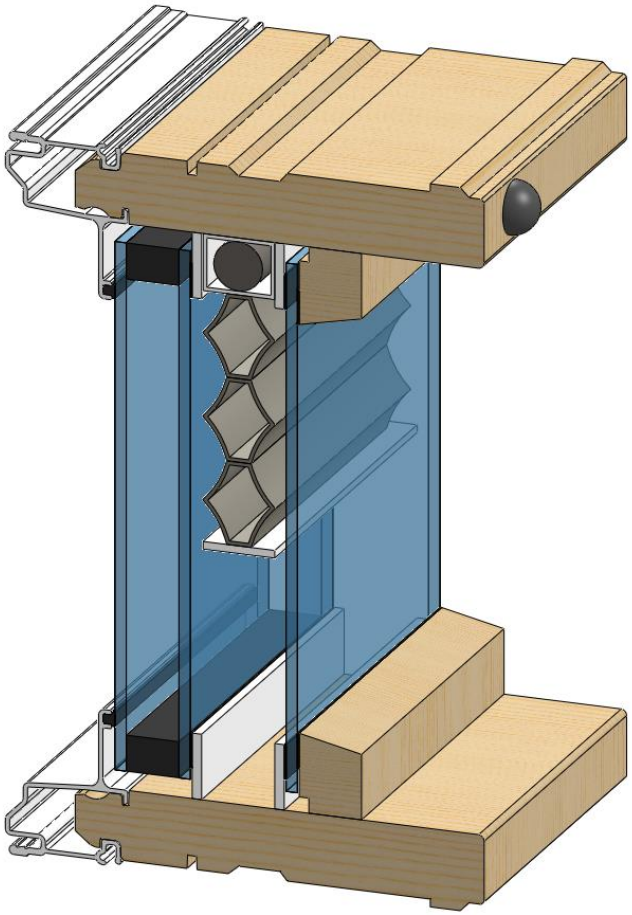
Highly insulating Residential Windows Using Smart Automated Shading

2015 Building Technologies Office Peer Review



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

Project Summary

Timeline:

Start date: 04/01/2013

Planned end date: 03/31/2016

Key Milestones

1. Measured thermal performance of static prototype windows is within 0.03 Btu/hr-ft2F (NFRC tolerance) of design specifications 09/30/2014
2. Operational prototype that is autonomous, networked, durable and reliable. Passes Pella's internal Performance & Material Testing Criteria for Motorized Shades 12/31/2014

Budget:

Total DOE $ to date: $861K (Start – Dec 2014)

Total future DOE $: $538K (Jan 215 – End)

Target Market/Audience:

Initial design is focused on window manufacturers targeting residential, cold climate applications but it can be modified for all US climates and for commercial sector.

Key Partners:

Pella Corporation	

Project Goal:

Create highly insulating residential windows with integrated sensors, control logic and motorized shades. The default control algorithm in these windows will minimize heating and cooling energy consumption by allowing solar gains when beneficial, and blocking solar gains at other times to reduce cooling loads.

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Purpose and Objectives

Problem Statement: Current window products are static and have R-values around R-3. Current trend for static properties with low U and low SHGC is not optimum for many northern climates. Shades added to most windows are manually operated by home owners in an inefficient manner. Complexity of home automation integration of all components is still a market challenge.

Target Market and Audience: Heat transfer through windows in all buildings accounts for ~4 Quads of annual energy use (10% of total buildings energy use), and add substantially to the peak cooling load of buildings. Window manufacturers are beginning to offer motorized shading devices but without any sensors or energy optimized control algorithms. A highly insulating, dynamic window that is reliably controlled can dramatically reduce the heating and cooling energy associated with windows.

Impact of Project: Planned outcome (a) create economically viable, proof-of-concept prototypes; (b) assess measured energy savings and occupant reaction in a house with Smart Windows, (c) publish energy optimized algorithms, (d) work on building energy codes recognition for dynamic products, (e) publish a Smart Window API and (f) help our partner and other manufacturers bring products to market that incorporate these features. Achievement can be measured in number of different companies that develop product lines that incorporate similar “smart” window features and a future shift from “static” solutions to “intelligent” solutions for next-gen windows.

Approach

Approach: Create a highly insulating window with a high solar heat gain unshaded state, a motorized shade, integrated sensors and a 'brain' with internet access. This window will significantly reduce heating and cooling energy consumption of a home compared to standard ENERGY STAR windows. The shade is motorized and automated, rather than relying on manual user control (but allows user override). It will work autonomously with no special setup or be part of whole building networked system.

Key Issues:

- Glazing package with high SHGC but with low U
- Shade thermal and optical properties and window temperature impacts
- Power supply options
- Sensor integration and control sequence of operations
- Autonomous and networked intelligence

Distinctive Characteristics:

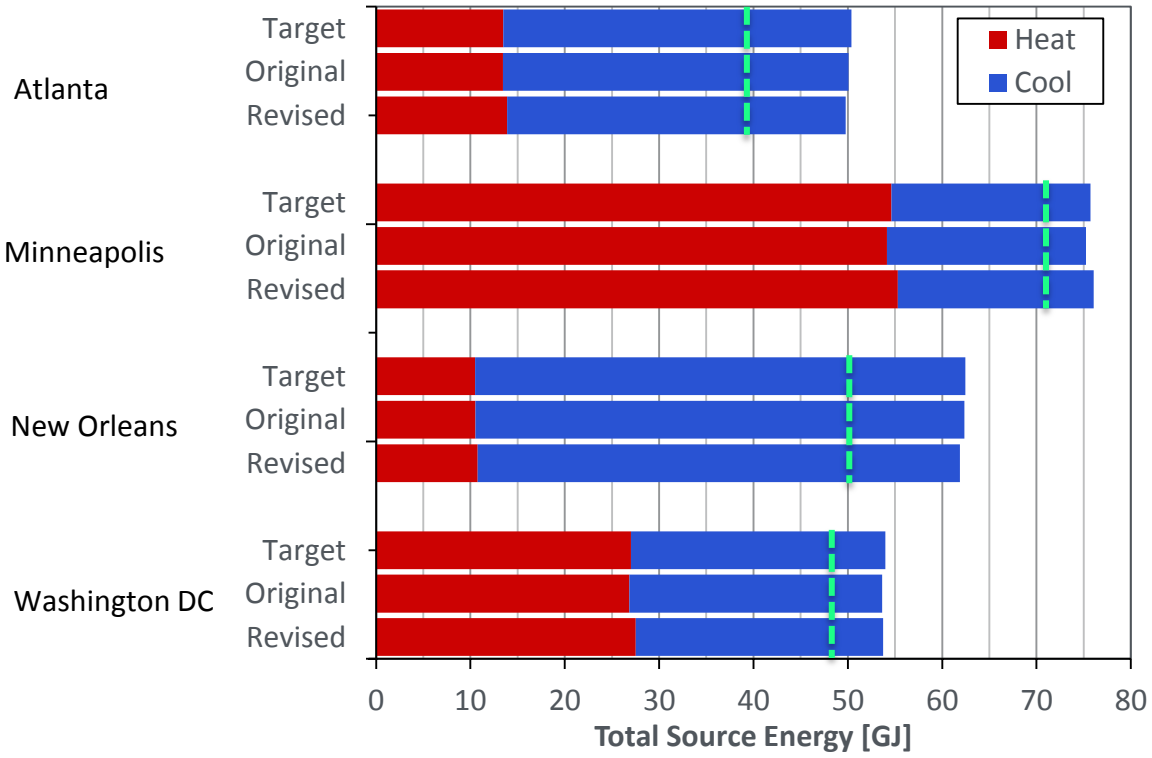
- Stand alone window, works without whole house automation system
- Shade between glass provides better solar control, lower maintenance
- Complete integration ensures no extra cost in window installation, and less chance of installation/setup mistakes.
- Platform for further feature development

Window Design and Predicted Energy Savings

FY13 DOE BTO Peer Review

Refocused Hi-R window to simpler, cheaper design with net energy focus

	U-factor [Btu/h-ft^2-F]	SHGC – UP [-]	SHGC –DWN [-]
Original	0.14	0.45	0.18
Revised	0.21	0.42	0.15



Energy savings potential impact is **minimal**

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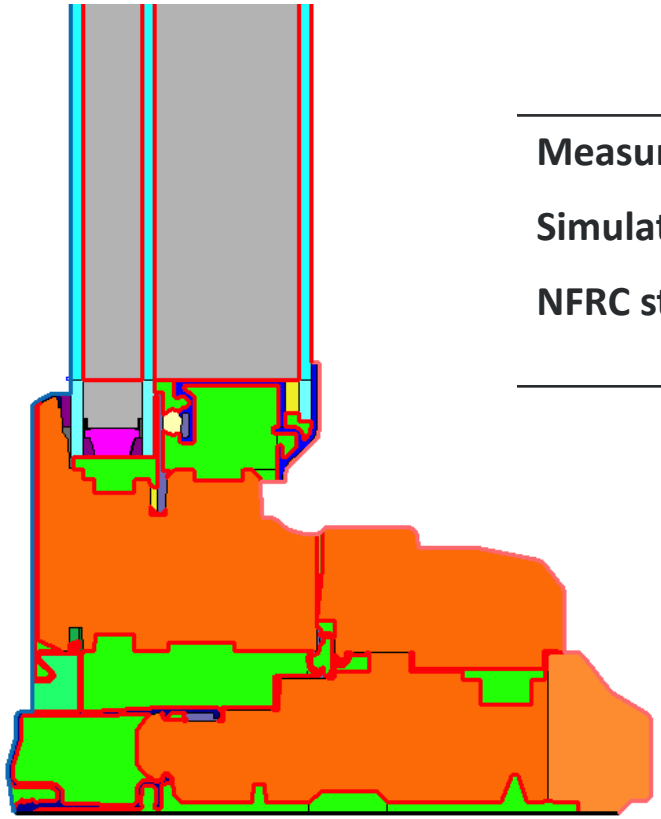
U-factor and SHGC validation

Deliverable

NFRC simulation & validation



		U-factor [Btu/h-ft^2-F]		SHGC [-]	
	Size [in]	Shade UP	Shade DWN	Shade UP	Shade DWN
Measured	36 x 48	-	-	0.35	0.13
Simulated	36 x 48	0.22	0.22	0.36	0.14
NFRC std	47 x 59	0.21	0.19	0.42	0.15

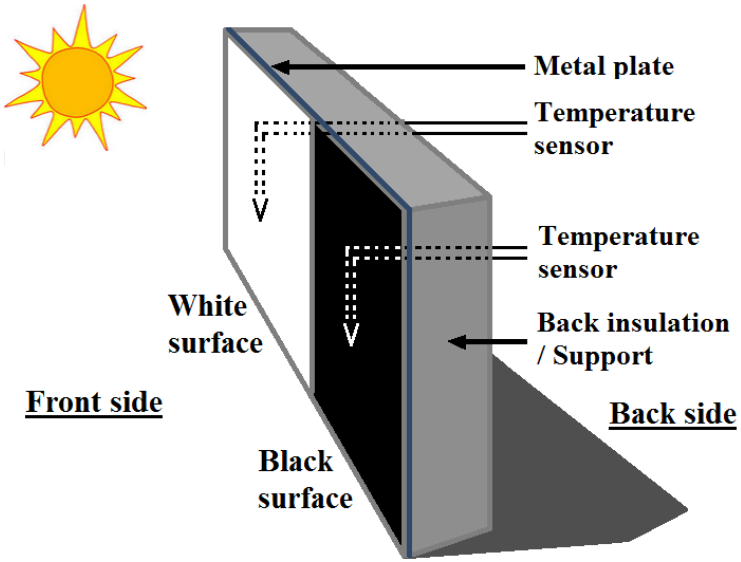
Sensor Development

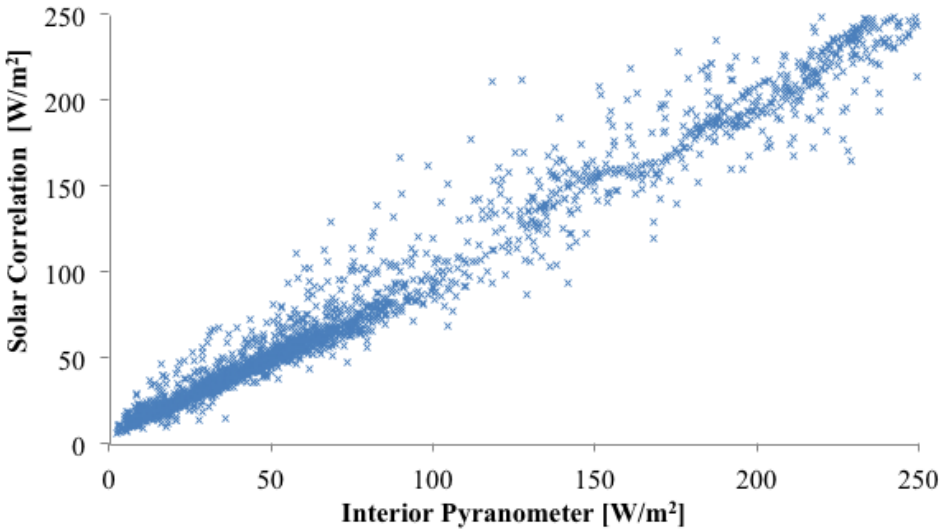
Indoor Temperature

Outdoor Temperature

Solar heat gain

Occupancy





Black/White solar sensor
low cost thermistors
independent of spectral profile
installed between glass

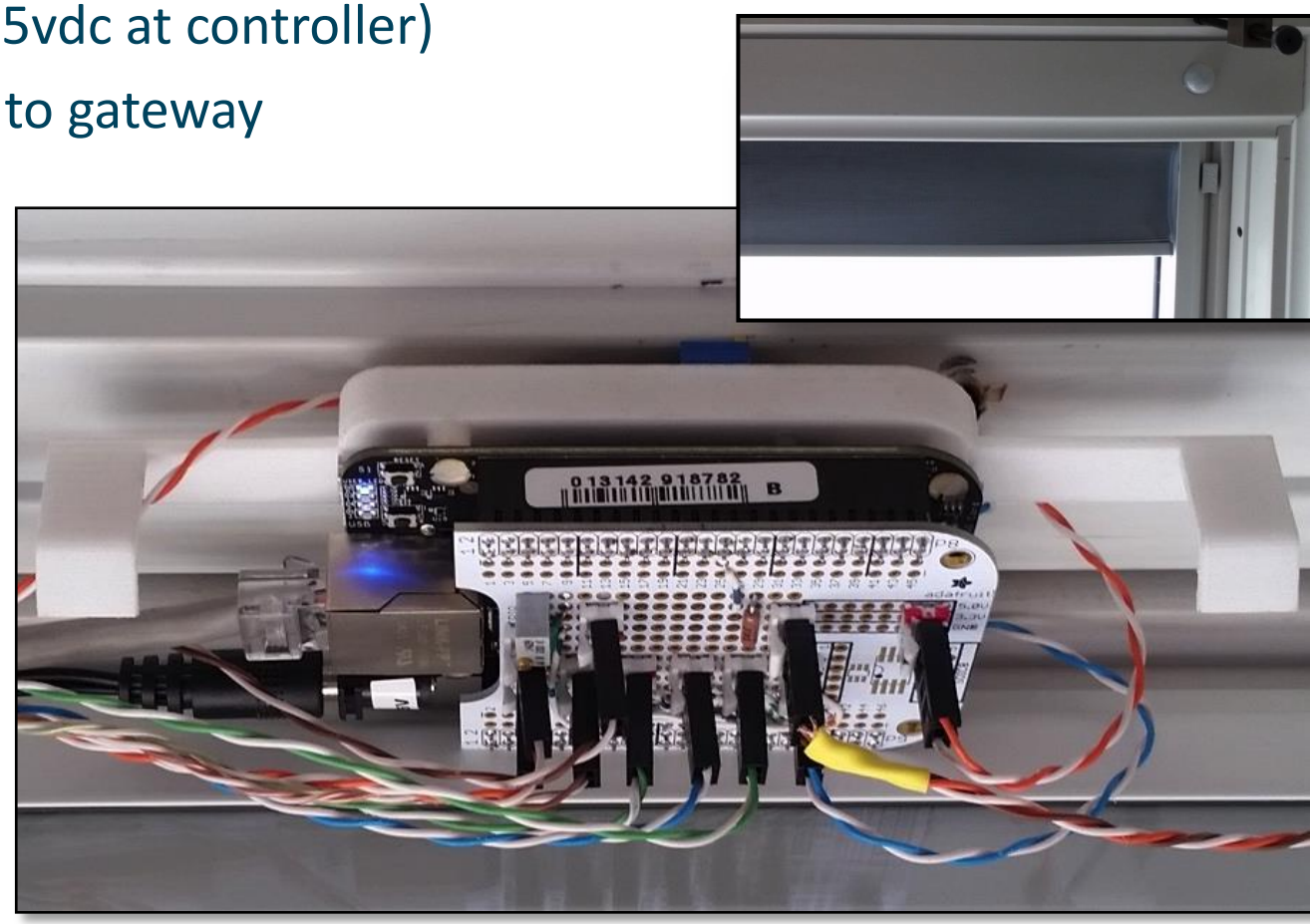
Control system

Acts external to Pella's current system

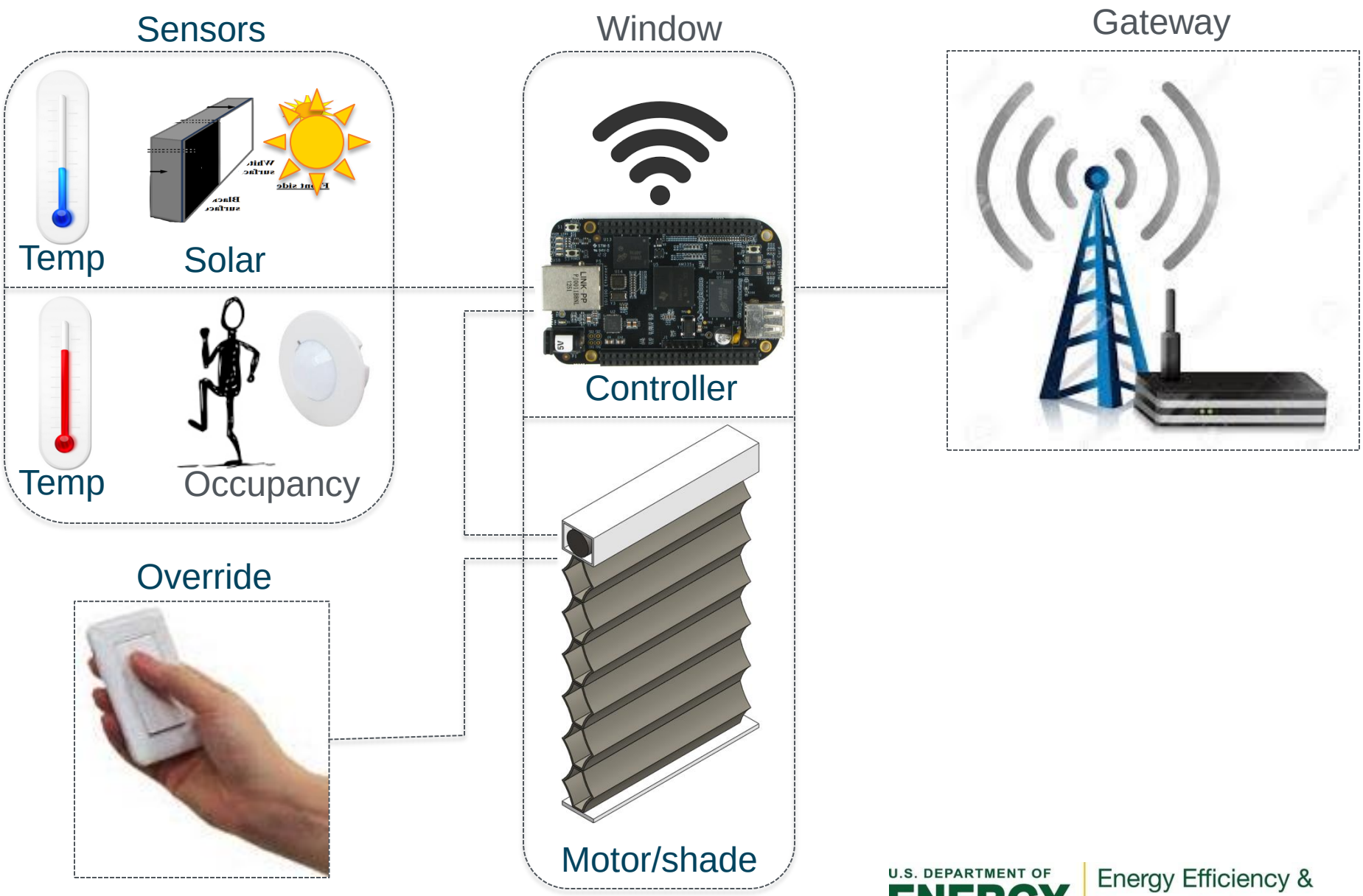
Serial connection to Pella motor

Powered by 120vac (5vdc at controller)

Wireless connection to gateway

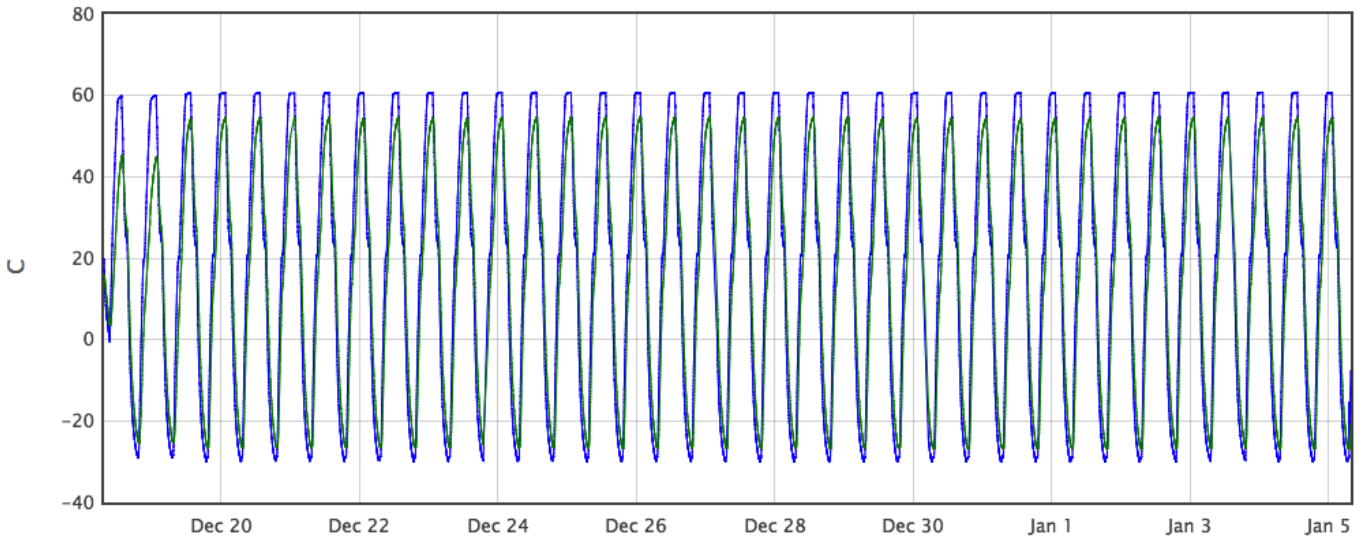


Communication system



Durability testing of window and sensor package

7 testing standards
Pella internal qualification of products (most incorporate ASTM stds)
3 months of testing



140°F

-22°F

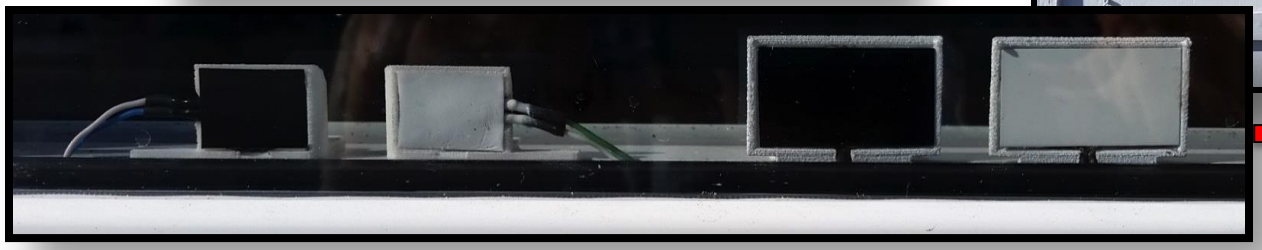
- Frost Resistance
- Solar Stress
- **Hot/Wet/Cold Cycles**
- Polymer Fogging
- Packaging Durability – Vibration
- Packaging Durability – Tip, Drag, Drop
- Standard Salt Fog Cabinet

Product testing

Currently testing in 2 locations

- LBNL (MoWiTT)
- Pella, IA

Revising sensor designs based on durability results



Field testing

For more flexibility, split survey and testing
- Testing in MoWiTT
- Occupancy surveys in homes

User survey

Part 3. Automated shading operation

1. Indicate the rooms and orientations of windows that have the Pella automated shading system installed as part of this study. If there are no automated shades or you do not have a given room in your home mark N/A.

	North	Northeast	East	Southeast	South	Southwest	West	Northwest	N/A
Master Bedroom	o	o	o	o	o	o	o	o	o
Living room	o	o	o	o	o	o	o	o	o
Family room	o	o	o	o	o	o	o	o	o
Kitchen	o	o	o	o	o	o	o	o	o
Dining room	o	o	o	o	o	o	o	o	o

2. Approximately how often do you override each shade state by manually changing its position per week? If there are no automated shades or you do not have a given room in your home mark N/A.

	Never	1-2	3-4	5-6	7-8	9-10	>10	N/A	Don't know
Master Bedroom	o	o	o	o	o	o	o	o	o
Living room	o	o	o	o	o	o	o	o	o
Family room	o	o	o	o	o	o	o	o	o
Kitchen	o	o	o	o	o	o	o	o	o
Dining room	o	o	o	o	o	o	o	o	o

3. Indicate the time of day when you typically override each shade state by manually changing its position. Select all that apply. If there are no automated shades or you do not have a given room in your home mark N/A.

	Never	Morning	Mid-day	Afternoon	Evening	Night	N/A	Don't know
Master Bedroom	o	o	o	o	o	o	o	o
Living room	o	o	o	o	o	o	o	o
Family room	o	o	o	o	o	o	o	o
Kitchen	o	o	o	o	o	o	o	o
Dining room	o	o	o	o	o	o	o	o

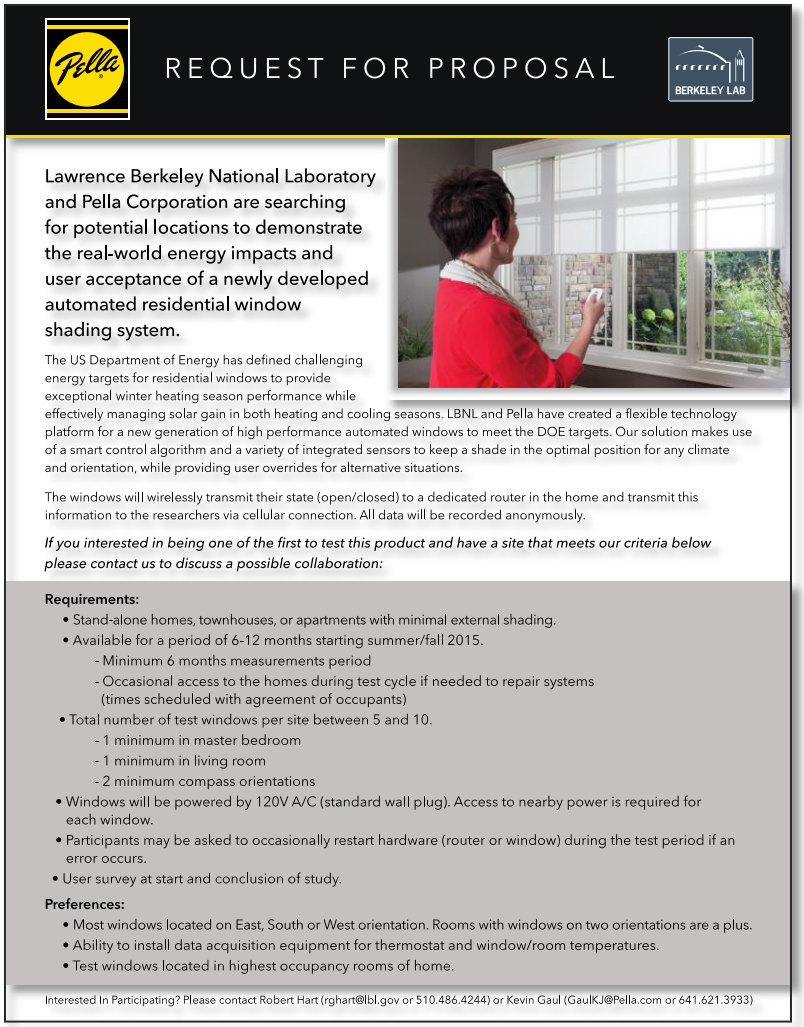
4. Indicate your reasons for overriding each shade state by manually changing its position. Select all that apply. If there are no automated shades or you do not have a given room in your home mark N/A.

	View	Privacy	Glare	Too bright	Too dark	Too hot	Too cold	N/A	Other
Master Bedroom	o	o	o	o	o	o	o	o	o
Living room	o	o	o	o	o	o	o	o	o
Family room	o	o	o	o	o	o	o	o	o
Kitchen	o	o	o	o	o	o	o	o	o
Dining room	o	o	o	o	o	o	o	o	o

If other is marked above please explain:_____

Part 4. Automated shading experience

1. Overall, how satisfied are you with the Pella automated shade windows?
   - o Not at all satisfied
   - o Somewhat satisfied
   - o Satisfied
   - o Very satisfied
   - o Delighted



REQUEST FOR PROPOSAL

BERKELEY LAB

Lawrence Berkeley National Laboratory and Pella Corporation are searching for potential locations to demonstrate the real-world energy impacts and user acceptance of a newly developed automated residential window shading system.

The US Department of Energy has defined challenging energy targets for residential windows to provide exceptional winter heating season performance while effectively managing solar gain in both heating and cooling seasons. LBNL and Pella have created a flexible technology platform for a new generation of high performance automated windows to meet the DOE targets. Our solution makes use of a smart control algorithm and a variety of integrated sensors to keep a shade in the optimal position for any climate and orientation, while providing user overrides for alternative situations.

The windows will wirelessly transmit their state (open/closed) to a dedicated router in the home and transmit this information to the researchers via cellular connection. All data will be recorded anonymously.

If you interested in being one of the first to test this product and have a site that meets our criteria below please contact us to discuss a possible collaboration:

Requirements:

- Stand-alone homes, townhouses, or apartments with minimal external shading.
- Available for a period of 6-12 months starting summer/fall 2015.
  - Minimum 6 months measurements period
  - Occasional access to the homes during test cycle if needed to repair systems (times scheduled with agreement of occupants)
- Total number of test windows per site between 5 and 10.
  - 1 minimum in master bedroom
  - 1 minimum in living room
  - 2 minimum compass orientations
- Windows will be powered by 120V A/C (standard wall plug). Access to nearby power is required for each window.
- Participants may be asked to occasionally restart hardware (router or window) during the test period if an error occurs.
- User survey at start and conclusion of study.

Preferences:

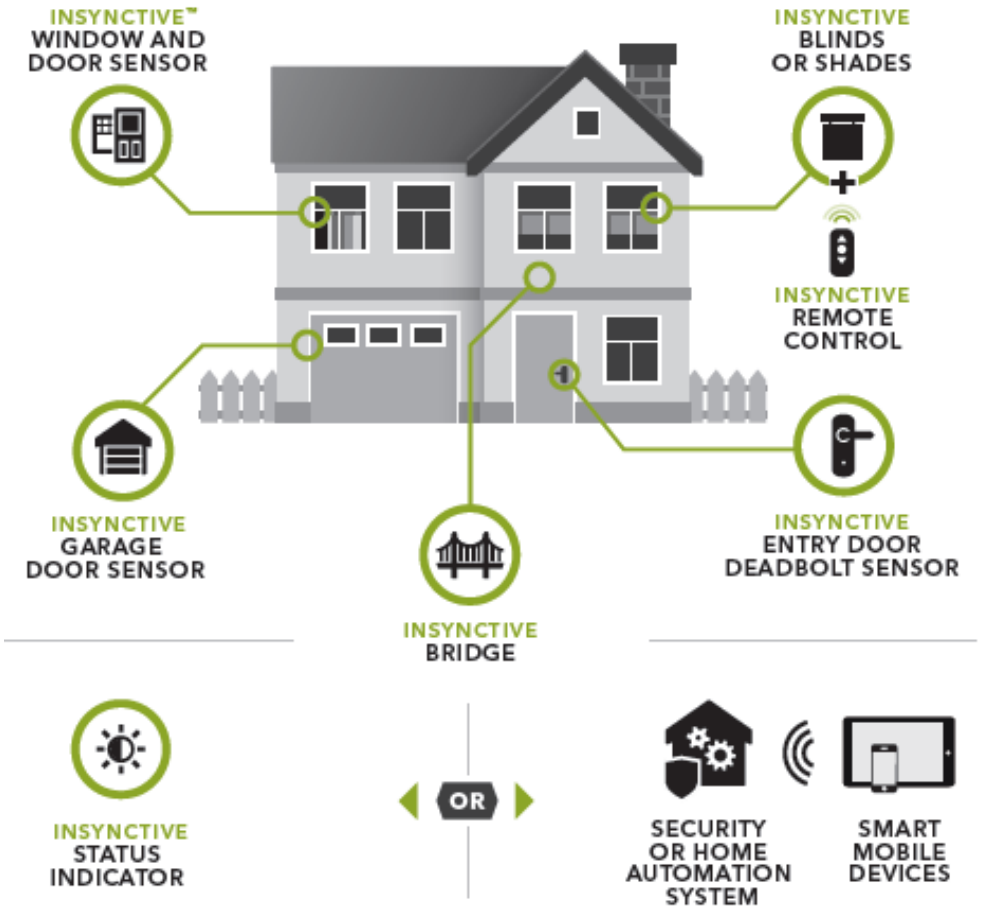
- Most windows located on East, South or West orientation. Rooms with windows on two orientations are a plus.
- Ability to install data acquisition equipment for thermostat and window/room temperatures.
- Test windows located in highest occupancy rooms of home.

Interested In Participating? Please contact Robert Hart (rghart@lbl.gov or 510.486.4244) or Kevin Gaul (GaulKJ@Pella.com or 641.621.3933)

Call for locations

New Pella Product Lines: Insynctive Devices Ecosystem

Ecosystem



Consumer Benefits

SECURITY

COMFORT

CONVENIENCE

Provides Benefits Customers are Looking For

Market Impact – Pella

Motorized

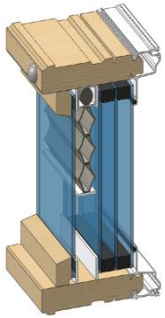
Motorized Shade Solutions

Bali your home, your style

Pella

somfy

Motorized and Integrated



Pella

Wireless

Integrated

Motorized

Traditional Windows

Andersen AW WINDOWS • DOORS

Pella

MARVIN Windows and Doors Built around you.

Milgard WINDOWS & DOORS

Integrated Shades

ODL

Pella

Integrated

Progress and Accomplishments

Lessons Learned:

- Response to our call for test locations has been low due to our strict requirements. Therefore we have revised our original field test plan (FY16) into a two-pronged approach of energy saving and user interaction.

Accomplishments:

- Revised focus and window design based on FY13 DOE BTO Peer Review – softened focus on highly insulating windows to reduce cost at no energy impact
- Completed all design optimization and energy impact studies
- Hackathon- demonstrated value of open API for new apps
- Tested static window to validate U-factor and SHGC simulations
- Tested automated window with focus on sensor package
- Completed durability testing of sensor package
- Developed user testing survey

Market Impact:

- Expands Market pull from “Comfort/Amenity” to include Energy
- Takes powered shades (integrated and non-integrated) to a new place
- Ability to interact with other smart products and systems
- Change the energy discussion away from static numbers
- Formation of “Dynamic Systems” advisory group has begun-assure market acceptance of operable systems, Energy Star, Codes, etc
- Partnering with major window manufacturer for impact

Project Integration and Collaboration

Project Integration: LBNL project staff is actively engaged with key industry partner, Pella; exploring other related smart window projects, working with other sensors and controls projects at LBNL/DOE and closely following the home automation and integration market and integrating with products such as the Nest thermostat, Philips Hue LED, many other market players.

Partners, Subcontractors, and Collaborators: Bi-weekly conference calls with our industry partner Pella Windows (2nd largest window manufacturer in US). Pella is building the prototypes and collaborating on sensor placement, marketing issues, cost etc. Approached by other major window suppliers to test other automated shading options. UC Berkeley Haas Business School team spent 500 hours on market study and willingness-to-pay.

Communications: Presentations at window industry and utility events: NFRC, Façade Tectonics, CEE, AAMA, WDMA, GANA, and at UC Berkeley's Cleantech 2 Market, AEC Hackathon at Facebook.

Next Steps and Future Plans

Next Steps and Future Plans:

- Create networked prototypes - links to other windows
- Work with advisory group to ensure “recognition” and “credit” for dynamic products in Energy Star Most Efficient category, codes and standards.
- Engage with industry to push for interoperability
- Test Smart Windows running in energy saving mode with MoWiTT facility to validate predicted energy savings.
- Test Smart Windows running in occupied homes to determine real world user interaction and acceptance of the product.

REFERENCE SLIDES

Project Budget

Project Budget: $1,400k total budget for 3 year project
Variances: None
Cost to Date: $861K (Start – Dec 2014)
Additional Funding: None

Budget History					
April 1 2013 – FY2014 (past)		FY2015 (current)		FY2016 – March 31 2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$757k	$27k	$474k	$40k	$169k	$0

Project Plan and Schedule (add milestones for fy16?