NREL Window Core Program

National Renewable Energy Laboratory
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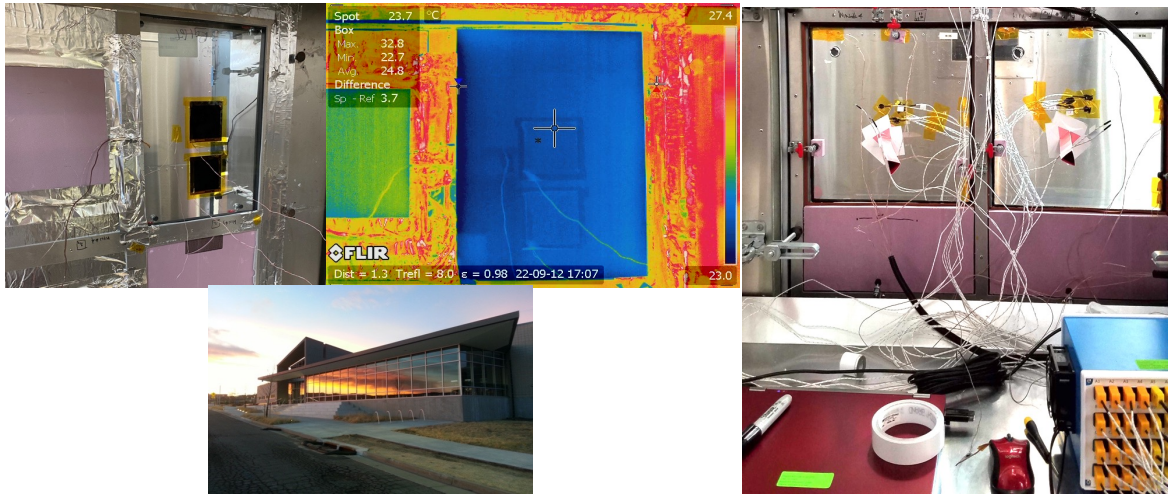
WBS 3.1.3.16

Project Summary

Objective and Outcome

This project supports accelerated deployment of energy-efficient fenestration technologies by providing early-stage technology developers, large manufacturers, and consumers access to state-of-the-art methods and required knowledge to assess the performance and durability of energy saving and carbon emission reducing technologies.

This work will transfer knowledge as well as capability to the private sector for deployment of durable emerging fenestration technologies leading to job creation and ensuring that energy efficiency and carbon emissions reductions of advanced fenestration technologies are realized.



Team and Partners

- NREL
- LBNL
- University of Sydney
- University of Colorado, Boulder
- University of Illinois, Chicago
- QAI Laboratories
- WinBuild, Inc.
- Glass Dynamics, Inc.
- University of Maryland

Stats

Performance Period: 10/01/2022–9/30/2025

DOE Budget: $1.8M, Cost Share: $0k

Milestone 1: Development and Publication of NREL Enhanced IGU Evaluation Guideline

Milestone 2: Transfer of ASTM E-2141 to Industry Partner

Milestone 3: Report on Size of Sample on Vacuum Insulating Glass Durability Evaluation

Problem: Ensuring Long-Term Performance in Fenestration

Window performance is specified at install, but value is delivered over time

Consumers

Need performance over time to obtain energy savings and emission reductions.

Manufacturers

Must guarantee performance over time to the consumer.

Innovators

Need verification of performance over time to build credibility with manufacturers and consumers.

Alignment and Impact: Emissions Reduction, De-Risking Investment, and Creating Jobs

Buildings impact ~36% of U.S. carbon emissions

Windows impact 43% of U.S. building energy use

Combating climate change requires action NOW!

We cannot wait on tomorrow's technologies to save us

Window Energy/Emissions Reduction Impact Paths	CO_2 Emissions Reduction/Year (Mt CO_2)
Retrofit Using Existing Technologies	94,000,000
Adoption of Emerging Technologies	69,000,000

Investment in emerging technologies drives economic growth

Investors Want…

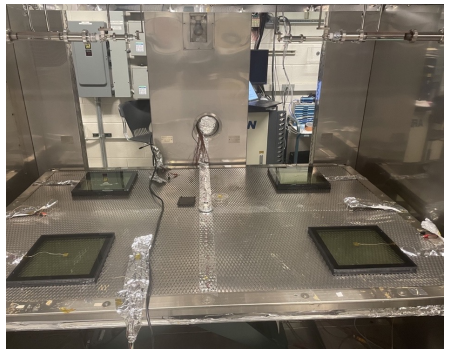
- Performance
- Durability
- Low-Cost
- Manufacturability

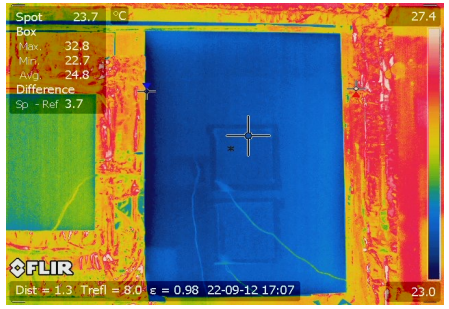
Investment leads to job creation and energy/emissions reductions

These impacts can only be realized if retrofit and emerging technologies have performance that lasts!!

https://glassforeurope.com/wp-content/uploads/2019/05/Glazing_potential_brochure_2019.pdf

Approach/Benefit Alignment

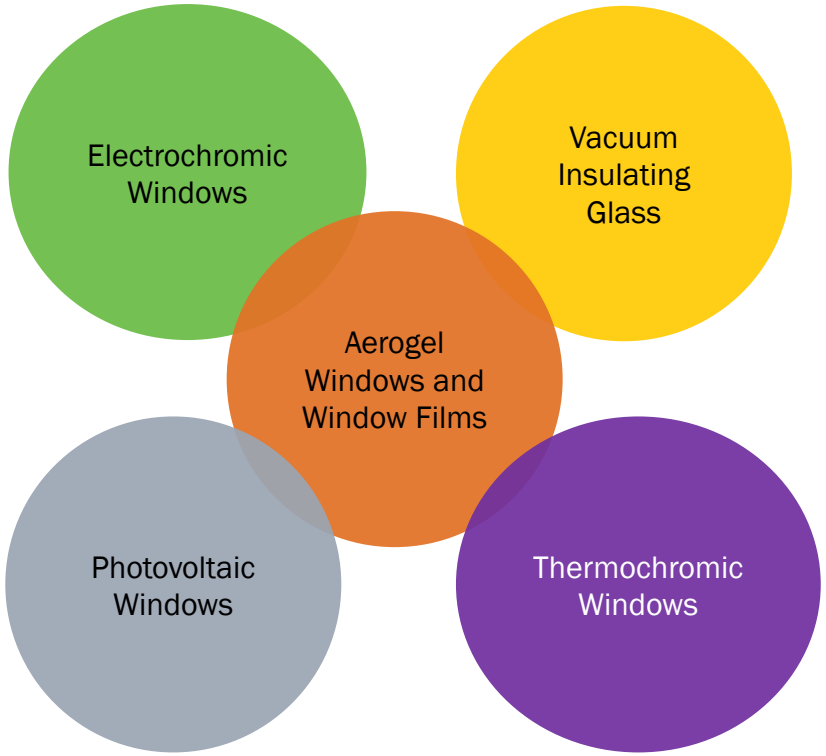




Approach	Benefit
Failure analysis and standards development for emerging technologies	Increased investment in job growth, energy and emissions reductions
Enhanced durability evaluation of existing products	Increased confidence in performance over time
Alignment of durability evaluation with energy performace	Confidence that we measure what matters

Approach: Emerging Tech

Research on Durability of Emerging Technologies



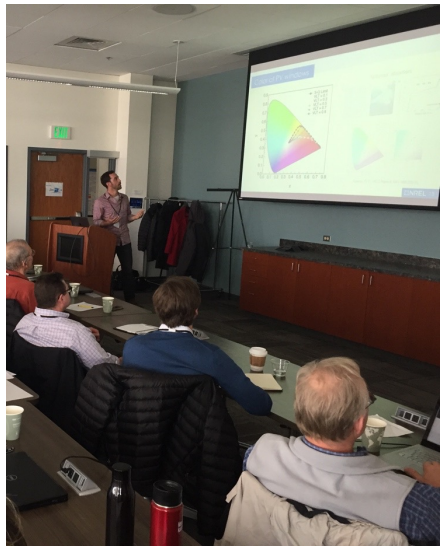
Assistance to early technology developers

Knowledge transfer to developers, standards and certification bodies

Standardized methods for durability evaluation

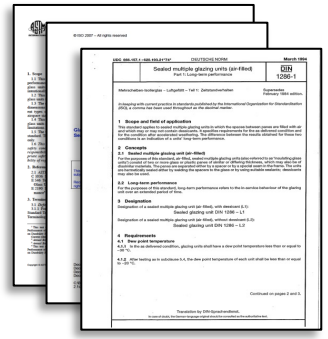
Approach: Enhanced Durability Evaluation Method Development

Industry Engagement

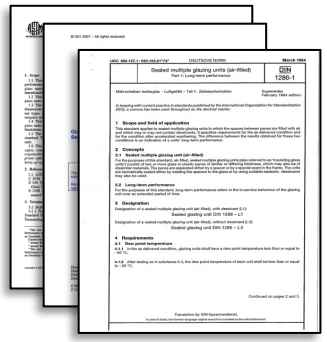


- Workshops
- Interviews
- Webinars
- Reviews

Review of Existing Standards



Review of Scientific Literature



Guidelines and Specifications for Enhanced Durability Evaluation of Insulating Glass and Vacuum Insulating Glass Units

Alliston Watts[1], Bipin Shah,[2] and Robert C. Tenent[1,3]

1 National Renewable Energy Laboratory
2 WinBuild, Inc.
3 Renewable and Sustainable Energy Institute, University of Colorado at Boulder

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Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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NREL/TP-5K00-83550
September 2022

Third-party verification of ”enhanced” durability of emerging and present market technologies

Iterative refinement through research with industry partners

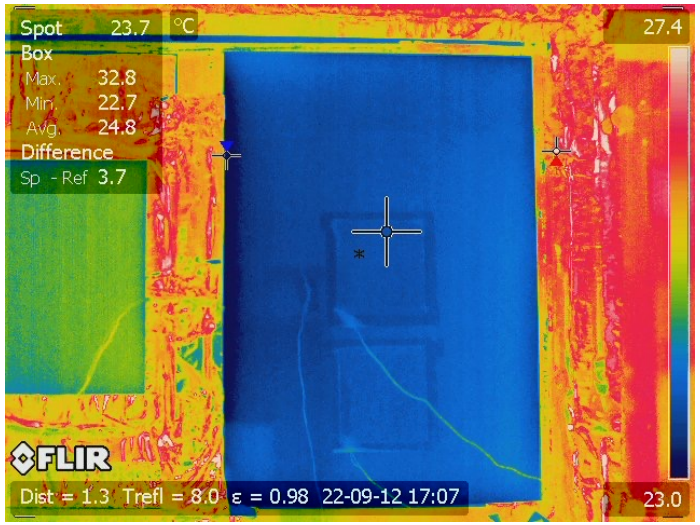
Approach: Field Validation/Lab Correlation Study

- Modeling analysis of the energy impact of performance degradation.
- Field measurement protocol development under laboratory conditions.
- Identification of potential sites for field evaluation.
- Field study/evaluation to identify most impactful degradation processes for energy performance.

Lab and field test: to develop in-situ ready test methods and protocols

Heat flux meter method
ISO 9869-1

Coupling



Infrared imaging
ISO 9869-2

Potential initial field evaluation sites

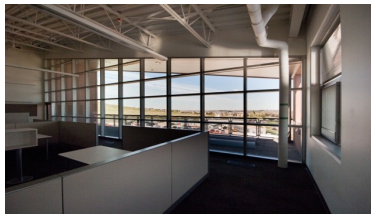
NREL South Site Entrance

SW, SE and NE exposures

NREL Cafeteria

S, SE and exposures

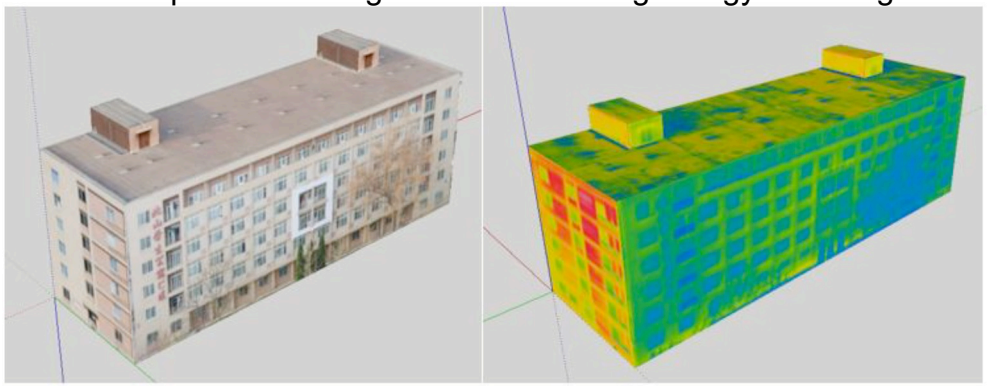
NREL RSF



N,S,E and W exposures

Additional discussions with CUNY, UI-Chicago and Southeast Energy Efficiency Alliance for paired field evaluations.

Incorporation of degradation in building energy modeling



Joint with CU-Boulder through iBUILD program

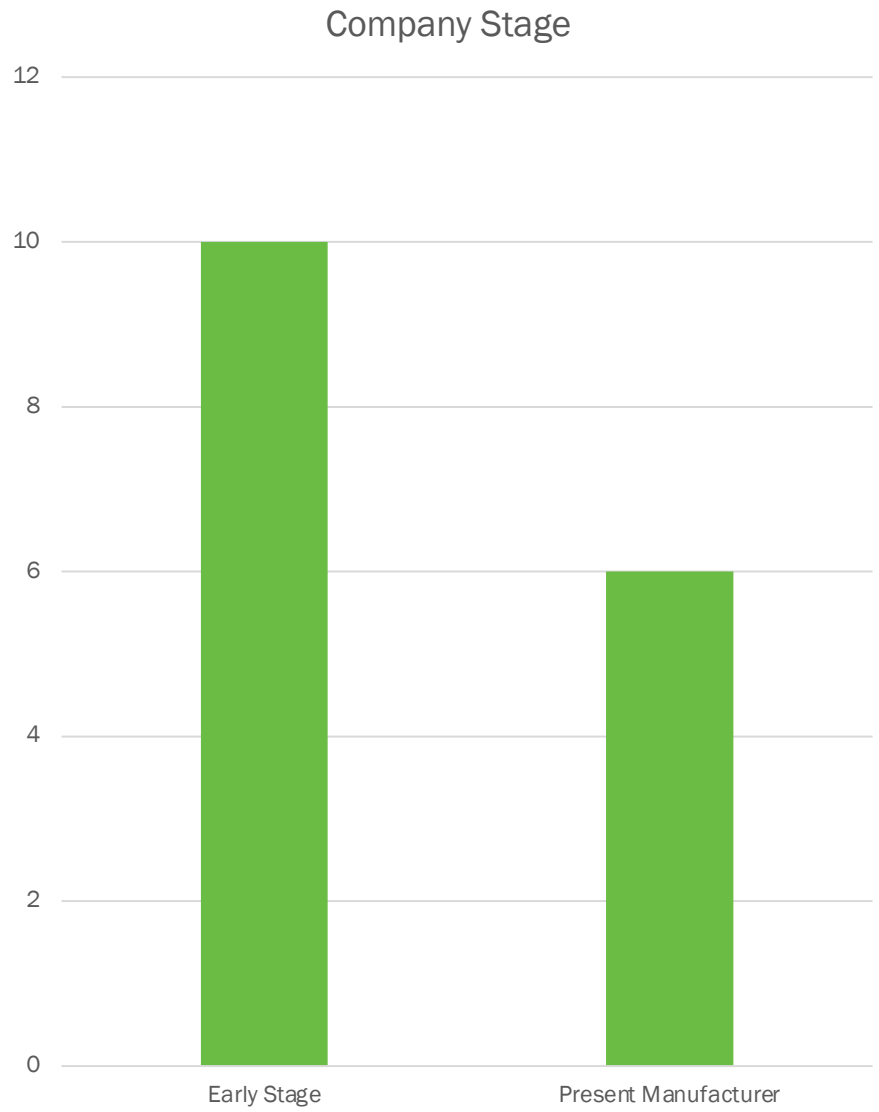
Progress: Industry Engagement and Support

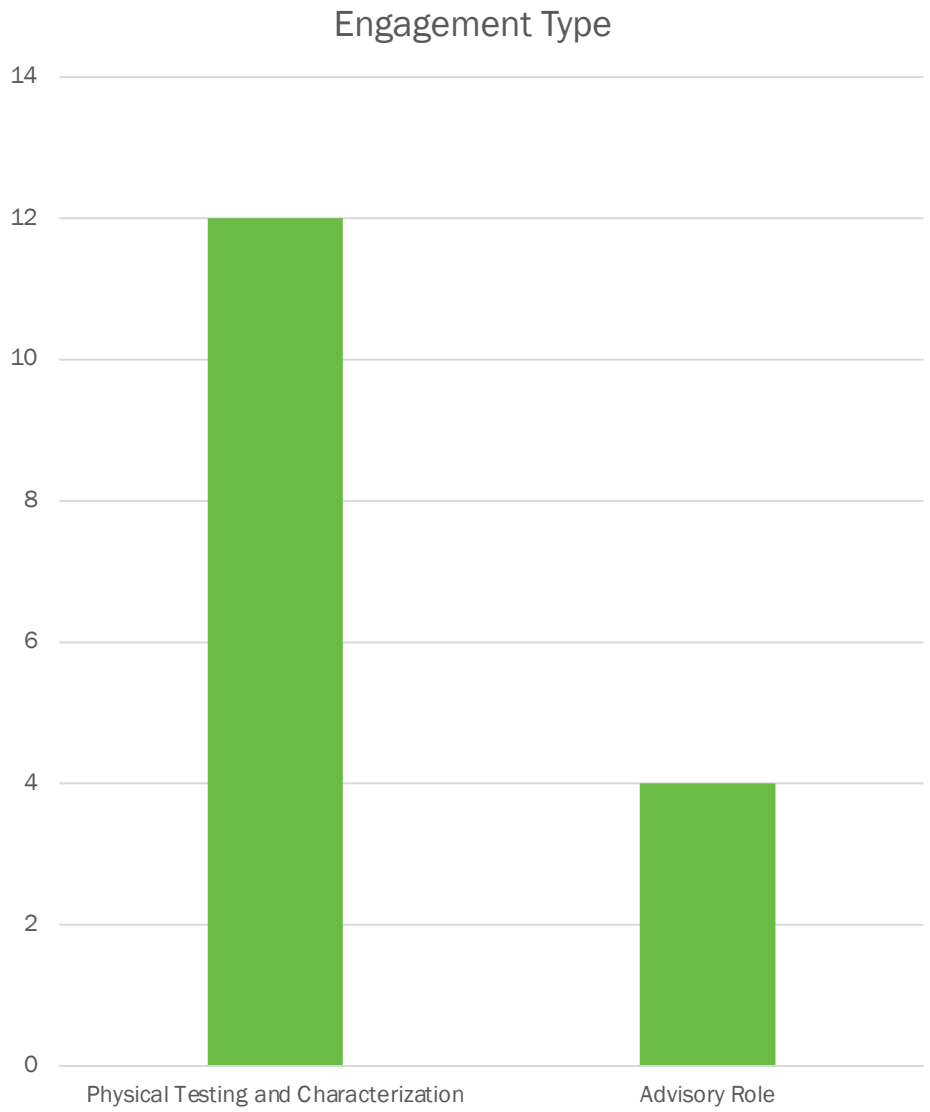
NREL supported 16 industry partners in FY22.

Physical testing and analysis as well as advisory roles for early-stage developers.

Application of existing or custom stress factors and failure analysis.

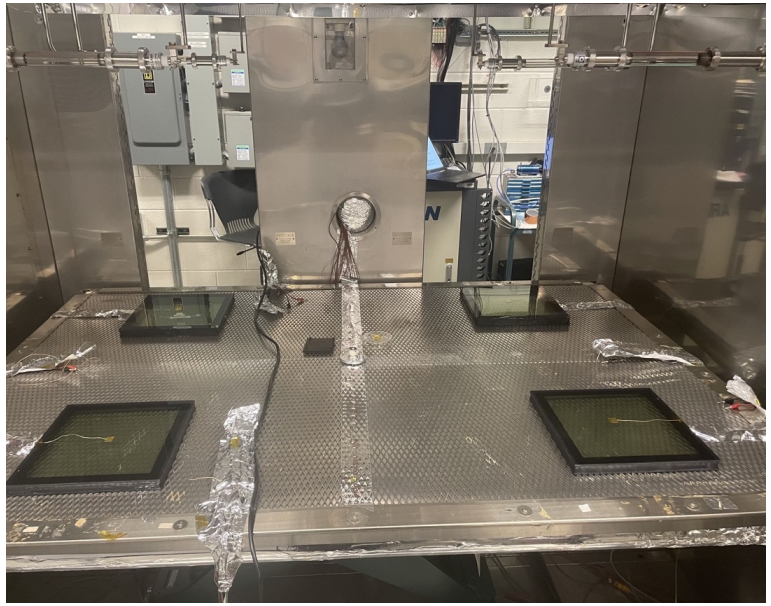
Connecting developers with test houses and advising on internal durability laboratory construction.





Progress: Transfer of Electrochromic Method to Private Sector

- NREL transferred the ASTM E-2141 and E-2953 methods to QAI Laboratories through an interlaboratory comparison study.
- QAI has filed required paperwork with ANSI to initiate certification.
- NREL has held initial discussions on potential certification with NFRC.



		NREL			QAI		
Highest Transmission (%), τH	Exposure hours	0	1000		0	1000	
Lowest Transmission (%), τL		initial	final	% Change*	initial	final	% Change*
IGU1	τH	68.06	66.77	1.30	65.13	66.67	-1.53
	τL	2.14	1.66	0.48	2.30	2.05	0.25
IGU2	τH	64.58	66.07	-1.49	64.32	62.48	1.84
	τL	1.83	1.51	0.32	2.12	2.18	-0.05
IGU3	τH	65.57	66.28	-0.71	66.21	64.93	1.29
	τL	1.78	1.64	0.15	2.67	3.02	-0.35
IGU4	τH	64.14	66.10	-1.96	64.91	65.60	-0.69
	τL	2.01	2.98	-0.97	2.80	2.88	-0.08
IGU5-Reference	τH	66.02	63.86	2.16	66.15	63.62	2.53
	τL	2.18	1.44	0.74	2.82	2.57	0.25
				*Pass requirement: % change < (+/-) 5%			

Progress: Laboratory Equipment Upgrades

Differential Thermal Cycling Unit (DTCU)

Chamber modifications to increase functionality.

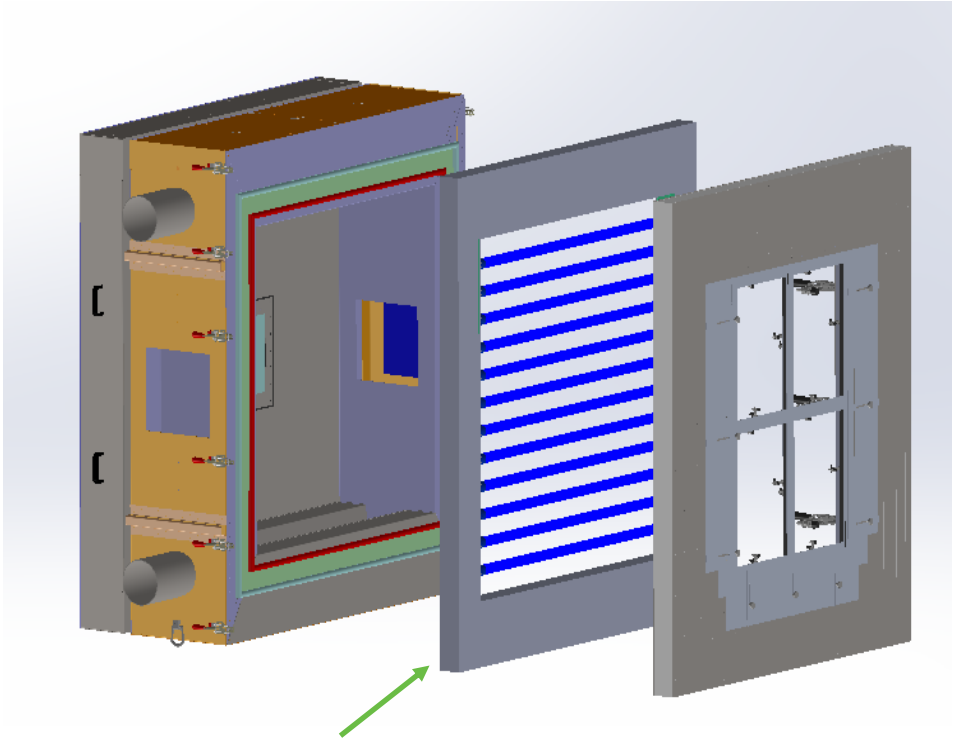
Existing stress factors – temperature and RH.

Additional stress factors – UV, water spray, and pressure

Measurement of thermal transmittance under varied conditions.

Software control of stress factor application.

Simulation of varied installation environments for exploratory failure mode research of emerging technologies.

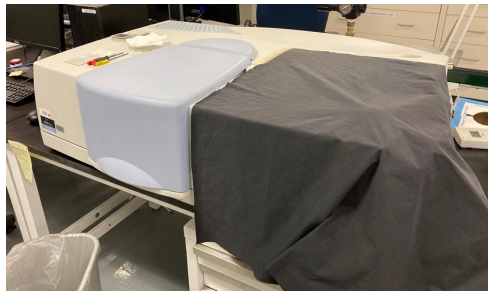


12 UV lights embedded in a new sample holder.

Additional Performance Characterization Capabilities

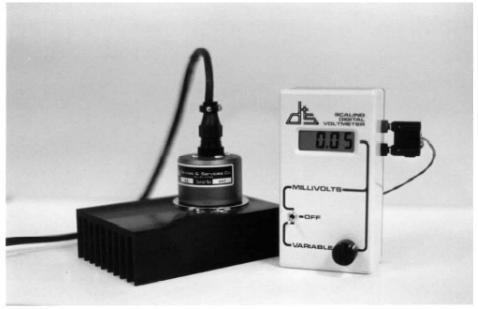
Optical Characterization

UV-Vis



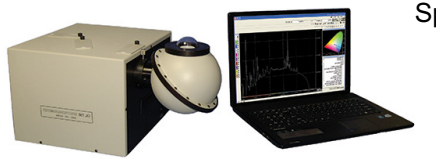
Infrared

Emissometer



Gas Fill Measurement

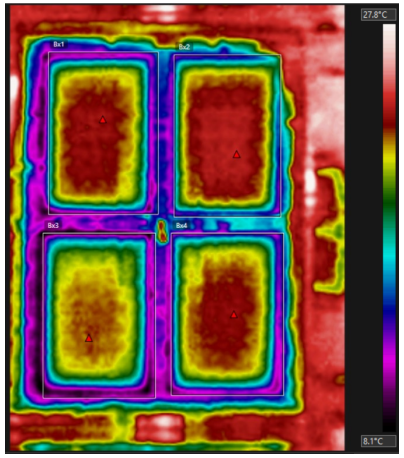
Frost Point Test



Spectroradiometer

Glass Thickness Low-e

Infrared Imaging

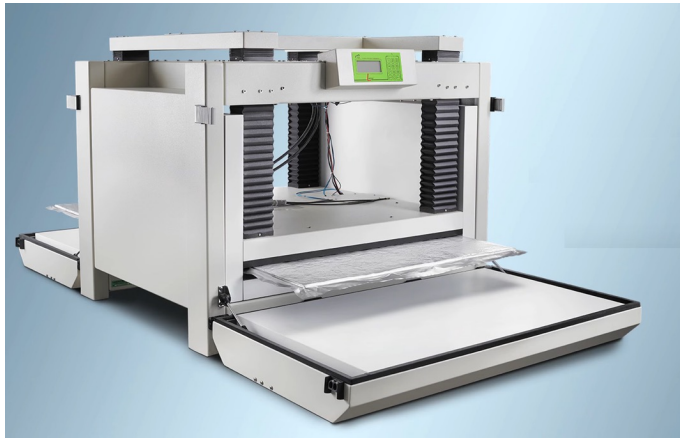


Industry standard methods brought in house.

Leveraging materials analysis capabilities from additional NREL labs.

Glass Deflection Measurements

FOX 600 Heat Flow Meter



Materials Permeability

Residual Gas Analyzer (RGA)

Why Is Enhanced IGU Durability Evaluation Needed?

Greensburg, KS Tornado

Jersey Shore, Hurricane Sandy

Global weather patterns are showing an increase in extreme conditions.

This represents a risk to emission and energy reductions from advanced envelope technologies.

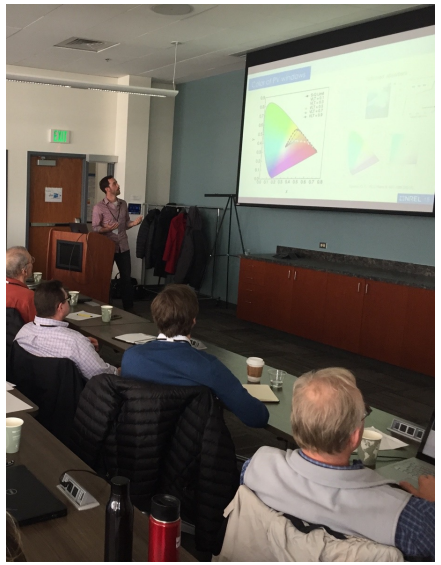
Tomorrow's technologies must survive tomorrow's climate…

…but today's technologies need to as well!

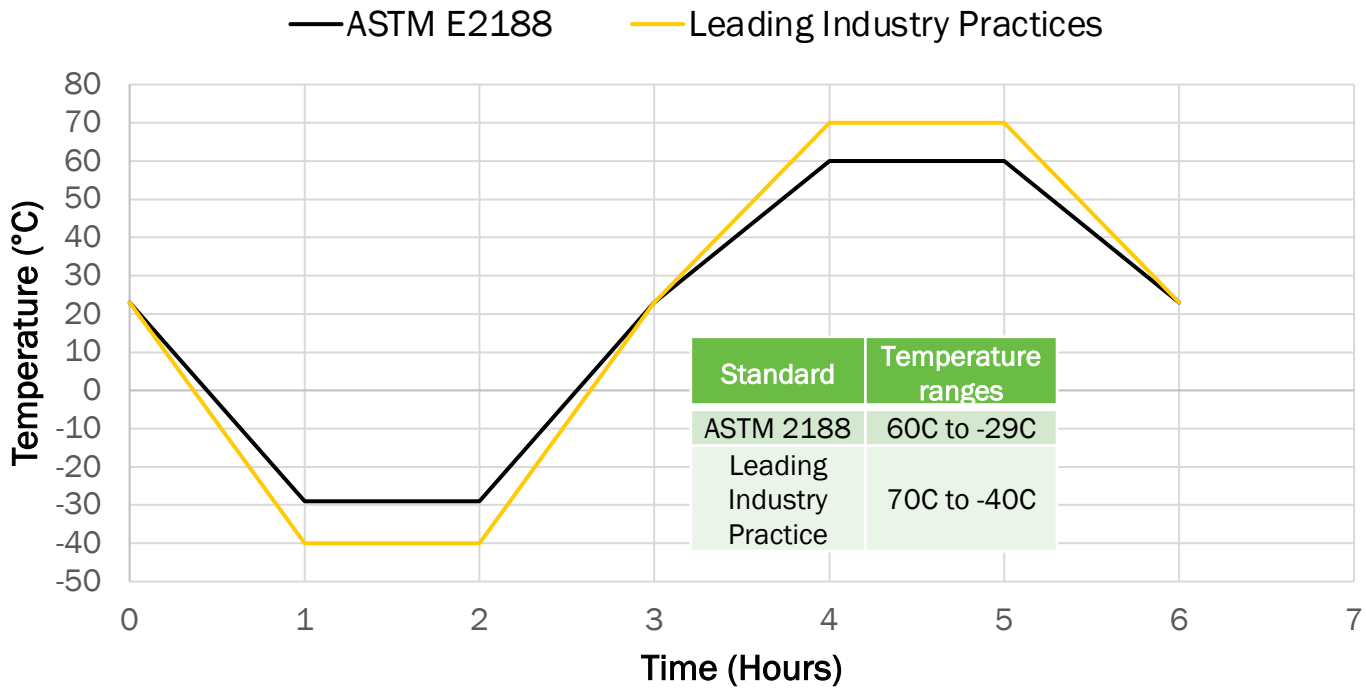
Window Energy/Emissions Reduction Impact Paths	CO_2 Emissions Reduction/Year (Mt CO_2)
Retrofit Using Existing Technologies	94,000,000
Adoption of Emerging Technologies	69,000,000

Progress: Summary of Leading Industry Practice

Working Group Meetings



Focused Discussions



Common Features to "Beyond 2188"

- Increased UV exposure duration and intensity.
- Increased thermal cycling range.
- Repeated tests to increase number of cycles.
- Incorporation of and variations in applied pressure.

Additional Metrics

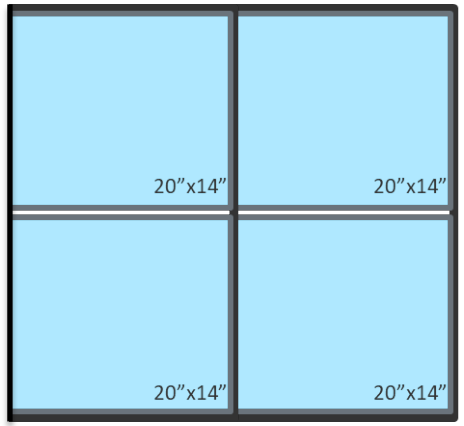
- Viewing improvement for E-2189.
- Moisture uptake in desiccant.

Progress: NREL Guideline for Enhanced Durability Evaluation of IGU and VIG

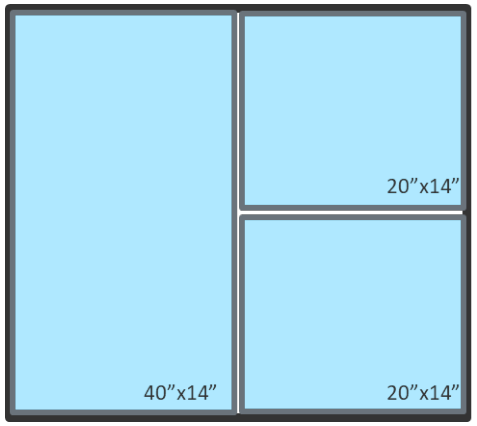
Modified Stress Factors*

Cyclic Pressure: 25 lb/ft^2
Temperature range: 70℃ to -40℃
Cycle time: 3 hours
Total Cycles: 504
Sample Sizes: IGU - 14” by 20”
VIG – 14” by 20” and 14” by 40”

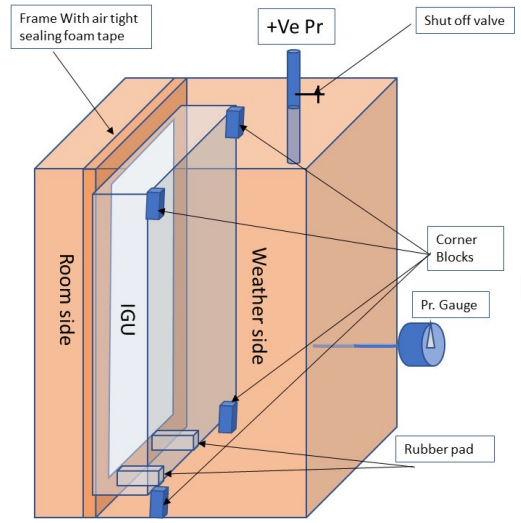
IGU Test Configuration



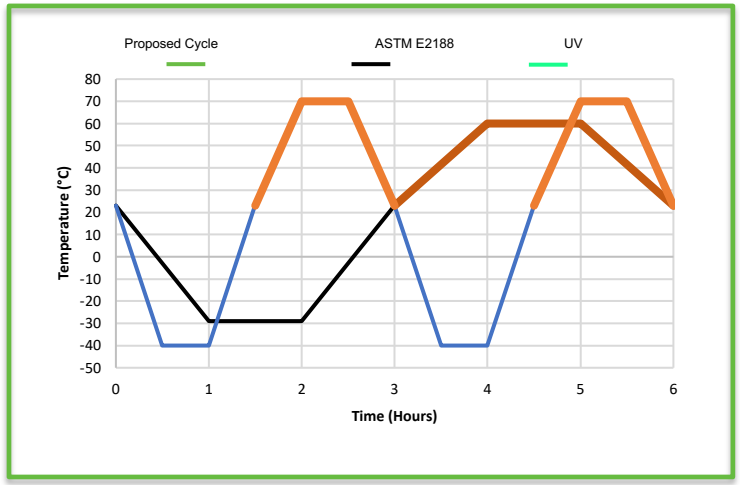
VIG Test Configuration



Initial Cyclic Pressure Test



Expanded Weather Cycling



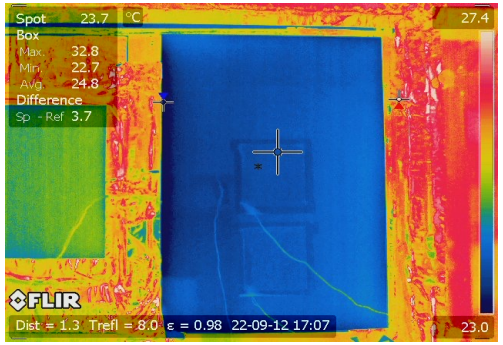
Metrics	Goal
Frost Point	Per ASTM E-2188/2190
Gas Content	Per ASTM E-2188/2190
Optical Properties	Evaluation of Coatings Degradation
Thermal Conductivity	Independent Verification of Thermal Performance
Desiccant Properties	Enables Lifetime Projection

*Compared to ASTM E-2188/E-2190

Progress: Field Evaluation of Fenestration Degradation Processes

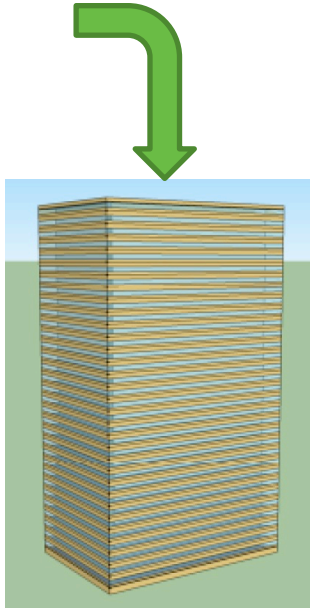
Laboratory evaluation of potential field measurements.

Modeling studies to determine energy impact of degradation.

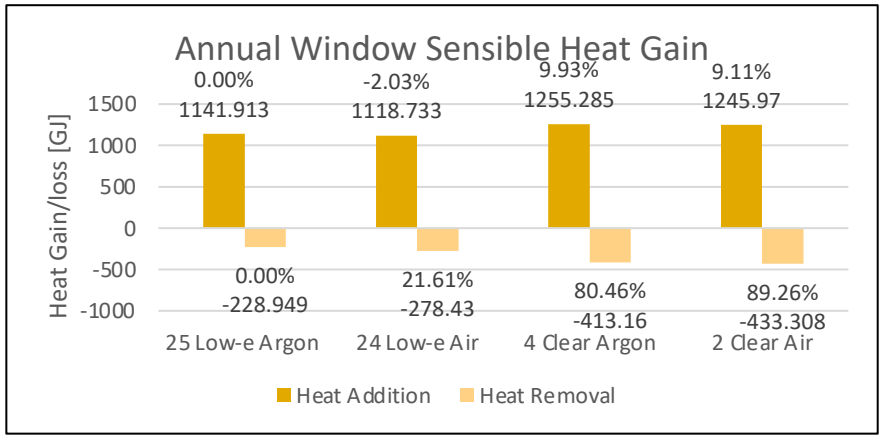


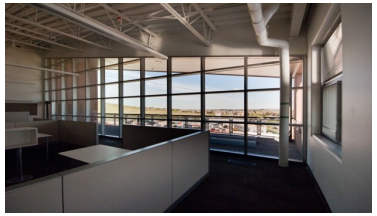
Hybrid in-situ test method

Energy and system implications of actual building element behaviors including degradation.



Whole-building energy modeling





Sites are being evaluated for initial field characterization study.

Developing Collaborations

Prof. Didem Ozevin

Prof. Aslihan Karatas

University of Illinois - Chicago

Maggie Kelley Riggins

Southeast Energy Efficiency Alliance (SEEA)

UIC – In situ window performance characterization methods.
SEEA – Field evaluation of low-income housing in southeast U.S.

Thank You

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WBS 3.1.3.16

REFERENCE SLIDES

Project Execution

	FY2023				FY2024				FY2025			
Planned budget	$600,000				600,000				$600,000			
Spent budget					TBD				TBD			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Q1 Milestone: Transfer of ASTM E-2141/E-2953 to Commercial Test Laboratory Partner												
Q2 Milestone: Webinar Presenting NREL Enhanced IGU Durability Evaluation Guideline												
Q3 Milestone: Report on Development of Electrochromic Durability Certification Paths												
Q4 Milestone: Publication of Enhanced IGU Durability Guideline												
Q1 Milestone: Report on Industry Review Feedback on Enhanced IGU Durability Guideline												
Current/Future Work												
Q3 Milestone: Report on Method Development for Field Validation of IGU Performance												
Q4 Milestone: Report on the Impact of Sample Size on Durability Evaluation of Vacuum Insulating Glass												

Team

Core Durability Team

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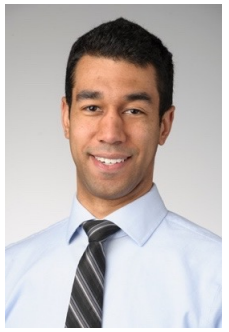

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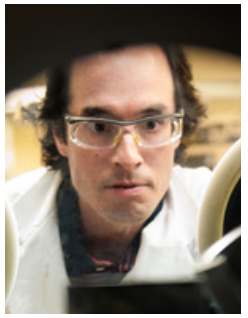

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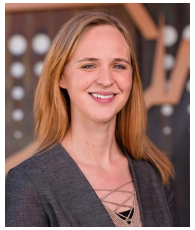

Dr. Katherine Jungjohann
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Materials Degradation Science

Multiple university, startup and large manufacturing partners
Engagement with NFRC, FGIA and ASTM