Pacific Northwest
NATIONAL LABORATORY

Energy Performance of Cellular Shades

December 10th, 2019

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U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Project Overview

- Sponsored by Silicon Valley Power and the American Public Power Association's Demonstration of Energy and Efficiency Developments Program
- EnergyPlus and WINDOW software
- Model calibration with data from the PNNL Lab Homes
- Savings potential of cellular shades
  - 13 climate zones
  - Three prototype home layouts
  - Two variations of window areas
  - Two window types
  - Two cellular shade performance levels

Project Team

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Project Manager

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Principle Investigator

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Product Description

Technologies	Description	Picture
Triple Cell Cellular Shades	Hunter Douglas Duette® Architella® Trielle™ honeycomb fabric shades are made with six layers of fabric including two opaque layers and five insulating air pockets.	
Double Cell Cellular Shades	Hunter Douglas Double-cell semi-transparent Duette Elan cellular shades, honeycomb fabric shades made with 4 layers of fabric .	

Triple Cell (opaque)

Double Cell (semi-transparent)

What can *change* the savings that a cellular shade provides to a home?

- Type of cellular shade
- Structural characteristics of a home
- Primary window characteristics
- Climate zone
- Operating schedules

Less Window Area

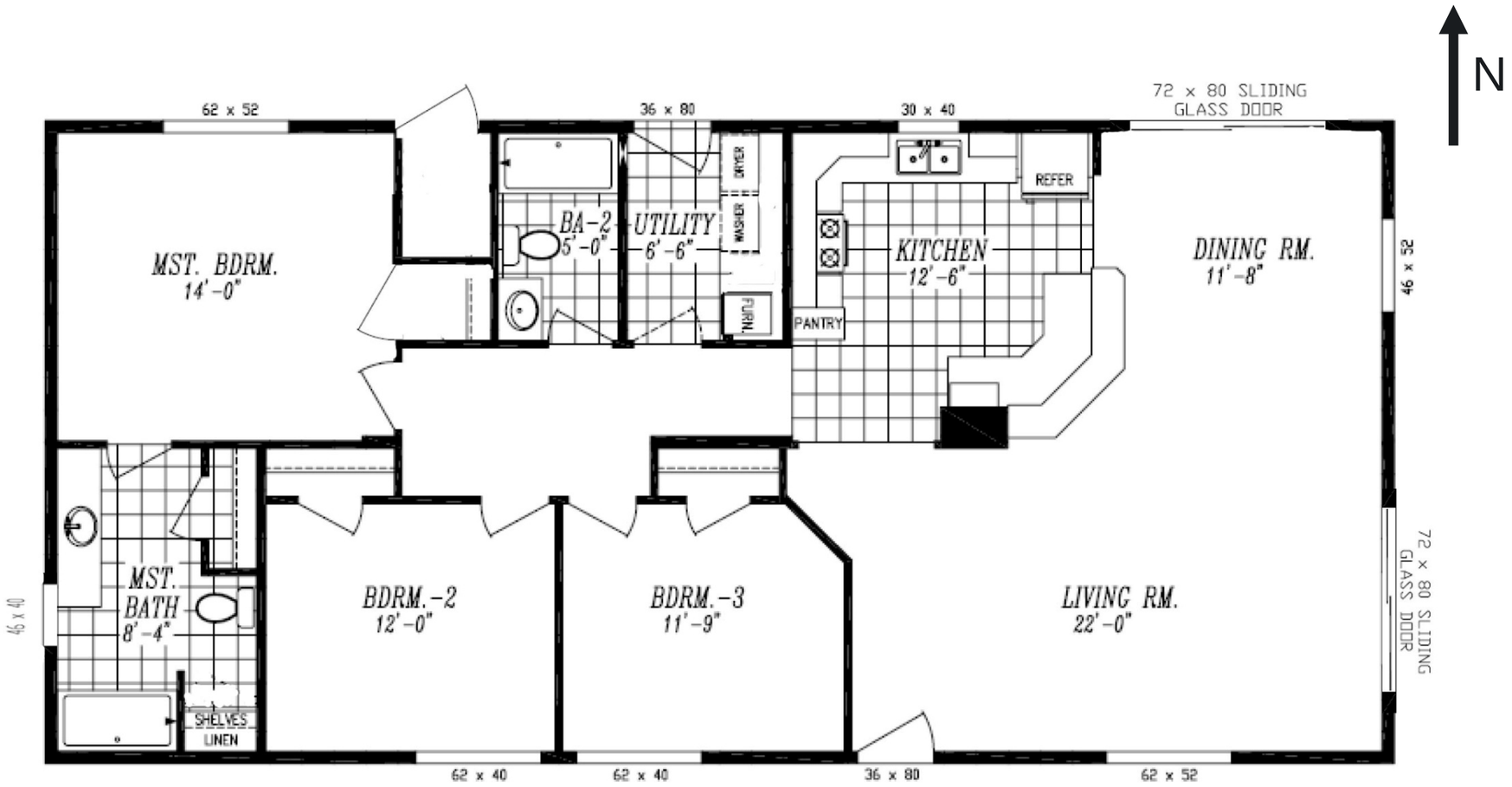
More Window Area

Model Calibration using Lab Homes Data

Lab Homes Characteristics

- Specified to represent existing manufactured and stick-built housing
- 3 BR/2BA, ~1500 ft^2
- All-electric with 13 SEER/7.7 HSPF heat pump central HVAC + alternate Cadet fan wall heaters throughout
- R-22 floors, R-11 walls & R-22 ceiling with composition roof
- 195.7 ft^2 (13%) window area with double-pane clear glass aluminum-framed windows

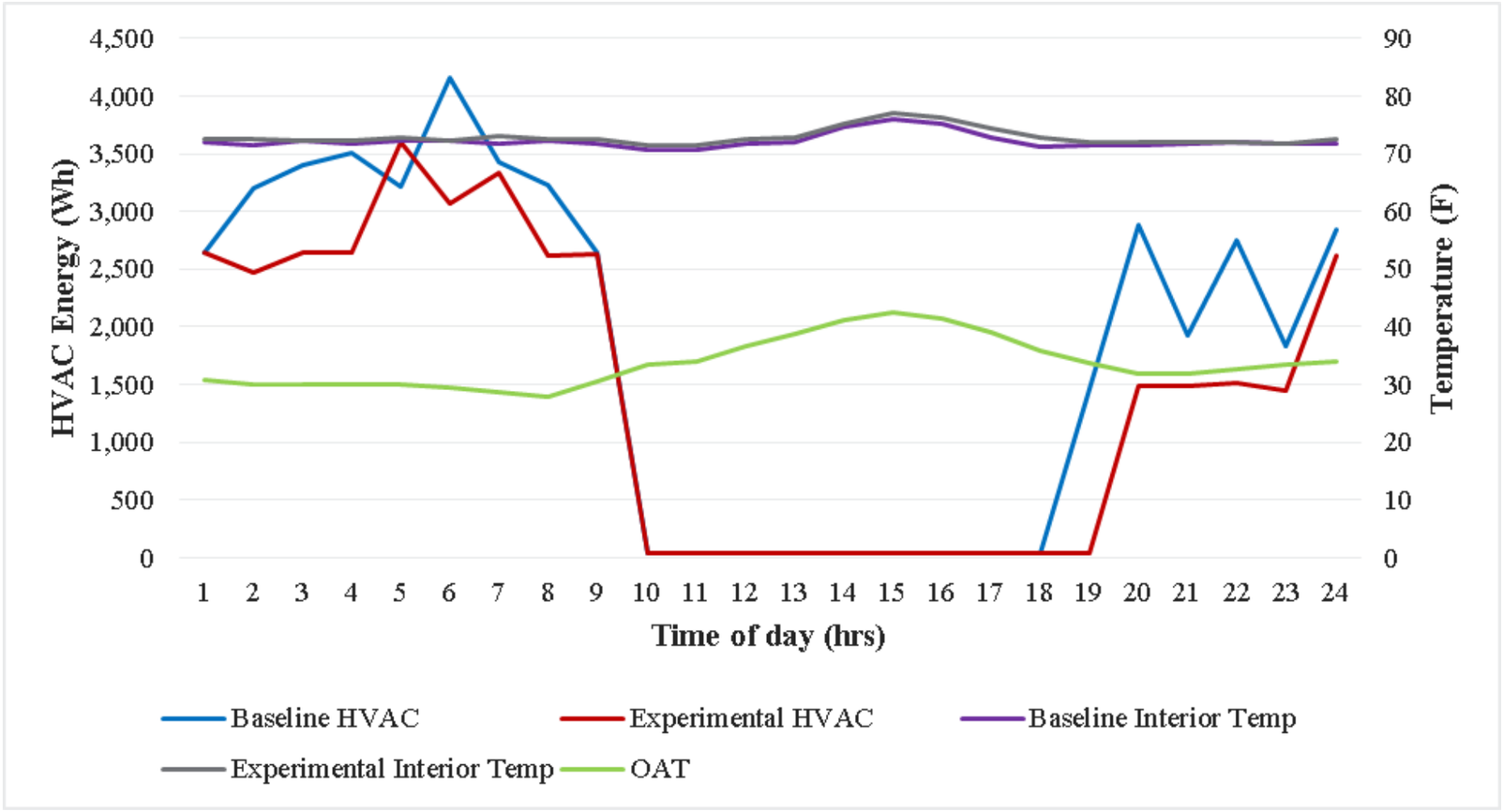
Model Calibration using Lab Homes Data

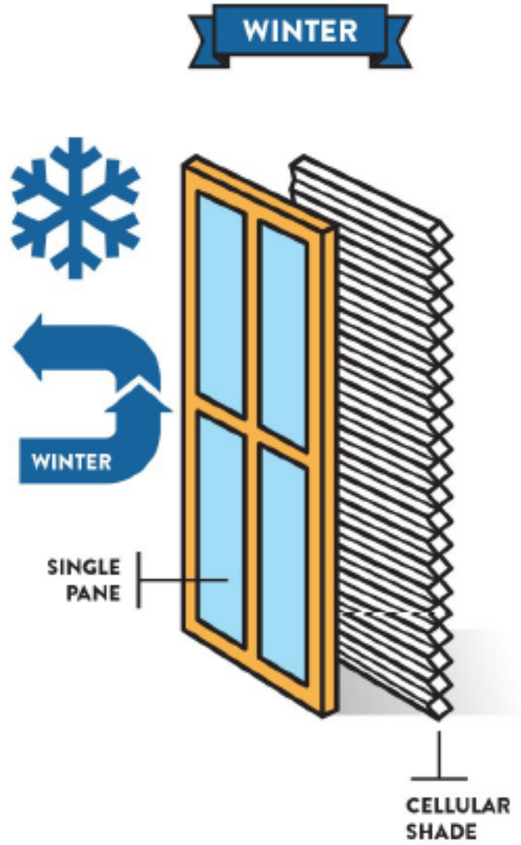


Baseline Home had no shades

Experimental home had either double cell or triple cell shades

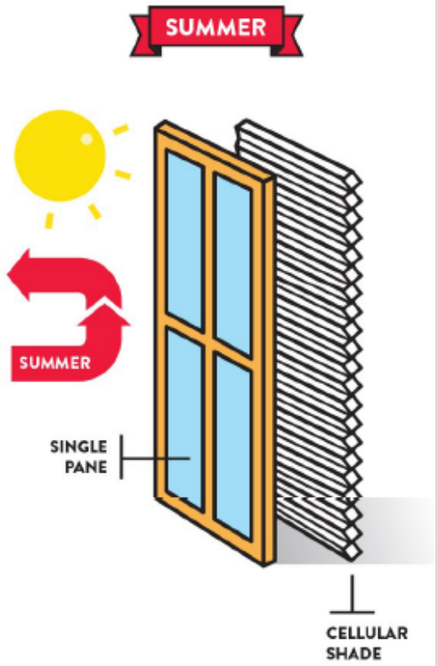
Previous PNNL Lab Homes Testing of Cellular Shades during Heating Season (2015-2016)

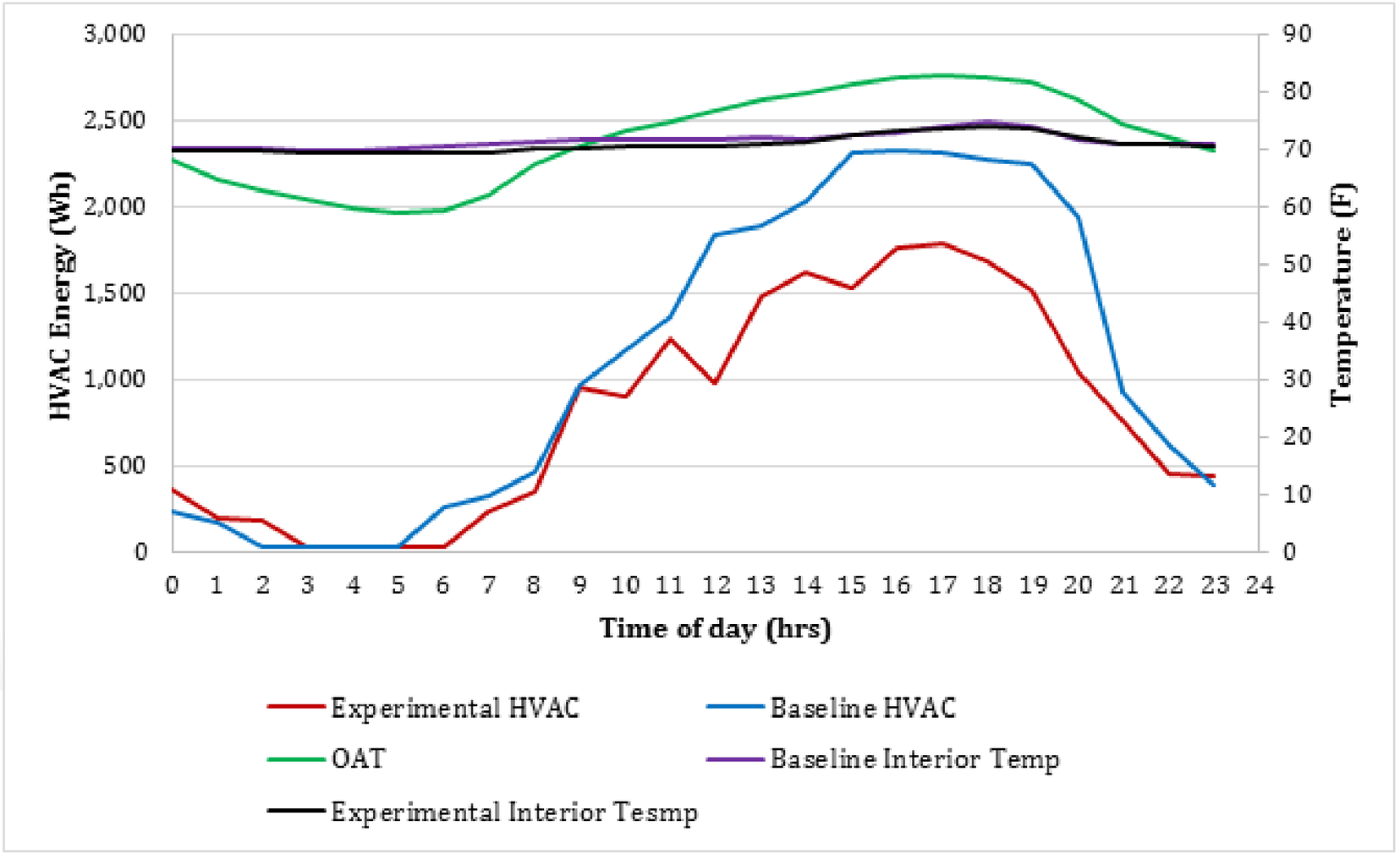




Energy Savings on a Winter Day in Richland, WA
(cellular shades testing, December 2015)

Lab Homes Testing of Cellular Shades during Cooling Season (2016)





Energy Savings on a Summer Day in Richland, WA
(cellular shades testing, July 2016)

Modeled Properties of Window Objects in WINDOW Software

- Double cell cellular shades:
  - Fabric type C-22, semi-opaque and production fit
  - Edge gaps measured in Lab Homes: 0.276 in., 0.172 in., 0.135 in., and 0.067 in. on the left, right, top, and bottom sides, respectively
  - Pleat size of 0.75 in.
  - Inner wall length 6/16 in.
  - Cell height between 0.5 and 0.75 in
- Triple cell
  - Fabric type C83, opaque
  - Production fit
  - Same edge gaps
  - Pleat size: 1.5 in
  - Inner wall length 6/16 in.
- Gap between window and shade = 0.5 in

Modeling Assumptions

- Cooling system is SEER 13 AC and Heating system is electric furnace
- Window area distributed evenly around the homes
- Ideal Schedule:
  - Cooling season is April to September. Always down.
  - Heating season is October to March. Shades up from 6am to 6pm. Down from 6pm to 6am.
- Plug loads and lighting follow rules by the simulation-based performance path in the IECC
- Cooling set point was 75°F and heating set point was 72°F, enabled simultaneously. Heating and cooling could be used on the same day.
- Time step of 10 minutes

Model Calibration Results

Table 2. Energy Use during Experimental Days						
Control or Experimental Home	With or Without Shades	Season	Experimental (Actual) HVAC Energy Use (kWh)	Experimental (Actual) Total Energy Use (kWh)	Modeled HVAC Energy Use (kWh)	Modeled Total Energy Use (kWh)
Control	Without	Cooling	48.7	75.2	46.3	72.7
Experimental	With	Cooling	35.2	63.6	30.5	58.8
Control	Without	Heating	83.1	157.8	92.3	166.0
Experimental	With	Heating	102.1	176.2	117.3	190.7

Model Calibration Results

Table 3. Predicted Savings, Experiment vs. Model			
Type of Savings Due to Shades	Season	Percent Savings between Two Homes (HVAC only)	Percent Savings between Two Homes (whole house)
Experiment	Cooling	28%	15%
Model	Cooling	34%	19%
Experiment	Heating	-23%	-12%
Model	Heating	-27%	-15%

Parametric Variables Prototypes

- Prototype 1 (New Average Home)
  - 2400 ft^2 home
  - New home characteristics (e.g., roof, wall, and floor characteristics up to latest energy code for respective climate zone)
- Prototype 2 (Existing Average Home)
  - Existing 2400 ft^2 home
  - U-factor of .68 assumed for windows, R-11 walls, R-22 roofs and floor
- Prototype 3 (Existing Small Home)
  - Existing 1500 ft^2 home
  - U-factor of .68 assumed for windows, R-11 walls, R-22 roofs and floor

- 2 separate window-to-wall ratios (15% and 18%) are run for each prototype

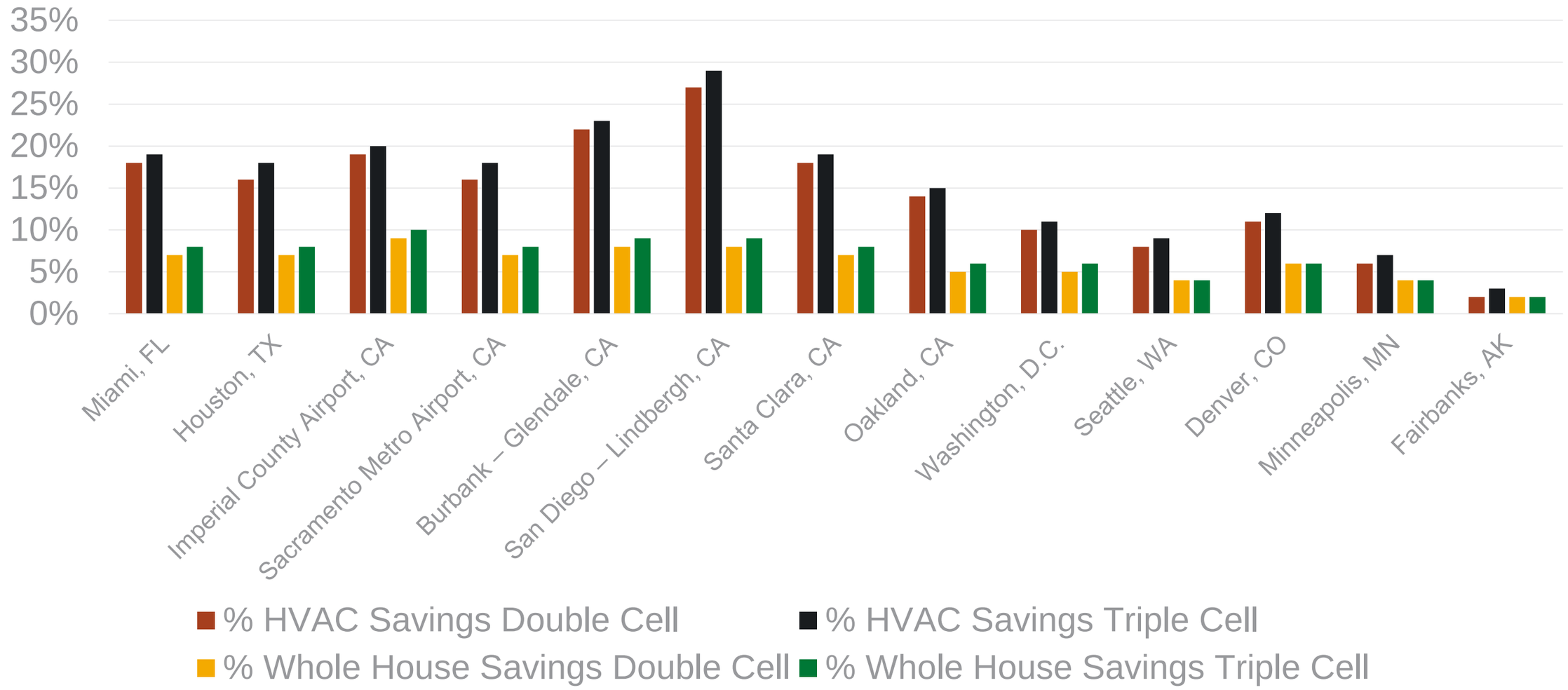
Parametric Variables
Climate Zones

Location	California Climate Zone	IECC Climate Zone Category	DOE Building America Climate Zone
Miami, FL	N/A	1A	Hot-Humid
Imperial County Airport, CA	15	2B	Hot-Dry
Houston, TX	N/A	2A	Hot-Humid
Sacramento Metro Airport, CA	12	3	Hot-Dry
Burbank – Glendale, CA	9	3	Hot-Dry
San Diego – Lindbergh, CA	7	3	Hot-Dry
Santa Clara, CA	4	3	Marine
Oakland, CA	3	3	Marine
Washington, DC	N/A	4A	Mixed-Humid
Seattle, WA	N/A	4C	Marine
Denver, CO	N/A	5B	Cold
Minneapolis, MN	N/A	6A	Cold
Fairbanks, AK	N/A	8	Very Cold

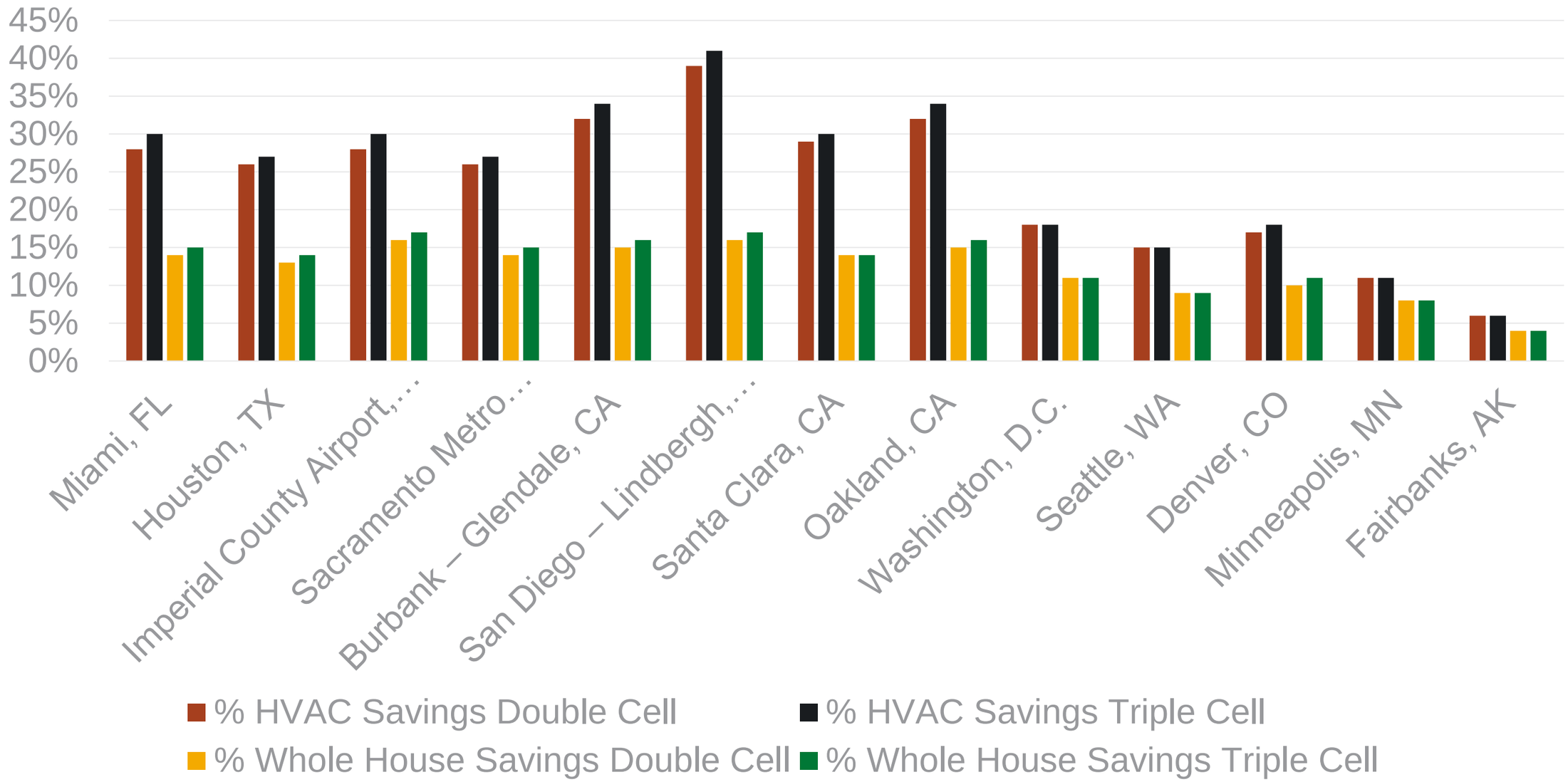
Examples of Results – San Diego, CA

Table 6. Modeled HVAC Energy Use and Savings in Climate Zone 3						
Prototype	Window-to-Wall Area (%)	HVAC Energy Use (kWh/yr) Based on Cellular Shade Performance Level			Percent Savings Compared to No Shades	
		No Shades	Double Cell	Triple Cell	% Savings of Double-Cell Shades	% Savings of Triple-Cell Shades
Prototype # 1 (U=0.32)	15%	4832	3693	3604	24%	25%
	18%	5100	3726	3613	27%	29%
Prototype #2 (U=0.68)	15%	7537	4900	4763	35%	37%
	18%	8223	4994	4817	39%	41%
Prototype #3 (U=0.68)	15%	4736	3320	3225	30%	32%
	18%	5192	3521	3401	32%	34%

Results Summary for Prototype #1 (New Home)



Results Summary for Prototype #2 (Existing Home)



Education and Outreach Needs

- Cellular shades can save a significant amount of HVAC energy when used properly
  - High insulating value relative to many other window coverings (product ratings coming soon from AERC)
  - Year-round energy savings in multiple climate zones
  - Savings are achievable in new and existing homes
- Recommendations to make the most of these insulated shades:
  - Leave shades down as much as possible during the day throughout the cooling (summer) season.
  - Pull shades down in the evenings during the winter heating season, but try to pull them up in the winter during the day to realize beneficial heat gains through the windows. This is especially helpful for west- and south-facing windows.
- Consider automated shades

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Thank you