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Energy Savings of Cellular Shades

City of Santa Clara with Silicon Valley Power

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PNNL-SA-134378

What are Window Attachments?

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Interior Shutters

Horizontal Blinds

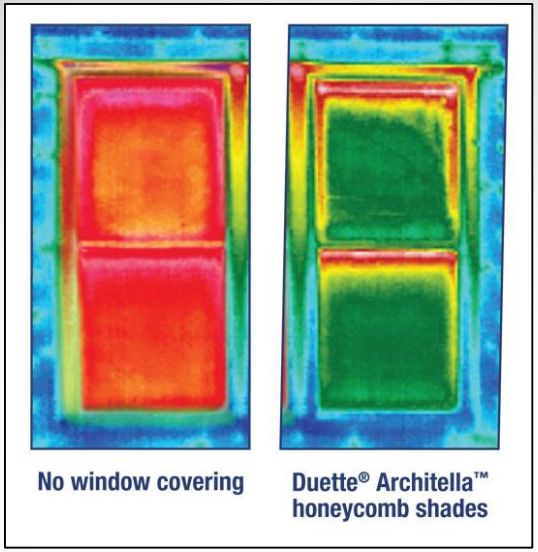
Focus of Study

Cellular Shades

Roller Shades

Cellular Shades Value Proposition

- Demonstrated significant heating and cooling energy savings lab home setting
  - Year-round savings potential
  - Applicable in multiple climate zones
  - Retrofit technology
- Affordable (prices vary, but median price is $70/window)
- Aesthetically pleasing
- Operable
- Automation commercially available
- Adds comfort and privacy year-round



- Heating Savings: Can reduce heat loss through windows by 40% or more
- Cooling Savings: Reduces unwanted solar heat through windows by up to 80%

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 employed for study
  - Aligns with AERC modeling process; however, AERC_Calc (underlying tool for AERC rating) not employed for this study
- 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

Details of project and results documented in project report: "Modeling Cellular Shades in EnergyPlus," December 2017, PNNL-27187

Modeled Performance of Cellular Shades: Product Description

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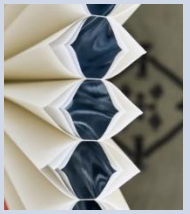
Technologies	Description	Picture
Triple Cell Cellular Shades	Hunter Douglas Duette® Architella® Trielle™ honeycomb fabric shades are made with six layers of fabric including two opaque layers and five insulating air pockets.	
Double Cell Cellular Shades	Hunter Douglas Double-cell semi-transparent Duette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

Triple Cell (opaque)

Double Cell (semi-transparent)

Climate Zones Modeled

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

Prototype Characteristics

- 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

Savings Estimates Available for Climate Zone Near You

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Santa Clara, CA (for example)

	Window-to-Wall Area (%)	HVAC Energy Use (kWh/yr) Based on Cellular Shade Performance Level			Percent Savings Compared to No Shades	
Prototype		No Shades	Double Cell	Triple Cell	% Savings of Double-Cell Shades	% Savings of Triple-Cell Shades
Prototype # 1 (U=0.32)	15%	7750.2	6608.3	6502.9	15%	16%
	18%	7877.5	6473.3	6341.9	18%	19%
Prototype #2 (U=0.68)	15%	10809.8	8135.1	7998.2	25%	26%
	18%	11409.2	8127.6	7936.5	29%	30%
Prototype #3 (U=0.68)	15%	5965.3	4280.5	4172.2	28%	30%
	18%	6417.8	4399.2	4257.0	31%	34%

- Shade operation assumptions to simulate energy use and estimate annual energy savings:
  - Shades are pulled down in the summer (cooling season is assumed to be from April to September)
  - Shades are up during the day and pulled down at night during the winter (heating season is assumed to be from October to March)

Summary Results

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- Significant savings realized with cellular shades; however, the difference in savings between double-cell shades vs. triple-cell shades was minimal
- Savings are the most significant in smaller, existing homes with relatively high window-to-wall ratios (18%)
  - **Annual HVAC energy savings potential ranges from 10-34% depending on climate zone**
- Example from Burbank, CA (Near Los Angeles)

	Window-to-Wall Area (%)	HVAC Energy Use (kWh/yr) Based on Cellular Shade Performance Level			Percent Savings Compared to No Shades	
Prototype		No Shades	Double Cell	Triple Cell	% Savings of Double-Cell Shades	% Savings of Triple-Cell Shades
Prototype # 1 (U=0.32)	15%	7244.8	5894.8	5774.5	19%	20%
	18%	7484.6	5873.6	5727.5	22%	23%
Prototype #2 (U=0.68)	15%	10428.4	7478.1	7311.1	28%	30%
	18%	11149.9	7585.4	7364.5	32%	**34%**
Prototype #3 (U=0.68)	15%	6050.9	4362.6	4256.1	28%	30%
	18%	6549.8	4536.2	4399.1	31%	33%

Key Takeaways

- Triple-cell shades tend to save 0 to 2% more than double-cell shades for a given prototype. The colder the climate, the less the cellular shade performance level makes a difference.
- Well-insulated new homes with relatively high performing windows generally provide less energy savings potential than existing homes with the same square footage (comparing prototype #1 as a new home, to prototype #2 as an existing home with the same square footage).
- The more window area a home has, the more energy savings cellular shades can provide.
- Smaller existing homes tend to realize more energy savings than larger existing homes with the same house characteristics and window types (based on comparing results from prototype #2 at 2400 square feet and prototype #3 at 1500 square feet with no other differences).
- Energy savings (for triple-cell shades) associated with HVAC operation ranges from 3 to 29% for relatively large new homes with large window area, depending on climate zone.
- Energy savings (for triple-cell shades) associated with HVAC operation ranges from 10 to 34% for a relatively small existing home with a large window area, depending on climate zone.

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Energy Savings of Ducted Mini-split Heat Pumps

Bonneville Power Administration

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Ductless Mini-split vs. Ducted Mini-split

- Outdoor unit (compressor, fan and coil)
- Hot or cold refrigerant provided to indoor units
- Wall mounted fan unit
- Typically best for open concept living
- Cost is typically around $2,500

- Outdoor unit (compressor, fan and coil)
- Hot or cold refrigerant provided to indoor units
- Hidden mounted fan unit
- Meant to distribute conditioned air to bedrooms
- Cost for unit is about the same as ductless + the cost of installation in walls/ceiling

Project Scope

- Collaborative effort between PNNL and NREL

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EnergyPlus

BEopt
Building Energy Optimization

Project Scope

Climate Zones

City	BPA Heating Zone	Heating Degree Days (HDD)
Portland, OR	Zone 1	<6000 HDD
Spokane, WA	Zone 2	6001-7499 HDD
Missoula, MT	Zone 3	>7500 HDD

Prototypes

Prototype #	Sq ft	New/Existing	Ceiling type	Foundation	Duct Location
1	924	New	Attic	Crawlspace	Crawlspace
2	2200	New	Vaulted ceiling	Crawlspace	Crawlspace
3	2688	New	Attic	Finished basement	Attic and finished basement
4	2200	Existing	Attic	Crawlspace	Crawlspace
5	2688	Existing	Vaulted ceiling	Finished basement	Finished basement
Lab Homes	1500	Existing	Vaulted ceiling	Crawlspace	Crawlspace

Assumptions

Assumption/Change	Reasoning
Duct leakage set to 4%	Leakage rates are likely much smaller in DEDs compared to central systems due to the smaller duct size, shorter duct length, and the low tolerance these systems have for high external static pressure.(a)
Duct insulation set to R-6	Assumed to be common insulation levels for the region.
Supply duct area multiplier set to 50% of House Simulation Protocol (HSP)(b) value for central systems	The duct length is a parameter that is limited in a field installation. However, this is not a variable that can be entered into BEopt. Therefore, the surface area of the ducts is the only parameter that can help account for the smaller diameter and shorter duct lengths required by the DED units. Assuming 50% of that number is based on engineering judgment. Unfortunately, the duct length does not directly affect fan power in EnergyPlus due to software constraints.
Return duct area set to 0	It is assumed that the DED units do not have return ducts, but rather a central grill for each indoor unit that is on the unit itself.

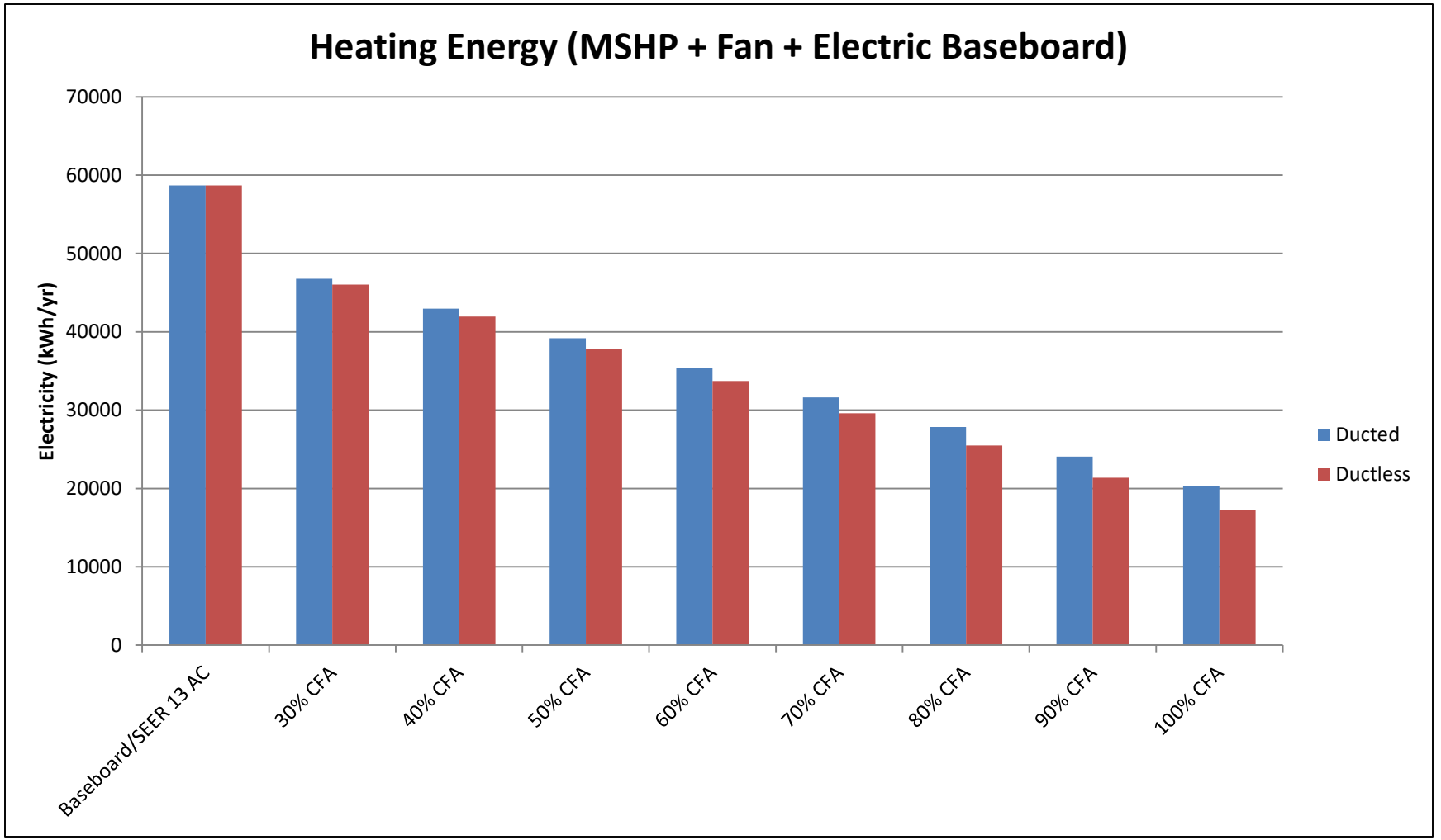
(a) Duct leakage estimated to be "lower" than central AC systems by Charlie Stephens of NEEA, based on his experience with the DEDs in the field. DED systems are notorious for performing qualitatively much worse than other systems under high external static pressure conditions. Therefore, manufacturers and designers are typically much more cautious about not exceeding the rated static pressure conditions during installation.

(b) The Building America HSP specifies the duct surface area based on the square footage of the home.

Sensitivity Studies

Parameter	Baseline DED					
	Assumption	Heating Energy Use (kWh/yr)	Assumption	% Difference from baseline DED	Assumption	% Difference from baseline DED
Duct Location	Attic	20,281	Crawlspace	-2.0%	Conditioned Space	-2.0%
Duct Surface Area	50% of whole-house assumption		40%	-0.2%	60%	0.2%
Duct Leakage	4%		8%	1.3%	2%	0.2%
Duct Insulation	R-6		None	3.7%	R-8	-0.2%
Fan Power Level	0.18		0.07	1.2%	0.30	-1.5%

Sensitivity Cont. (Prototype #4)



Results

Climate Zone	Prototype Number	Total Energy Use of Zonal Electric with Window AC Baseline (kWh/yr)	Air Source Heat Pump Percent Savings Above Baseline	Ducted Mini-split Percent Savings Above Baseline	Ductless Mini-Split Percent Savings Above Baseline
Heating Zone 1 – Portland					
	#1	5,000	65%	68%	75%
	#2	11,400	63%	71%	77%
	#3	7,800	65%	68%	76%
	#4	37,600	68%	71%	76%
	#5	29,500	67%	72%	76%
	Lab Homes	5,900	57%	68%	75%
Heating Zone 2 – Spokane					
	#1	8,800	60%	57%	63%
	#2	19,700	44%	63%	69%
	#3	14,300	59%	60%	67%
	#4	58,700	54%	65%	71%
	#5	46,800	61%	66%	71%
	Lab Homes	10,200	52%	56%	63%
Heating Zone 3 – Missoula					
	#1	9,300	59%	55%	62%
	#2	20,800	40%	62%	68%
	#3	14,700	58%	58%	65%
	#4	61,400	51%	64%	70%
	#5	48,600	59%	65%	70%
	Lab Homes	10,900	49%	55%	62%

Key Takeaways

- Ducted mini-split systems performed similarly in each climate zone within the same prototype building. For example, Prototype #3 had the largest percent difference between climate zones; with 33% savings in Portland, and 38% savings in Spokane and Missoula
- Energy saved in heating zone 1 was generally less than what was saved in heating zones 2 and 3.
- Homes with finished basements (prototype #3 and 5) typically saved less energy than similarly sized homes that did not have finished basements (prototype #2 and 4).

Prototype #	Sq ft	New/Existing	Ceiling type	Foundation	Duct Location
1	924	New	Attic	Crawlspace	Crawlspace[(a)]
2	2200	New	Vaulted ceiling	Crawlspace	Crawlspace
3	2688	New	Attic	Finished basement	Attic and finished basement[(b)]
4	2200	Existing	Attic	Crawlspace	Crawlspace
5	2688	Existing	Vaulted ceiling	Finished basement	Finished basement
Lab Homes	1500	Existing	Vaulted ceiling	Crawlspace	Crawlspace

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THANK YOU!

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