DOCKETED

Docket Number:	17-BSTD-02
Project Title:	2019 Title 24, Part 6, Building Energy Efficiency Standards Rulemaking
TN #:	222851
Document Title:	Velux - Roger LeBrun Comments Prescriptive Table RE Skylights
Description:	N/A
Filer:	System
Organization:	Velux/Roger LeBrun
Submitter Role:	Public
Submission Date:	3/5/2018 1:04:52 PM
Docketed Date:	3/5/2018

Comment Received From: Roger LeBrun
Submitted On: 3/5/2018
Docket Number: 17-BSTD-02

Prescriptive Table RE: Skylights

There has never been any CASE report I know of that has addressed the cost justification for setting skylight u-factor equal to window U-factor. In fact, I met with the CASE report team dealing with windows before they completed their initial report, and explained the fallacy of lumping skylights with windows in great detail. To this date, they did nothing to justify setting the maximum where only very exotic and expensive custom units can comply prescriptively (not even TDDs can comply).
This is highly discriminatory, especially considering the high efficacy of skylights for providing the most daylight, ALL day long, of any other fenestration type. And venting skylights are as efficient in moving air as whole house fans, but do not require any power.
The Commission would be well served to revisit this topic, and would open up the possibility of more efficient homes with optimal fenestration deployment (due to less total fenestration area being required for daylight).

Additional submitted attachment is included below.

Energy Impacts of Residential Skylights: Study 2, Phase I

A Study of residential fenestration in a 2-story home.

DRAFT

May 17, 2013

Prepared for:

VELUX®

Prepared by:

Group14 Engineering

Elizabeth Gillmor, P.E.
Alison Theriot
Sue Reilly, P.E.

Group14 Engineering
1325 E. 16th Avenue
Denver, CO 80218
www.Group14Eng.com

Contents

Tables and Figures

1 Executive Summary

This study is the a continuation of the ongoing research into the energy cost impacts of achieving good minimum daylight levels in a single-family "home" through varied fenestration.

Table 1: Timeline of Skylight Research

Study Title	Description	Issue Date	Subject
Study 1 – Phase I	Energy Impacts of Residential Skylights in Different Climates	11/16/2011	Impact of residential skylights in a single-story home in two California climate zones.
Study 1 – Phase II	Energy Impacts of Residential Skylights in Different Climates	2/19/2012	Expansion of the first study to include seven more cities.
Study 1 – Phase III	Energy Impacts of Residential Skylights in Different Climates	Draft: 12/12/2012	A focus on the energy impacts on existing homes that may have lower performing skylights already installed in six different cities.
Study 2 – Phase I	Energy Impacts of Residential Skylights in a Two Story Home	Draft: 5/17/2013	Impact of residential skylights in a two story home in six cities.

This analysis uses similar methodology as the first three analyses, but considers a two-story home instead of a single story home, and implements additional modeling assumptions and parameters commonly used in residential energy code development.

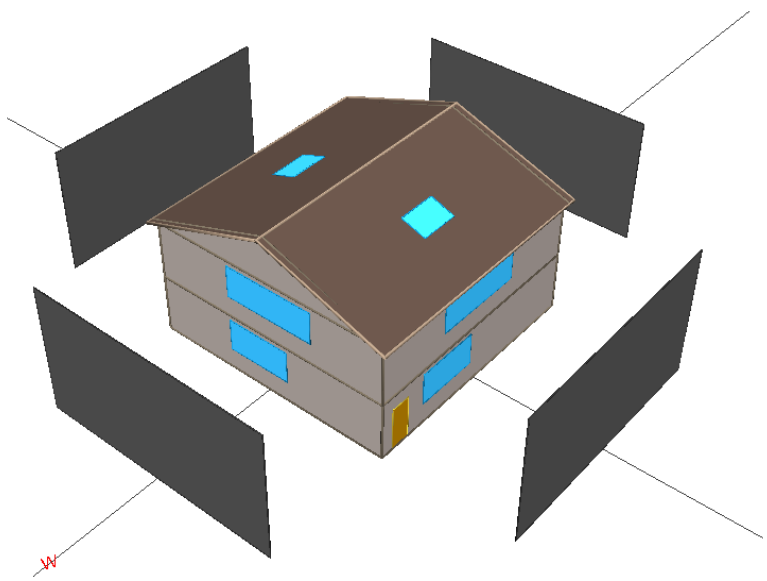


Figure 1: Modeled Home in Study 2 (shown with skylights for reference)

This study revealed the energy cost benefits of thoughtful fenestration orientation, especially when comparing the results by city to the results in Study 1. This resulted in the following observations:

- In a 2-story home, there are energy savings to be had when using skylights in lieu of windows. However the savings are lessened when less of the home can be impacted by skylights, or in a more urban/suburban environment which has more nearby shading effects.

- As was noted in the Study 1, the greatest savings can occur when using skylights to reduce east/west-facing windows.
- Great care should be taken with skylight placement in cooling-dominated climates such as Los Angeles, as south-facing skylights have the potential to increase energy costs. Conversely, using skylights for passive solar heating in heating-dominated climates such as Minneapolis can result in energy savings.

Please see Section 1.3 for full graphical results, and section 2.1 for a comparison to the results found in Study 1.

1.1 Background

Study 1 was a three-phase study entitled “A Study of the Energy Impacts of Residential Skylights in Different Climates”. It considered windows and skylights that used a high quality low-e, low-SHGC glazing with argon fill (center-of-glass U-0.24, SHGC-0.27), and evaluated only the heating and cooling energy cost impacts in a 2000 square foot single story home. Phase II of Study 1 evaluated energy cost impacts in 9 different cities: Boston, Chicago, Denver, Dallas, Minneapolis, Orlando, Seattle, Los Angeles, and Napa, CA.

The baseline modeled home in Study 1 has a maximum 20% window to floor area (with no skylights), which represents the prescriptive limit allowed by California Building Code. Windows are evenly distributed on all facades. This baseline was found to achieve an average daylight factor of 5%. The window area was varied, reduced to as low as 8% window to floor area (minimum allowed by local building codes), and grouped in two different ways: Either equally distributed on all facades, or distributed with 70% of the window area on the north and south facades. Skylight area was added as necessary on the sloped roof to maintain the baseline average daylight factor of 5% under a CIE overcast sky. Skylights were distributed three ways: north-facing, south-facing, or with equal distribution.

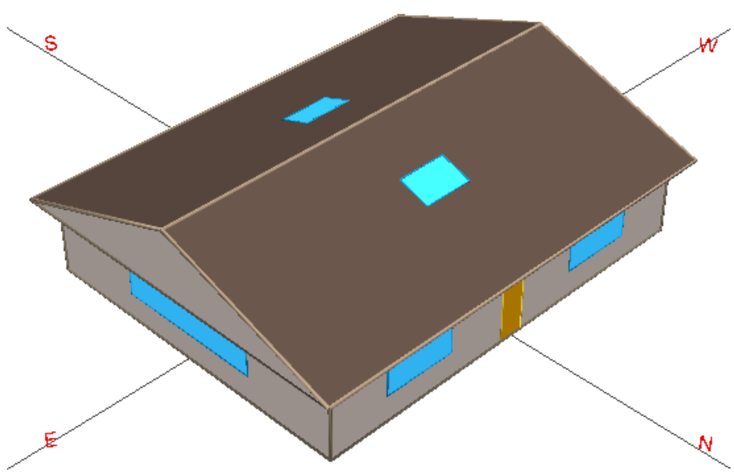
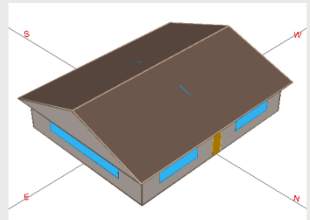
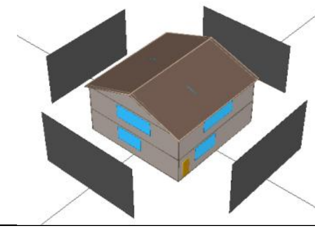
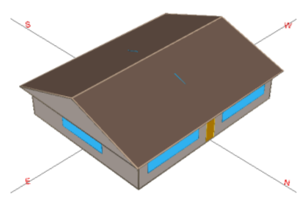
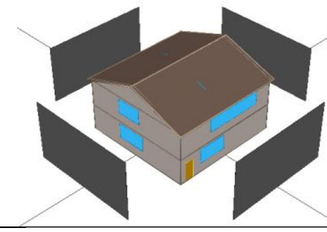
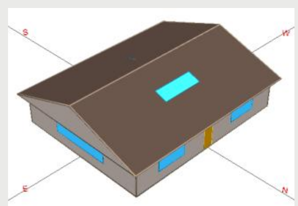
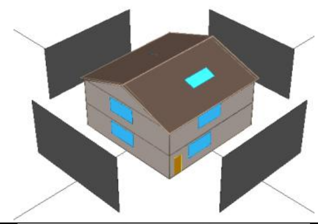
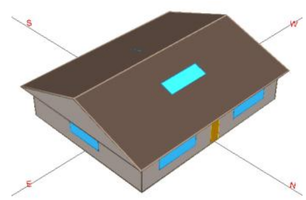
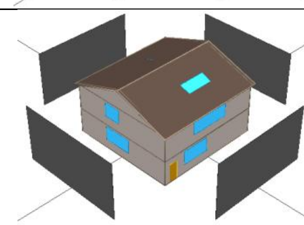
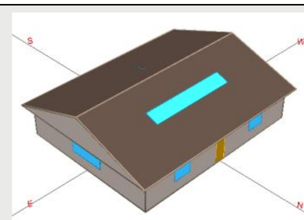
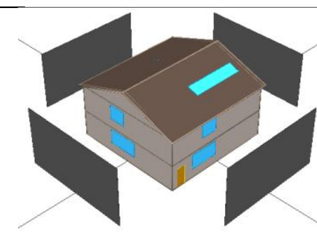
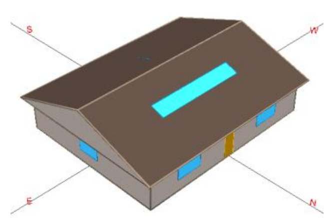
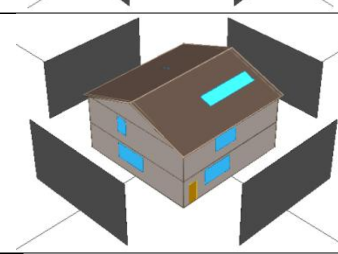
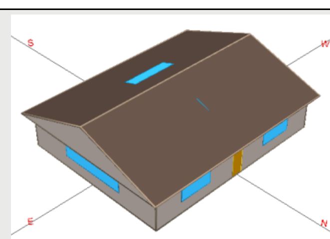
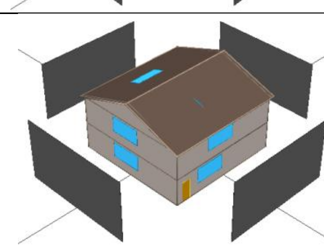
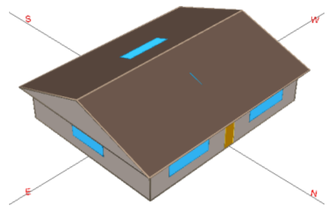
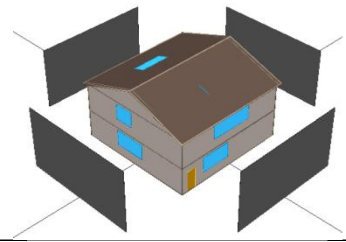
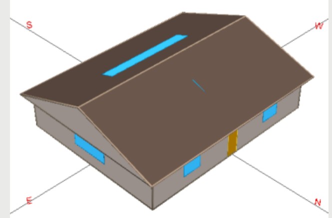
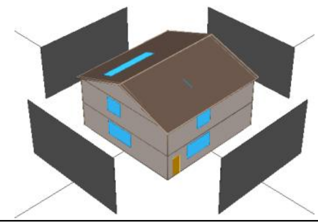
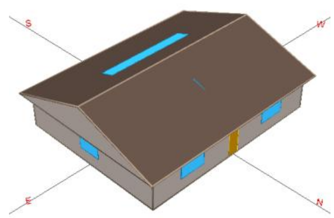
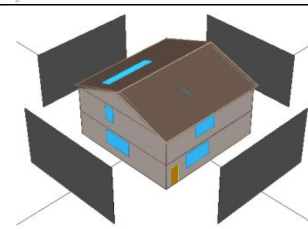
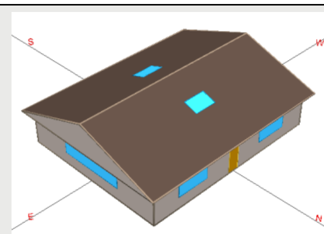
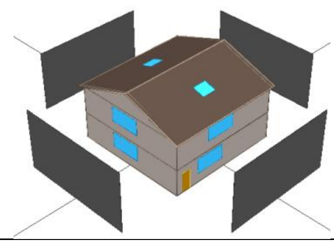
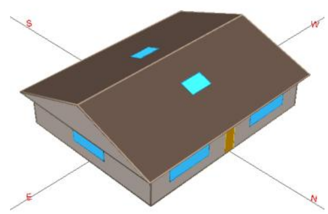
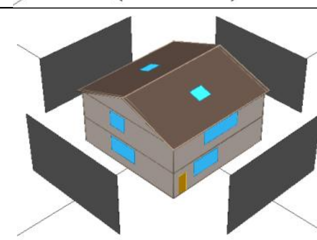
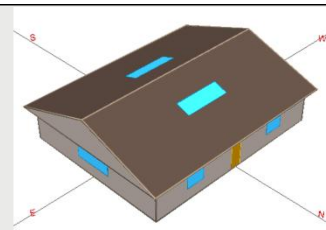
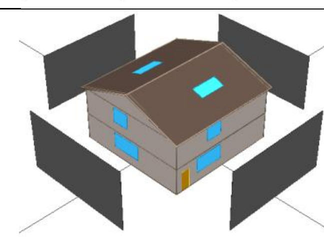
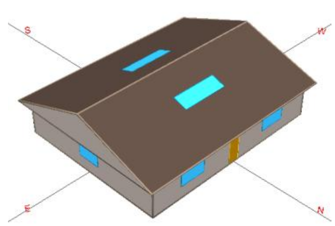
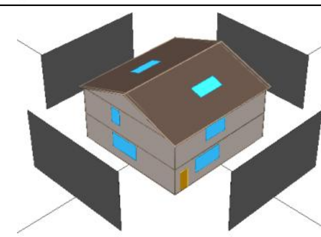


Figure 2: Modeled Home in Study 1, Phases I-III (shown with skylights for reference)

This methodology, which used combinations of three window to floor area ratios (20%, 14%, and 8%), two window distributions (equal on all facades, or 70% north/south and 30% east/west), three skylight orientations (all north, all south, or equal distribution north and south), generated a total of 14 different model test runs per city analyzed as follows:

Table 2: Model Run Parameters

Model Number	Skylight Orientation	Window Area	Vertical Window Distribution	Study 1, Phases I-III	Study 2
1 (Baseline)	None	Maximum (20% window to floor area)	50% N/S, 50% E/W		
2			70% N/S, 30% E/W		
3	North only	Average (14% window to floor area)	50% N/S, 50% E/W		
4			70% N/S, 30% E/W		
5		Minimum (8% window to floor area)	50% N/S, 50% E/W		
6			70% N/S, 30% E/W		
7	South only	Average (14% window to floor area)	50% N/S, 50% E/W		

Model Number	Skylight Orientation	Window Area	Vertical Window Distribution	Study 1, Phases I-III	Study 2
8			70% N/S, 30% E/W		
9		Minimum (8% window to floor area)	50% N/S, 50% E/W		
10			70% N/S, 30% E/W		
11	50% North, 50% South	Average (14% window to floor area)	50% N/S, 50% E/W		
12			70% N/S, 30% E/W		
13		Minimum (8% window to floor area)	50% N/S, 50% E/W		
14			70% N/S, 30% E/W		

With fourteen runs in nine cities, this resulted in a total of 126 separate model runs.

The window area parameters (maximum, minimum, and average) were selected based on the maximum and minimum allowable glazing areas given by California codes as outlined in Study 1. Please refer to the first study for more information on the basis of selection of these model parameters.

Phase III of Study 1 used the same methodology as Phases I and II, but instead evaluated the use of clear fenestration, focusing on the energy cost impacts of existing homes that may have lower performing skylights installed. The goal of this study was to illustrate energy cost savings for skylight upgrades on north or south facing roofs for those considering investing in upgrades.

1.2 Methodology

Study 2 extends the methodology used in the Study 1 and adapts it for a two story home. Six of the original cities were selected for this second analysis: Dallas, Los Angeles, Seattle Boston, Denver, and Minneapolis. These cities were selected to present a relatively broad picture of climate zones in major cities across the United States. The methodology for this analysis was also updated to align more closely with the modeling parameters used to influence residential energy codes: RESFEN and NFRC 901 reference homes. Refer to Appendix B for more details on the reference sources and their use in generating this methodology.

Additional modeling parameters include:

- 2,800 square foot home, with a square footprint, split evenly between two floors
- The fenestration in the second story is varied exactly the same as in the first two studies, sized to achieve a consistent daylight factor of 5%.
- The windows on the first story are kept constant, at an average of 14% window to floor area ratio[1].
- All insulation and HVAC/DHW efficiencies follow local prescriptive codes.
- Natural ventilation is modeled using the Sherman-Grimsrud method, allowing for ventilation with operable skylights as well as windows.
- Interior walls and furniture modeled as additional internal mass
- Exterior obstructions are modeled to simulate the effects of trees and nearby buildings found in a suburban and urban environment. These obstructions are modeled with a transmittance of 67%, and are the same height as the house, 20’ away on all sides.
- Heating and cooling setbacks/setups are modeled minimally to simulate the effects of programmable thermostats (see Appendix A).
- The potential solar heat gain reduction and insulating effects of blinds and shades on the windows and skylights have not been included.

[1] Found to be the “typical” US home window-to-floor-area ratio by the Department of Energy using data from the Residential Energy Consumption Survey (RECS)

1.3 Results

The charts below show the HVAC energy cost savings for each city compared to the baseline runs (#1). The following trends can be noted:

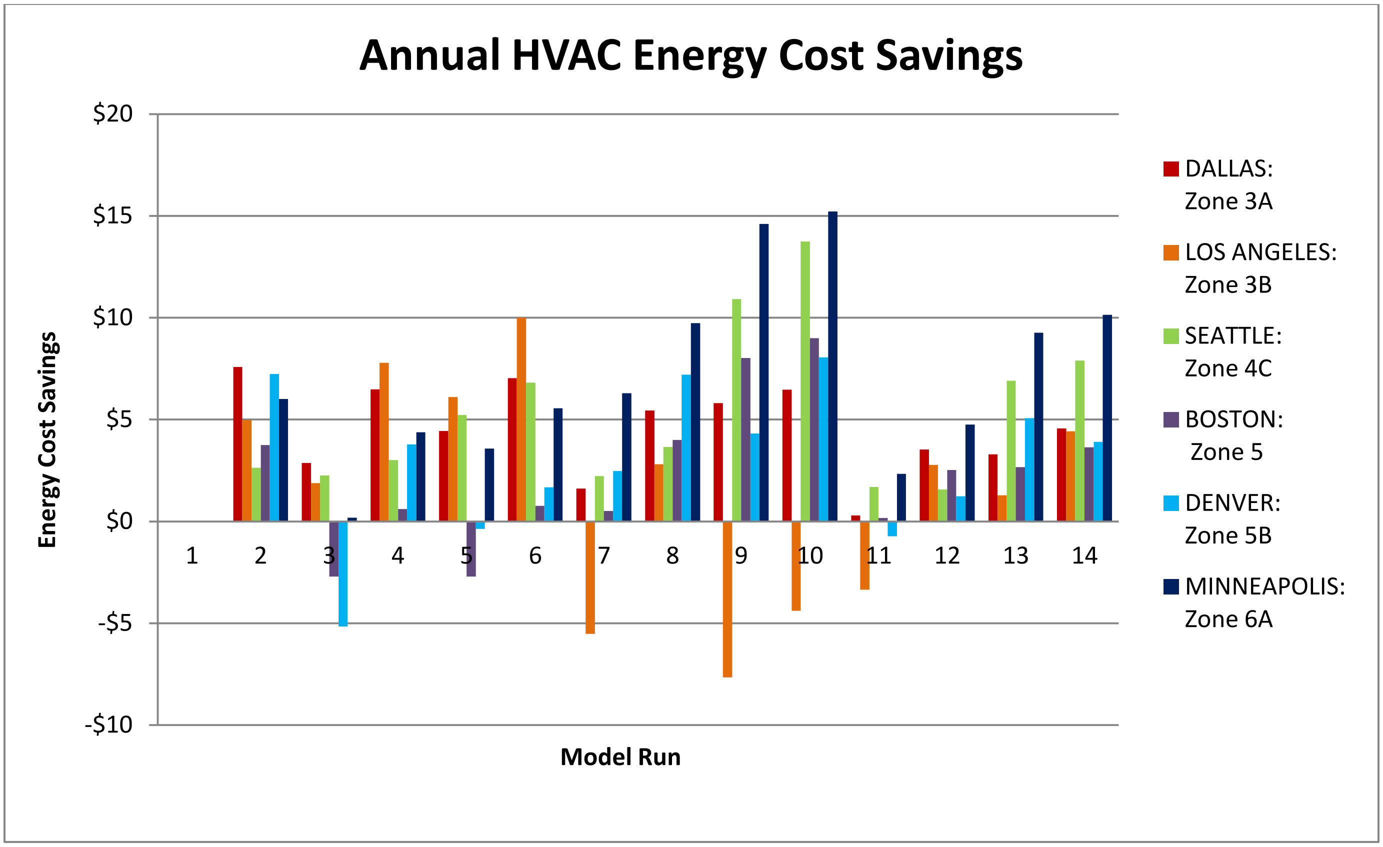
- When compared to the Study 1 (specifically the results in Phase II), the percentage of HVAC savings found in Study 2 is lower, which is as to be expected since only half of the 2-story home is affected by skylights and the impact of windows is lessened by shading. However, both studies follow the same savings trends within each city. This adds to the validation of the results in Study 1, even with the variation in modeling parameters of the one-story home verses the two-story home. See Section 2 for more details.
- In general, with only a few exceptions, the greater the skylight area, the greater the savings.
- The highest potential energy cost increase is found in Los Angeles, when the maximum south facing skylights are employed (runs #9 and 10). North skylights provide better savings in this city.
- Small energy cost increases also occur in Boston and Denver with the implementation of north-only skylights. These cities benefitted the most from south facing skylights.
- The highest potential energy cost savings are found in Minneapolis, when the maximum south facing skylights are employed (run #10).
- Reducing east/west facing windows always results in energy savings.

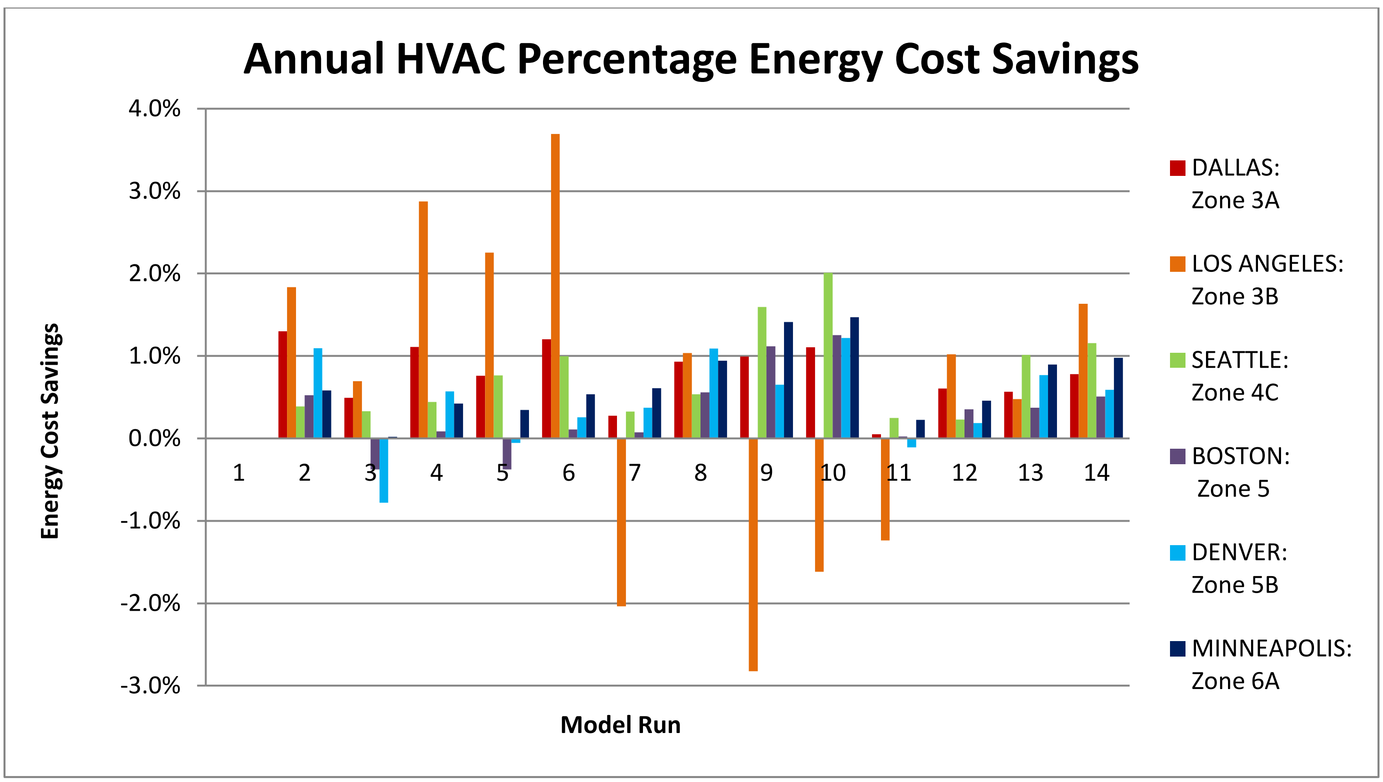
Table 3: Annual HVAC Energy Cost Savings Relative to Model 1

Model Number	DALLAS: Zone 3A	LOS ANGELES: Zone 3B	SEATTLE: Zone 4C	BOSTON: Zone 5	DENVER: Zone 5B	MINNEAPOLIS: Zone 6A
1	-	-	-	-	-	-
2	$8	$5	$3	$4	$7	$6
3	$3	$2	$2	-$3	-$5	$0
4	$6	$8	$3	$1	$4	$4
5	$4	$6	$5	-$3	$0	$4
6	$7	$10	$7	$1	$2	$6
7	$2	-$6	$2	$1	$2	$6
8	$5	$3	$4	$4	$7	$10
9	$6	-$8	$11	$8	$4	$15
10	$6	-$4	$14	$9	$8	$15
11	$0	-$3	$2	$0	-$1	$2

12	$4	$3	$2	$3	$1	$5
13	$3	$1	$7	$3	$5	$9
14	$5	$4	$8	$4	$4	$10

Figure 3: Annual HVAC Energy Cost Savings Comparisons



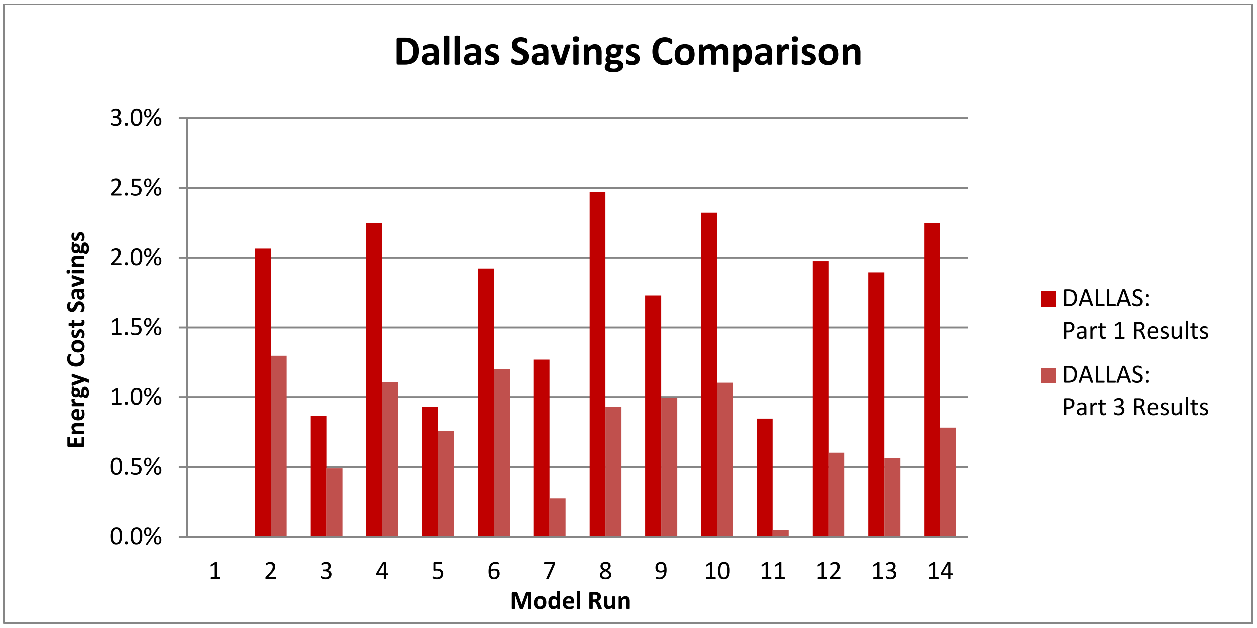


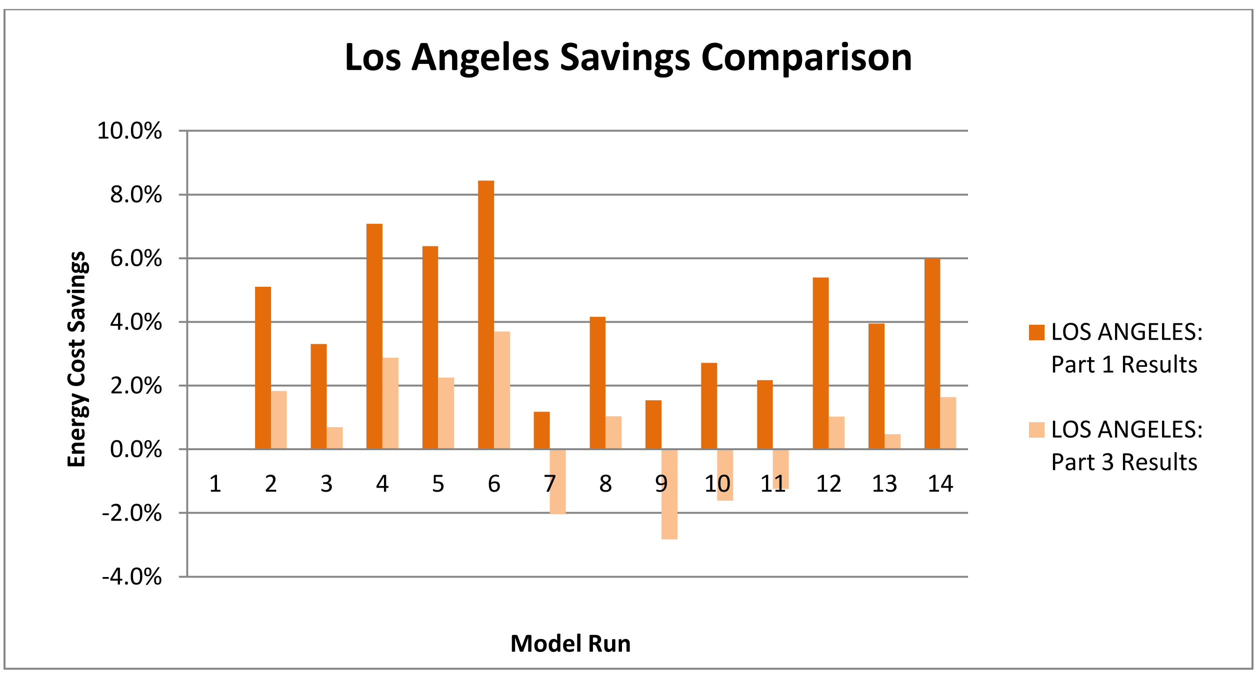
2 Additional Discussion

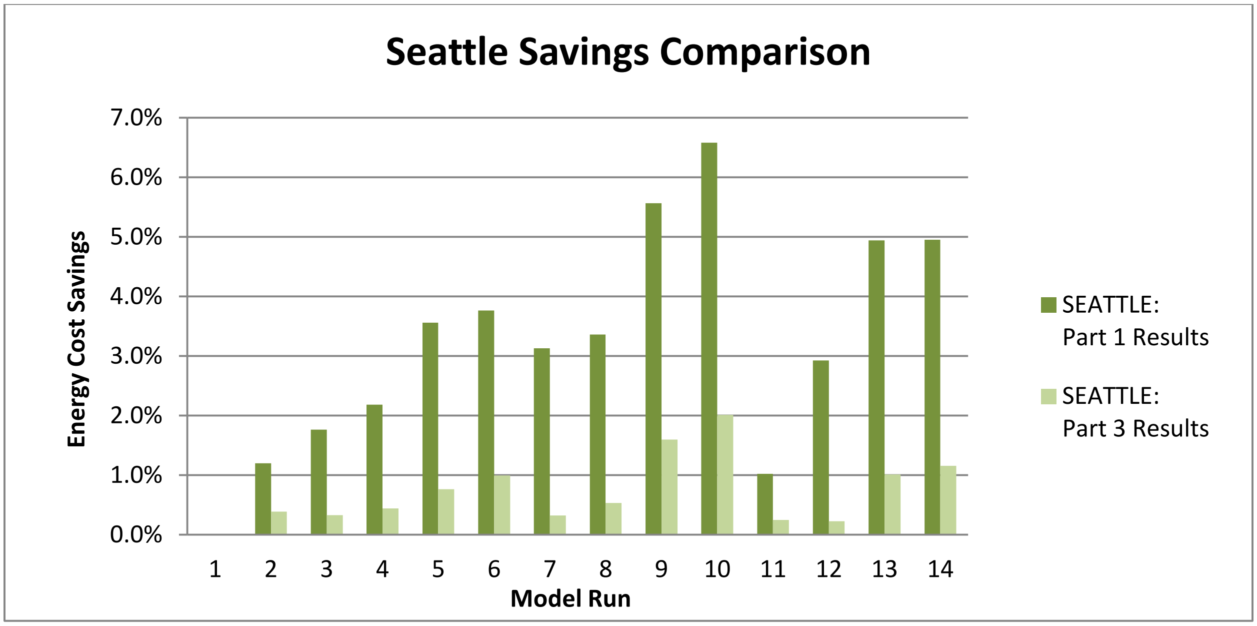
2.1 Comparison to Study 1

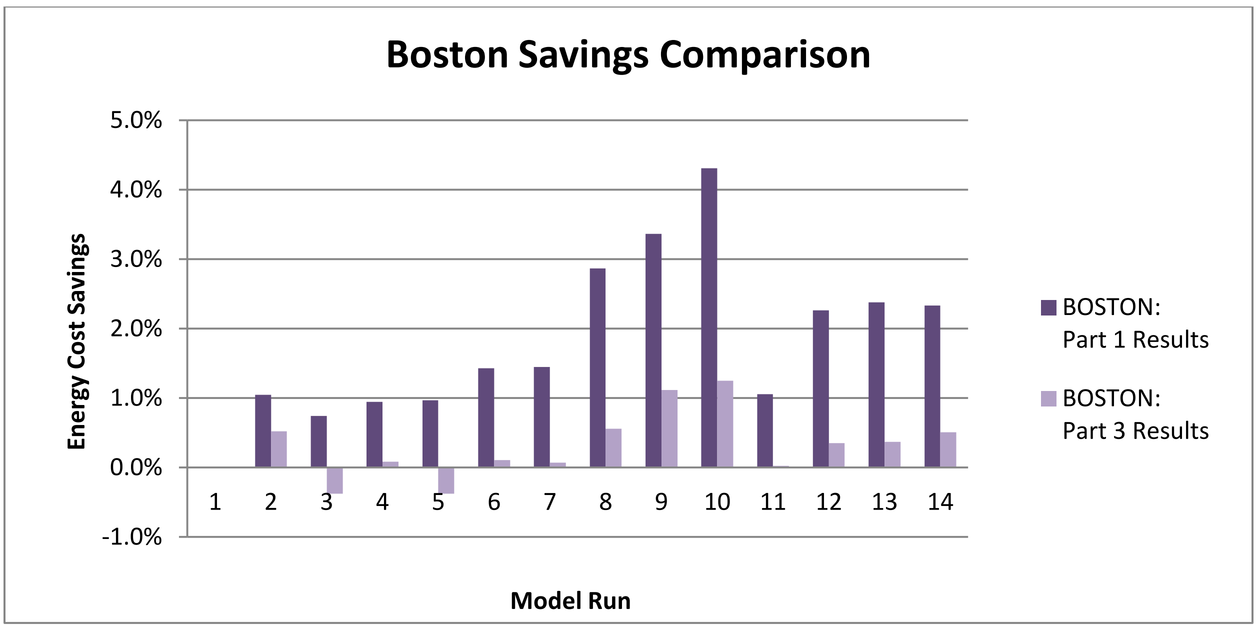
The following charts compare the percentage of HVAC energy cost savings from Study 1, Phase II results to the Study 2 results.

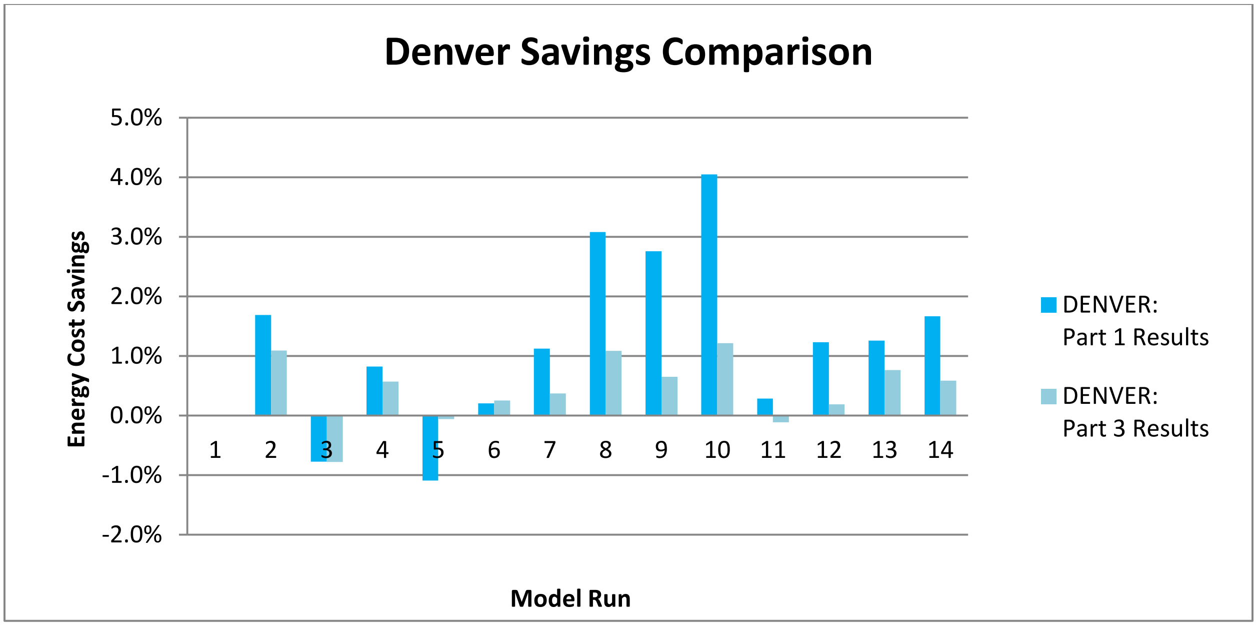
Figure 4: Comparison of Study Results by City

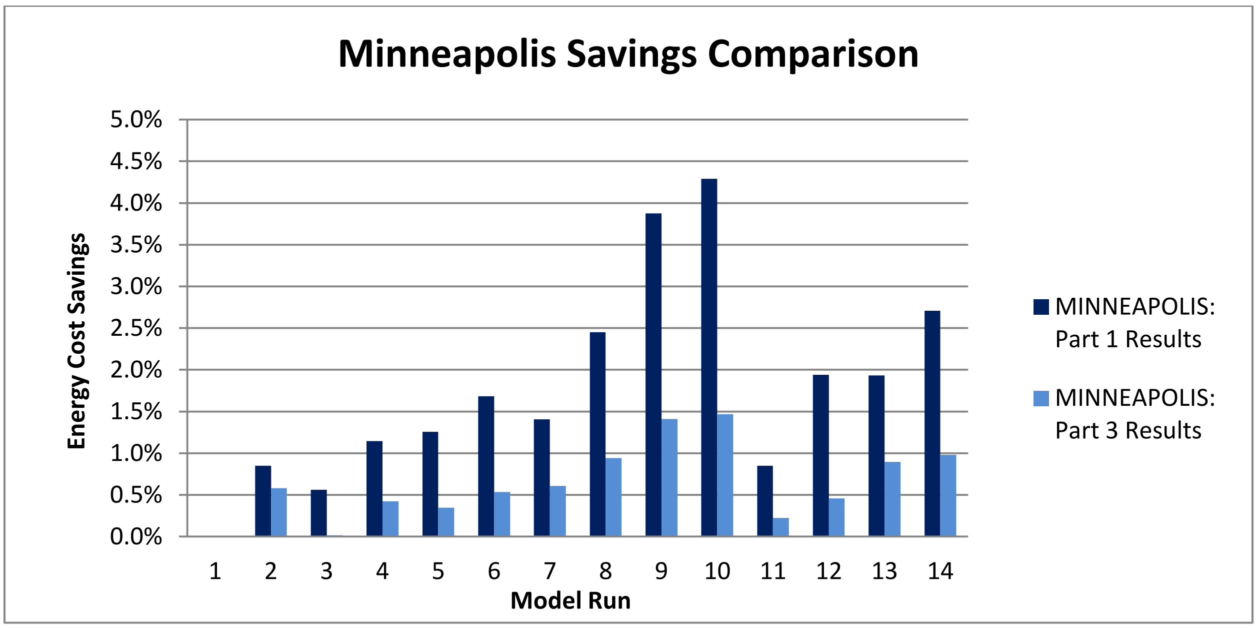





Seattle Savings Comparison
Energy Cost Savings
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Model Run
SEATTLE: Part 1 Results
SEATTLE: Part 3 Results


Boston Savings Comparison
Energy Cost Savings
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
-1.0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Model Run
BOSTON: Part 1 Results
BOSTON: Part 3 Results





2.2 Cost Effectiveness Analysis

Reducing windows in favor of skylights is not necessarily a cost savings to the homeowner. Using RS Means data for window and skylight materials and installation costs, a 48”x54” window costs $682 (or about $38 per square foot), while a 41”x57” skylight costs $1,169 (or about $72 per square foot). Applying this cost per square foot data to our window and skylight area results in the following costs.

Table 4: Window and Skylight Materials and Installation Costs

Model Number	Skylight Orientation	Window Area	Vertical Window Distribution	Window Cost	Skylight Cost	Total Cost
1 (Baseline)	None	Maximum (20% window to floor area)	50% N/S, 50% E/W	$9,018	$0	$9,018
2			70% N/S, 30% E/W	$9,018	$0	$9,018
3	North only	Average (14% window to floor area)	50% N/S, 50% E/W	$7,426	$3,228	$10,654
4			70% N/S, 30% E/W	$7,426	$3,228	$10,654
5		Minimum (8% window to floor area)	50% N/S, 50% E/W	$5,835	$6,082	$11,916
6			70% N/S, 30% E/W	$5,835	$6,082	$11,916
7	South only	Average (14% window to floor area)	50% N/S, 50% E/W	$7,426	$3,228	$10,654
8			70% N/S, 30% E/W	$7,426	$3,228	$10,654
9		Minimum (8% window to floor area)	50% N/S, 50% E/W	$5,835	$6,082	$11,916
10			70% N/S, 30% E/W	$5,835	$6,082	$11,916
11	50% North, 50% South	Average (14% window to floor area)	50% N/S, 50% E/W	$7,426	$3,228	$10,654
12			70% N/S, 30% E/W	$7,426	$3,228	$10,654
13		Minimum (8% window to floor area)	50% N/S, 50% E/W	$5,835	$6,082	$11,916
14			70% N/S, 30% E/W	$5,835	$6,082	$11,916

Since the energy cost savings in each city are relatively small, applying these cost increases to the annual savings by city does not result in a viable payback based on HVAC energy savings alone, as shown in the table below.

Table 5: Payback time in years for changing windows to skylights

Model Number	DALLAS: Zone 3A	LOS ANGELES: Zone 3B	SEATTLE: Zone 4C	BOSTON: Zone 5	DENVER: Zone 5B	MINNEAPOLIS: Zone 6A
1	base	base	base	base	base	base
2	-	-	-	-	-	-
3	570	870	727	-	-	9089

4	252	210	544	2727	433	374
5	653	474	555	-	-	809
6	412	290	425	3764	1725	522
7	1016	-	734	3146	662	260
8	301	582	448	409	227	168
9	500	-	266	361	671	198
10	449	-	211	322	360	190
11	5641	-	968	9624	-	702
12	463	591	1049	649	1319	344
13	878	2247	419	1089	572	313
14	634	654	367	796	743	286

2.3 Future Research

The results of this analysis lead to additional questions that can be pursued:

- The natural ventilation effects simulated in DOE2 and RESFEN use the Sherman-Grimsrud method. How do operable skylights affect the airflow through a single and two story home, and how can this impact summer cooling costs?
- There are some real benefits to using skylights in cold climates for passive solar heating. Can skylights be added without changing window area and still achieve energy savings? For what climates, home types, and window layouts can this occur?

Appendix A: Modeling Parameters

The EQuest 3.6 interface for DOE-2.2 building energy simulation program was used for the building energy analysis. The two figures below show sketches of the eQuest model building envelope geometry and zoning. The geometry is typically simplified for modeling purposes to accurately simulate energy transfer through all surfaces in the building. Windows or skylights on the same orientation and zone are often grouped together to decrease simulation time; this does not affect results of the model.

The model is zoned with a single zone per floor.

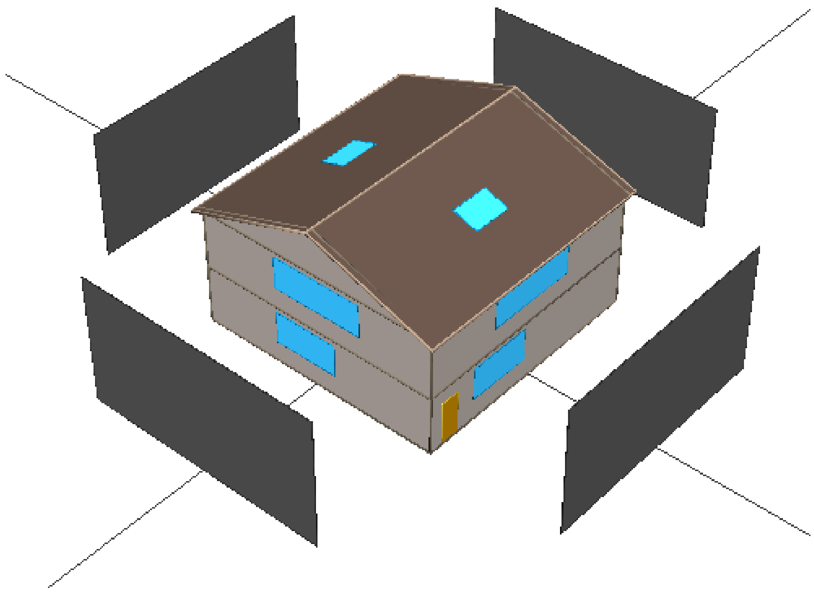


Figure 5: EQuest Sketch of Energy Model

The baseline model was created using a combination of the parameters used in the original analysis as well as those outlined in RESFEN and NFRC 901 reference house models. Parameters were selected so as to be most relevant to actual residential usage, and to parallel that which is used in residential code development. Please see sources and reasoning for these selections in the following tables.

Table 6: Building Envelope Model Inputs

Element	Modeled	Sources
Conditioned Floor Area	2,800 SF	RESFEN parameters have been used whenever possible because RESFEN was initially developed around hourly DOE2 simulations in an effort to provide accurate calculations of newer glazing products, which aligns with the goals of this analysis.
Unconditioned Floor Area	none	
Above Grade Stories	2	
Below Grade Stories	0	Size and construction matches RESFEN base model – deemed "most average" home from which analyses of other house sizes are based (allowing variation from 1,000 - 4,000 sf).
Floor-to-Ceiling Height	9'-0"	
Roof		
Construction Type	Wood framed attic	Construction type matches RESFEN base model. Refer to Appendix B for code details by city.
Insulation	By local code	
Total U-Factor	By local code	
Exterior Walls		
Construction Type	Wood frame 16" on center	Construction type matches RESFEN base model. Refer to Appendix B for code details by city.
Insulation	By local code	
Total U-Factor	By local code	
Ground Floor		
Construction Type	Slab on grade	Matches RESFEN base model
Insulation	none	
Total F-Factor	F-0.038	
Fenestration		
Window Type	operable double pane	Window sizes and orientation are variable in the study (refer to report body for details of these selections). Performance values are calculated using WINDOW5 software following NFRC guidelines.
Whole Window U-Factor	U-0.49	
Whole Window SHGC	SHGC-0.66	
Skylight Type	Operable double pane	
Whole Skylight U-Factor	U-0.59	
Whole Skylight SHGC	SHGC-0.71	
Center-of-Glass Performance (both)	U-0.47, SHGC-0.75	
Frame Type (both)	Wood with aluminum cladding	
Frame U-Factor (both)	U-0.53	
Shading		
Overhangs	1' deep on all façades	Overhangs and obstructions match RESFEN base model (intended to average 2' overhangs and zero overhangs)

Element	Modeled	Sources
Obstructions	Same height as building, 20' away on all sides, 67% transmittance to represent adjacent buildings and trees	
Dirt Depreciation	10% depreciation for windows 30% depreciation for skylights	Windows: Matches RESFEN Skylights: Uses the DOE2 default which is used as the basis for ASHRAE 90.2 (also matches original analysis).
Internal Mass		
Internal Walls	2.44 lbs/sf	This is the standard for both RESFEN & NFRC 901
Furniture	8 lbs/sf	

*Refer to Appendix B for code details

Table 7: HVAC, DHW, Lighting, and Interior Loads Model Inputs

Element	Baseline Building	Sources
Primary System Type	Residential system: Gas-fired furnace and DX air conditioner	ASHRAE 90.1-Appendix G gas baseline – selected as the most common residential system type
Air-Side		
Supply Fan Control	Intermittent	Modeling parameters follow ASHRAE 90.1-Appendix G standards for residential systems.
Return Air Path	Ducted	
Fan Power	1.0 inWg, 53% fan efficiency	
Ventilation Air (cfm)	1441	
Duct losses	None modeled	
Heating		
Space Setpoints	70°F, setback to 68°F (Setback weekdays 11pm-5am, 9am-4pm)	This choice is based in the values used for RESFEN defaults, but has been slightly modified to lessen setbacks. (Peffer, Pritone and Meier)
Heating Equipment	Gas-fired furnace	Selected as most common heating type. Refer to Appendix B for local code details.
Heating Efficiency	By local code	
Cooling		
Space Setpoints	76°F, setback to 78°F (Setback weekdays 11pm-5am, 9am-4pm)	This choice is based in the values used for RESFEN defaults, but has been slightly modified to lessen setbacks. (Peffer, Pritone and Meier)
Cooling Equipment	split DX	Selected as most common cooling type. Refer to Appendix B for local code details.
Cooling Efficiency	By local code	

Modeled EIR	By local code	
Water Heating		
DHW Equipment	natural gas water heater	Selected as most common cooling type, and following ASHRAE 90.1-2007 modeling guidelines for temperature. Refer to Appendix B for local code details.
DHW Heating Efficiency	By local code	
DHW Loop Temperature	110° F	
Lighting		
Lighting Power (peak W/ft^2)	0.61 W/SF on for 750 hours per year	Source: Loads calculated from California Title 24 regulations and studies on how people use the lighting in their homes(Tacoma Public Utilities). This data was used because it represents a more accurate energy use breakdown of an energy-efficient home, whereas RESFEN uses a generic BTU/sf for all loads.
Daylighting Controls	none	
Occupancy Sensors	none	
Exterior Lighting (peak kW)	0.20 kW	
Loads		
Elect. Equipment (W/ft^2)	0.35 W/SF	Details from California Saturation Study, Energy Star. This data was used because it represents a more accurate energy use breakdown, whereas RESFEN uses a generic BTU/sf for all loads.
Cooking Equipment (W/ft^2)	0.085 W/SF (lower level only)	
Refrigeration Equipment (W/ft^2)	0.170 W/SF (lower level only)	
Occupancy	6 people	
Infiltration	Modeled with Sherman-Grimsrud method Specific Leakage Area = 0.00036	Used as analysis method for RESFEN & NFRC 901 (Sherman and Dickerhoff)

Appendix B: Code details by city

While local utilities have made some small rate adjustments since Study 1, the utility rates in this analysis are kept consistent between the three studies for ease of calculation comparisons.

*Table 8: Code Name and Utility Rate Structures by City**

City:	Building Code	Energy Code	Details on electric rates	Details on gas rates
LOS ANGELES (CA-CZ9)	California Building Code 2011	California Title 24 Energy Code 2010, Package D	City of Burbank Water & Power: • Tier 1 (0-250 kWh): $0.1124/kWh • Tier 2 (250-750 kWh): $0.1502/kWh • Tier 3 (751+ kWh): $0.1713/kWh	Southern California Gas: $0.16438/day + $0.7465/therm
BOSTON	Massachusetts State Building Code for One- and Two-Family Dwellings, amended 7th Ed.	MA Stretch Code: 2009 IECC with MA Amendments	Nstar: Residential A1 $6.43/month + $0.08015/kWh	Nstar: $12/month + $0.7010/therm
DALLAS	2006 International Residential Code with Dallas Amendments	Dallas Energy Conservation Code" - 2009 IECC with Dallas Amendments	Xcel (June-Sept): $6/month + $0.095167/kWh (Oct-May): $0.084967/kWh	Atmos: RRC Tariff No 24126 - $17.28/month + $0.7055/therm
DENVER	2009 International Residential Code	2009 IECC	Xcel: $6.87/month, (Tier 1 + Winter) $0.08826/kWh, or (Tier 2) $0.13301/kWh. Tier 1 = summer first 500 kWh	Xcel: $11.73/month + $0.62742/therm
SEATTLE	Seattle Residential Code	2009 Seattle Energy Code (2009 WSEC w/ 2009 Seattle amendments)	Seattle City Light: $3.62/month + $0.0476/kWh (first 10 kWh/day) + $0.0987/kWh (additional)	Puget Sound Energy: $10/month + $0.37372/th delivery + $0.67838/th gas = $1.02562/th
MINNEAPOLIS	Minnesota State Building Code	2006 IECC (with Minnesota Amendments)	Xcel: $6.65/month + $0.07363/kWh summer (June-Sept), $0.06365/kWh winter	Xcel: $9/month + $0.78202/therm April-Oct, $0.8398/therm Nov-March

*Utility rates are current as of February, 2012

Table 9: Building and Energy Code Requirements by City

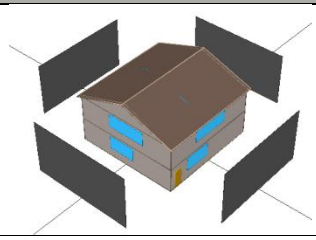
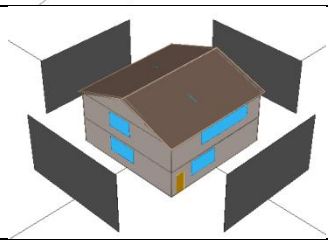
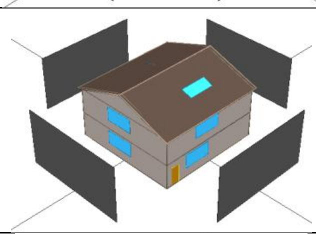
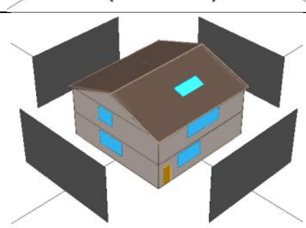
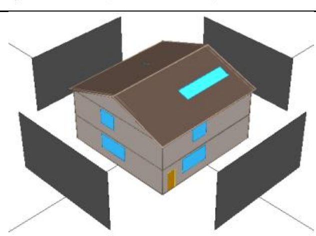
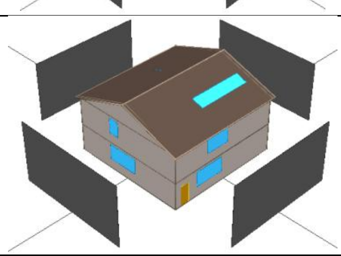
City:	Wall min R	Roof min R	Window max U	Skylight max U	Fenestration max SHGC	Min % Window to Floor area	Max % Window to Floor area	Max % skylight of roof area	Air-cooled air conditioner EER <135,000 BTU/H	Furnace AFUE <225,000
LOS ANGELES (CA-CZ9)	R-13 (wood-framed) U-0.089	R-30 batt in wood framed attic - U-0.034	0.4	0.4	0.4	not less than 8% floor area	20% (includes skylight area). Not more than 5% on the west.	included in max % window area	11.2 EER - EIR=0.2539	78% AFUE or 80% eff
BOSTON	R-19 (wood framed) - U-0.067	R-38 batt in wood framed attic - U-0.027	0.35	0.6	none	not less than 8% floor area	none	none	13.0 SEER, EIR=0.2527	78% AFUE or 80% eff
DALLAS	R-13 (wood framed) U-0.089	R-30 batt in wood framed attic - U-0.034	0.5	0.65	0.3 (windows and skylights)	not less than 8% floor area	15% (includes skylights area - higher % allowed via performance method)	included in max % window area	Federal efficiency standard (Southeastern Region): SEER = 14, EIR=0.2327	Federal efficiency standard (National): AFUE=81%
DENVER	R-20 or R-13+R-5 rigid c.i. (wood-framed) - U-0.065	R-38 wood framed attic - U-0.027	0.35	0.6	none	not less than 8% floor area	none	none	Federal efficiency standard (National): SEER = 13, EIR=0.2527	Federal efficiency standard (Northern Region): AFUE=81%
SEATTLE	R-21 (wood framed) - U-0.063	R-49 batt in wood framed attic - U-0.021	0.32	0.5	none	not less than 8% floor area	25% (Climate zone 1, path II option)	included in max % window area	11.2 EER - EIR=0.2539	78% AFUE or 80% eff
MINNEAPOLIS	R-19 or R-13 + R-5 (wood framed) - 0.067	R-38 wood framed attic - U-0.027	0.35	0.6	none	not less than 8% floor area	none	none	Federal efficiency standard (National): SEER = 13, EIR=0.2527	Federal efficiency standard (Northern Region): AFUE=81%

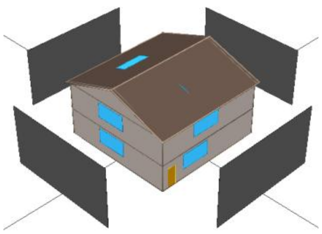
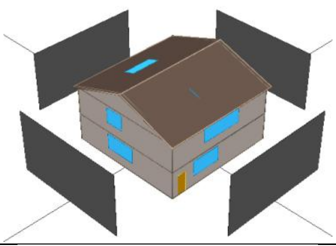
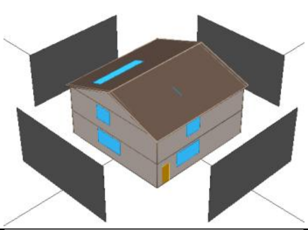
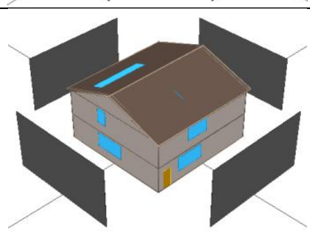
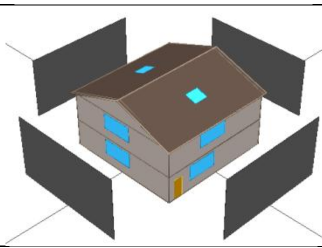
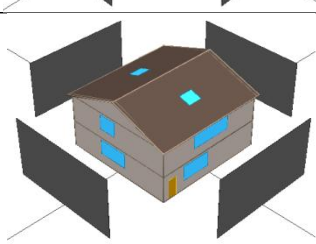
Table 10: Weather and Site Data by City

City:	Weather File	Latitude	Longitude	Elevation	HDD (65)	CDD (50)	Climate Zone (90.1-2007)
LOS ANGLELES (CA-CZ9)	CZ2\CZ09.bin	34.20 N	118.35 W	699 ft	1458	4777	3B
BOSTON	TMY2\BOSTONMA.bin	42.37 N	71.03 W	20 ft	5641	2897	5
DALLAS	TMY2\FORT-WTX.bin	32.85 N	96.85 W	440 ft	2259	6587	3A
DENVER	TMY\DENVERCO.bin	39.77 N	104.87 W	5286 ft	6020	2732	5B
SEATTLE	TMY2\SEATTLWA.bin	47.65 N	122.30 W	20 ft	4611	2120	4C
MINNEAPOLIS	TMY2\MINNEAMN.bin	44.89 N	93.23 W	980 ft	7981	2680	6A

Appendix C: Detailed Results Tables

Table 11: Annual Cost Savings by City

Model Number	Image	Annual HVAC Cost Savings					
		DALLAS: Zone 3A	***LOS ANGELES: Zone 3B***	***SEATTLE: Zone 4C***	***BOSTON: Zone 5***	***DENVER: Zone 5B***	***MINNEAPOLIS: Zone 6A***
1 (Baseline)		-	-	-	-	-	-
2		$8	$5	$3	$4	$7	$6
3		$3	$2	$2	-$3	-$5	$0
4		$6	$8	$3	$1	$4	$4
5		$4	$6	$5	-$3	$0	$4
6		$7	$10	$7	$1	$2	$6

Model Number	Image	Annual HVAC Cost Savings					
		DALLAS: Zone 3A	*LOS ANGELES: Zone 3B*	*SEATTLE: Zone 4C*	*BOSTON: Zone 5*	*DENVER: Zone 5B*	*MINNEAPOLIS: Zone 6A*
7		$2	-$6	$2	$1	$2	$6
8		$5	$3	$4	$4	$7	$10
9		$6	-$8	$11	$8	$4	$15
10		$6	-$4	$14	$9	$8	$15
11		$0	-$3	$2	$0	-$1	$2
12		$4	$3	$2	$3	$1	$5

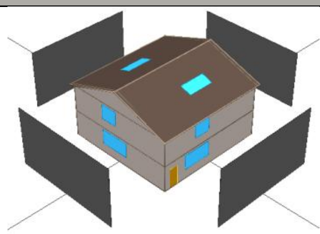
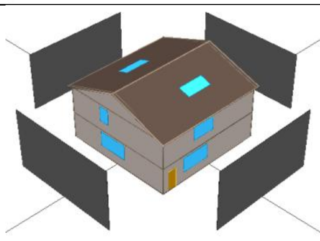
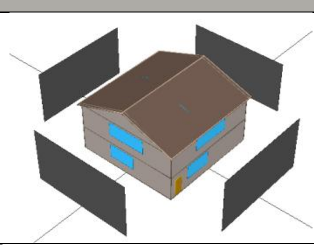
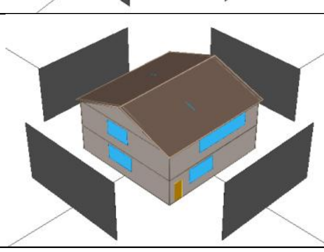
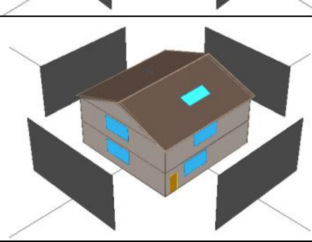
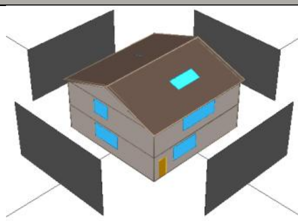
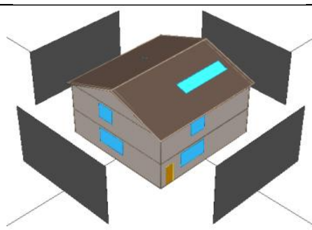
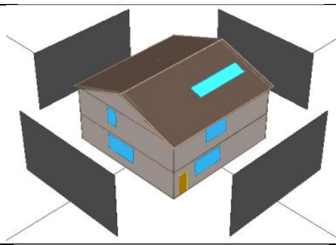
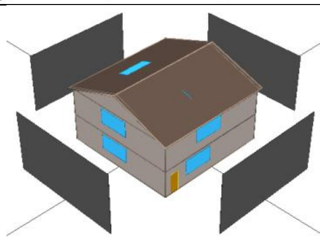
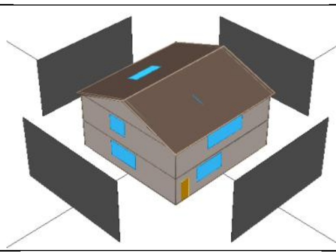
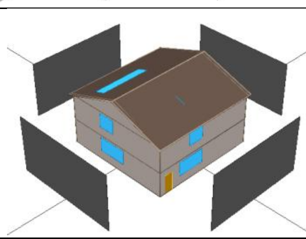
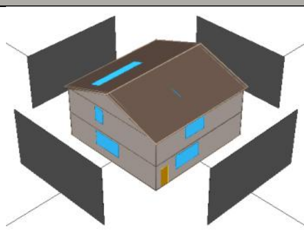
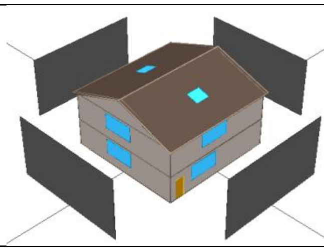
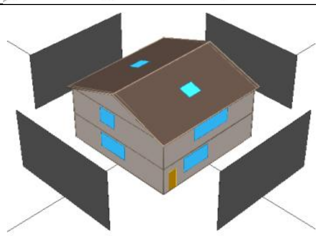
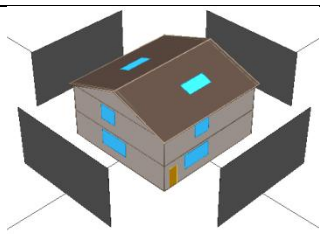
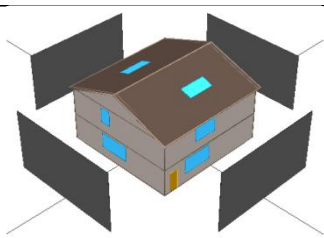
Model Number	Image	Annual HVAC Cost Savings					
		DALLAS: Zone 3A	*LOS ANGELES: Zone 3B*	*SEATTLE: Zone 4C*	*BOSTON: Zone 5*	*DENVER: Zone 5B*	*MINNEAPOLIS: Zone 6A*
13		$3	$1	$7	$3	$5	$9
14		$5	$4	$8	$4	$4	$10

Table 12: Annual Percentage HVAC Cost Savings by City

Model Number	Image	Annual Percentage of HVAC Cost Savings					
		DALLAS: Zone 3A	*LOS ANGELES: Zone 3B*	*SEATTLE: Zone 4C*	*BOSTON: Zone 5*	*DENVER: Zone 5B*	*MINNEAPOLIS: Zone 6A*
1 (Baseline)		-	-	-	-	-	-
2		1.3%	1.8%	0.4%	0.5%	1.1%	0.6%
3		0.5%	0.7%	0.3%	-0.4%	-0.8%	0.0%

Model Number	Image	Annual Percentage of HVAC Cost Savings					
		DALLAS: Zone 3A	*LOS ANGELES: Zone 3B*	*SEATTLE: Zone 4C*	*BOSTON: Zone 5*	*DENVER: Zone 5B*	*MINNEAPOLIS: Zone 6A*
4		1.1%	2.9%	0.4%	0.1%	0.6%	0.4%
5		0.8%	2.3%	0.8%	-0.4%	-0.1%	0.3%
6		1.2%	3.7%	1.0%	0.1%	0.3%	0.5%
7		0.3%	-2.0%	0.3%	0.1%	0.4%	0.6%
8		0.9%	1.0%	0.5%	0.6%	1.1%	0.9%
9		1.0%	-2.8%	1.6%	1.1%	0.7%	1.4%

Model Number	Image	Annual Percentage of HVAC Cost Savings					
		***DALLAS:* Zone 3A**	***LOS ANGELES:* Zone 3B**	***SEATTLE:* Zone 4C**	***BOSTON:* Zone 5**	***DENVER:* Zone 5B**	***MINNEAPOLIS:* Zone 6A**
10		1.1%	-1.6%	2.0%	1.3%	1.2%	1.5%
11		0.0%	-1.2%	0.2%	0.0%	-0.1%	0.2%
12		0.6%	1.0%	0.2%	0.4%	0.2%	0.5%
13		0.6%	0.5%	1.0%	0.4%	0.8%	0.9%
14		0.8%	1.6%	1.2%	0.5%	0.6%	1.0%

References

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. ASHRAE 90.1 Appendix B. 2007, n.d.

California Code of Regulations. California Administrative Code. Vols. Part 6, Subchapter 8. Washington, D.C.: International Code Council, 2010.

California Energy Commission. 2008 Building Energy Efficiency Standards for Residential and Non-Residential Buildings. California Energy Commission, 2008.

—. Reference Appendices for the 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. California Energy Commission, 2008.

Christofferson, Jens. "Daylight and Building Regulations." 9 May 2007. The Daylight Site. <www.thedaylightsite.com>.

Crisp, VHC and Littlefair, PJ. "Average Daylight Factor Prediction." Proceedings CIBS National Lighting Conference. London: University of Cambridge, 1984.

David DiLaura, Kevin Houser, Richard Mistrick, Gary Steffy. The Lighting Handbook, Tenth Edition. The Illuminating Engineering Society of North America, 2011.

Laouadi, A. and Atif, M.R. "Daylight availability in top-lit atria: Prediction of skylight transmittance and daylight factor." International Journal of Lighting Research and Technology (2000).

Lynes, J.A. "A Sequence for Daylighting Design." Lighting Reseach & Technology (1979).

Mardaljevic, Dr. John. Climate-Based Daylight Analysis for Residential Buildings. The Gateway, Leicester, UK: Institute of Energy and Sustainably Development at De Montfort University, 2010.

N. Lukman, B.N. Hibrahim, and S. Hayman. Daylight Design Rules of Thumb. 2002.

Peffer, Therese, et al. "How People Use Thermostats in Homes: A Review." 2011.

Reinhart, C.F.; Mardaljevic, J.; Rogers, Z. Dynamic daylight performance metrics for sustainable building design. National Research Council of Canada, 2006.

Sherman, Max and Darryl Dickerhoff. "Air-Tightness of US Dwellings." White Paper. 1998.

Tacoma Public Utilities. "Residential Lighting: The Data to Date." White Paper. 1996.