U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

BERKELEY LAB

ENERGY TECHNOLOGIES AREA

Window Attachments

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Project Summary

Timeline:

Start date: 10/1/2018

Planned end date: 9/30/2020

Key Milestones

1. Report with awnings models and algorithms ready for implementation in window software tools; 9/30/2019
2. Release CGDB database; 3/31 and 9/30/2019
3. Design experiment customized for testbed

Budget:

Total Project $ to Date:

- DOE: $600K
- Cost Share: $50K (estimated)

Total Project $:

- DOE: $1,200K
- Cost Share: $150K (estimated)

Key Partners:

AERC	PAMA
Hunter-Douglas	ESSA
Spring Fashions	NEEA
Rollease	ES-SO

Project Outcome:

Develop models and methods for the **roller shutters, awnings** and remaining window attachment **products Phase 3** from the initial plan). Support the development of **AERC rating** procedure for **commercial buildings** window attachment products. Perform **field validation** of energy performance of **exterior shading** and insulated **interior shading** in a testbed.

Team


Charlie Curcija


Christian Kohler


Robert Hart


Howdy Goudey

LBNL team is led by **Dr. Charlie Curcija**, Charlie is heat transfer expert, with extensive experience in windows and building envelope energy performance. **Christian Kohler** is Building Technologies Department Head with expertise in windows and building envelope heat transfer, and sensors and controls. **Robert Hart** is a scientist with the expertise in both modeling and measurements of heat transfer. **Howdy Goudey** is the manager of Windows group Thermal Lab, with extensive experience in the measurement of heat transfer.


Mahabir Bhandari


Simon Pallin


Andre Desjarlais


Katherine Cort


Cheryn Metzger

ORNL team is led by **Dr. Mahabir Bhandari**, R&D staff with expertise in thermal and whole building energy modeling, **Dr. Simon Palin** is R&D staff with expertise in moisture and durability analysis. **Andre Desjarlais** is the Program Manager for the Building Envelope Systems Research Program, with expertise in Heat transfer, moisture and durability.

PNNL window attachments team is led by Katherine Cort, a senior economist with over 20 years experience with building energy analysis. **Cheryn Metzger** is the PNNL Lab Homes manager, with expertise in residential building energy and **Joshua McIntosh** leads the field testing.

Challenge

Window attachments represent a **cost-effective** opportunity to save energy in **new and existing buildings**. Improved properties of window attachments will increase energy savings potential of these products. These products have the economic potential to save nearly **800 TBtus by 2030**.

High performance solutions for **residential and commercial** window attachments therefore offer large short-term energy savings potential. Due to the wide variety of window attachment solutions, energy savings can be accomplished in **all climates** by utilizing systems that reduce **heating energy**, reduce **cooling energy**, or both. These products can also reduce mechanical heating and/or cooling **system sizing** and improve indoor **thermal comfort**. Some high-performance products are available today but more rapid market adoption would be facilitated by better optimization and selection criteria, e.g. **fair performance comparison and rating labels**.

Over the past several years, we have developed models and measurement methods for 7 classes of window attachment products (developed during Phase 1). Few other product classes remained (**Phase 2** and **Phase 3**), most notably examples of exterior products, **roller shutters** and **awnings**. Also, better understanding of needs in **commercial buildings** attachment products is needed to develop effective rating and certification program.

Gain better understanding of the energy and occupant impacts of interior and exterior window attachments through **field testing and performance review**

Approach

Three national labs working with industry partners:

- Develop models and measurement methods for roller shutters, and fixed and operable awnings (Phase 2)
- Initiate development of models and methods for final group of window attachments (Phase 3)
- Measure the complex optical properties of window attachment materials.
- Explore reasons why exterior shades and particularly integral shades are not utilized much in US and Canada vs. Europe
- Perform field validation of energy performance of indoor insulated shade in a testbed and investigate heat build-up between a shade and window
- Explore value proposition for exterior attachment integration with the window system
- Perform field validation of energy performance of exterior shading in a testbed
- Provide range of solar control options that can be exploited by an automated control system
- Explore aspects of energy performance of commercial buildings window attachments to support the development of rating and certification for commercial products and also to provide aid to designers and professionals
- Engage with CBI team to develop comprehensive plan for commercial building products

Window Attachment Product Classes

Exterior attachments


Low-e Storm Window


Fixed Awning


Dynamic Awning


Roller Shutter - Window


Roller shade


Solar screen

Interior attachments


Drapes


Louvered blinds


Roller shades


Surface applied film


Cellular shade


Window quilt


Seasonal film kit

Between glass attachments (applies to non-sealed glazing systems only – applied as a retrofit option)


Louvered blinds


Roller shades


Cellular shades


Solar screens


Surface applied films

Technical Research Plan & Progress

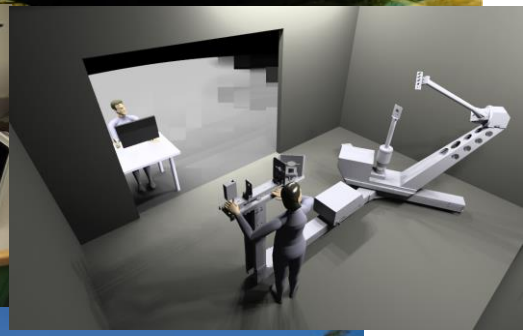
Phase	No.	Product Type		Test Procedure									Simulation - U; SHGC; VT						Simulation - EP		
				IN			OUT			BG			IN		OUT		BG		IN	OUT	BG
				T	S	O	T	S	O	T	S	O	T	S	T	S	T	S			
Phase 1	1	Cellular Shade	Research																		
			Deployable																		
	2	Slat Shade	Research																		
			Deployable																		
	3	Roller Shade	Research																		
			Deployable																		
	4	Window Panel	Research																		
			Deployable																		
	5	Pleated Shade	Research																		
			Deployable																		
	6	Solar Screen	Research																		
			Deployable																		
	7	Surface Applied Films	Research																		
			Deployable																		
Phase 2	8	Window Quilts	Research																06/19		
			Deployable																09/19		
	9	Roller Shutter	Research																	06/19	
			Deployable																	09/19	
	10	Awnings	Research					09/19								09/19				03/20	
			Deployable					03/20								12/19				06/20	
Phase 3	11	Louvered Shutter	Research																		
			Deployable																		
	12	Roman Shade	Research																		
			Deployable																		
	13	Drapes	Research																		
			Deployable																		
	14	Sheer Shade	Research																		
			Deployable																		

Currently Available
Under development
Development not started

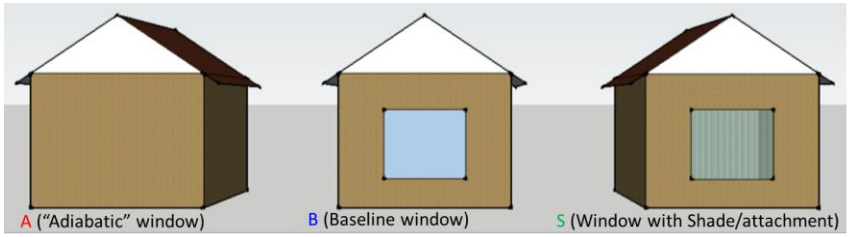
IN: Indoor mounted
OUT: Outdoor mtd.
BG: Between glazing

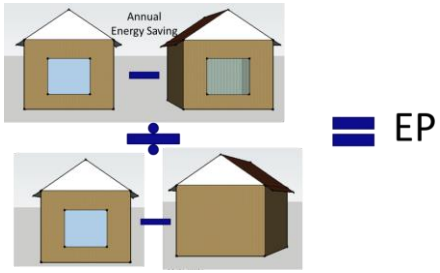
T: Thermal
S: Solar Heat Gain
O: Optical

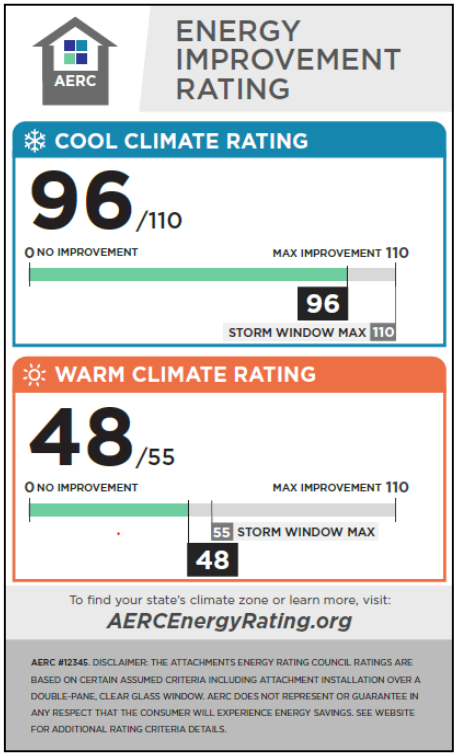
Test Facilities



Definition of Energy Performance Index (EP)







(1) EP < 0 means the attachment has negative impact on the energy performance of window ($EB_{BS} > EB_{BW}$)

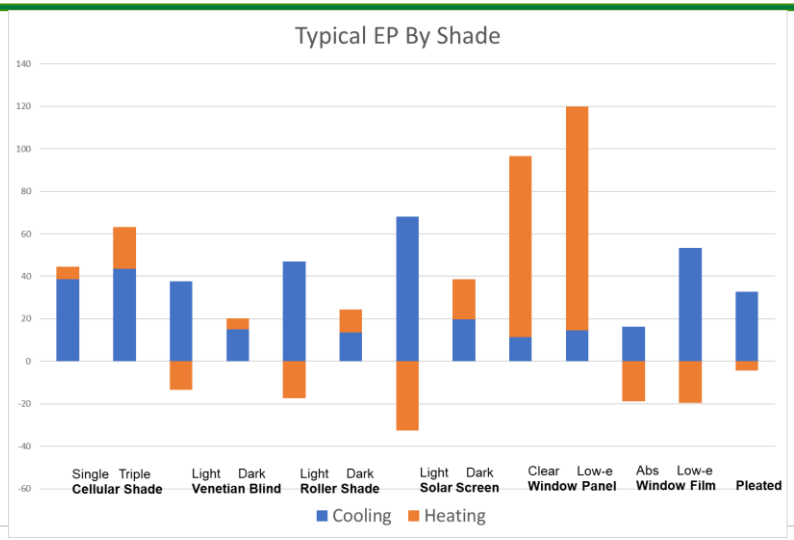
(2) EP = 0, means the attachment does not have any impact on the energy performance of window ($EB_{BS} > EB_{BW}$)

(3) 0 < EP < 1, means the attachment has positive impact on the energy performance of window and saves portion of energy ($E_{BS}<E_{BW}$); most of attachments would be in this case.

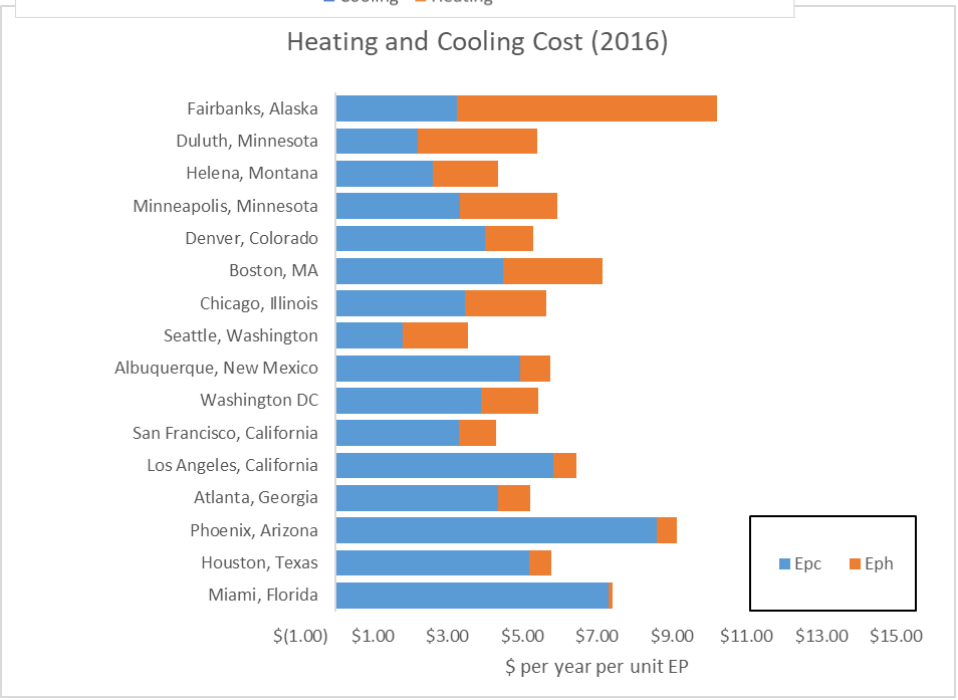
(4) EP = 1, means the attachment makes the window system a zero net energy window ($E_{BS}=E_{BN}$); in other words, window system has NO energy impact on the house.

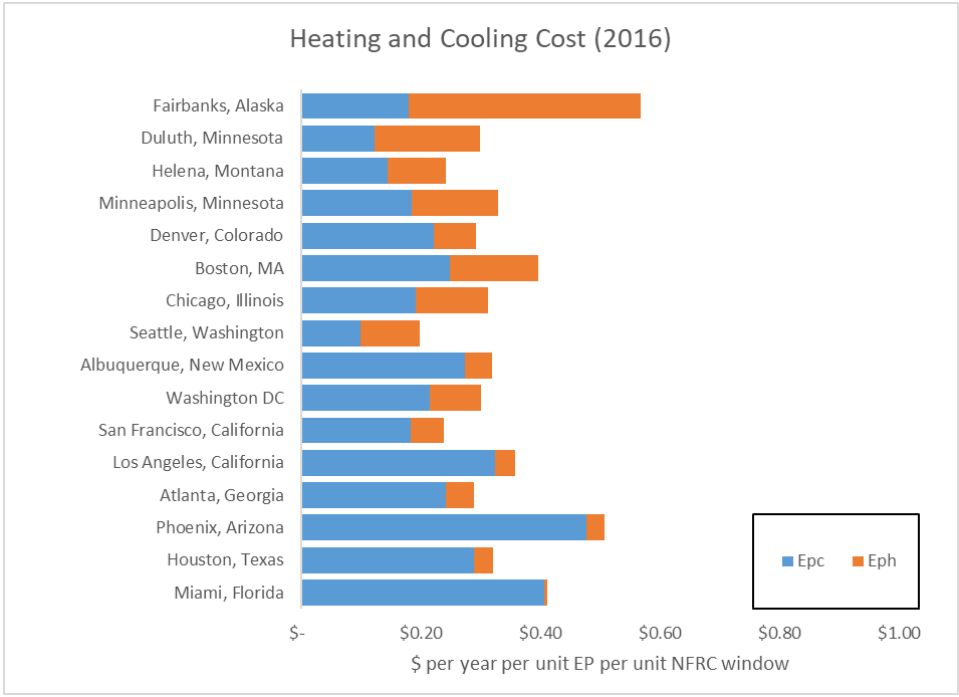
(5) EP > 1, means the attachment makes the window system a net energy-producer window ($E_{BS} > E_{BN}$); Examples are PV-integrated attachments

Attachment Energy Savings By Climate Zone



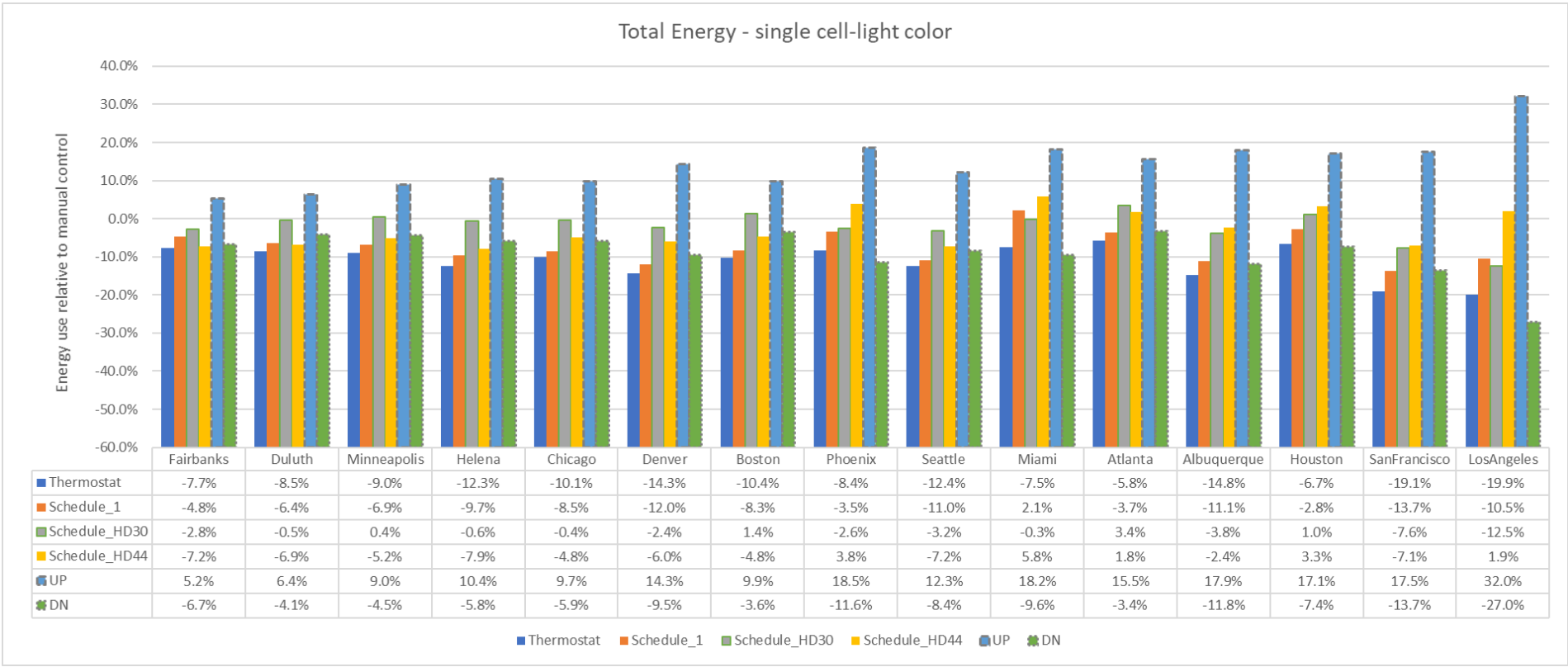
- To obtain energy savings by shade, multiply typical EP (LEFT) of the shade by Heating and Cooling savings (BELOW)





Automation Algorithms Analysis

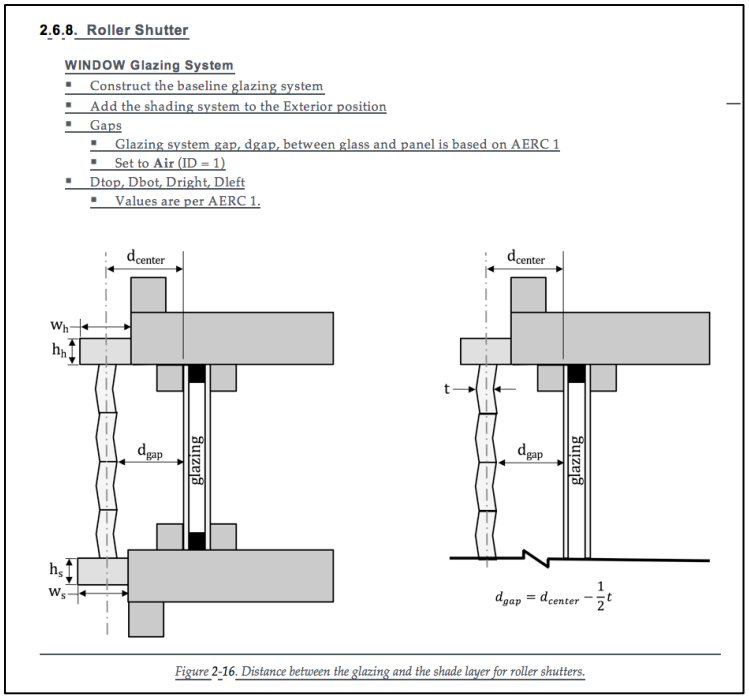
- Cellular shades with single cell configuration
- No automation (manual operation) is baseline
- Automation algorithms summary:
  - Thermostat: shades up if heating and shades down if cooling
  - Schedule 1: based on external temperature and solar radiation measurement
  - Schedule HD30, HD44: Proprietary Hunter-Douglas algorithms
  - UP, DN: Shades always up and always down



	Fairbanks	Duluth	Minneapolis	Helena	Chicago	Denver	Boston	Phoenix	Seattle	Miami	Atlanta	Albuquerque	Houston	SanFrancisco	LosAngeles
Thermostat	-7.7%	-8.5%	-9.0%	-12.3%	-10.1%	-14.3%	-10.4%	-8.4%	-12.4%	-7.5%	-5.8%	-14.8%	-6.7%	-19.1%	-19.9%
Schedule_1	-4.8%	-6.4%	-6.9%	-9.7%	-8.5%	-12.0%	-8.3%	-3.5%	-11.0%	2.1%	-3.7%	-11.1%	-2.8%	-13.7%	-10.5%
Schedule_HD30	-2.8%	-0.5%	0.4%	-0.6%	-0.4%	-2.4%	1.4%	-2.6%	-3.2%	-0.3%	3.4%	-3.8%	1.0%	-7.6%	-12.5%
Schedule_HD44	-7.2%	-6.9%	-5.2%	-7.9%	-4.8%	-6.0%	-4.8%	3.8%	-7.2%	5.8%	1.8%	-2.4%	3.3%	-7.1%	1.9%
UP	5.2%	6.4%	9.0%	10.4%	9.7%	14.3%	9.9%	18.5%	12.3%	18.2%	15.5%	17.9%	17.1%	17.5%	32.0%
DN	-6.7%	-4.1%	-4.5%	-5.8%	-5.9%	-9.5%	-3.6%	-11.6%	-8.4%	-9.6%	-3.4%	-11.8%	-7.4%	-13.7%	-27.0%

11

Roller Shutter Model



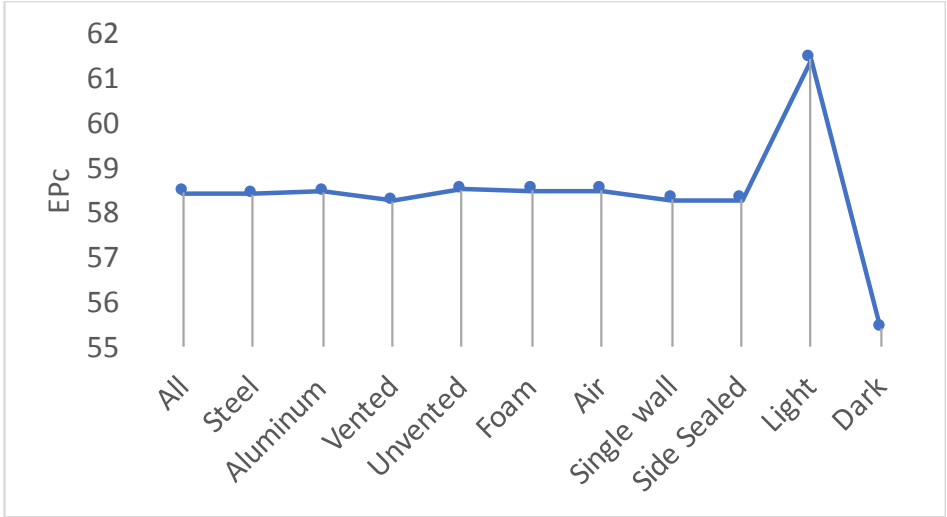
2.6.8. Roller Shutter

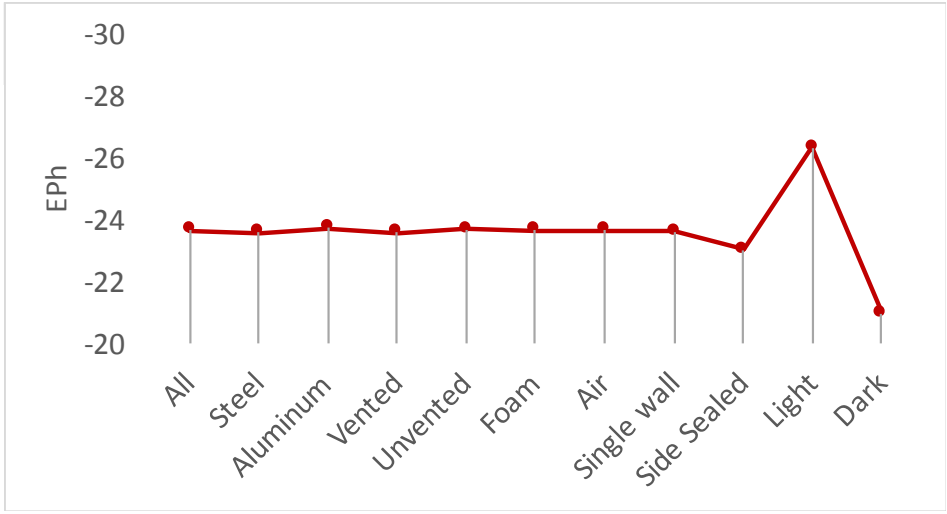
WINDOW Glazing System

- Construct the baseline glazing system
- Add the shading system to the Exterior position
- Gaps
  - Glazing system gap, dgap, between glass and panel is based on AERC 1
  - Set to **Air** (ID = 1)
- Dtop, Dbot, Dright, Dleft
  - Values are per AERC 1.

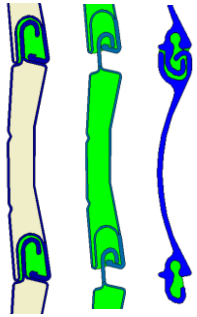
Figure 2-16. Distance between the glazing and the shade layer for roller shutters.

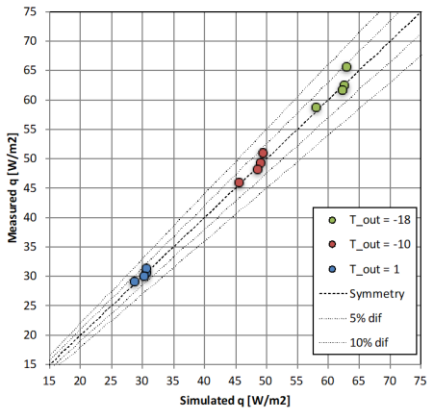
EP sensitivity analysis completed to determine AERC grouping potential





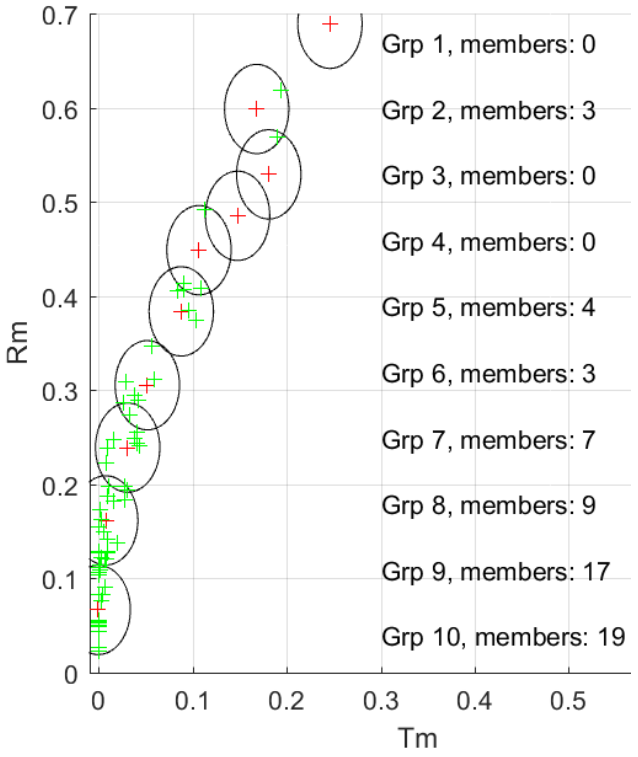
Models Implemented in WINDOW & THERM

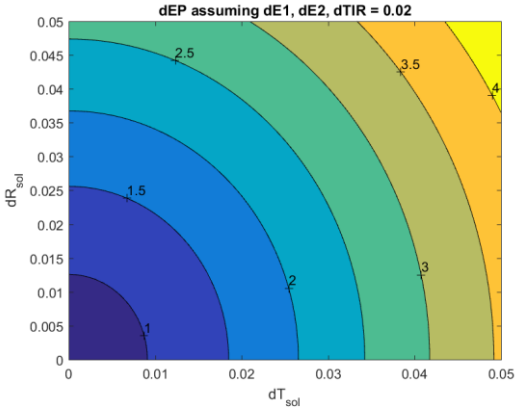




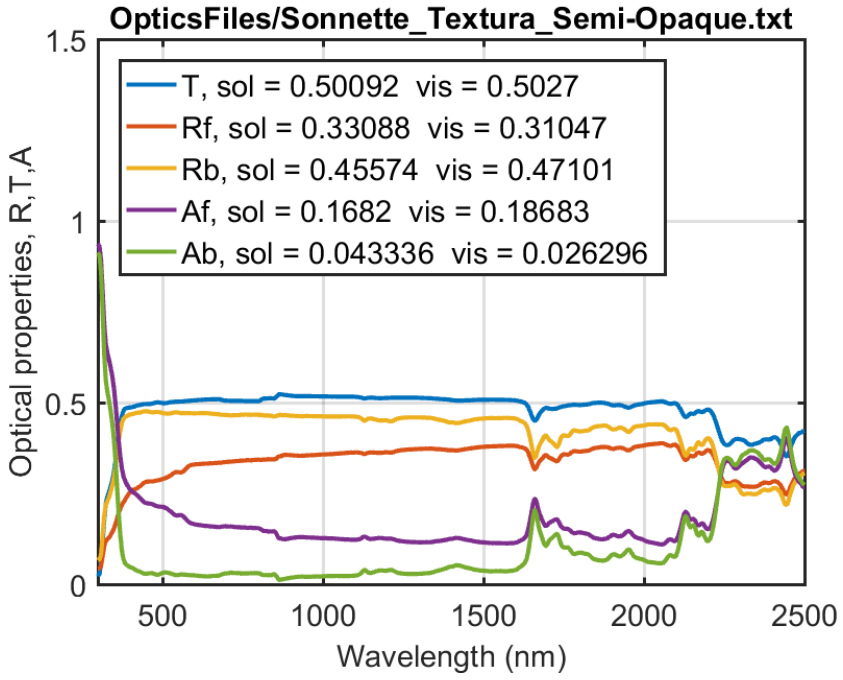
Development of Material Grouping Method

- **Measure limited properties to get a proxy for the full optical performance:**
  - Measure Transmittance and Reflectance 300-1000 nm, ε and TIR
- **Allow manufacturer to choose the "group leader"**
  - Could not choose a true worst because what is worse for EPc is not likely worst for EPh
- **Estimate the EP difference between the potential group members and the group leader:**
  - Use data from the sensitivity analysis, compute ΔEP
  - Use worst case multipliers for the sensitivity equation
- **Grouped members get a penalty of EPC -2.5 and EPH -2.5? Listed as grouped in certified product library.**





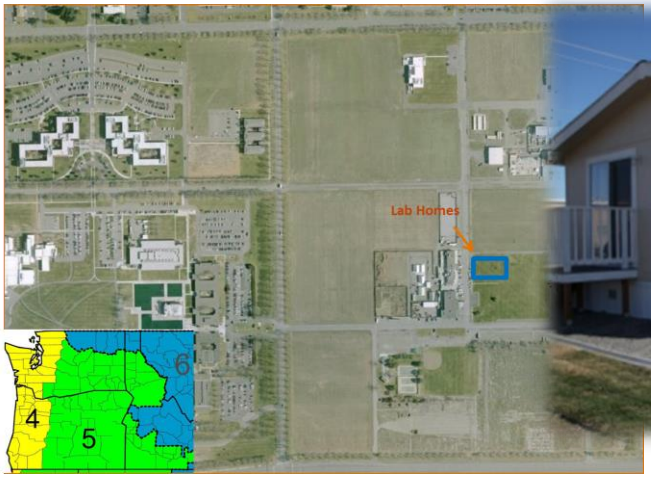
CGDB – first official submissions for AERC



Hunter Douglas(1/1)

Filename	Type	Tolerance	Tmin	Tmax	Median	Rmin	Rmax
Applause_-Opaque.txt	full	0.7642	0	0	0.924	0.918	0.927
Applause_Semi-Opaque.txt	full	11.87	0.499	0.591	0.542	–	–
Architella_Elan_-Opaque_Inner_-Cell.txt	full	0.7625	0	0	0.931	0.925	0.934
Architella_Elan_-Outer.txt	full	5.202	0.432	0.459	0.445	–	–
Architella_Elan_-Semi-Opaque_-Inner_Cell.txt	full	6.336	0.551	0.6	0.571	–	–
Architella_-Reception_Outer.txt	full	6.833	0.399	0.438	0.427	–	–
Sonnette_Elan_-Opaque.txt	partial	0.8419	0	0	0.736	0.734	0.741
Sonnette_Elan_-Outer.txt	partial	4.728	0.459	0.48	0.47	–	–
Sonnette_Elan_-Semi-Opaque.txt	partial	14.1	0.477	0.561	0.51	–	–
Sonnette_Textura_-Opaque.txt	partial	0.4532	0	0	0.736	0.735	0.738
Sonnette_Textura_-Outer.txt	partial	7.617	0.359	0.391	0.373	–	–
Sonnette_Textura_-Semi-Opaque.txt	partial	8.538	0.481	0.53	0.513	–	–

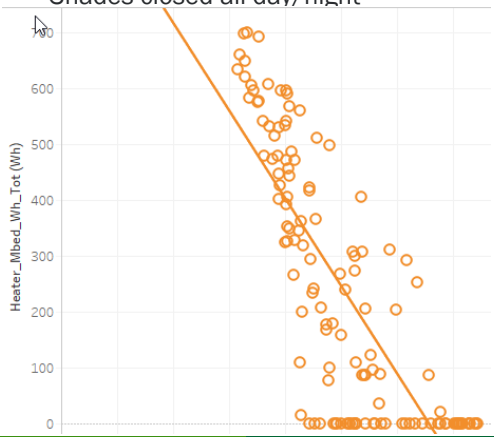
Field Measurements of Exterior Attachments



- **Energy metering**
  - 42 individually monitored breakers with ½ controllable and whole house
  - Itron smart billing meter
- **Temperature and relative humidity**
  - 15 interior room temperature thermocouples
  - 22 interior and exterior glass surface temperature thermocouples
  - 2 room relative humidity sensors
  - 2 mean radiant temperature sensors
- **Water and environment**
  - Controllable water flows at fixtures
  - Solar insolation (pyranometer) inside home
  - Site weather station
- **Data collection via 2 Campbell Scientific data loggers/home**
  - 1 minute, 15 minute, and hourly

Field Measurements of Interior Attachments

- Test house is an unoccupied house in a residential neighborhood
- south facing window (Bedroom) and a west facing window (master bath) was selected for this shade study
- Measured data for heating energy savings from a single cell cellular shade in real building
  - Spring Windows fashion
  - Most popular product was selected for the study for the highest impact and cost effectiveness
  - Inside mount – Garden retreat 3/” single cell cordless control
- Zone temperature of 72F with 1 deg dead band was maintained
- Measurements were done for 5-days each :
  - Base case : no shade
  - Shades closed at 8 pm and open at 7:30 am
  - Shades closed all day/night



South Window (30” x 60”)

West Window (34” x 34”)

Stakeholder Engagement

- **Fully engaged with shading and window attachment industry to develop infrastructure for product characterization, rating & certification, and design support**
  - Technical support to AERC – models and methods and document/standards development
  - Software tools for AERC rating and certification
  - Activities and standards development with ISO. ISO TC160, TC163, and TC205.
  - Coordination with industry organizations, domestic (WCMA) and international (ES-SO, AFRC)
  - Joint 3 yr. project with Fraunhofer-ISE, Freiburg, Germany to develop measurement methods for scattering window systems and to harmonize databases of product information
  - Industry shows and workshops (R+T Germany; IWCE, US)
- **Partners and Subcontractors**
  - PNNL – exterior shading field validation
  - ORNL – Interior shading field validation

AERC Attachments Energy Rating Council

ISO

WCMA Window Covering Manufacturers Association

ES-SO EUROPEAN SOLAR SHADING ORGANIZATION

Energy Savings & Comfort

Fraunhofer ISE

IWCE INTERNATIONAL WINDOW COVERINGS EXPO 2019 NASHVILLE, TN · March 8-10

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Remaining Project Work

- **Phase 2 of the development of models and methods for window attachments**
  - Non-coplanar shading devices (e.g., awnings)
  - Update software tools to handle awnings
- **Phase 3 of the development of models, methods and tools for window attachments**
  - Louvered shutters, drapes, etc.
  - Update software tools for these products
- **Continue technical support for residential attachments rating & certification**
- **Develop methods and procedures to select, rate and aid in design of commercial window attachments**
  - Indices of performance (energy, daylighting, comfort), databases, tools
- **Field measurements of exterior window shading**
  - Complete measurements that have started (ORNL) and initiate other measurements (PNNL)
  - Review early data and make adjustments to measurement plan and process
  - Complete measurements and reduce measurement data for reporting and use in modeling
  - Model energy performance in EnergyPlus and calibrate with measured data
  - Extend EnergyPlus models to all of typical climate zones
  - Explore reasons for minimal presence of exterior shading in US and propose further actions
  - Investigate potential for heat build-up in insulating interior shades

Thank You

ENERGY TECHNOLOGIES AREA

LBNL **ORNL,** **PNNL**

D. Charlie Curcija, Staff Engineer, Mahabir Bhandari, Scientist; Cheryn Metzger, PI

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REFERENCE SLIDES

LBNL Project Budget

Project Budget: $600K. Estimated to be $1,800K over 3 years
Variances: None
Cost to Date: $55K
Additional Funding: $10K for samples from shading manufacturers

Budget History					
New		FY 2019 (current)		FY 2020 – FY2021 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
NA	NA	$600K	$50K	$1,200K	$100K

Project Plan and Schedule