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

BUILDING TECHNOLOGIES PROGRAM

Measure Guideline: Energy-Efficient Window Performance and Selection

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NorthernSTAR

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Building America U.S. Department of Energy

NOTICE

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Measure Guideline:
Energy-Efficient Window Performance and Selection

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Unless otherwise noted, all figures were created by the NorthernSTAR team.

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Definitions

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Progression Summary

NEW CONSTRUCTION

Identify local energy code (IECC) and ENERGY STAR zone performance requirements.

↓

Look for efficient window properties on the NFRC label.

↓

Use the Window Selection Tool to compare performance of generic window types in a typical new home.

↓

Use RESFEN to compare performance of specific window types in a specific new home.

If possible:
- optimize building orientation based on climate;
- optimize window area by orientation;
- optimize shading conditions by orientation.

↓

Ensure proper window installation.

EXISTING CONSTRUCTION

Identify local energy code (IECC) and ENERGY STAR zone performance requirements.

↓

Determine to improve, retrofit, or replace existing windows.

Improve
- check existing wi ows
- caulk and weathe rip

nce

Ensure proper installation.

Retrofit
- sash replacemen
- add attachments
  - storm winc
  - solar conti
  - exterior sh ing

Ensure proper installation.

Replace
- replace in existin
- full window repla

Use the Window Selection Tool to compare perforr of generic window types in a typical existing home

Use RESFEN to compare performance of specific window types in a specific home.

Ensure proper window installation.

1 Introduction

2 Measuring Window Performance

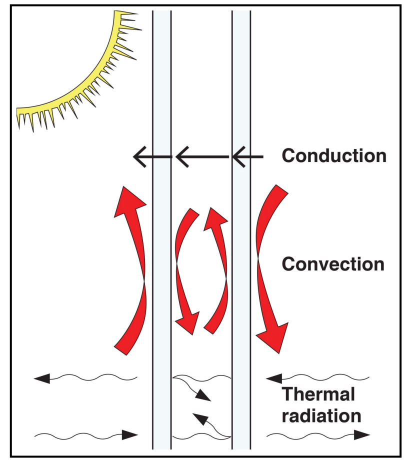

Figure 1. Heat flow through a window

- **Insulating value**

- **Heat gain from solar radiation**

- **Infiltration**

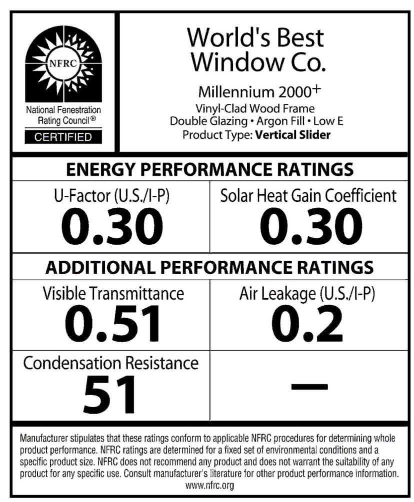

Figure 2. Window properties on the NFRC label

(Image courtesy of NFRC)

2.1 U-Factor

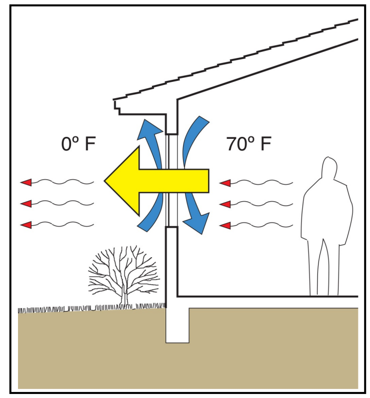

Figure 3. Heat loss through a window by conduction, convection, and radiation

2.2 Solar Heat Gain Coefficient

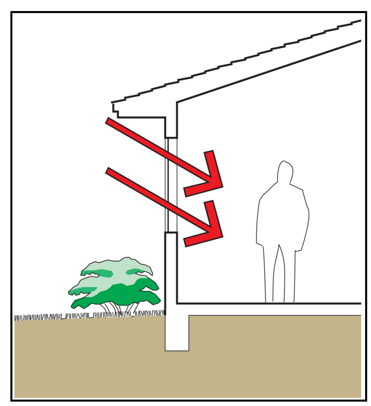

Figure 4. Solar gain through a window

2.3 Visible Transmittance

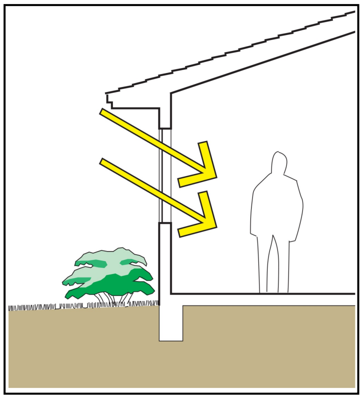

Figure 5. Visible light through a window

2.4 Air Leakage

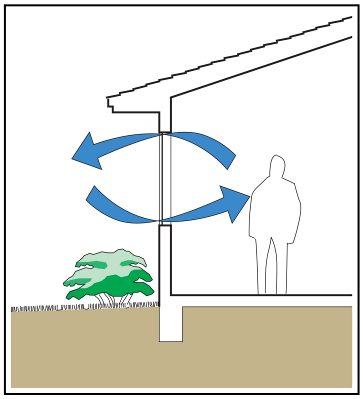

Figure 6. Air leakage through window assembly

2.5 Condensation Resistance

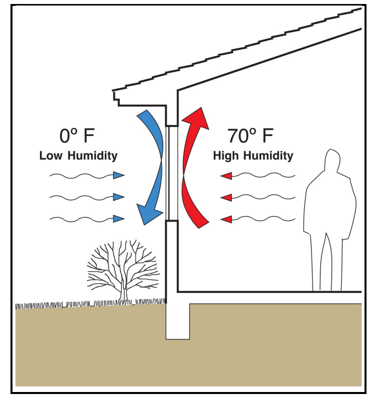

Figure 7. Condensation on window surface

3 Window Technologies

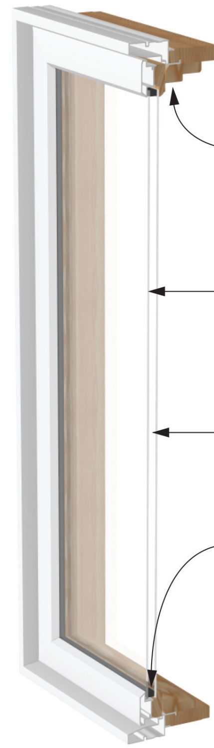

Figure 8. Advancements to improve energy efficiency

3.1 Glazing Types

3.1.1 Multiple Layers

3.1.1.1 Suspended Films

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

3.1.2 Low-Emittance Coatings

emissivity

spectrally selective coatings

3.1.2.1 High-Solar-Gain Low-Emittance Coatings

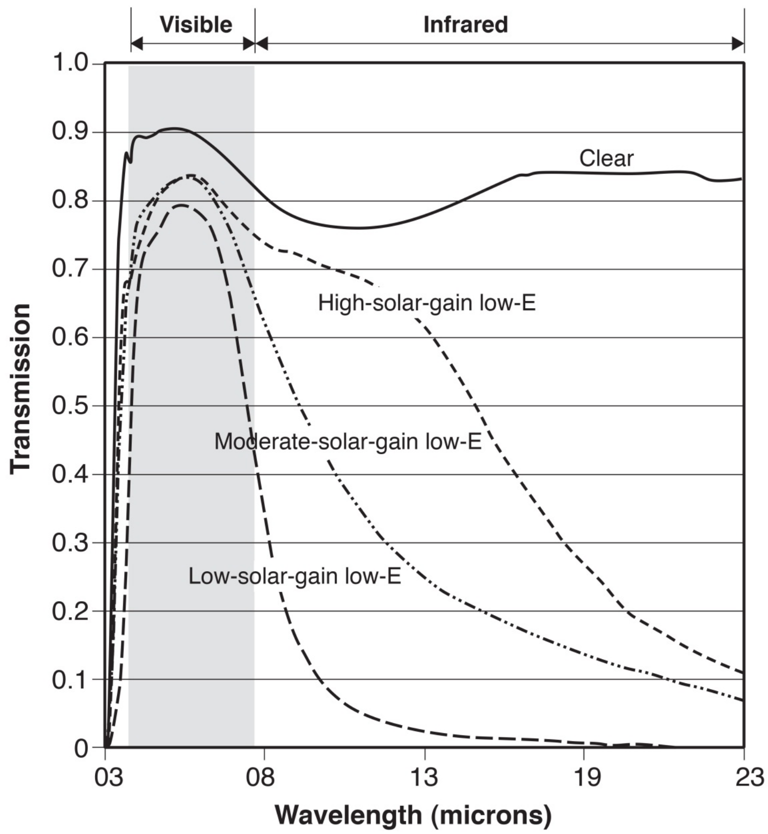

Figure 9. Spectral transmittance curves for glazings with low-e coatings

3.1.2.2 Moderate-Solar-Gain Low-Emittance Coatings

3.1.2.3 Low-Solar-Gain Low-Emittance Coatings

3.1.2.4 Coating Placement

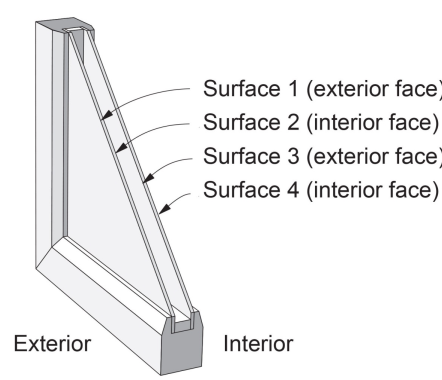

Figure 10. Surface placement of low-e coatings

3.2 Low-Conductance Spacers and Gas Fills

3.2.1 Low-Conductance Gas Fills

ch

3.2.2 Warm Edge Spacers

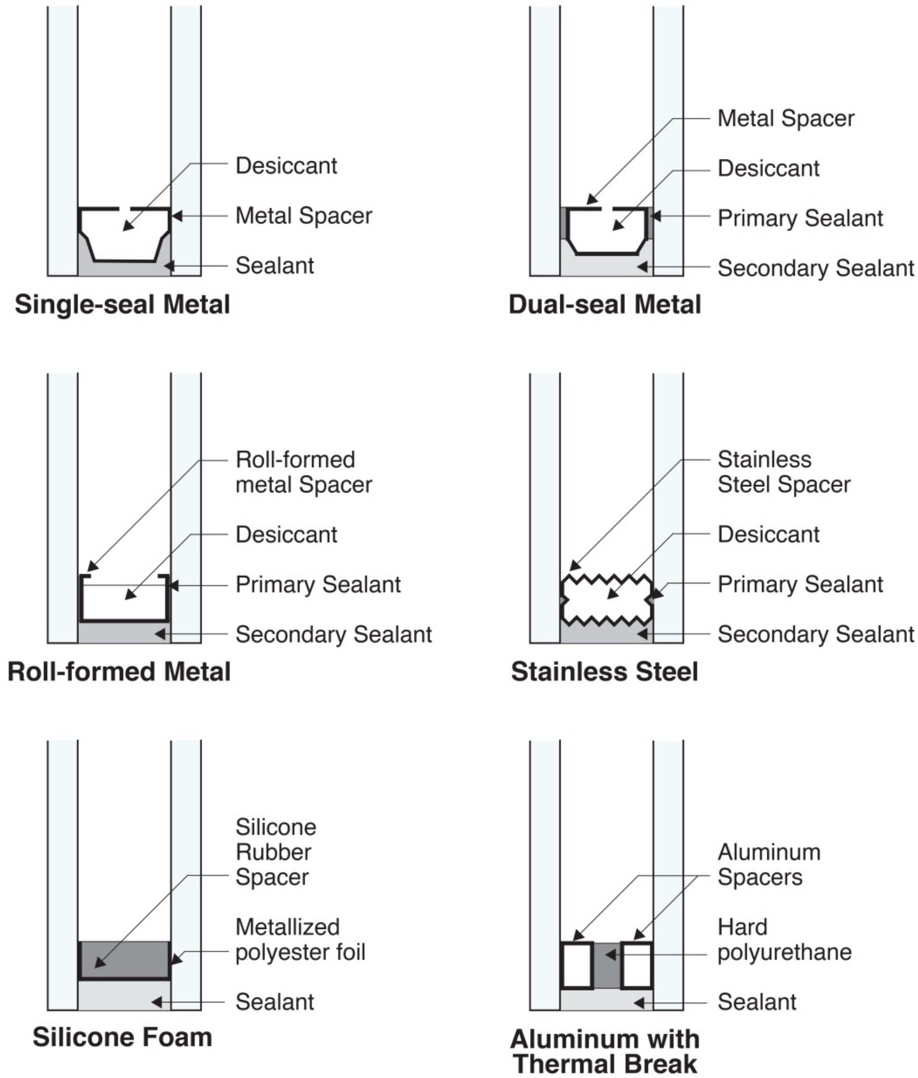

Figure 11. Various metal and nonmetal spacer systems

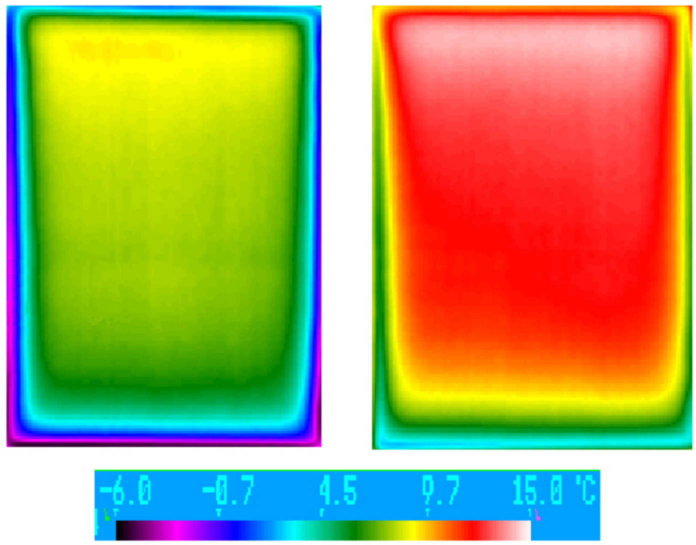

Figure 12. Thermogram of double-glazed clear window with an aluminum spacer (left) and double-glazed low-e window with an insulating spacer (right). Cold regions in purple and blue represent the large amounts of heat flowing through the spacer.
(Image courtesy of LBNL)

3.3 Frame Types

3.3.1 Metal Frames

3.3.2 Thermally Broken Metal Frames

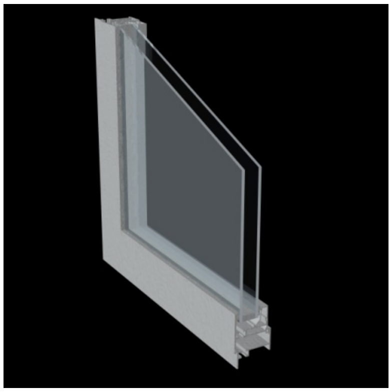

Figure 13. Aluminum frame

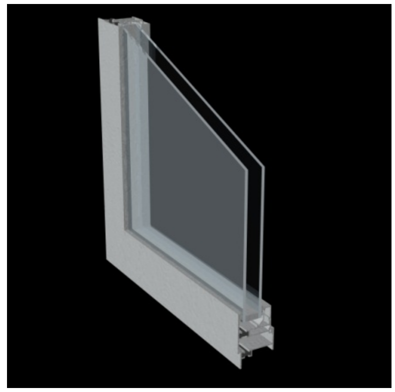

Figure 14. Aluminum frame with thermal break

3.3.3 Nonmetal Frames

3.3.3.1 Wood

. .

3.3.3.2 Wood Clad

Figure 15. Wood frame

Figure 16. Wood with clad frame

3.3.3.3 Vinyl

3.3.3.4 Hybrid

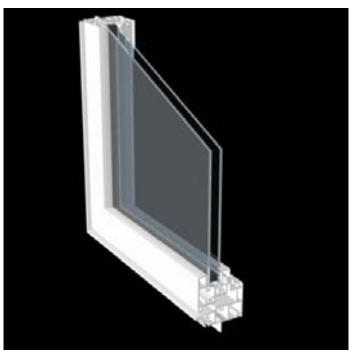

Figure 17. Vinyl frame

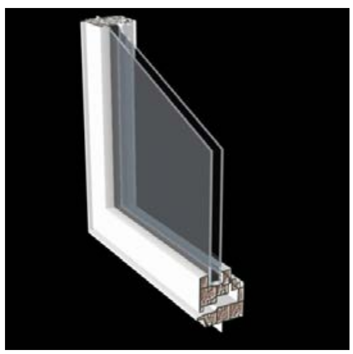

Figure 18. Insulated vinyl frame

Figure 19. Hybrid frame

3.3.3.5 Composite

3.3.3.6 Thermally Improved or Insulated Vinyl

3.3.3.7 Fiberglass or Engineered Thermoplastics

3.3.3.8 Thermally Improved Wood and Composite Frames

. .

Table 1. Properties of Generic Set of Windows

(EWC 2012a)

ID	Glazing	Frame	U	SHGC	VT
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

4 Window Selection Process

Meet code

Look for the ENERGY STAR label

Look for performance properties on the NFRC label

Use the Window Selection Tool (EWC 2012b)

Use RESFEN (LBNL 2012)

Use BEopt (NREL 2012a)

4.1 Energy Codes

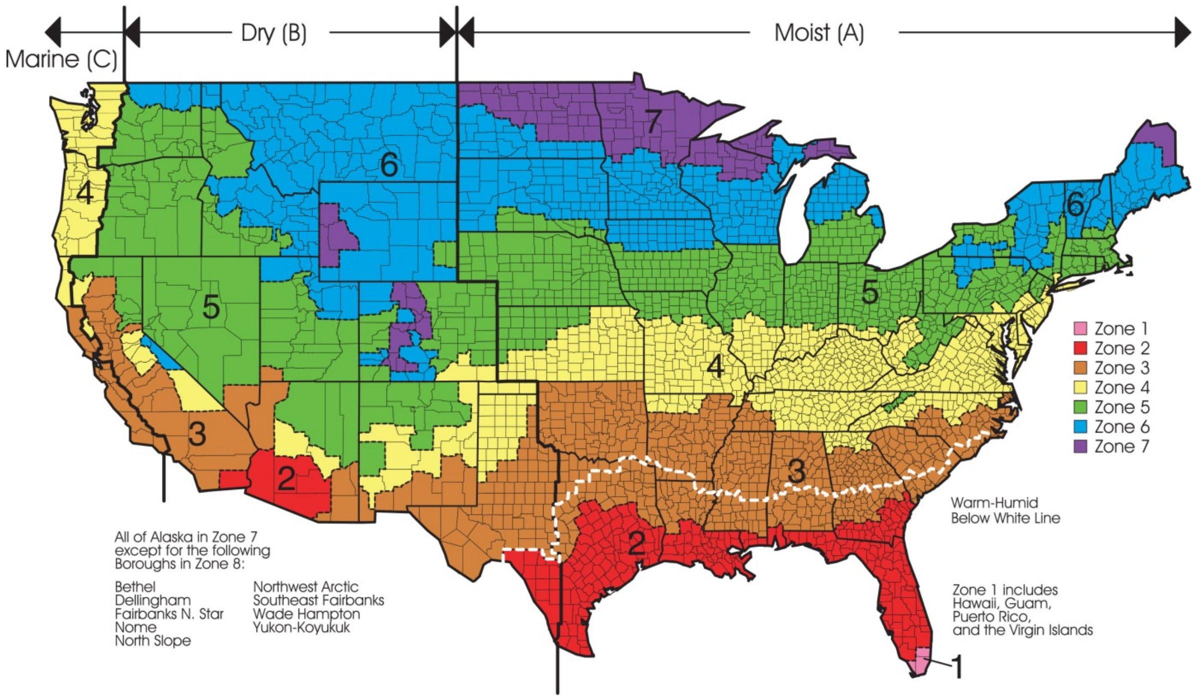

Figure 20. Climate zone map referenced in IECC 2006 and later versions

4.1.1 Windows in the 2009 International Energy Conservation Code

Table 2. Prescriptive Window Requirements in the 2009 IECC

Climate Zone	Window U-Factor	Skylight U-Factor	Window and Skylight SHGC*
1			
2			
3			
4 except Marine			
5 and Marine 4			
6			
7 and 8			

4.1.2 Windows in the 2012 International Energy Conservation Code

Table 3. Prescriptive Window Requirements in the 2012 IECC

Climate Zone	Window U-Factor	Skylight U-Factor	Window and Skylight SHGC
1			
2			
3			
4 except Marine			
5 and Marine 4			
6			
7 and 8			

4.2 ENERGY STAR

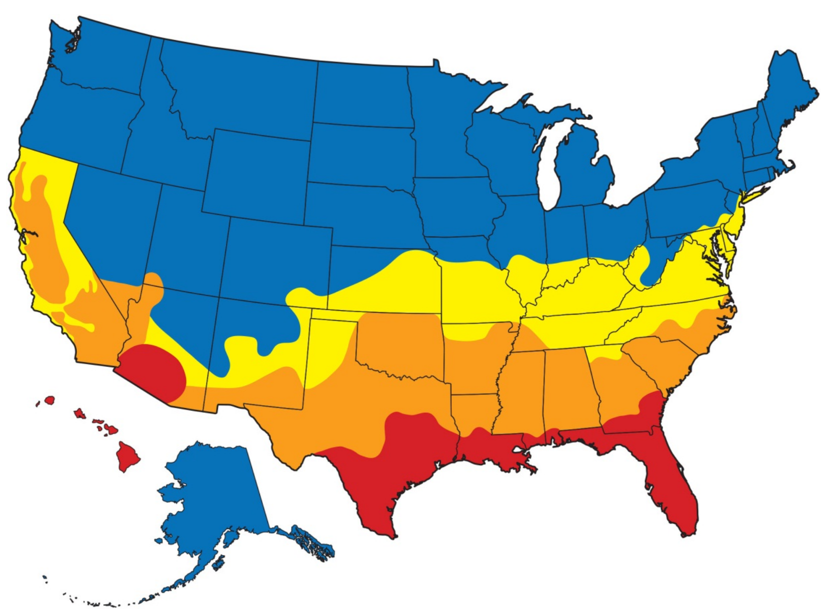

Figure 21. ENERGY STAR zone map

(Image courtesy of EPA)

Table 4. Current ENERGY STAR Performance Requirements

Climate Zone	Window U-Factor	Window SHGC	Skylight U-Factor	Skylight SHGC
North	≤0.30 	 ≥0.35 ≥0.40	≤0.55	
North Central	≤0.32	≤0.4	≤0.55	≤
South Central	≤0.35	≤0.30	≤0.57	≤0.30
South	≤0.60	≤0.27	≤0.70	≤0.30

•

•

•

•

•

s, as well as air leakage (≤0.30 cfm/ft

Table 5. Proposed 2013 ENERGY STAR Performance Requirements

Climate Zone	Window U-factor	Window SHGC	Skylight U-factor	Skylight SHGC
North Tradeoff	≤0.27 	 ≥0.32	≤0.45	≤0.35
North Central	≤0.29	≤0.40	≤0.47	≤0.30
South Central	≤0.31	≤0.25	≤0.50	≤0.25
South	≤	≤0.25	≤0.	≤0.25

4.3 Window Selection Tool

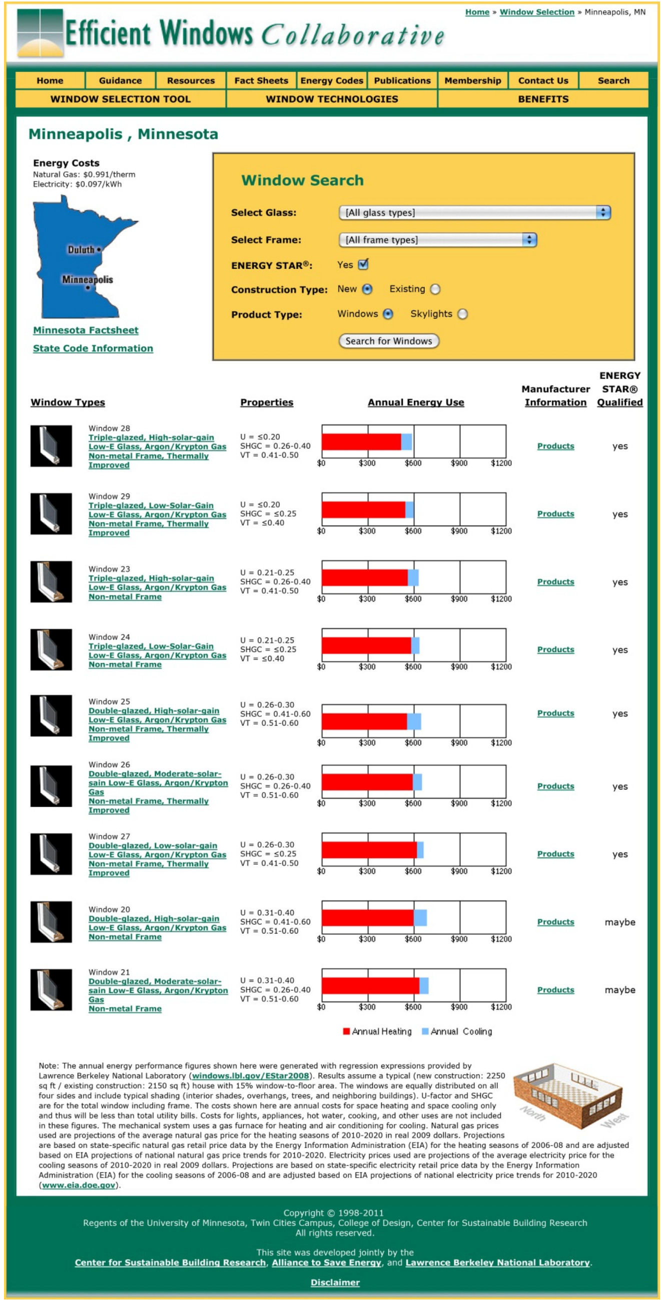

Figure 22. Results from the Window Selection Tool

Minneapolis, Minnesota

Window 28
Triple-glazed, High-solar-gain Low-E Glass, Argon/Krypton Gas
Non-metal Frame, Thermally Improved

U = ≤0.20
SHGC = 0.26-0.40
VT = 0.41-0.50

Manufacturer	View Products
Accurate Dorwin	Products Available»
Fibertec Window & Door Mfg.	Products Available»
Marvin Windows and Doors	Products Available»
Paradigm Window Solutions	Products Available»
Serious Materials	Products Available»
Wasco Windows	Products Available»

Disclaimer: Manufacturers have agreed that products listed here meet the energy performance requirements of the Efficient Windows Collaborative and have been tested and certified according to NFRC standards.

The Efficient Windows Collaborative does not provide any guarantees of service or useability for products or services purchased from these merchants.

Figure 23. Manufacturers listed for a specific window in the Window Selection Tool

Minneapolis, Minnesota

Window 28
Triple-glazed, High-solar-gain Low-E Glass, Argon/Krypton Gas
Non-metal Frame, Thermally Improved

U = ≤0.20
SHGC = 0.26-0.40
VT = 0.41-0.50

«Back to Manufacturers List

Manufacturer	Product Line	U-factor	SHGC	VT	AL
Marvin Windows and Doors http://www.marvin.com	Clad Ultimate Double Hung Picture - tri-pane, low-E 179, argon/krypton	0.20	0.43	0.52	
	Wood Magnum Tilt-Turn - tri-pane, low-E 179, krypton/argon	0.20	0.38	0.46	
	Wood Ultimate Awning - tri-pane, low-E 179, krypton/argon	0.20	0.37	0.45	

Disclaimer: Manufacturers have agreed that products listed here meet the energy performance requirements of the Efficient Windows Collaborative and have been tested and certified according to NFRC standards.

The Efficient Windows Collaborative does not provide any guarantees of service or useability for products or services purchased from these merchants.

Figure 24. Products by a manufacturer listed in the Windows Selection Tool

4.4 RESFEN

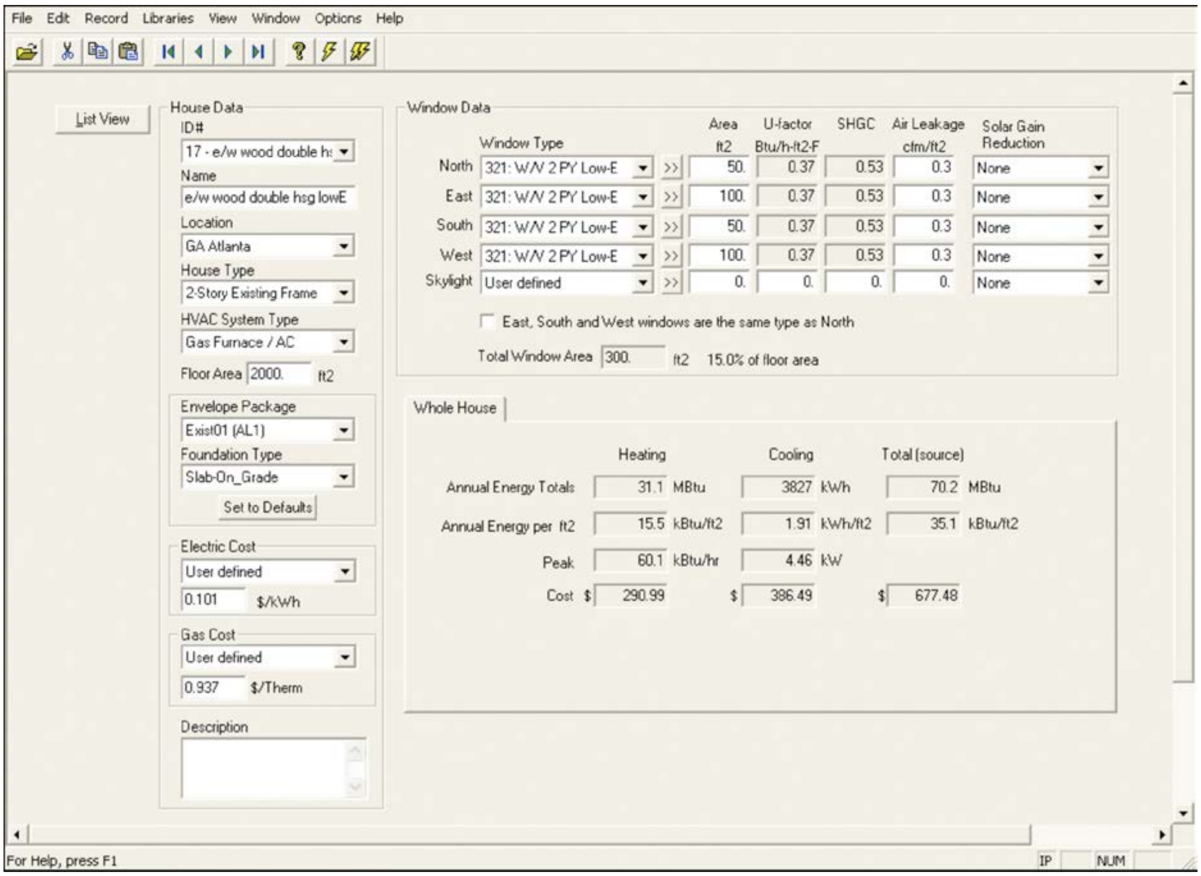

Figure 25. RESFEN computer simulation data entry screen
(Image courtesy of LBNL)

5 Cost and Performance

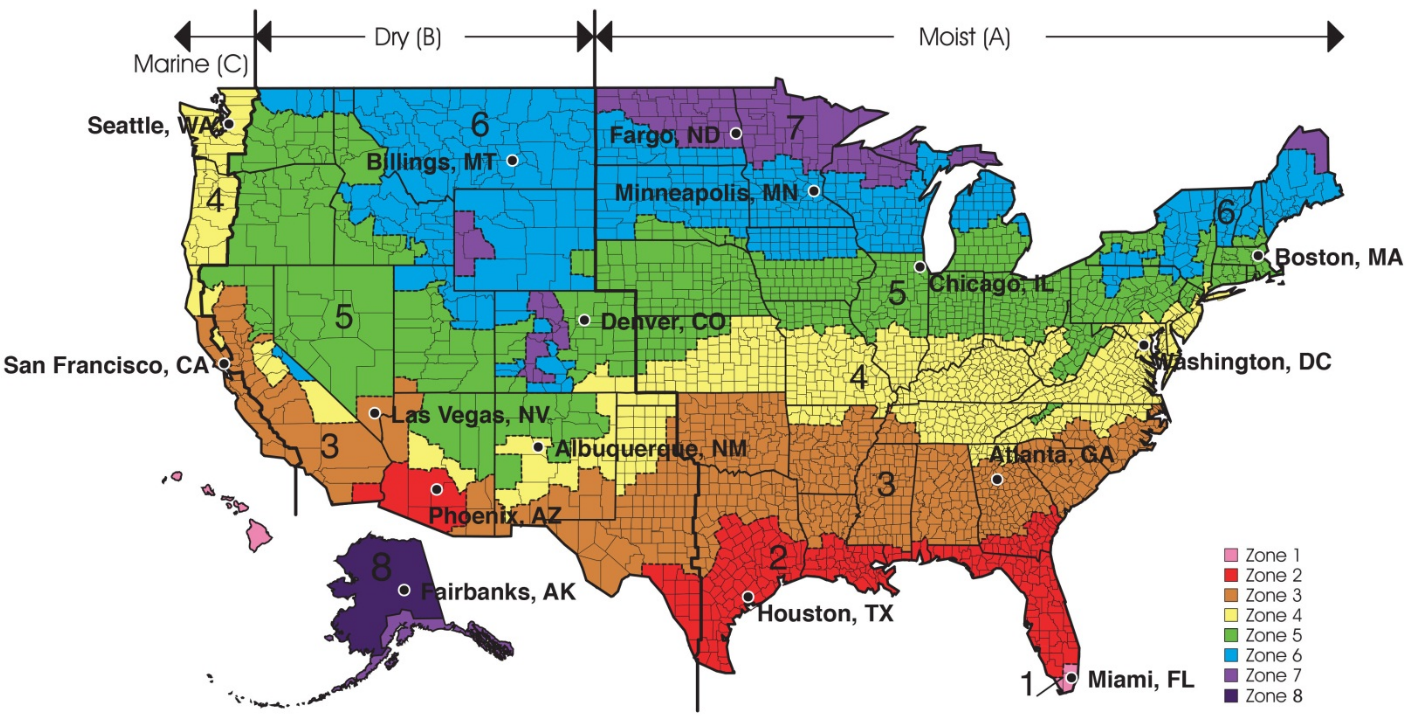

Figure 26. IECC climate zone map with cities used in simulations

5.1 Energy and Cost Savings for New Windows

5.1.1 Savings for New Windows in Climate Zones 1 and 2

Table 6. Properties of Windows Used in Climate Zones 1 and 2

ID	Glazing	Frame	U	SHGC	VT
6					
11					
16					
17					
20					

Table 7. Savings of New Windows in Miami, Florida

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
6											
11											
16											
17											
20											

Table 8. Savings of New Windows in Houston, Texas

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
6											
11											
16											
17											
20											

Table 9. Savings of New Windows in Phoenix, Arizona

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
6											
11											
16											
17											
20											

5.1.2 Savings for New Windows in Climate Zones 3 and 4

Table 10. Properties of Windows Used in Climate Zones 3 and 4

ID	Glazing	Frame	U	SHGC	VT
11					
15					
16					
17					
19					

Table 11. Savings of New Windows in Atlanta, Georgia

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11											
15											
16											
17											
19											

Table 12. Savings of New Windows in Las Vegas, Nevada

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11											
15											
16											
17											
19											

Table 13. Savings of New Windows in San Francisco, California

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11											
15											
16											
17											
19											

Table 14. Savings of New Windows in Washington, D.C.

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11											
15											
16											
17											
19											

Table 15. Savings of New Windows in Albuquerque, New Mexico

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11											
15											
16											
17											
19											

Table 16. Savings of New Windows in Seattle, Washington

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11											
15											
16											
17											
19											

5.1.3 Savings for New Windows in Climate Zones 5–8

Table 17. Properties of Windows Used in Climate Zones 5–8

ID	Glazing	Frame	U	SHGC	VT
15					
16					
17					
18					
19					

Table 18. Savings of New Windows in Chicago, Illinois

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

Table 19. Savings of New Windows in Boston, Massachusetts

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

Table 20. Savings of New Windows in Denver, Colorado

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

Table 21. Savings of New Windows in Minneapolis, Minnesota

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

Table 22. Savings of New Windows in Billings, Montana

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

Table 23. Savings of New Windows in Bismarck, North Dakota

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

Table 24. Savings of New Windows in Fairbanks, Alaska

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
16											
15											
17											
18											
19											

5.2 Energy and Cost Savings for Replacement Windows

5.2.1 Savings for Replacement Windows in Climate Zones 1 and 2

≤0.20) performs best

Table 25. Properties of Windows Used in Climate Zones 1 and 2

ID	Glazing	Frame	U	SHGC	VT
1					
7					
11					
17					
20					

Table 26. Savings of Replacement Windows in Miami, Florida

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
7											
11											
17											
20											

Table 27. Savings of Replacement Windows in Houston, Texas

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
7											
11											
17											
20											

Table 28. Savings of Replacement Windows in Phoenix, Arizona

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
7											
11											
17											
20											

5.2.2 Savings for Replacement Windows in Climate Zones 3 and 4

Table 29. Properties of Windows Used in Climate Zones 3 and 4

ID	Glazing	Frame	U	SHGC	VT
1					
11					
16					
17					
19					

Table 30. Savings of Replacement Windows in Atlanta, Georgia

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
11											
16											
17											
19											

Table 31. Savings of Replacement Windows in Las Vegas, Nevada

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
11											
16											
17											
19											

Table 32. Savings of Replacement Windows in San Francisco, California

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
11											
16											
17											
19											

Table 33. Savings of Replacement Windows in Washington, D.C.

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
11											
16											
17											
19											

Table 34. Savings of Replacement Windows in Albuquerque, New Mexico

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
11											
16											
17											
19											

Table 35. Savings of Replacement Windows in Seattle, Washington

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
1											
11											
16											
17											
19											

5.2.3 Savings for Replacement Windows in Climate Zones 5–8

Table 36. Properties of Windows Used in Climate Zones 5–8

ID	Glazing	Frame	U	SHGC	VT
13					
15					
16					
18					
19					

Table 37. Savings of Replacement Windows in Chicago, Illinois

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

Table 38. Savings of Replacement Windows in Boston, Massachusetts

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

Table 39. Savings of Replacement Windows in Denver, Colorado

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

Table 40. Savings of Replacement Windows in Minneapolis, Minnesota

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

Table 41. Savings of Replacement Windows in Billings, Montana

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

Table 42. Savings of Replacement Windows in Bismarck, North Dakota

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

Table 43. Savings of Replacement Windows in Fairbanks, Alaska

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
13											
15											
16											
18											
19											

5.3 Window Costs (New and Replacement)

Table 44. Example of Window Costs

Glazing Type	Frame Type	Average Costs New (ft^2)	Average Costs Replacement (ft^2)
Double, clear			
Double, low-e			
Triple, low-e			

Table 45. Simple Payback for New Windows

Annual Energy Savings	Simple Payback (Years) for Incremental Window Cost (ft^2)				
	$5	$10	$15	$20	$25
$50					
$100					
$150					
$200					
$250					
$300					
$350					
$400					
$450					
$500					
$550					
$600					

Table 46. Simple Payback for Replacement Windows

Annual Energy Savings	Simple Payback (Years) for Incremental Window Cost (ft^2)				
	$20	$25	$30	$35	$40
$50					
$100					
$150					
$200					
$250					
$300					
$350					
$400					
$450					
$500					
$550					
$600					

5.4 Life Cycle Cost Analysis

5.4.1 Life Cycle Cost Summary

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5.5 Other Benefits

5.5.1 Comfort

5.5.1.1 Sources of Discomfort From Windows

radiant asymmetry

5.5.1.2 Quantifying Discomfort

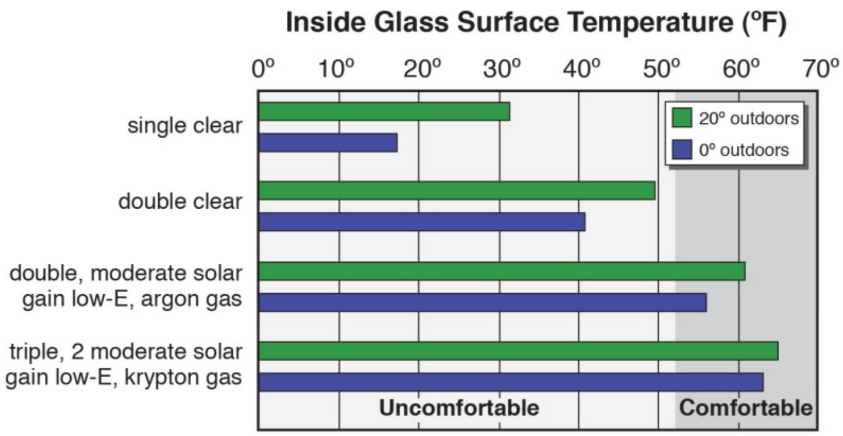

Figure 27. Comparison of inside glass surface temperature for different glazing types

(Image courtesy of LBNL)

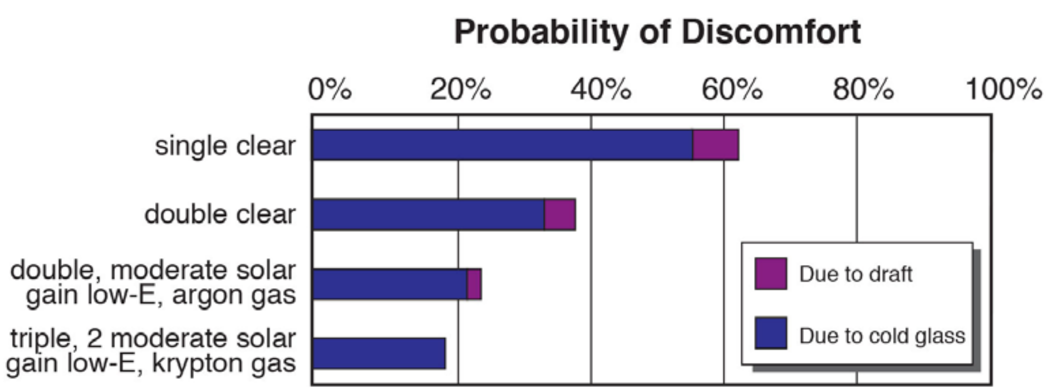

Figure 28. Probability of discomfort near a window in the winter

(Image courtesy of LBNL)

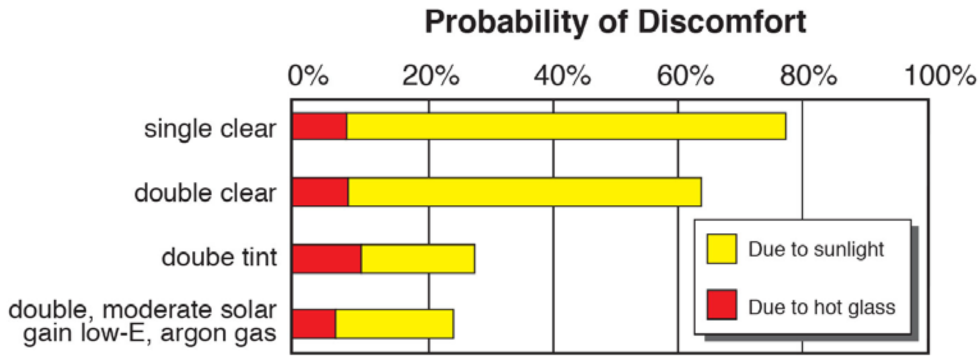

Figure 29. Probability of discomfort near a window in the summer
(Image courtesy of LBNL)

5.5.1.3 Comparing Windows Based on Thermal Comfort

Table 47. Winter and Summer Comfort Index for Typical Windows

(Huizenga et al. 2006)

Glazing	U	SHGC	VT	Winter Comfort Index Minimum Exterior Temperature (°F)	Summer Comfort Index Diffuse	Summer Comfort Index Direct
Single Clear						
Single Bronze						
Double Clear						
Double Medium Gain Low-e						
Double High Gain Low-e						
Triple Clear						
Triple Medium Gain Low-e						
Triple High Gain Low-e						

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5.5.2 Reduced Peak Demand and Heating, Ventilation, and Air Conditioning Costs

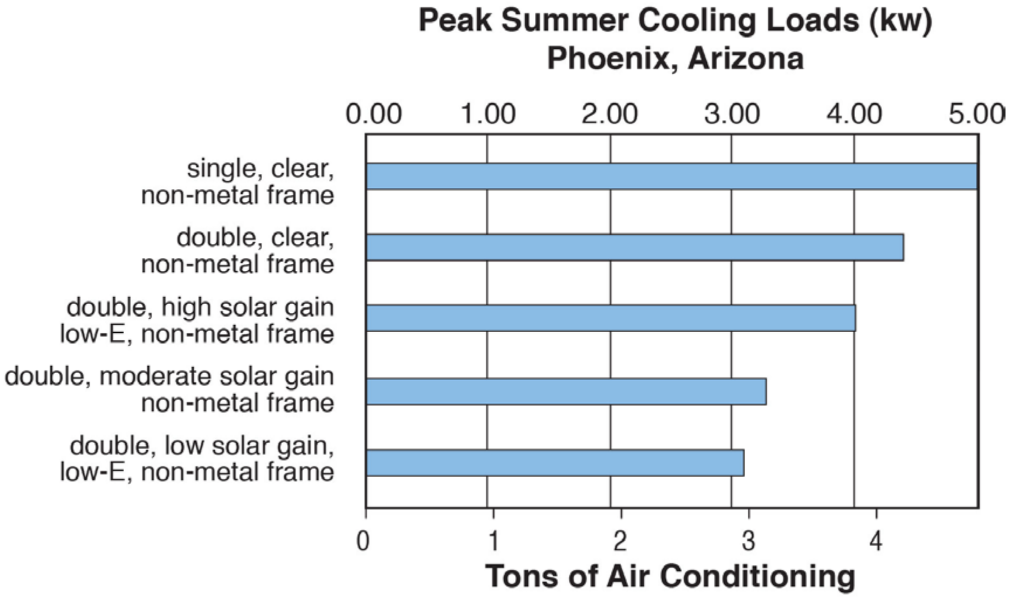

Figure 30. Peak summer cooling loads in Phoenix, Arizona

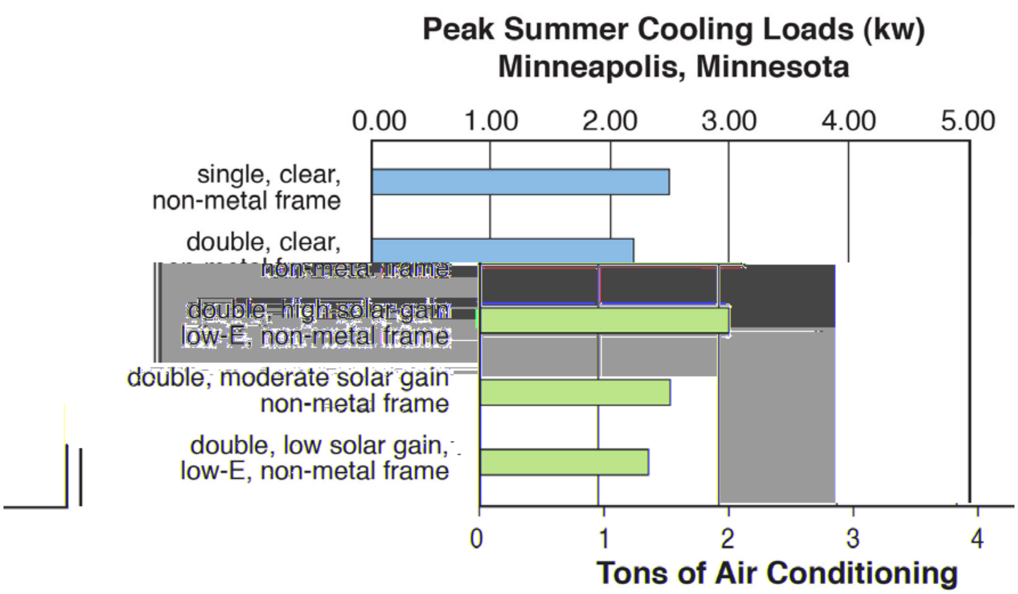

Figure 31. Peak summer cooling loads in Minneapolis, Minnesota

5.5.2.1 Rightsizing Heating, Ventilation, and Air Conditioning Systems

- **Health and comfort**
- **Mold prevention**
- **First cost savings**
- **Energy savings**

5.5.2.2 Heating, Ventilation, and Air Conditioning Sizing Tools

Handbook of Fundamentals

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6 Impact of Design on Performance

6.1 Orientation

6.1.1 Orientation in the Northern Zone (Heating Dominated)

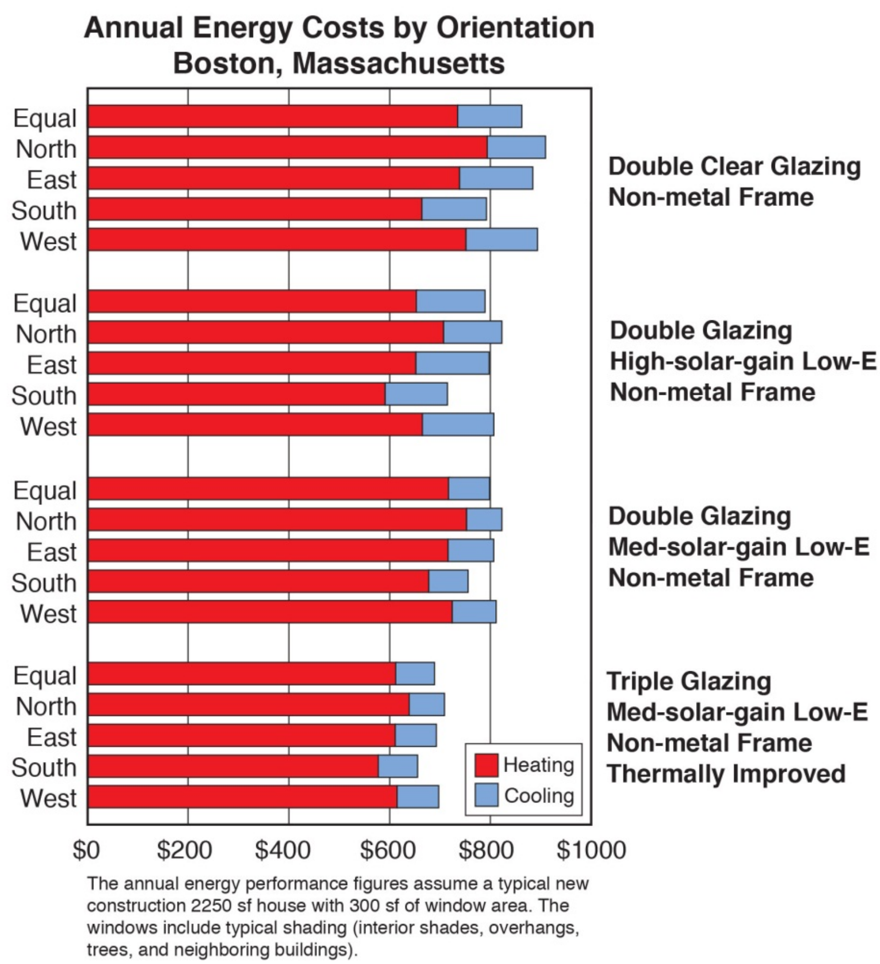
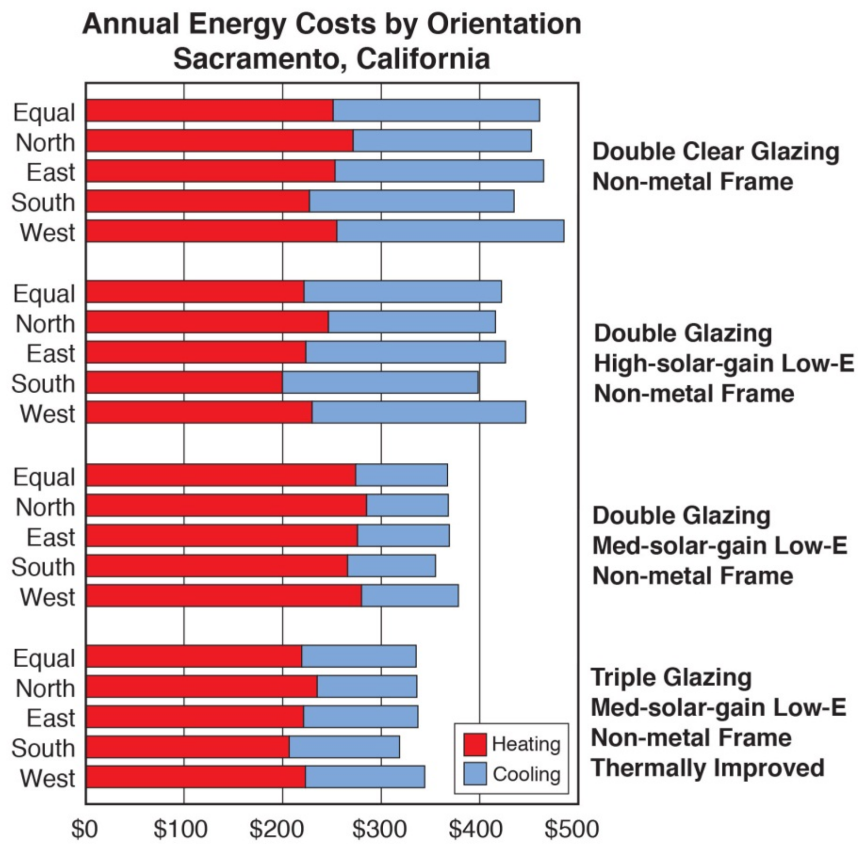


Figure 32. Annual energy cost by orientation in Boston, Massachusetts

6.1.2 Orientation in the Central Zones (Heating and Cooling)



The annual energy performance figures assume a typical new construction 2250 sf house with 300 sf of window area. The windows include typical shading (interior shades, overhangs, trees, and neighboring buildings).

Figure 33. Annual energy cost by orientation in Sacramento, California

6.1.3 Orientation in the Southern Zone (Cooling Dominated)

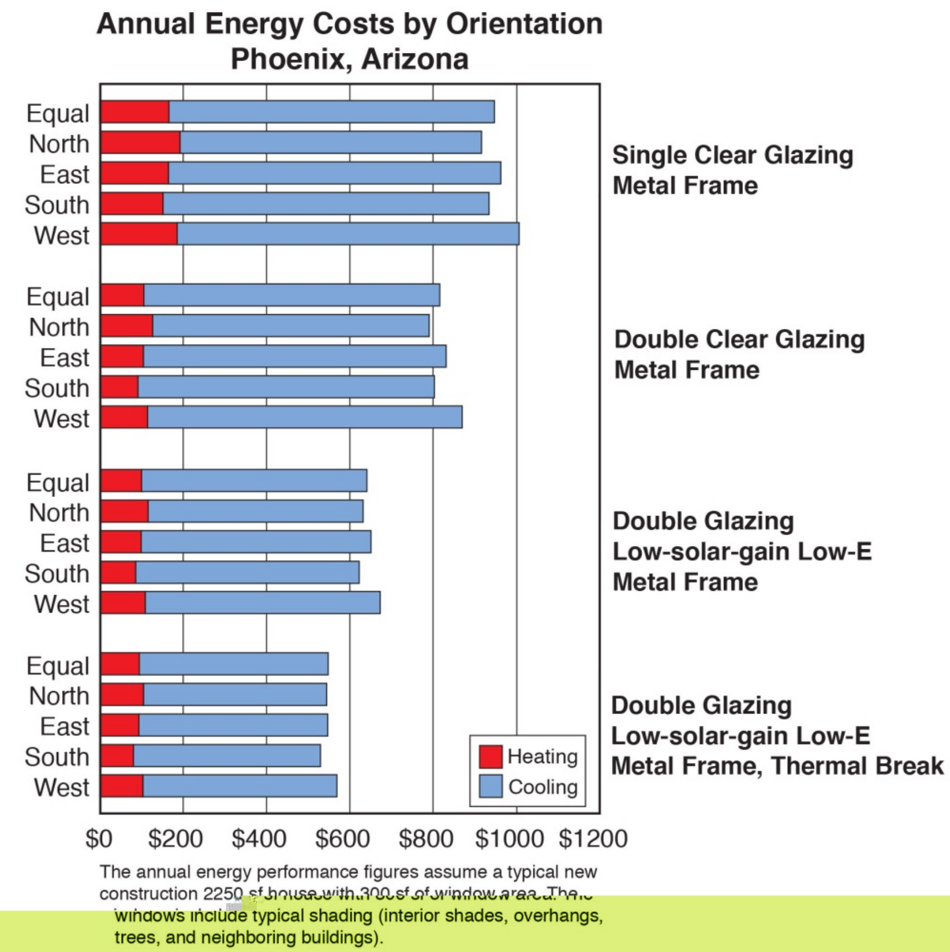


Figure 34. Annual energy cost by orientation in Phoenix, Arizona

6.2 Window Area

6.2.1 Window Area in the Northern Zone (Heating Dominated)

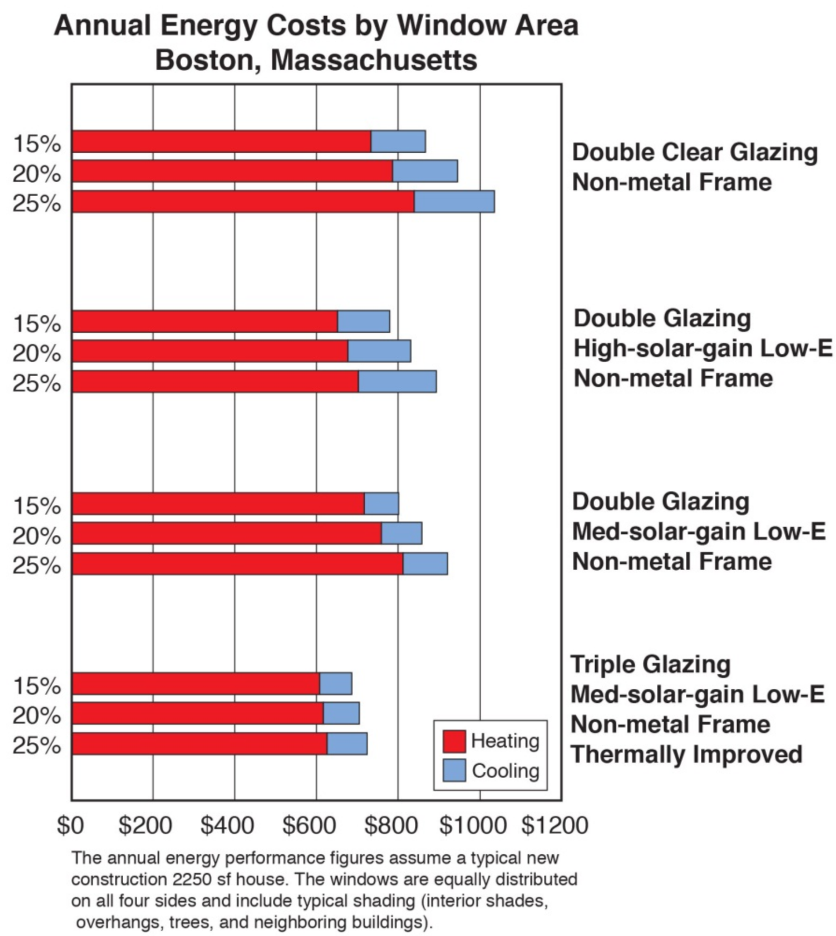


Figure 35. Annual energy cost by window area in Boston, Massachusetts

6.2.2 Window Area in the Central Zones (Heating and Cooling)

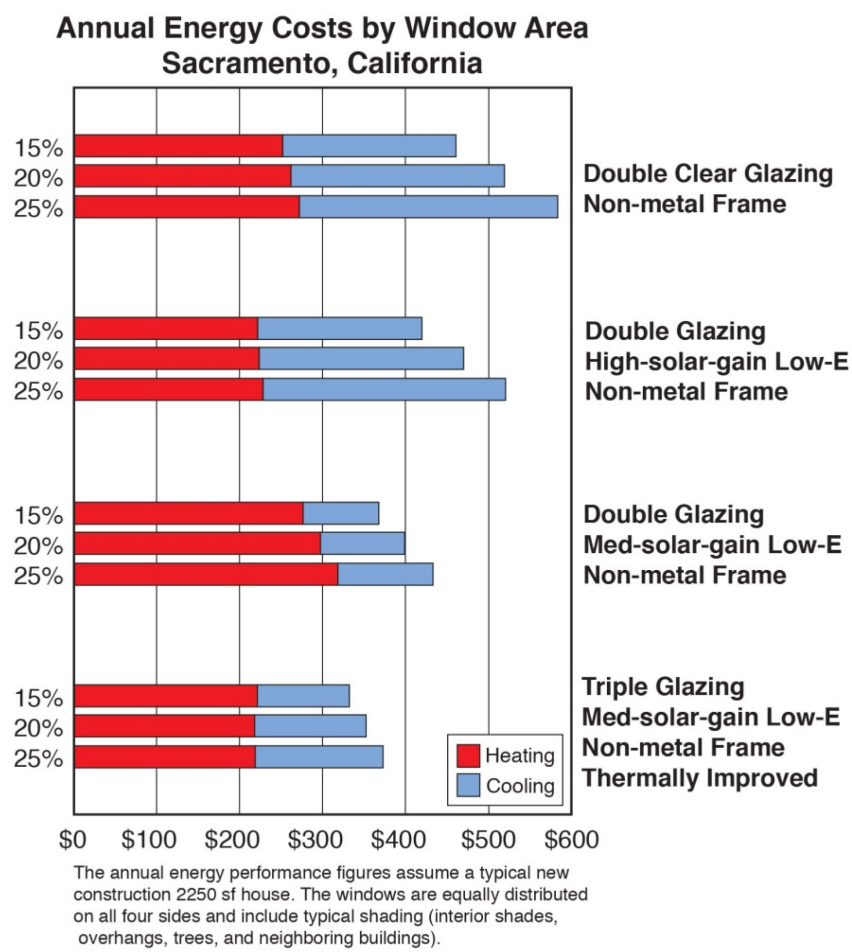


Figure 36. Annual energy cost by window area in Sacramento, California

6.2.3 Window Area in the Southern Zone (Cooling Dominated)

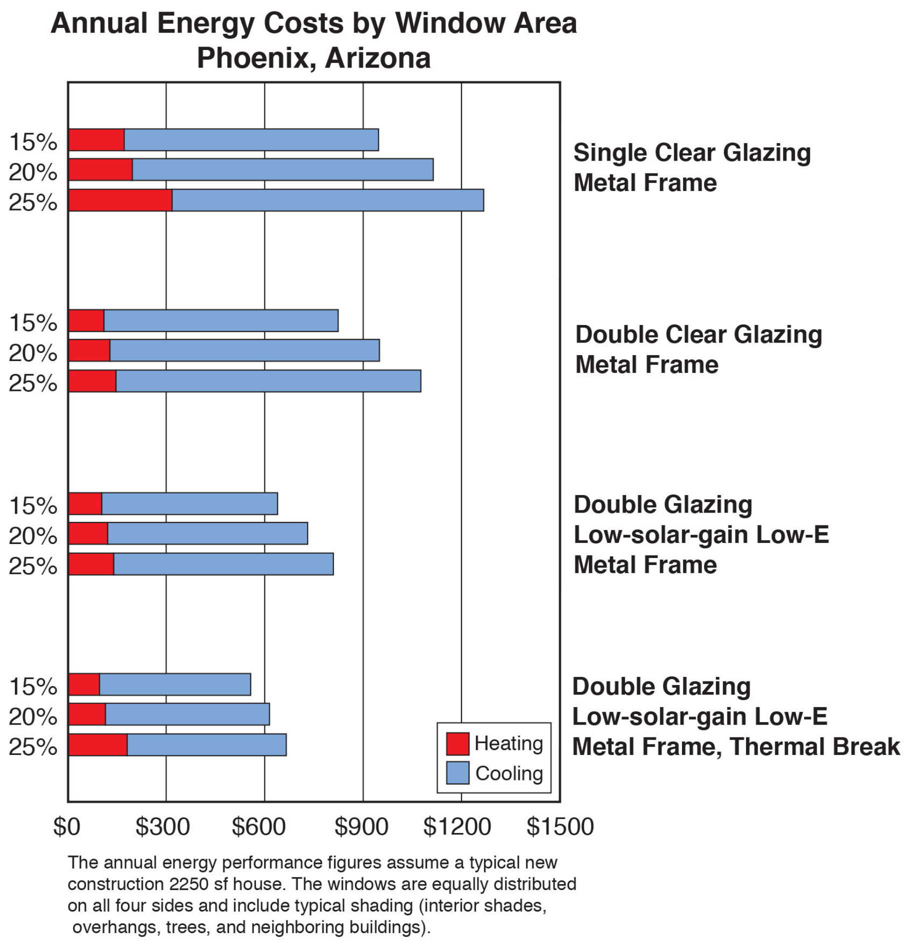


Figure 37. Annual energy cost by window area in Phoenix, Arizona

6.3 Shading

6.3.1 Shading in the Northern Zone (Heating Dominated)

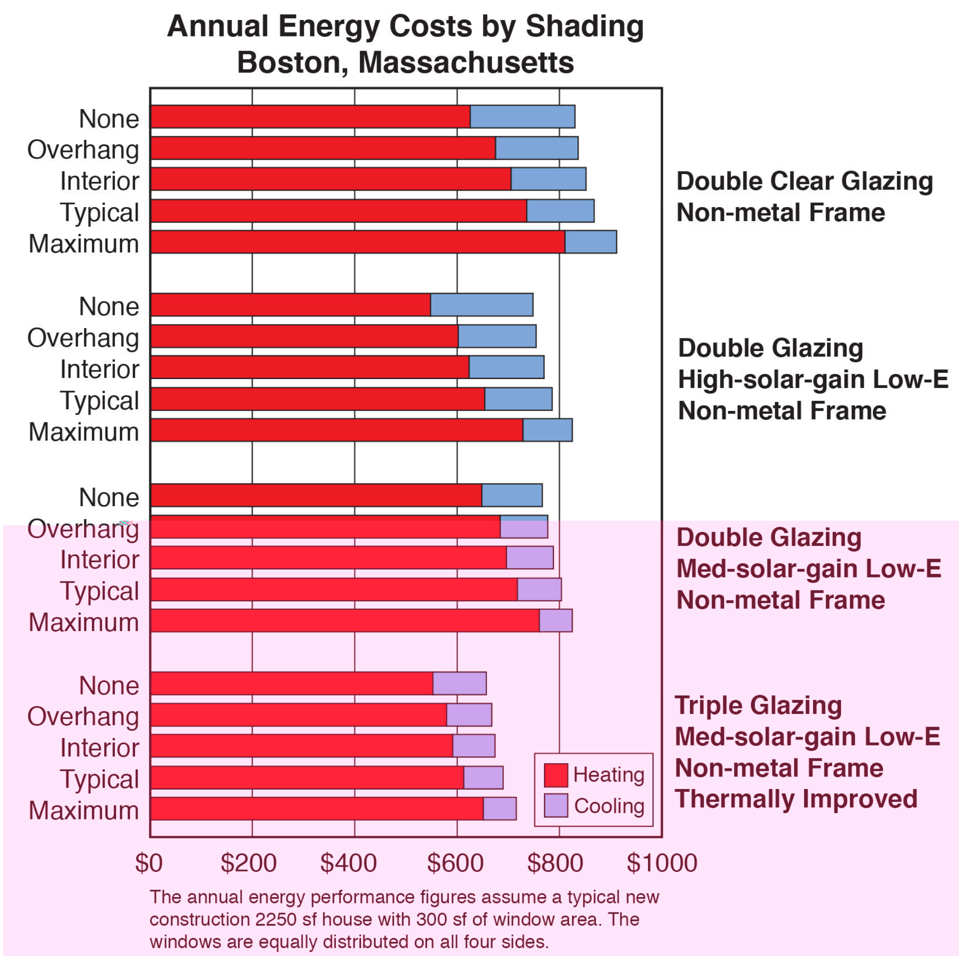


Figure 38. Annual energy cost by shading type in Boston, Massachusetts

6.3.2 *Shading in the Central Zones (Heating and Cooling)*

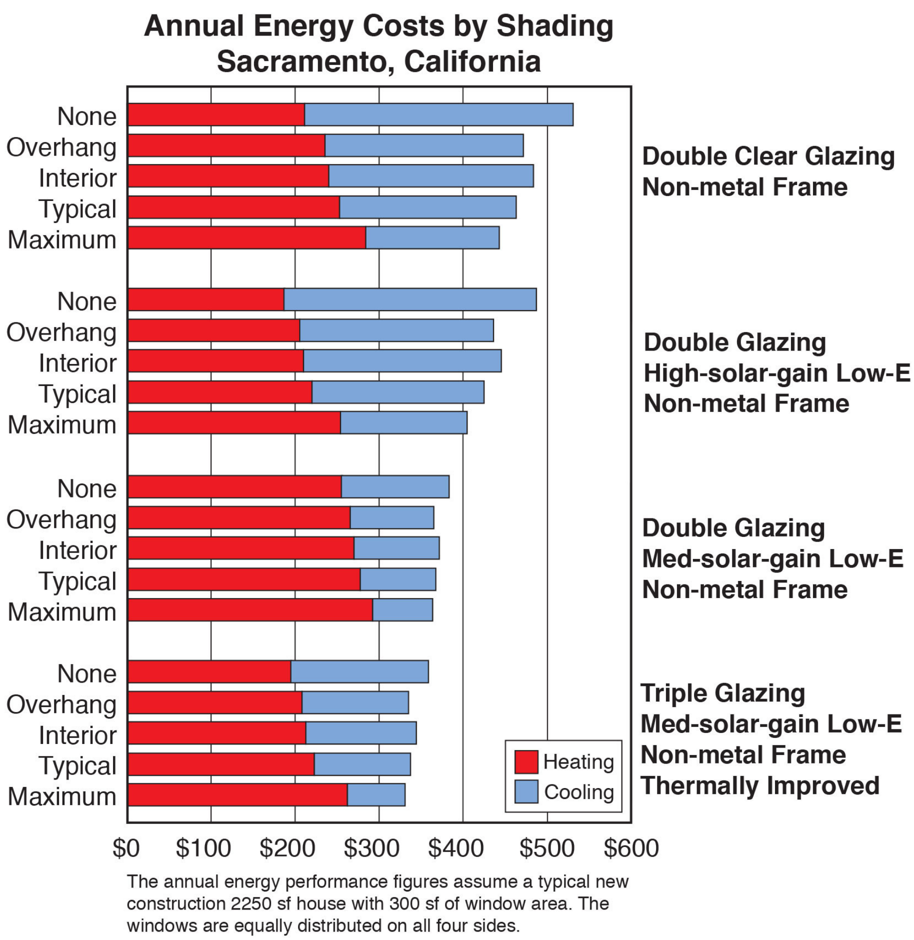


Figure 39. Annual energy cost by shading type in Sacramento, California

6.3.3 Shading in the Southern Zone (Cooling Dominated)

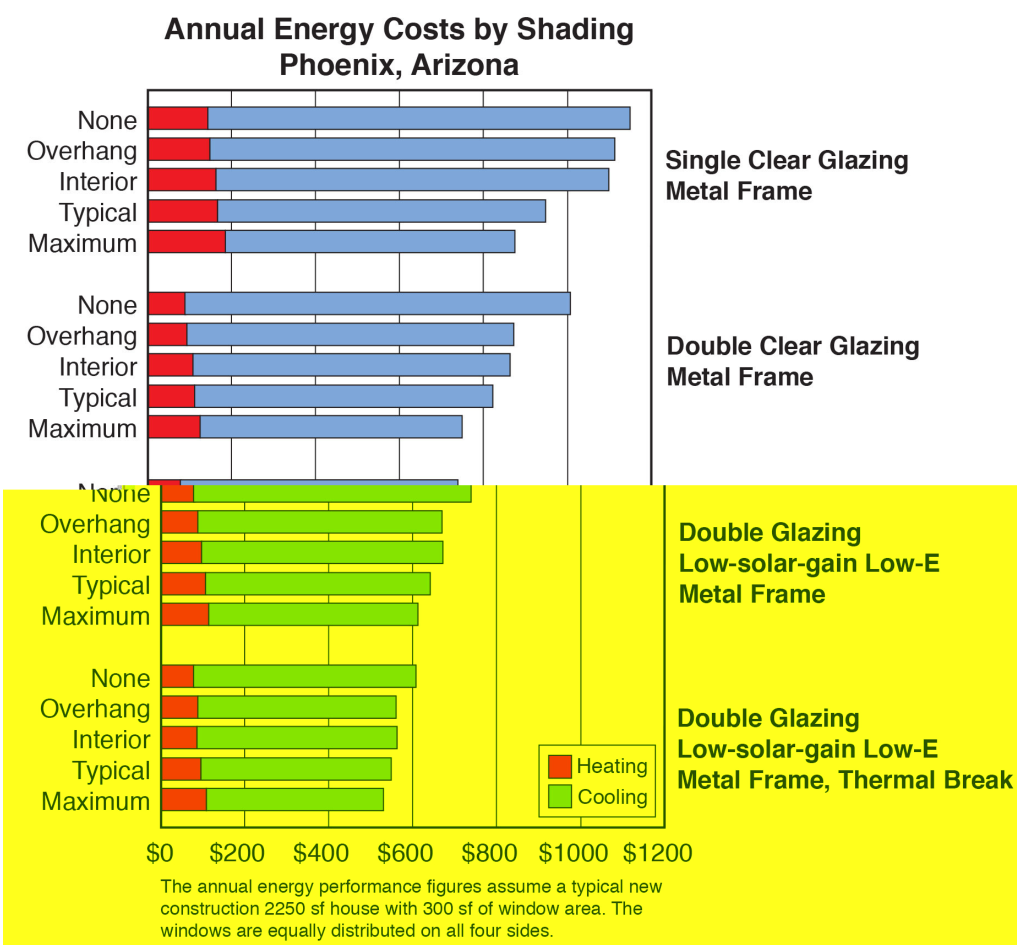


Figure 40. Annual energy cost by shading type in Phoenix, Arizona

7 Installation

Important Resources

ASTM E 2112, "Standard Practice for Installation of Exterior Windows, Doors and Skylights." www.astm.org/Standards/E2112.htm

Water Management Guide, by Joseph Lstiburek, is a guide that shows how to minimize water intrusion into home. This guide has many installation diagrams.

InstallationMasters includes a directory of certified installers in the United States. www.installationmastersusa.com

EPA brochure on lead-hazard for renovation, repair, and painting. www.epa.gov/lead/pubs/renovaterightbrochure.pdf

EPA website for lead in paint, dust, and soil. www.epa.gov/lead

7.1 General Installation Guidelines

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Water Management Guide

7.2 Watertight Installation

7.2.1 Storage or Mass Wall System

7.2.2 Perfect Barrier System

7.2.3 Drained Wall System

7.3 Replacement Windows and Sashes

-
-
-

References

Manual J Residential Load Calculation

Handbook—Fundamentals

Standard 55-2010: Thermal Environmental Conditions for Human Occupancy

Measure Guideline: Window Repair, Rehabilitation, and Replacement.

Residential Windows: A Guide to New Technologies and Energy Performance

Window Systems for High-performance Commercial Buildings

Window Performance for Human Thermal Comfort

Home Energy Magazine

buildingamerica.gov

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