** energy and GHG reductions, cost savings, occupant comfort and health

Facility Sustainability Policy - Implementation

- **SW TE+O** – first time trying ECLC, first blower door test, first pre-construction occupant survey

- **CHALLENGE**: design team was already engaged and ECLC, testing, and envelope improvements were not in the scope of work

SW & TE&O Assessment


Assessment Report

SW & TEO Renovation

4300 S. 29TH ST. ARLINGTON, VA 22206

viridiant

1431 West Main Street
Richmond, VA 23220

Viridiant.org
804.225.9843

November 28th, 2018

Assessment Methods:

✓Thermal comfort survey

✓Enclosure test

✓Field Observations & thermal imaging

✓Energy Benchmarking

Figure 1. SW & TEO located at 4300 29th Street South, Arlington County, VA.

Commercial Enclosure Definitions

Enclosure: part of any building that physically separates the exterior environment from the interior environment(s); (BSC, 2006)

Infiltration: the flow of outdoor air into a building through cracks and other unintentional openings and through the normal use of exterior doors for entrance and egress; (ASHRAE, 2009)

Exfiltration: is leakage of indoor air out of a building through through cracks and other unintentional openings; (ASHRAE, 2009)

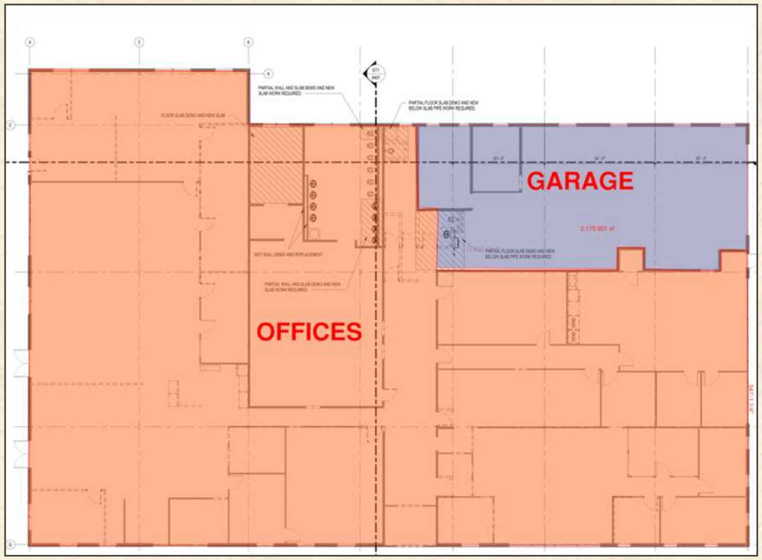
Air barrier: a plane that one intends to be the sole, or at least the primary , resistor to airflow; (Straube and Burnett, 2005)

EarthCraft Light Commercial: a regional green building certification program offering third-party recognition for environmentally responsible design and construction practices for small-scale commercial buildings in the Southeast (Southface, 2018)

Site and Building Context

CHARACTERISTIC	SW & TEO
Building Use Group	B-1
Building Conditioned Floor Area (Ft^2)	15,234*
Occupancy Load	130*

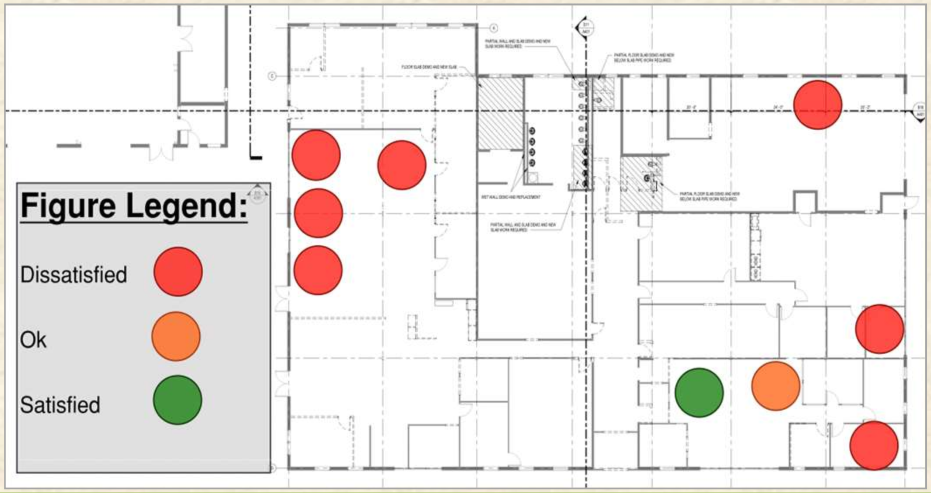
CLIMATE ZONE 4A | ARLINGTON, VA	
Elevation (ft.)	66
Mean Air Temperature (oF)	58.1
Mean Relative Humidity (%)	65.8
Daily Solar Ration (kWh/m2/d)	3.95
Atmospheric Pressure (kPa)	101.7
Mean Wind Speed (mph)	8.5
Earth Temperature (oF)	56
Heating Degree-Days, HDD (64.4 oF)	4001
Cooling Degree-Days, CDD (64.4 oF)	1524



User-centered Assessment

THERMAL COMFORT:

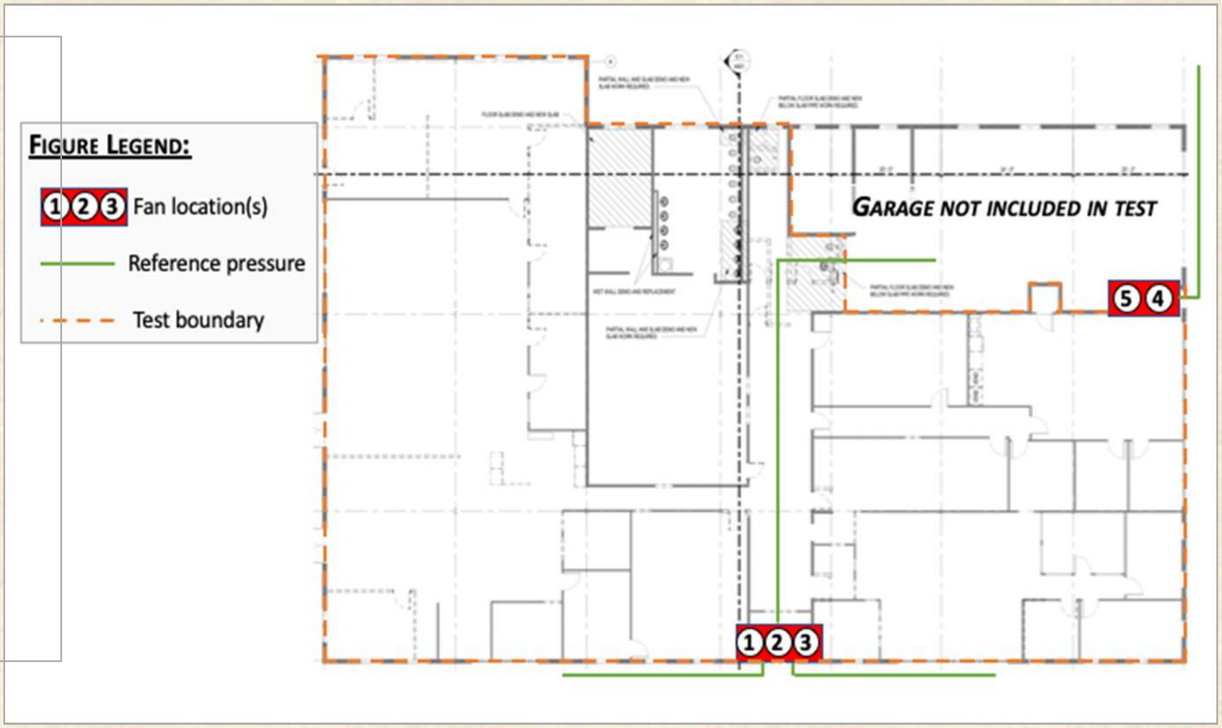
- ✓ 2-page survey
- ✓ Likert scale, multiple choice
- ✓ *Why?* Buildings are for people
- ✓ Users are rich sources of data



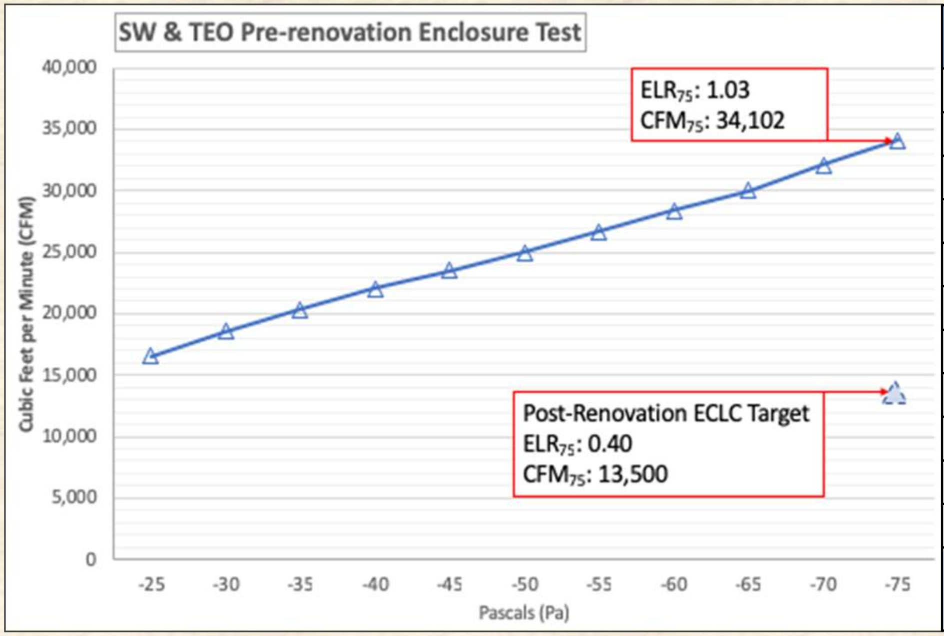
Enclosure Test Plan

OVERVIEW:

- ✓ Communication
- ✓ Define test boundary
- ✓ Identify power sources
- ✓ Identify system locations
- ✓ 3-4 hrs of prep for the test
- ✓ 4 staff x 5 hrs: 20 hrs

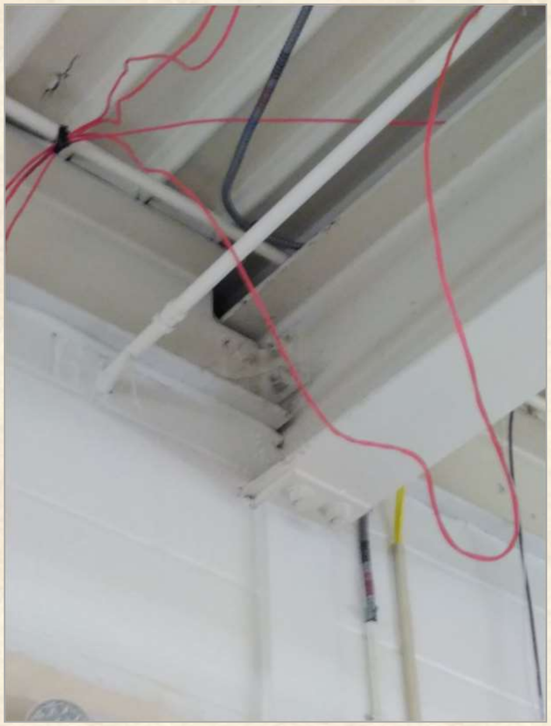


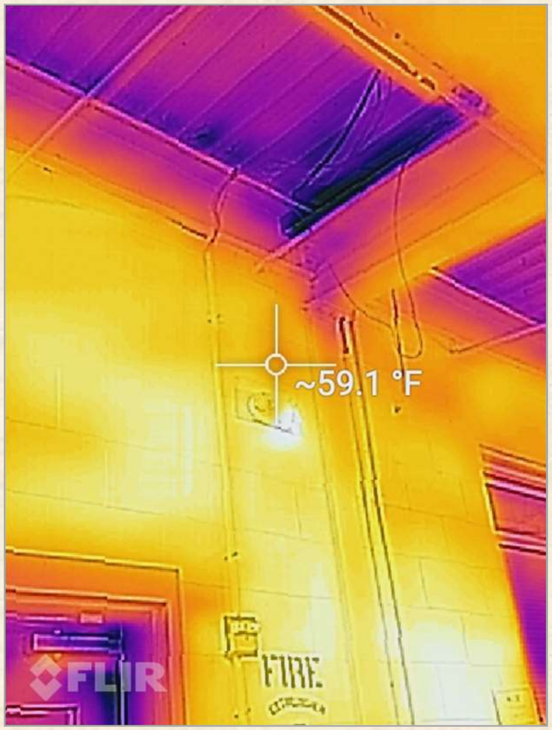
Enclosure Test Results



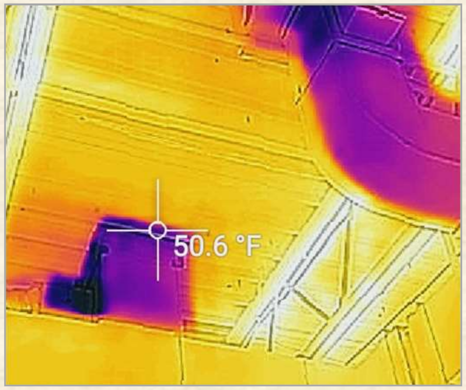
Pascal (Pa)	Cubic Feet/Minute (CFM)
-25	16,560
-30	18,521
-35	20,333
-40	22,072
-45	23,522
-50	25,012
-55	26,651
-60	28,420
-65	30,005
-70	32,133
-75	34,102
	Envelope Leakage $Ratio_{75}$: 1.03
	Coefficient of Determination (R^2): 0.996

Enclosure Improvement Opportunities





Enclosure Opportunities



ENCLOSURE PENETRATIONS

✓13 intentional holes

✓Sealed for test

✓Testing dampers

Project Team

PHILIP AGEE
Technical Director
Viridiant

- ▹***EarthCraft Light Commercial***
- ▹***ASHRAE Level Commercial Audits***
- ▹***DOE Advanced Commercial Building Initiative***

JESSICA ABRALIND
Green Building Planner
Arlington County
Government

JEREMY JENKINS
Construction Management Specialist
Arlington County Government

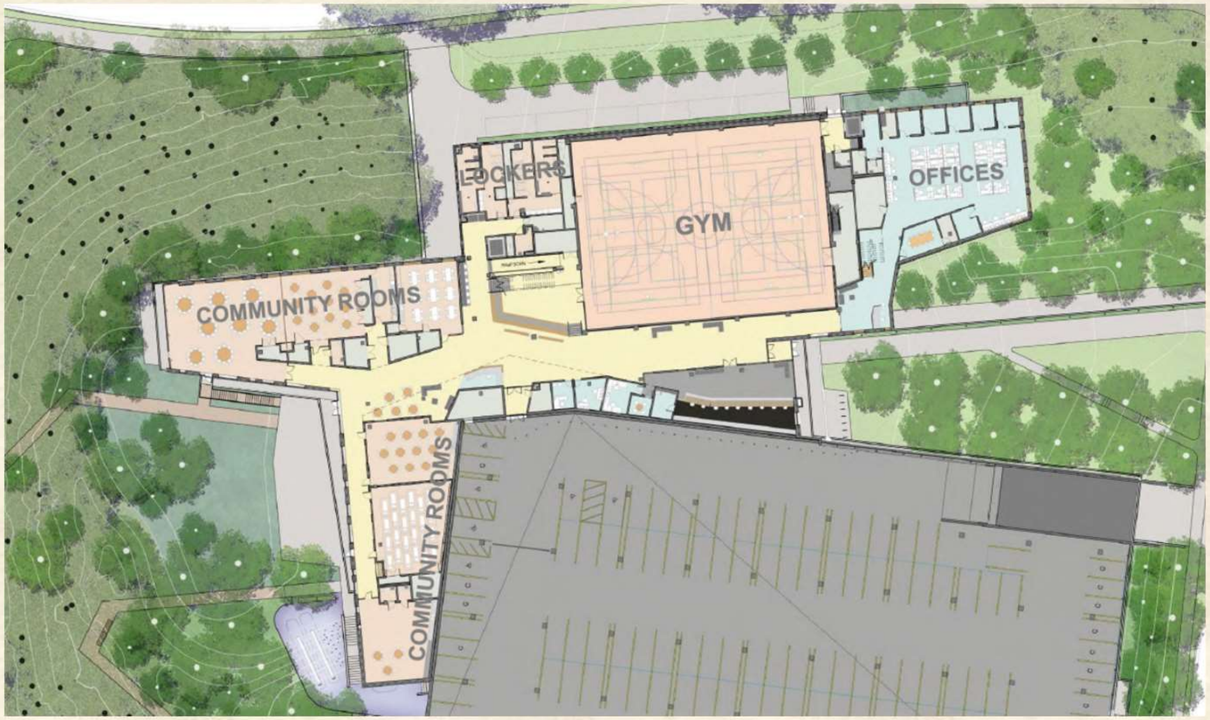
ARLINGTON
VIRGINIA

Lubber Run Community Center

- VMDO/ CMTA design team
- 53,000 s.f. new construction
- Targeting:
  - ✓ Net Zero Energy "Ready"
  - ✓ Energy Use Intensity (EUI) of 24 kbtu/s.f./year
  - ✓ LEED Silver
  - ✓ Building Enclosure Test

Lubber Run Community Center

Green building highlights
- ✓ Ground Source Heat Pumps
- ✓ LEDs
- ✓ 30% window to wall ratio (WWR)
- ✓ East-West building orientation
- ✓ Thermomass® Concrete Sandwich Panel



Thermomass® Concrete Sandwich Panel

Thermomass Concrete Sandwich Panel

Thank you!

Jessica Abralind, Green Building Planner

Arlington County, Virginia

Office of Sustainability and Environmental Management

Thank You

Provide feedback on this session
in the Summit App!

Download the app to your mobile device or go to
event.crowdcompass.com/bbsummit19

Contact Us

(Speakers)

- Mahabir Bhandari, Oak Ridge National Laboratory (ORNL)
  - bhandarims@ornl.gov
- Wendell Brase, University of California, Irvine
  - wcbrase@uci.edu
- Jessica Abralind, Arlington County (VA)
  - jabralind@arlingtonva.us

(Moderator)

- Cedar Blazek, DOE
  - cedar.blazek@ee.doe.gov