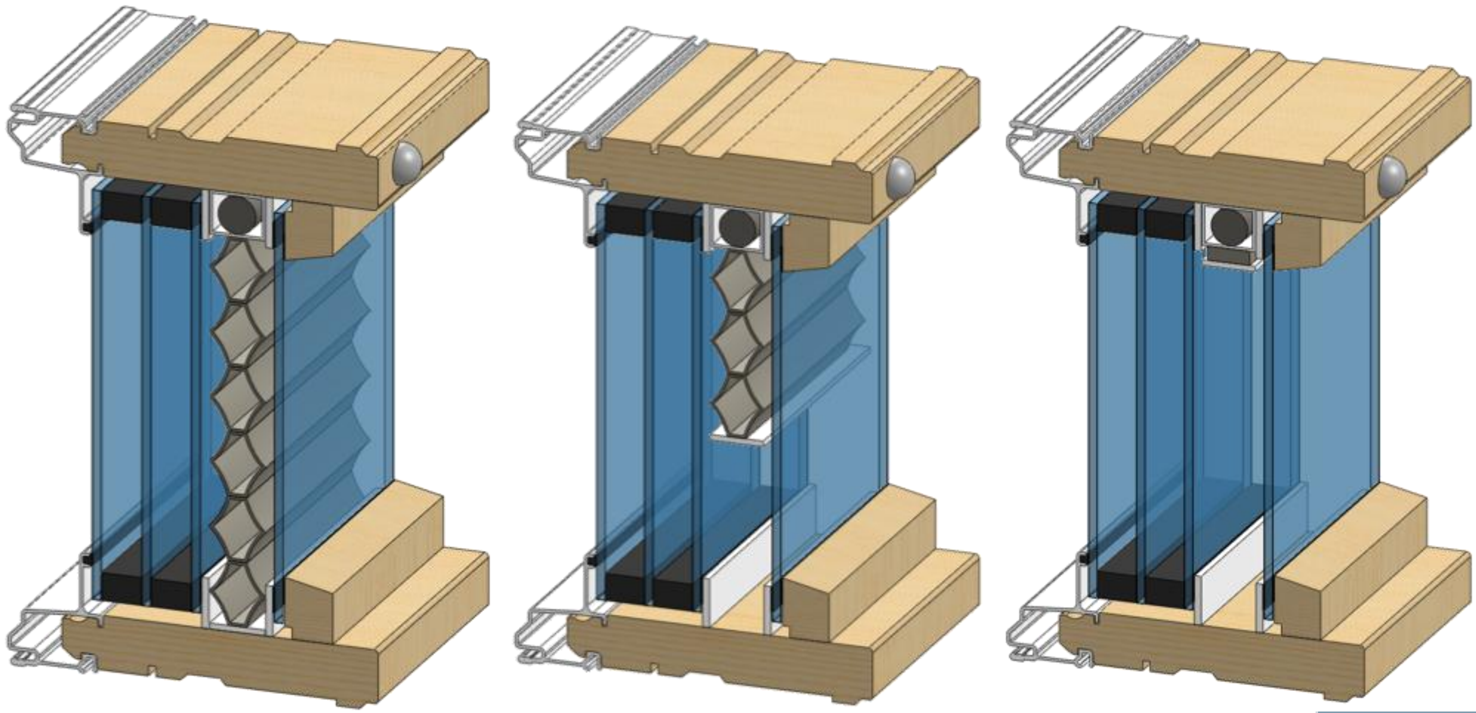
Highly insulating Residential Windows Using Smart Automated Shading

2014 Building Technologies Office Peer Review



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Project Summary

Timeline:

Start date: 4/1/2013

Planned end date: 3/31/2016

Key Milestones

1. Window designs meeting FOA targets 9/30/2013
2. Prototype window with integrated sensors, ENERGY STAR level performance 12/31/2013

Key Partners:

Pella Windows	

Budget:

Total DOE $ to date: $783k (FY13-FY14)

Total future DOE $: $617k (FY15-FY16)

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. Optimized performance from links to utility meter, home automation, thermostat, internet data, etc

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.

Purpose and Objectives

Problem Statement: Current window products are static and have R-values around R-3. Shades added to windows are manually operated by home owners in an inefficient manner.

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 can dramatically reduce the heating and cooling energy associated with windows.

Impact of Project: Planned outcome is (a) to create economically viable, proof-of-concept prototypes; (b) to show **measured** energy savings in a real house with SmartWindows, (b) publish energy optimized **algorithms**, (c) work on building **energy codes** recognition for dynamic products, (d) publish a SmartWindow **API** and (e) 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 these 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)

Key Issues:

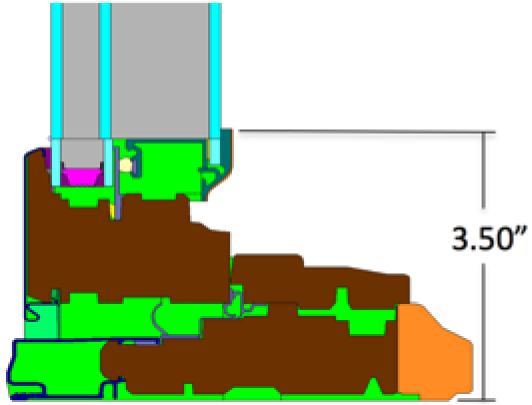
- Glazing package with high SHGC but with low U
- Sensor integration and control sequence of operations
- Autonomous and networked intelligence

Distinctive Characteristics:

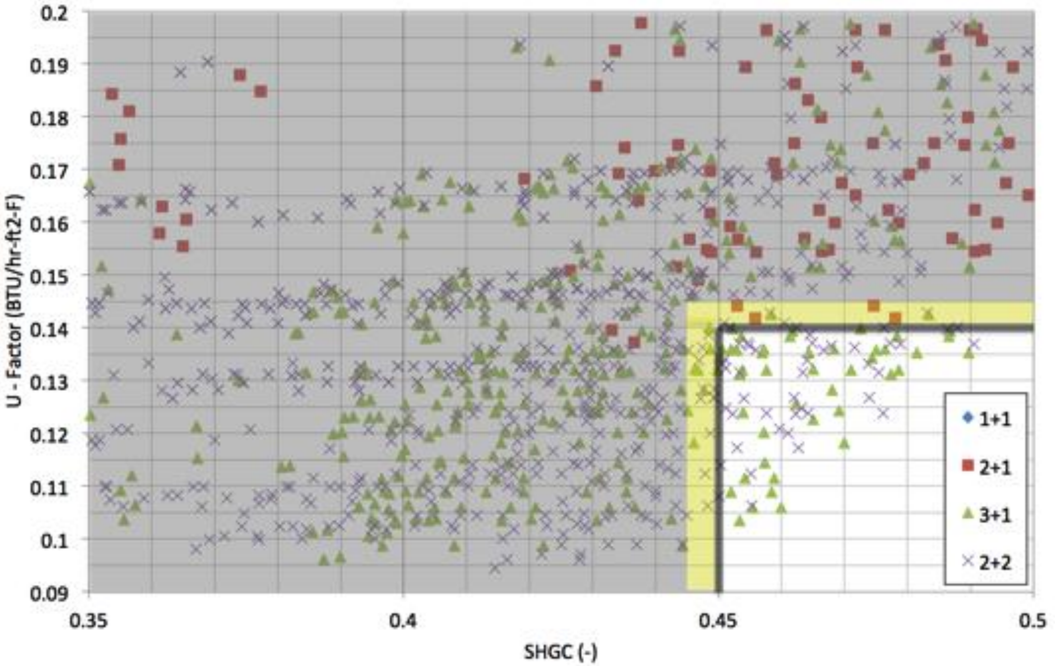
- Stand alone window, works without whole house automation system
- Shade between glass provides better solar control, lower maintenance
- Complete integration ensures no extra cost in window installation, and less chance of installation/setup mistakes.

Highly Insulating Window Design

- FOA targets: U<=0.14 Btu/hr-ft2-F, SHGC between 0.18 and 0.45
- Analyzed 56,000 different windows to find designs with low enough U-factor and high enough SHGC with shade retracted.
- Further refined by:
  - performance with shade down
  - temperature of shade (durability)
  - temperatures of glass (safety)
- Result: 3 designs that met all criteria (one triple, two quads)
- Exploring equal or better alternates



Whole window analysis for FOA targets. Wooden frame, double, triple and quadruple glazing options



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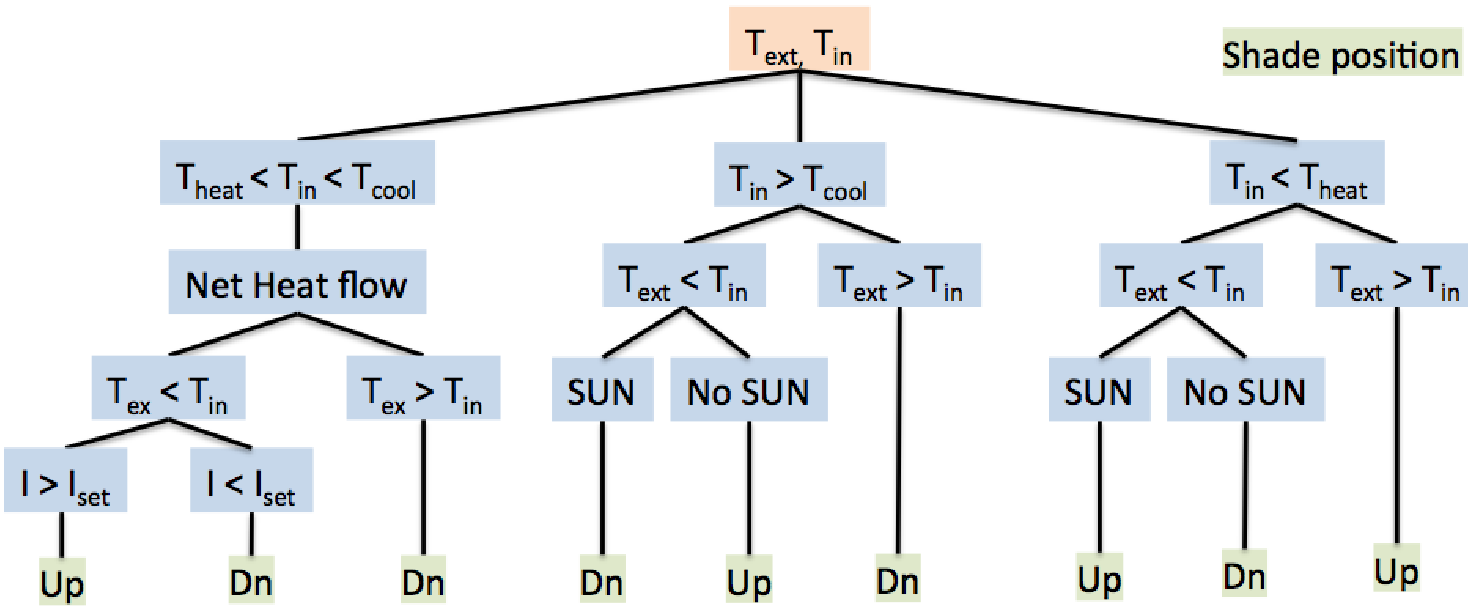
Control Algorithm Development

- The SmartWindow has a number of integrated sensors:
  - Interior and exterior temperature sensors
  - Exterior solar irradiance sensor
  - Occupancy sensor
- Control algorithm evaluates if homes is in heating, cooling or neutral mode, and determines optimal shade position
- Override actions are aware of occupancy



Complete automated ENERGY STAR level prototype

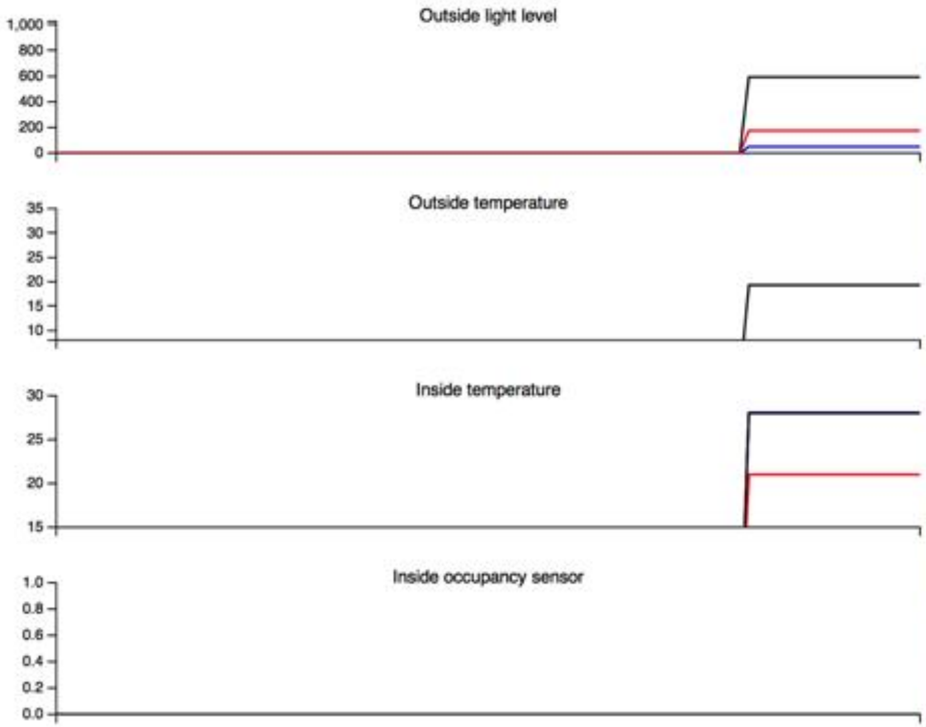
- Created prototype window with ENERGY STAR northern zone level performance
- Integrated temperature, solar irradiance and occupancy sensors
- Control algorithm embedded in window
- Mounted in MoWiTT test facility at LBNL and testing in progress

Demo

Last actuation time: 2014-03-26 15:34:43
Last actuation direction: Up
Last actuation reason: Override
Reason for current state: Override

Override

[More info and API spec]

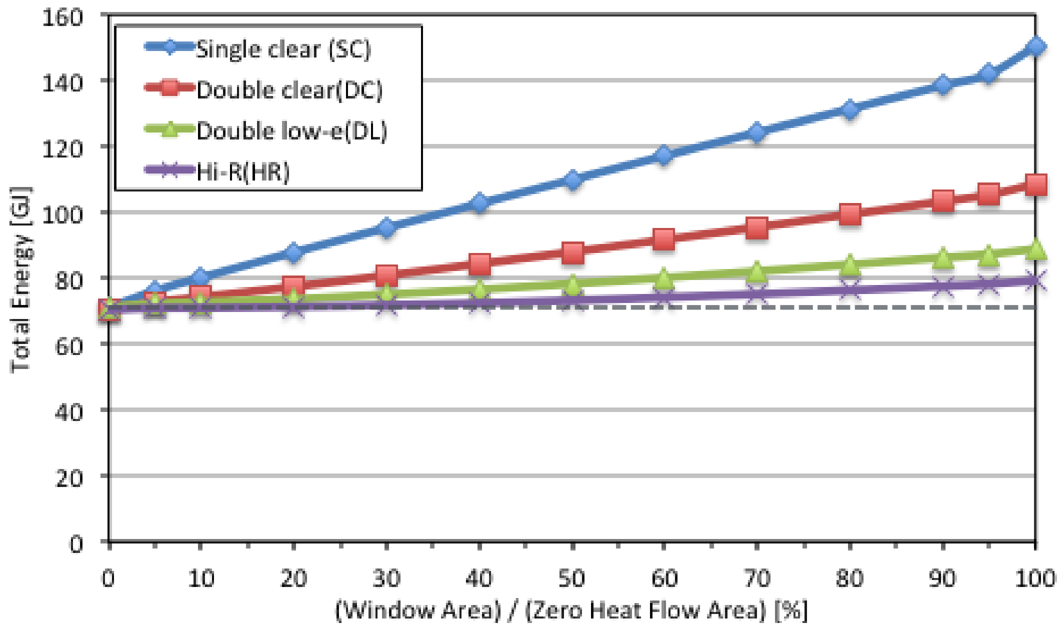


Go to http://SmarterWindow.lbl.gov to view this window live and control it.

Challenge: Creating Net Zero Energy Windows

- Base Case: PNNL EnergyPlus residential prototype houses with 15% window area to wall area ratio (358 ft2)
- Replacing all windows with a R-1000 wall (net zero wall) = 71.4 GJ energy/yr
- Modeling 4 different windows
  - Single clear
  - Double clear
  - Double low-e
  - Highly Insulating design
- Net Zero point specific to location, house design, thermostat setpoints etc.

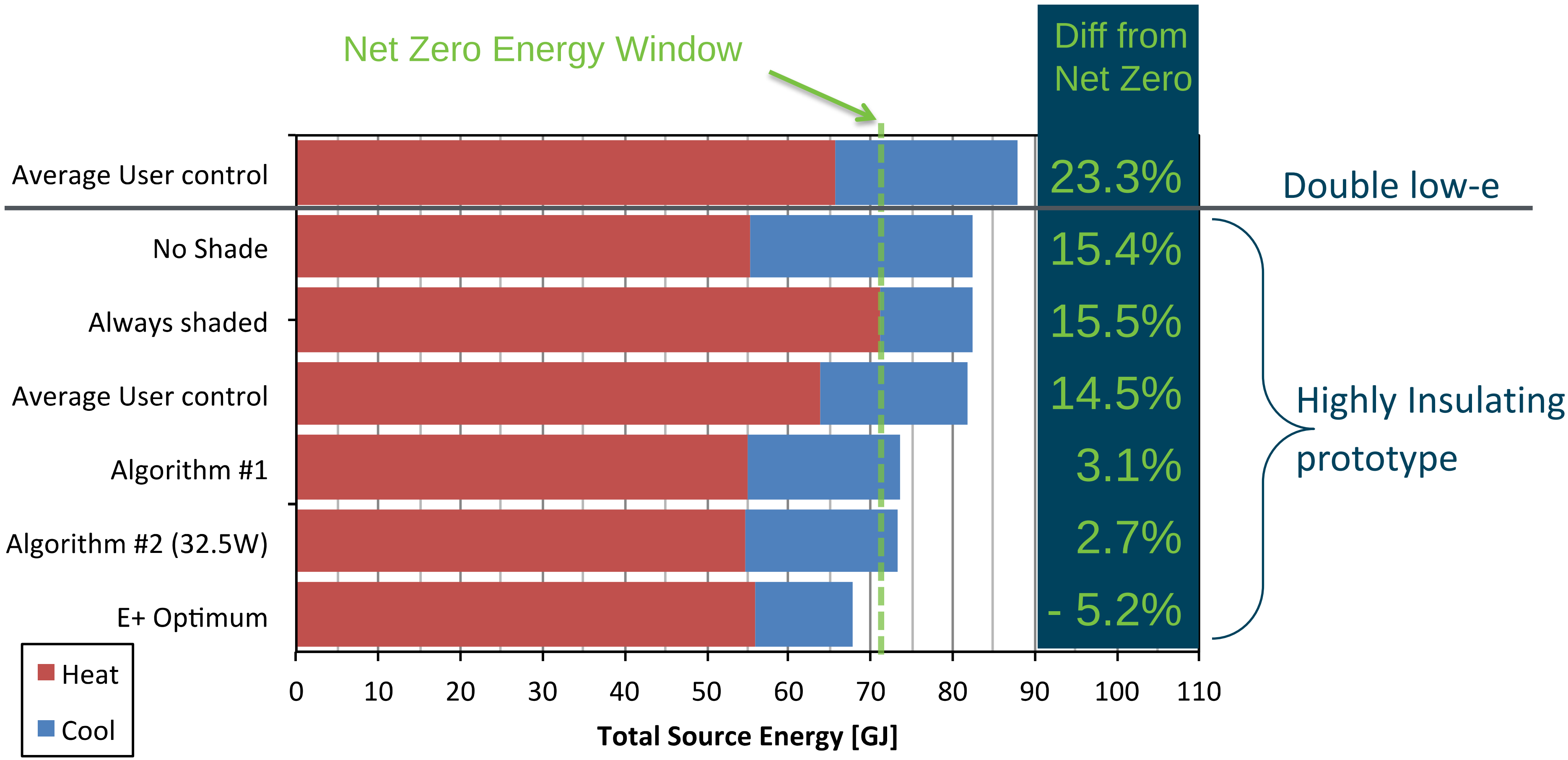
Conclusion:
Static highly insulating design approaches but not quite achieves net zero goal



Net Zero Energy Analysis for Minneapolis, unshaded 15% WWR, Thermostat 72/75F. Results 71.4 GJ

Net Zero Energy Windows - Minneapolis

- Whole house annual energy use is 71.4 GJ/year source energy for heating and cooling if all windows were Net Zero Energy Windows (NZEW)
- Intelligent Shade operation is key to exceeding net zero goal



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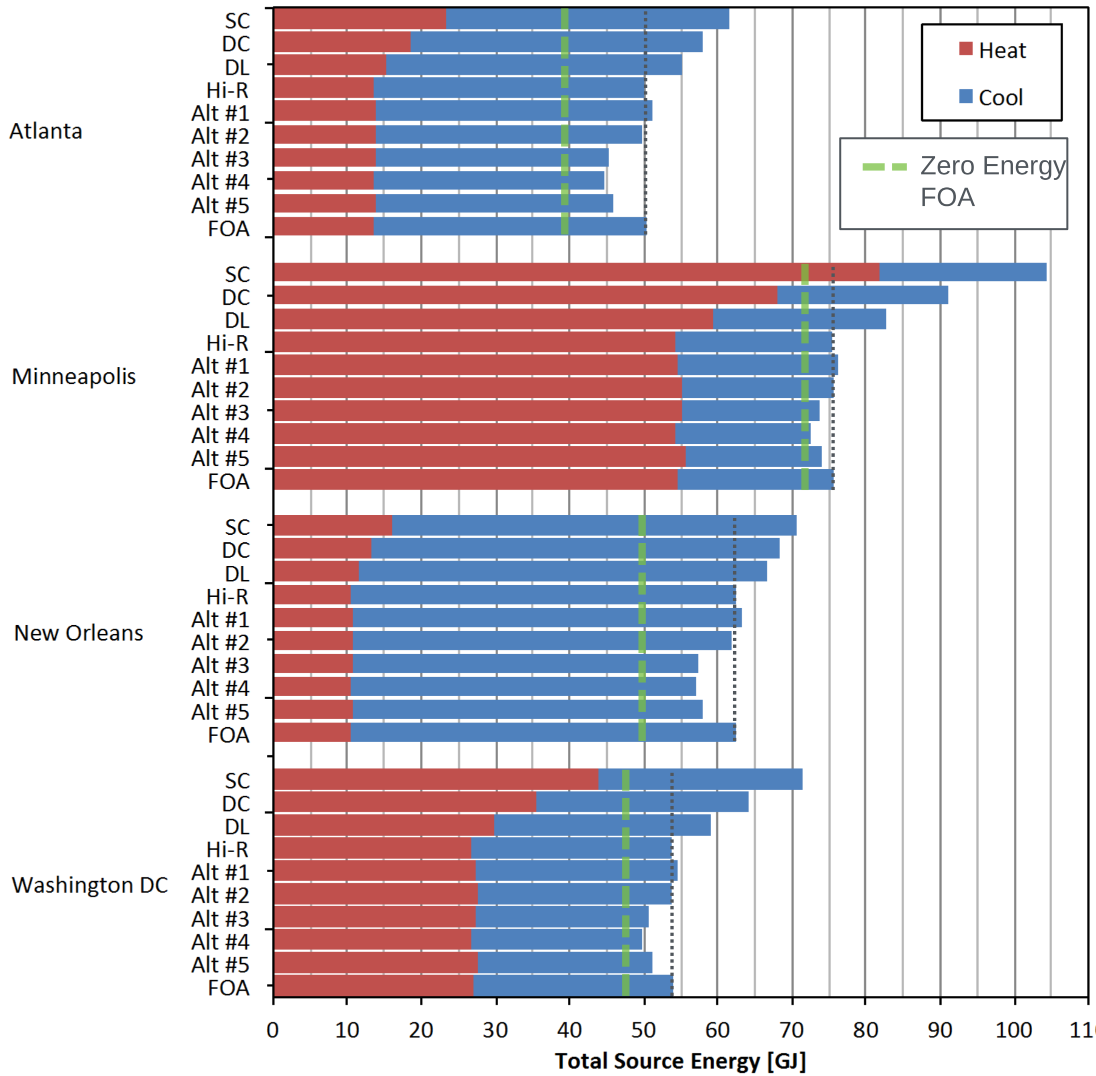
Net Zero Energy Windows – other climates

- Net Zero line not achievable in all climates
- **Current design (Hi-R) performs better than FOA targets in all climates**

Based on these performance based results, exploring modifications to target properties that will increase savings and reduce cost



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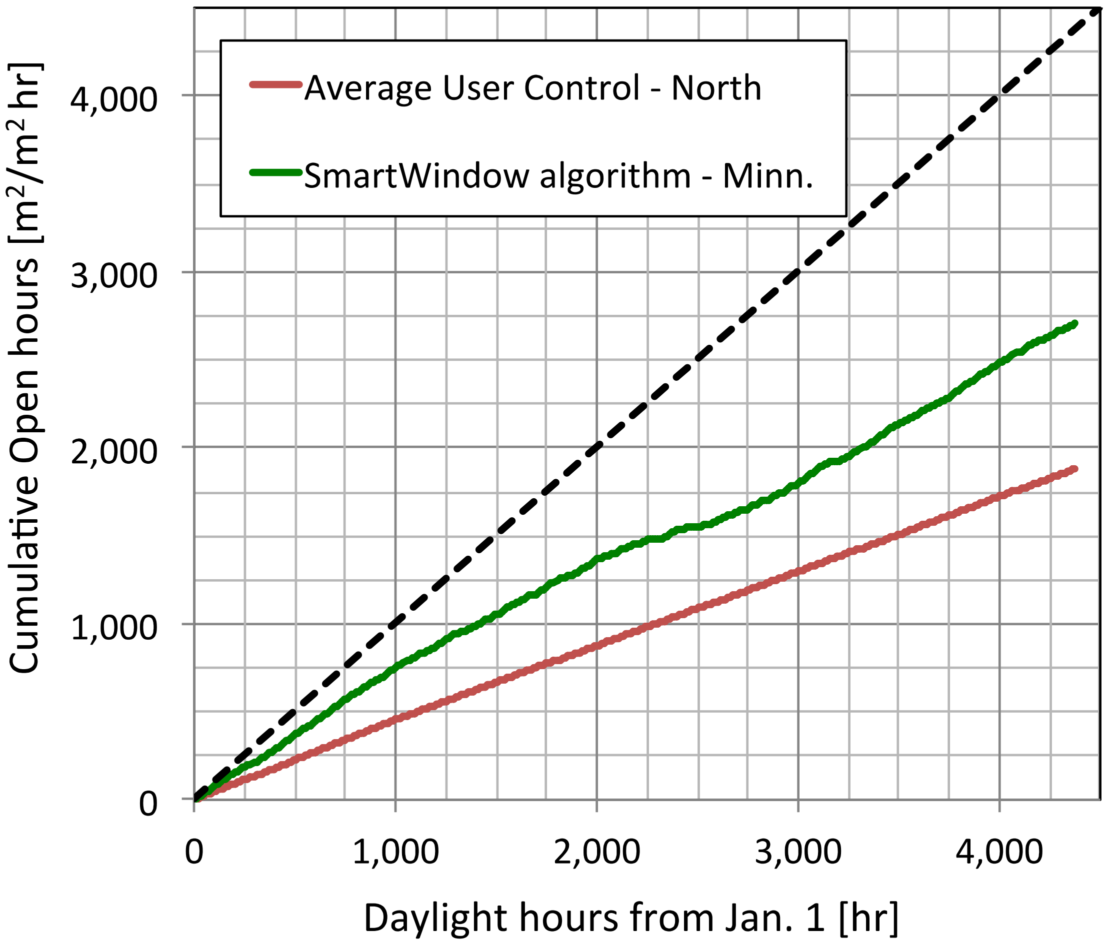
Daylighting, View and Shade Deployment

- Evaluate how often the shade is open during daylight hours
- Find optimum between energy savings and unobstructed view
- Energy Consumption reduced from 14.5% over NZEW to 2.7% over NZEW



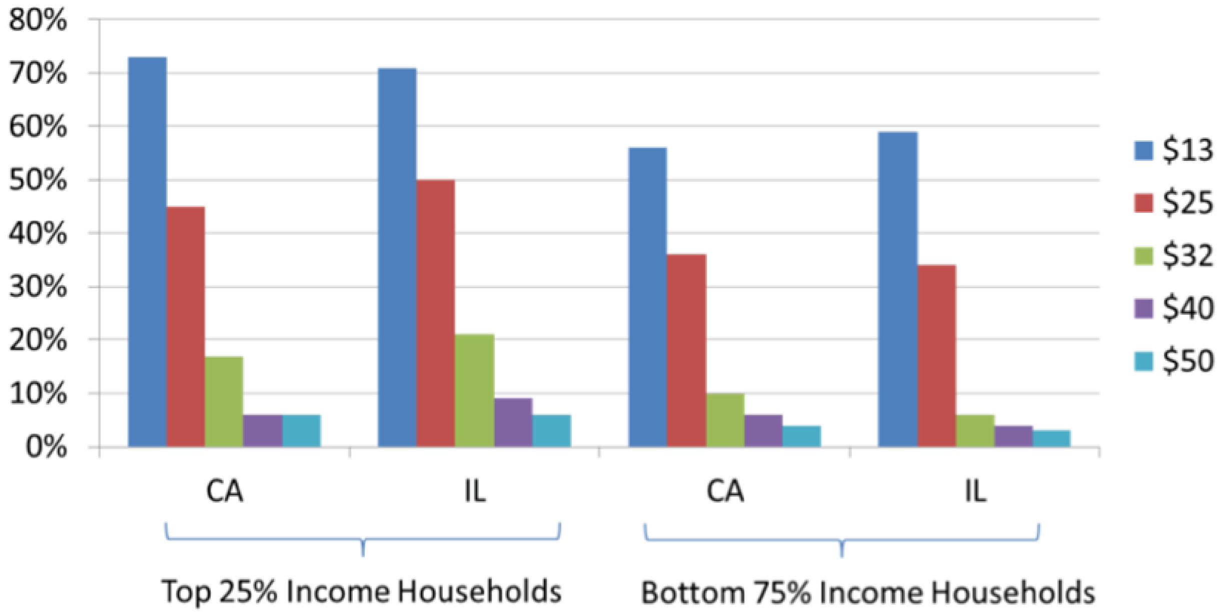
% of daylight hours that shade is open

62%

43%

Cost vs. Price Analysis

- Incremental price goal from DOE only based on energy savings benefit
- Large multipliers from manufacturer cost to homeowner price (2.5-3x)
- Study with UC Berkeley Haas Business School looked at complete value proposition: privacy, security, comfort, health
- Current cost estimate: \$18-\$25/ft^2. survey:30-40% of respondents would buy; more than adequate for market launch
- Market is not “rational”: Nest thermostat: \$250 (Google paid \$3 billion)



% of people who would buy windows with automated shades instead of regular windows with manual shades if it costs them \$x/ft^2

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New Outreach Options: AEC Hackathon at Facebook

- 12 teams of 2-6 people spend a weekend ‘hacking’ the built environment and the Architecture, Engineering and Construction industry. Generating creative new solutions.
- LBNL provided a SmartWindow onsite, access to a remote SmartWindow at LBNL and an API (application programming interface).
- Three teams chose to work with the LBNL API:
  - Integration between Echelon building automation system and SmartWindow
  - Smart Alarm Clock app, waking you up with natural light through the window or a LED light
  - Motion control and BIM integration of the SmartWindow

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Progress and Accomplishments

Accomplishments:

- Created window design to match FOA U-value and SHGC targets.
- Built physical ENERGY STAR level prototype with integrated sensors, motorized shade and embedded microprocessor with control algorithm.
- Published Application Programming Interface (API) for interfacing with SmartWindows.
- Annual Energy analysis of various designs and control algorithms completed

Market Impact: Successful collaboration with Pella Windows, bi-weekly conference calls, 2 prototype windows developed. Invited to participate in a AEC Hackathon at Facebook (March 2014). 3 out of 12 teams interfaced with the SmartWindow API. Chosen by UC Berkeley Haas School of Business Cleantech to Market (C2M) program as Fall 2013 project to study consumers willingness-to-pay.

Awards/Recognition: AEC Hackathon, UC Berkeley C2M program.

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 and Philips Hue LED

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. Discussions with Marvin Windows and Hunter Douglas on 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, and at UC Berkeley's Cleantech 2 Market, AEC Hackathon at Facebook.

Next Steps and Future Plans

Next Steps:

- Create a stand-alone highly insulating prototype with all sensors, motors and control
- Create networked prototypes- links to other windows, home automation, etc
- Work with code officials to ensure credit for dynamic products
- Test 4-6 windows in LBNL's FLEXLAB facility
- Test 25 SmartWindows in a cold climate house, with a control house with 25 regular windows

Future Plans:

- Incorporate glare sensing for extension to commercial buildings
- Add ventilation control for mixed mode cooling
- Explore optimization for other key climates
- Work with industry on potential open standards

REFERENCE SLIDES

Project Budget

Project Budget: $1,400k total budget for 3 year project
Variances: N/A
Cost to Date: $508k
Additional Funding: None

Budget History					
April 1 2013– FY2013 (past)		FY2014 (current)		FY2015 – April 1 2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$182k	0	$601k	$40k	$617k	$27k

Project Plan and Schedule

Project Schedule	
Project Start: 4/1/2013	Completed Work
Projected End: 3/31/2016	Active Task (in progress work)
	Milestone/Deliverable (Originally Planned)
	Milestone/Deliverable (Actual)

Task	FY2013 Q1 (Oct-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Oct-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)	FY2015 Q1 (Oct-Dec)	FY2015 Q2 (Jan-Mar)	FY2015 Q3 (Apr-Jun)	FY2015 Q4 (Jul-Sep)
Past Work												
Q3 Deliverable 1: Project Management Plan												
Q4 Miletstone: Window designs												
Q4 Deliverable: Test Sequence Plan												
Q1 Deliverable 1: Control Algorithm Description												
Q1 Deliverable 2: E* performance level prototype												
Q2 Milestone 1: Simulations show performance exceeds FOA target												
Q2 Milestone 2: Report mature market costs												
Current/Future Work												
Q3 Deliverable: Highly Insulating Static Prototype												
Q4 Milestone: Measured thermal performance within 0.03 Btu/hr-ft2-F												
Q1 Milestone: Operational Autonomous Prototype												
Q2 Milestone: Form advisory committee												
Project continues through FY 16												