February 25, 2014

ENERGY SAVINGS WITH WINDOW RETROFITS

Energy Design Conference & Expo, Duluth, MN

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cee
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Agenda

- Background
- What are window retrofits?
- Summary of the results
- Determining energy savings
- Residential building results
- Commercial building results
- Opportunities for market transformation

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Support of this project

- This project was supported in part by a grant from the Minnesota Department of Commerce through the Conservation Applied Research and Development (CARD) program.

Project Background

Minnesota Department of Commerce, Division of Energy Resources 2012 Conservation Applied Research and Development (CARD) grant project

- “Window Retrofit Technologies for Increased Energy Efficiency without Replacement”
- Determine cost-effectiveness
- Must create persistent savings
- Assumes energy performance of many windows can be improved prior to the time they need to be replaced

Project Team

- Center for Energy and Environment
  - Gustav Brändström
  - Chris Plum
  - Christie Traczyk
- Center for Sustainable Building Research
  - John Carmody
  - Kerry Haglund

What we do

- Program Design and Delivery
- Lending Center
- Engineering Services
- Innovation Exchange
  - Research
  - Education and Outreach
- Public Policy

Center for Energy and Environment

About CSBR

The Center for Sustainable Building Research's mission is to lead and support—through research, outreach, and education—the transformation of the regional built environment to provide for the ecological, economic, and social needs of the present without compromising those of the future.

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What are window retrofits?

- Anything added to an existing window
  - Blinds
  - Shades
  - Curtains
  - Shutters
  - Awnings
  - Screens
  - Exterior storm windows
  - Interior storm windows (panels)
  - Window films
  - New products
    - Electrochromic inserts
    - Solar films

www.efficientwindowcoverings.org

Technologies we will discuss

- Window panels and window films
  - Commercially available today
  - Create persistent savings
  - Don’t require behavioral interaction

Window Retrofit Technologies

- Window panels
  - Also called “Interior Storm Windows,” always save energy
- Window films
  - Primarily save cooling energy
  - Many products available, a few were found to save energy
  - The lower solar heat gain (tinted windows) often increases heating needs in winter, due to loss of warming sun
- Excluded technologies that require manual intervention and new higher cost technologies
  - Blinds, curtains, shades and shutters
  - Electrochromic windows, solar window films

The CARD Project

- Explore the potential for energy savings
- Focus is window panels and window films
- Residential and commercial uses
- Literature review
- Current product review
- Industry and building owner survey
- Modeling of technologies to determine cost-benefit
  - RESFEN, COMFEN, and ENERGY PLUS
- Suggest strategies for implementation

The Current Minnesota Window Stock

- In 1980 45% of all windows were double pane; now 97% are double pane.
- 56% of all new windows have a low-e coating (2005)
- Windows are typically replaced every 40 years
- About 2 million housing units in MN
  - 24% are apartments
- About 120,000 commercial buildings in MN
- Over 800,000 windows are installed annually
  - 2.5% of all existing buildings
  - 2/3 of window area is for residential windows

Window Panels

Interior glass window panels are heavier than plastic but more durable (although they can be broken), less likely to be scratched during cleaning, and available with low-emissivity (low-e) coatings that increase thermal insulation for improved energy efficiency and thermal comfort.

Terminology

The attachments described in this fact sheet are often called "interior storm windows," but that's a misleading term, since they really don't offer any storm protection. Here, we will refer to them as interior window panels.

Tracked interior window panels are just like exterior storms, but permanently installed on the inside of the window. With integral screens, they adjust for ventilation. Made of glass, they are durable, clean easily, and are available with low-e coatings.

Photo: BuildingGreen

Overall Thermal Performance

Interior window panels, when properly installed and deployed, bring a window's performance close to that of a double-paned clear window, by reducing air leakage and increasing thermal insulation. Interior glass window panels with low-e coatings bring a window's overall thermal performance close to the performance of a new double-paned low-e window.

When existing windows suffer from air leakage, a tight-fitting

When To Consider

- Historic codes, covenants, or condominium association rules preclude installation of exterior storm windows.
- Additional insulation needed for windows on upper floor where installation of exterior storm windows is difficult.
- Renters are reluctant to invest in more permanent window treatments, such as exterior low-e storm windows.
- Existing windows are leaky.
- Climate is moderate or cold and additional window insulation during heating season is desirable.
- Climate is hot, and interior window panel with solar heat gain control coating reduces need for interior cooling in warm season.
- Window egress is not an issue.

When to consider this retrofit—Ownership

✓	Homeowner
✓	Apartment Renter - Long Term
	Apartment Renter - Short Term
✓	Live in a Condo
✓	Live in a Historical District

When to consider this retrofit—Window conditions

✓	Existing window single-glazed
✓	Existing window double-glazed, no low-e*
	Existing window double-glazed with low-e

*low-emissivity coating

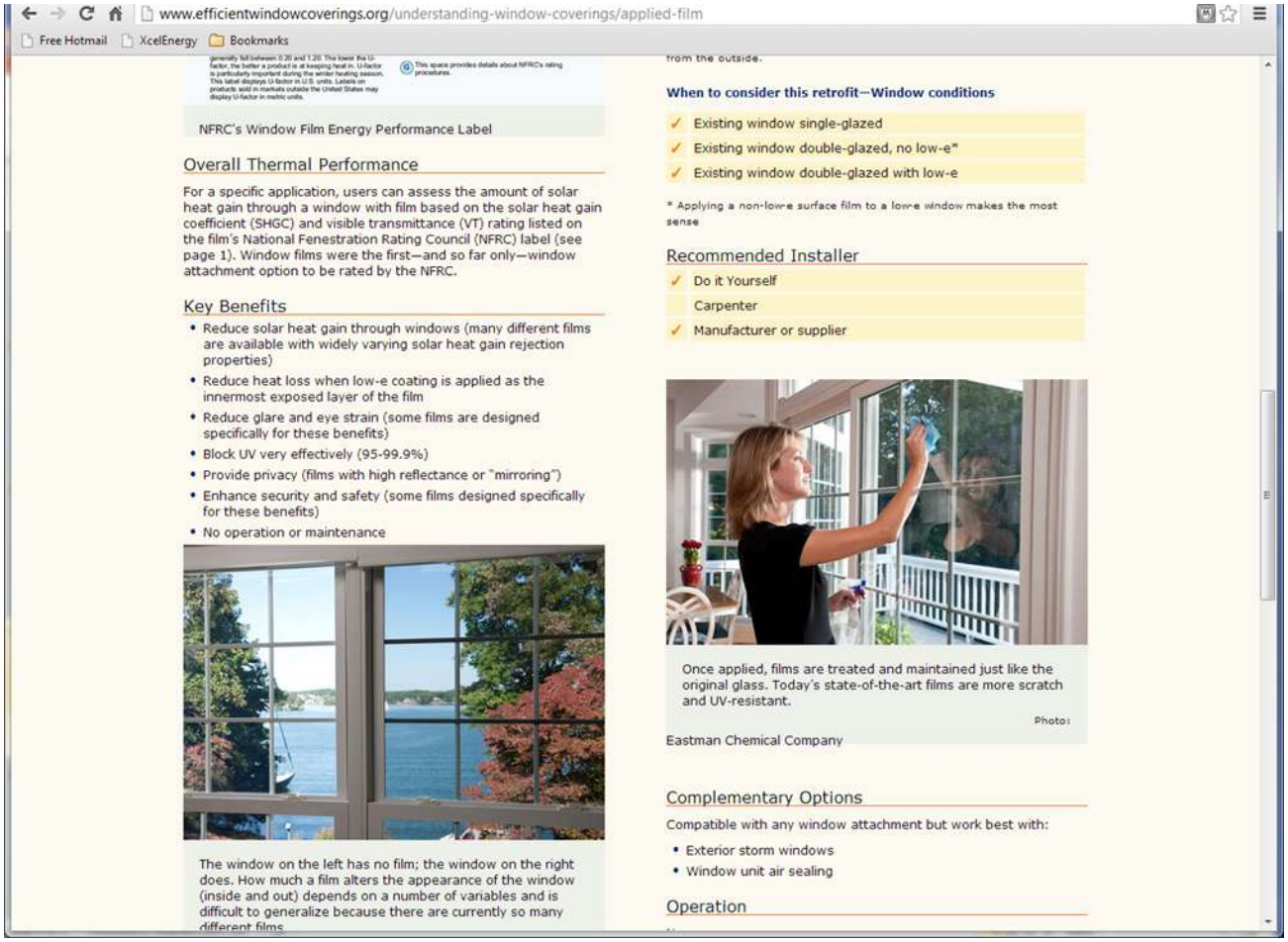
Recommended Installer

✓	Do it yourself
✓	Carpenter
	Manufacturer or supplier

Complementary Options

www.efficentwindowcoverings.org

Window Films



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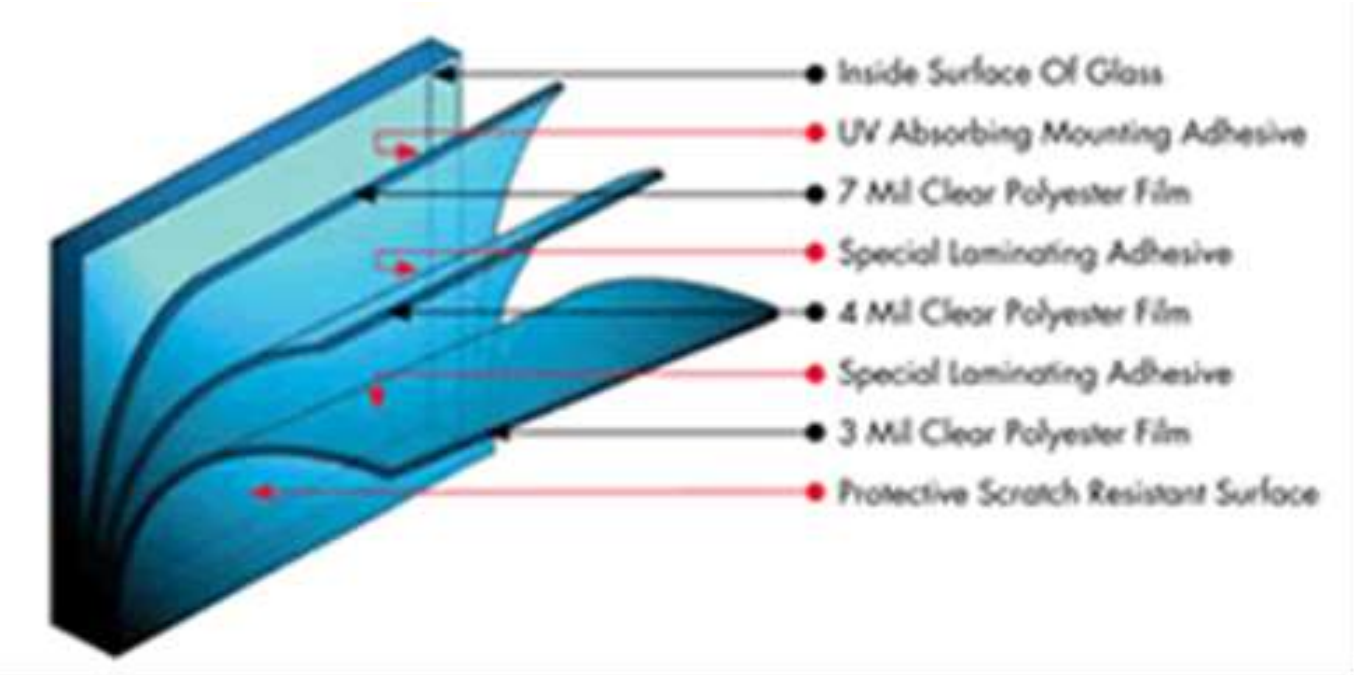
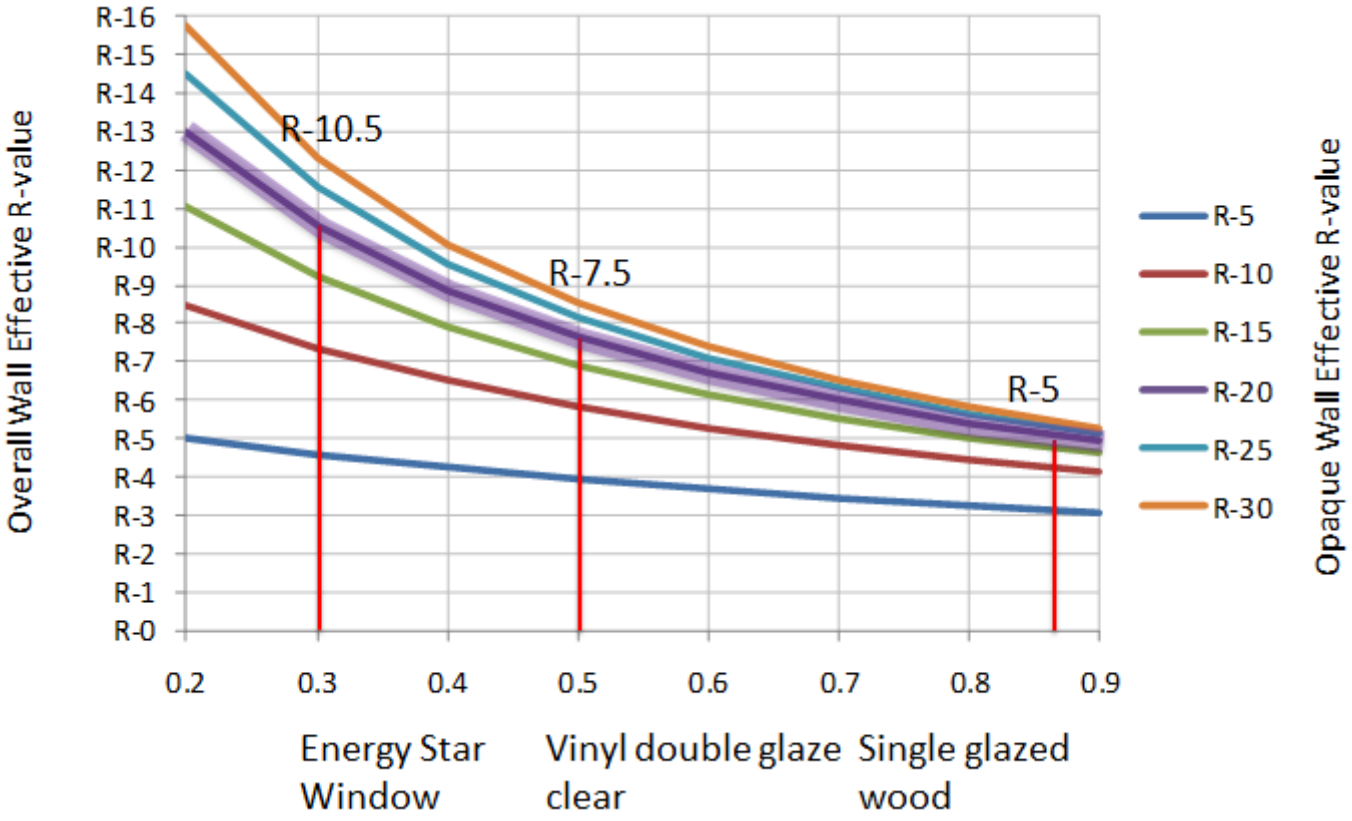
Window Films



Effect of Windows on Wall Insulation



Courtesy of Building Science Corporation

Solar Heat Gain Coefficient

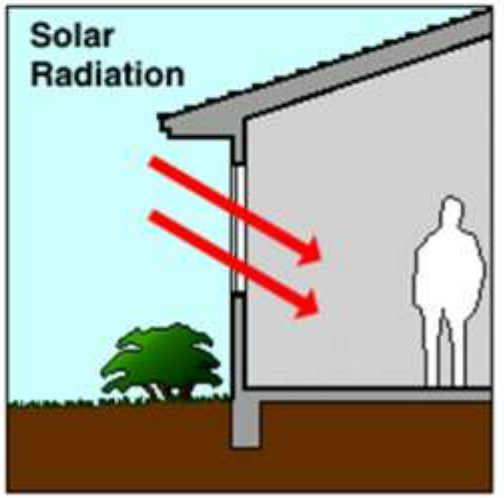
Efficient Windows Collaborative

New Construction Windows | Replacement Windows | Understanding Windo

Measuring Performance: Solar Heat Gain Coefficient (SHGC)

The SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.

The nationally recognized rating method by the National Fenestration Rating Council (NFRC) is for the whole window, including the effects of the frame. Alternately, the center-of-glass SHGC is sometimes referenced, which describes the effect of the glazing alone. Whole window SHGC is lower than glass-only SHGC, and is generally below 0.8.



Why is a SHGC important?

Solar heat gain can provide free heat in the winter but can also lead to overheating in the summer. How to best balance solar heat gain with an appropriate SHGC depends upon the climate, orientation, shading conditions and other factors. **ENERGY STAR** provides simplified guidance on recommended SHGC values for your climate; additionally, the **Window Selection Tool** compares average simulated energy costs for your location based on various window types.

Low-emissivity coating

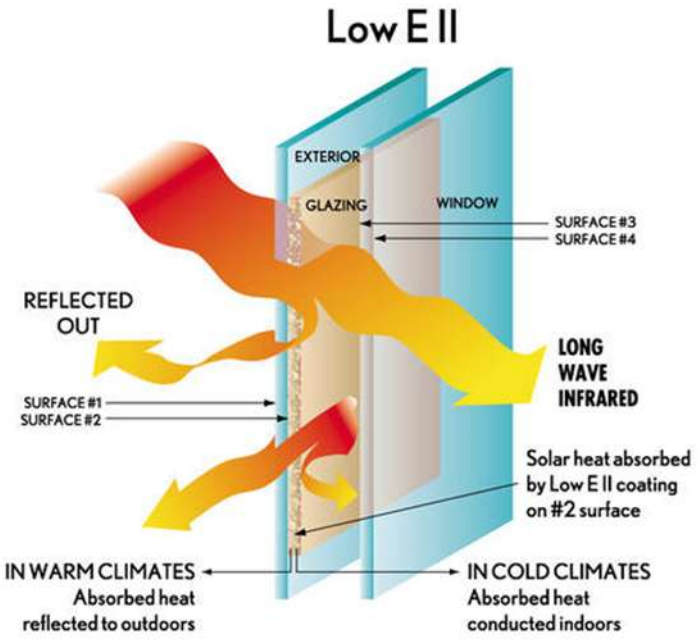
“Low-e”

Thin metal oxide film that reflects infra-red radiation

When on the inside of the window “keeps heat in”

In southern states used on the outside of the window to keeps heat out

Often does not save energy in Minnesota



Climate zones

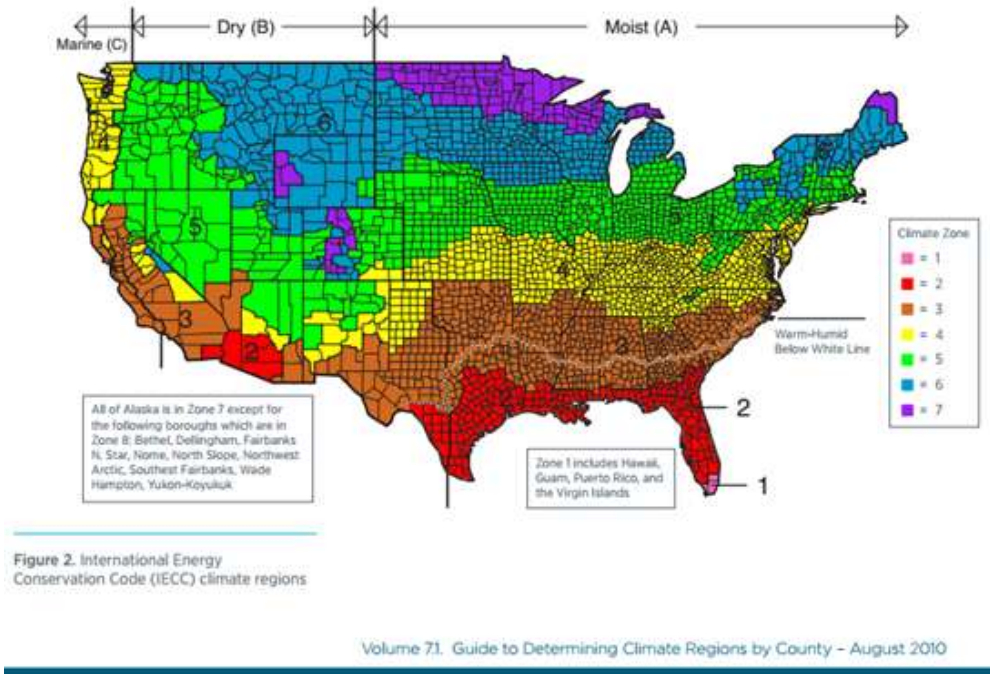
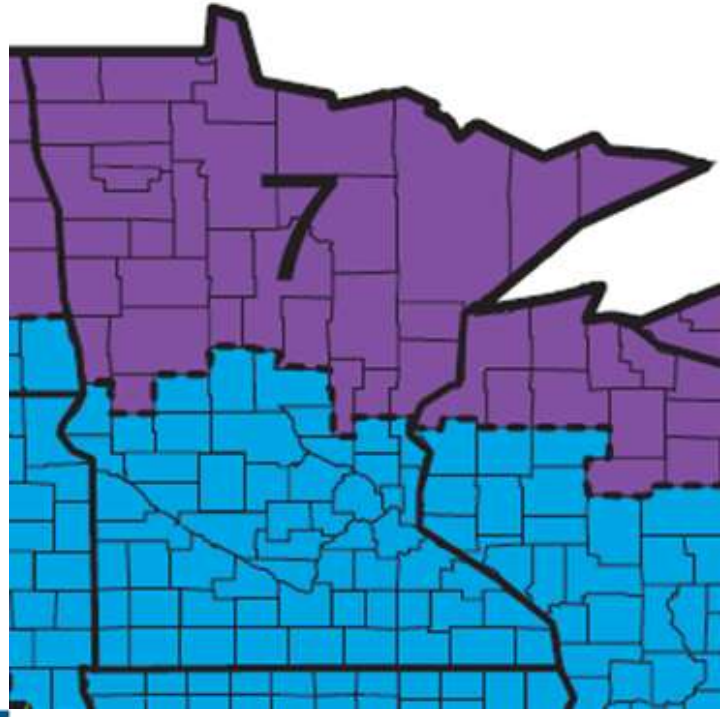


Figure 2. International Energy Conservation Code (IECC) climate regions

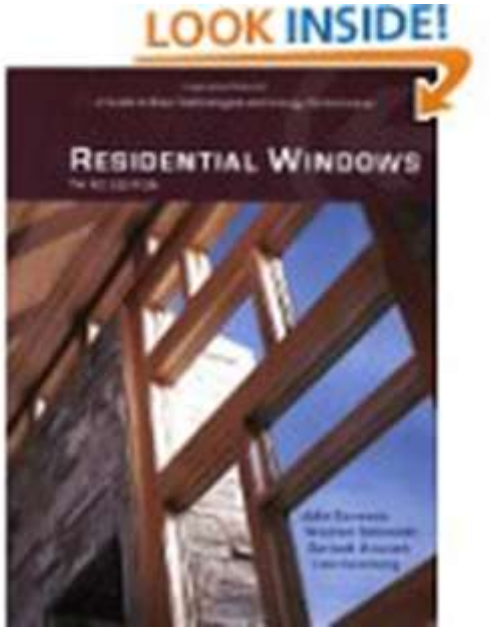
Volume 71. Guide to Determining Climate Regions by County – August 2010

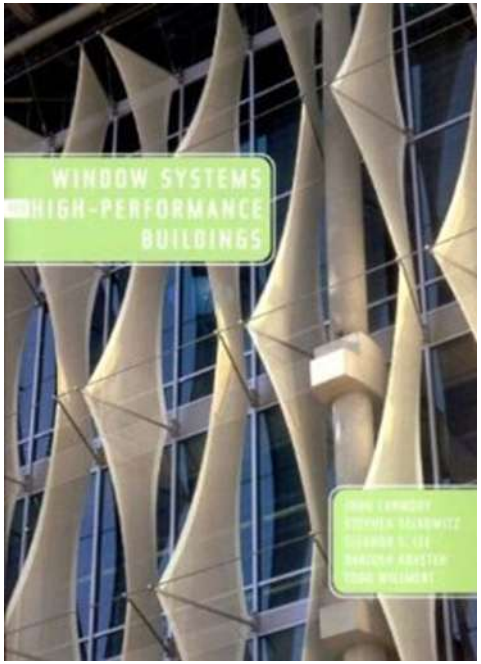


90% of US Population lives in zones 2, 3, 4 and 5.
We live in zones 6 and 7.

Literature Sources

- Hundreds of articles are available
- Our team includes recognized experts from the University of Minnesota





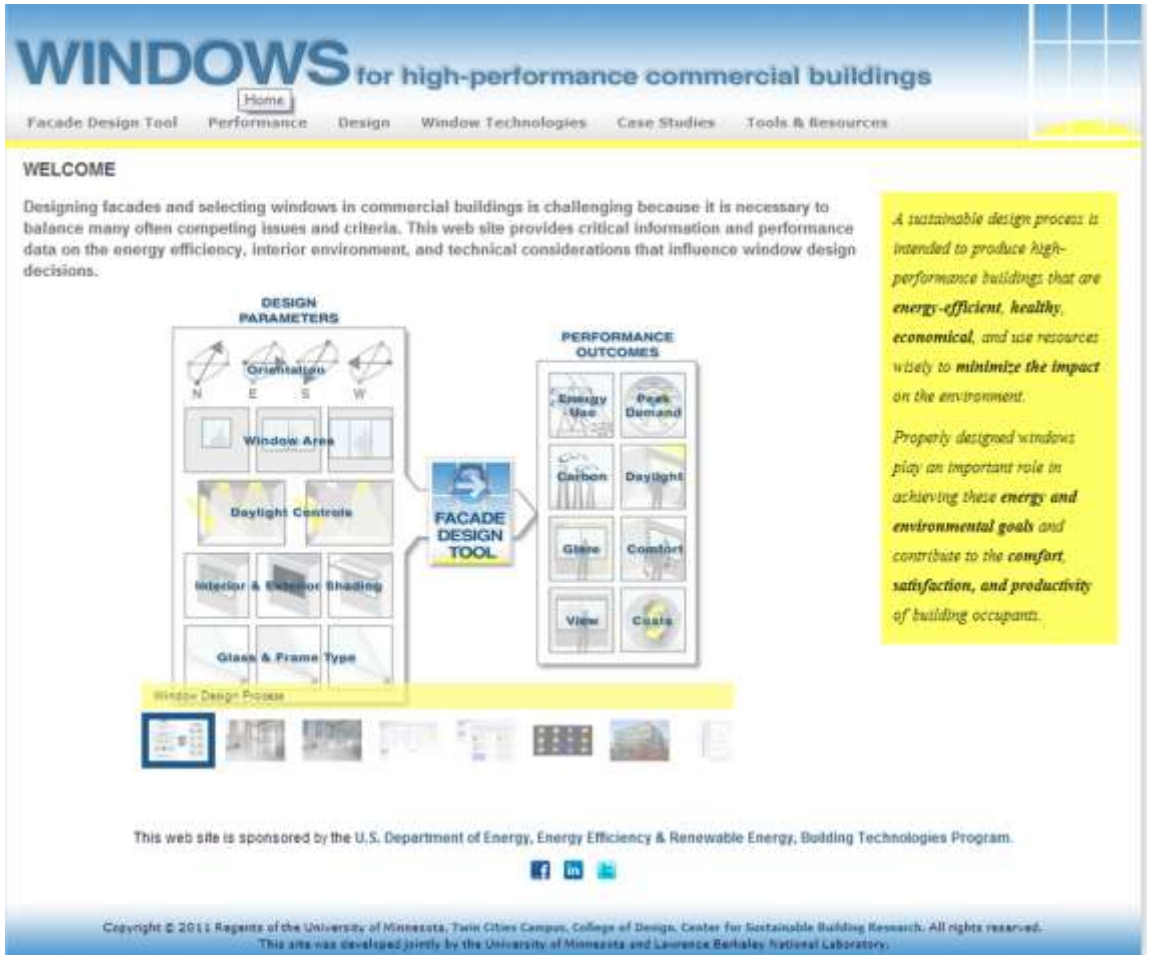
More Background

- The Impact of Window Energy Efficiency and How to Make Smart Choices
  - Webinar by John Carmody and Kerry Haglund available at http://mncee.org/Innovation-Exchange/Events-And-Webinars/The-Impact-of-Window-Energy-Efficiency-and-How-to-/
- Course offered at the University of Minnesota's Center for Sustainable Building Research
  - http://www.csbr.umn.edu/research/aia2030training.html

Web base tools and resources

- Commercial Windows
  - http://www.commercialwindows.org/
  - Joint development effort of University of Minnesota's Center for Sustainable Building Research, Lawrence Berkeley National Laboratory and Building America
- Efficient Windows (Residential)
  - http://www.efficientwindows.org/
- Efficient Window Coverings (Residential and Commercial)
  - http://www.efficientwindowcoverings.org/

Commercialwindows.org



Efficientwindows.org

Efficientwindowcoverings.org

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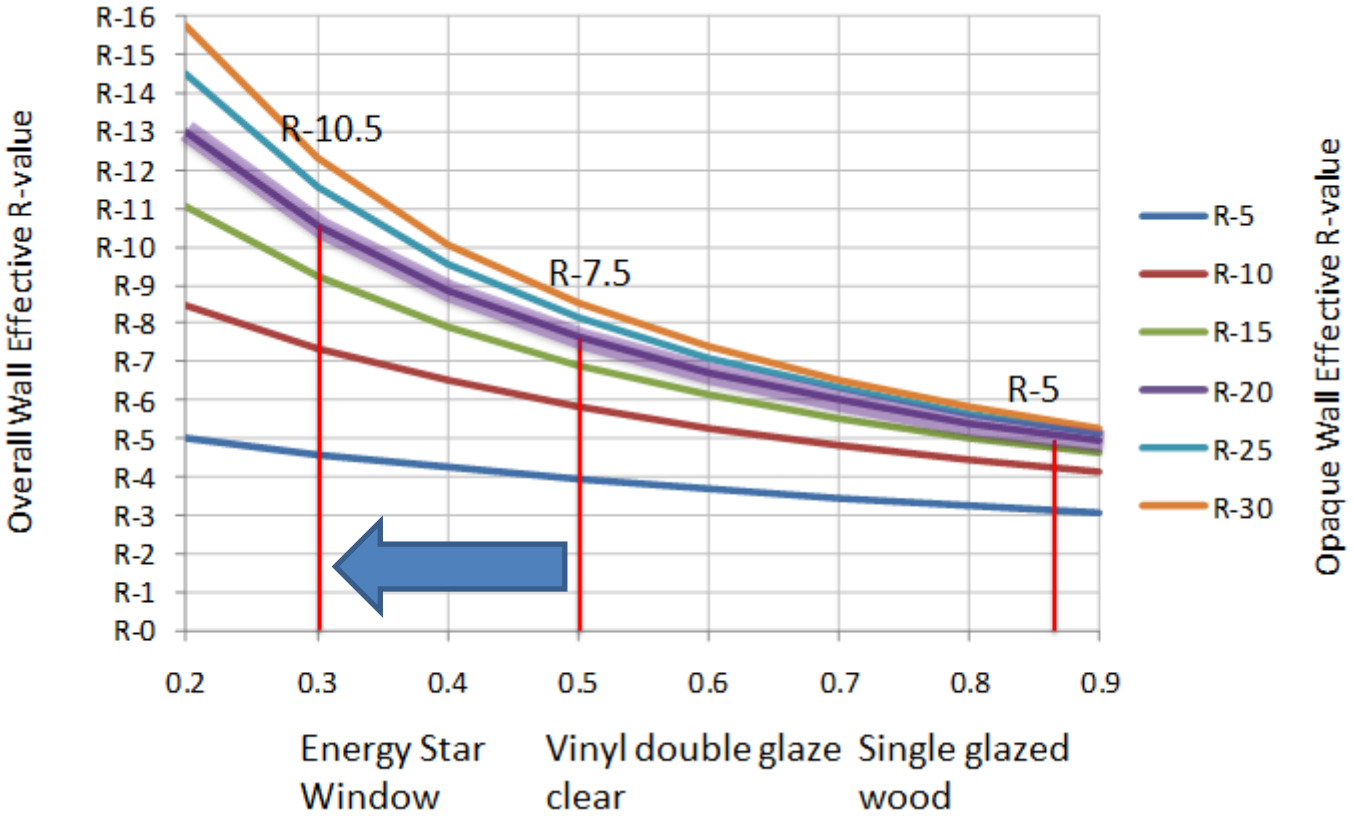
Summary of the results

- Adding a panel (inside or outside) to an existing window saves the same amount of energy as upgrading to a new window with one more pane
  - But costs much less
- Minnesota has more heating, less cooling than other parts of the US
  - Winter sun helps more than summer sun hurts
- Low-e coatings (heat rejection films or on a panel) that keep heat from passing through window sometimes save energy, but not always
  - Lower cooling energy can be less than increased heating

Effect of Windows on Wall Insulation



Courtesy of Building Science Corporation

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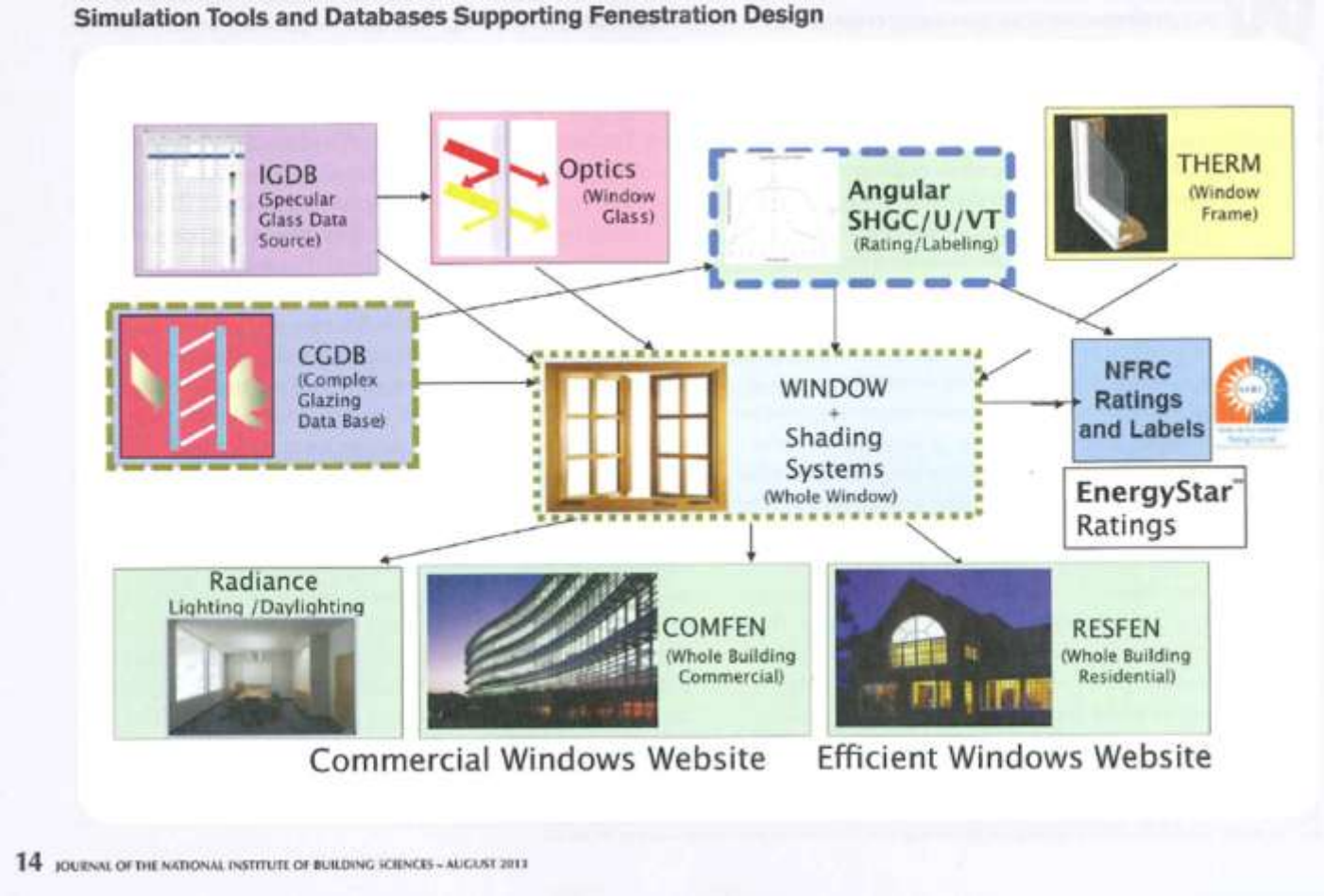
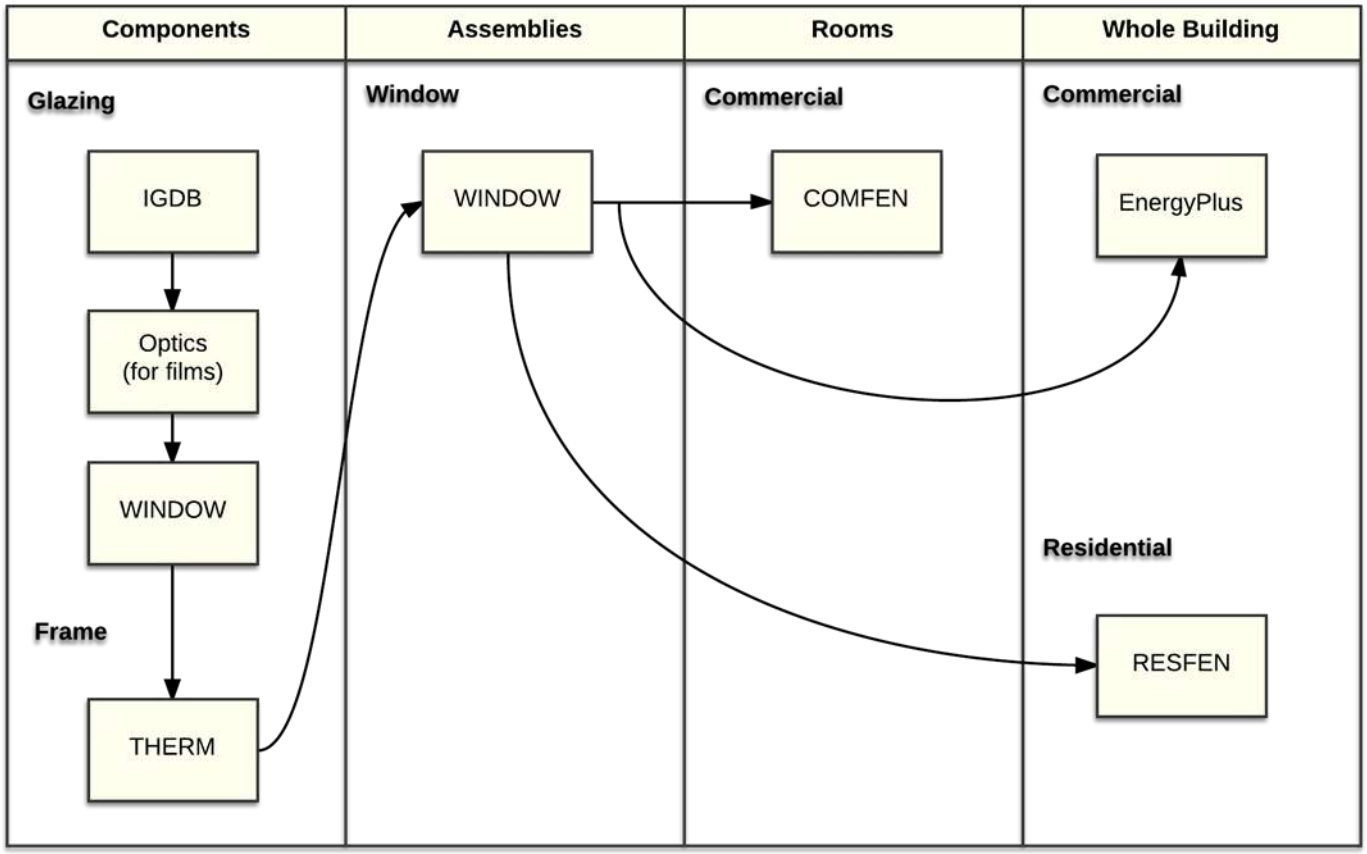
Determining energy savings

- Energy modeling
  - Established methods
  - Standard buildings
  - Representative of 2/3 of the state's building stock
- Change the windows but leave everything else the same
- Model output is energy used by heating, cooling, lighting, hot water, plugs loads, fans, pumps and motors

Components of the modeling process



Energy Modeling



Energy Modeling

- Levels of modeling
  - Components
    - Frame [THERM]
      - Get U-value for frame components
    - Glazing [WINDOW]
      - Get U-value for glazing unit
  - Assemblies
    - Frame and Glazing becomes Window [WINDOW]
      - Get total window U-value, SHGC, and Visual Transmittance in accordance with NFRC

Energy Modeling

- Levels of modeling (continued)
  - Room [COMFEN]
    - Frame and Glazing into wall in room
      - Get fenestration annual energy use
  - Whole Building (Commercial) [EnergyPlus]
    - Window properties into all windows in the building
      - Get entire building annual energy use
  - Whole Building (Residential) [RESFEN]
    - Window properties into all windows in the building
      - Get entire building annual energy use

Energy Modeling

- Energy Modeling for this project
  - Modeled ~4,000 runs with EnergyPlus
    - Specific product runs:
      - Solar blocking window film
      - Interior panel with clear acrylic
      - Interior panel with Low-e glass
    - Other runs:
      - Full scale U-values (0.25-1.25)
      - Full scale SHGC (0.1-0.9)
      - Full scale VT (0.1-0.9)
  - Modeled a variety of residential buildings with RESFEN
    - Validated the published research of DOE/PNNL

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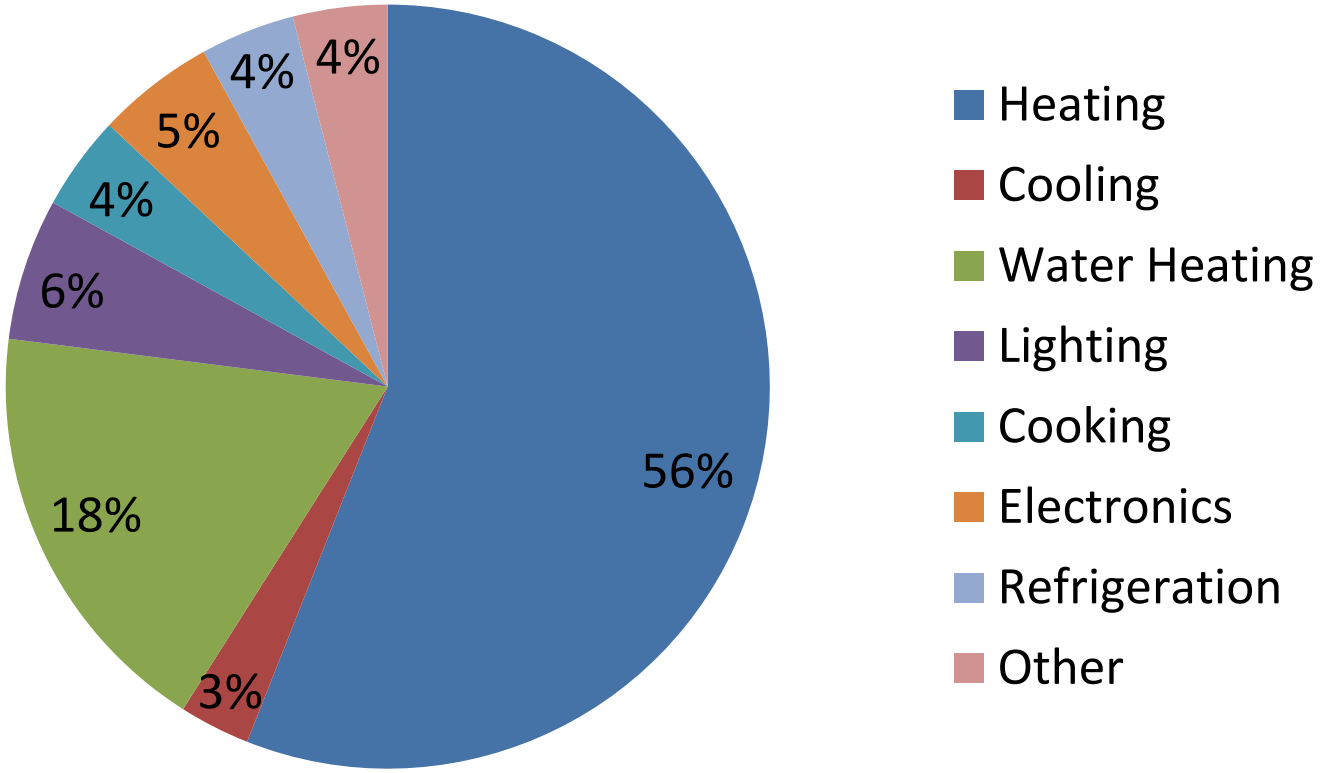
Residential building results

- Houses represent 82% of the energy saving potential from window retrofits in Minnesota
- Houses are “envelope driven” so window improvements will save energy
  - Assuming installation is done properly
- Clear window panels create ‘triple pane’ windows
  - Lower cost than a window replacement
- Adding a low e coating (either with an applied film or on the window panel) usually improves performance

Residential total energy use profile

- Over half of the typical home's energy is for heating and cooling
- Highly dependent on occupant behavior
  - Thermostat set point and setback
  - Use of curtains or shades
- Highly dependent on the local environment
  - Shading from trees
  - Protection from wind
  - Orientation of windows (where are south and west?)

Home energy use in Minnesota



Typical house

- 2,000 sq ft, with 255 sq ft of windows
- 25’ x 40’ footprint
- 8 ft wall height
- 17 windows
  - 3’x5’ each
  - Evenly distributed around the house
- 2 stories (includes “basement”)
- Wall area above ground 1,700 sq. ft. (15% window/wall ratio)
- Wall area below ground 500 sq. ft.

Simple model of heat loss ("Manual J")

Heat loss depends on:

- U value = U
- Surface area = A
- Temperature across the surface = ΔT
- We looked at both code and observed values
  - Roof R-40 (code) or R-20 (typical)
  - Walls R-13 (code) or R-10 (typical good)
  - Basement: used heat loss based on research work (~R-30)
  - Windows: Published values (R-2 to R-4)

Heat loss = U*A*∆T

Building Assembly	2007 Building Code	Typical House
Roof	R-40 (.025)	R-19 (.05)
Walls (above ground)	R-14 (.07)	R-10 (.10)
Walls (below ground)		R-10 (.10)
Basement floor		R-30 (.03)
Double clear window	R-2 (.50)	R-2 (.50)
Triple pane	R-3 (.33)	R-3 (.33)

R Values are followed by U-factor (in parentheses)
(U = 1/R), each has an appropriate use

Better wall insulation makes windows a larger route for heat loss

- 48% of heat loss through walls (excluding windows)
- 32% of heat lost through windows
- 12% of heat lost through ceiling
- 8% of heat lost through basement floor

2004 ASHRAE 90.1, adopted by Minnesota in 2007
(Window and wall improvements)

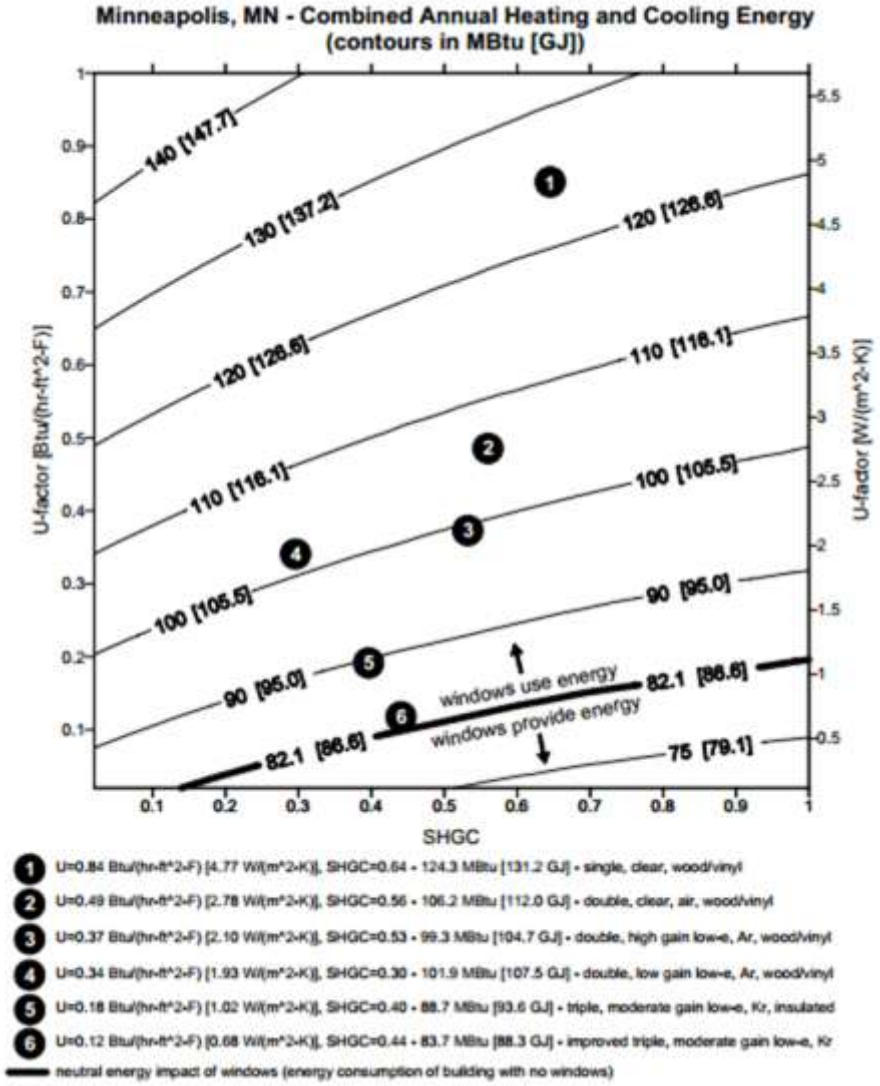
- 40% of heat loss through frame walls (R-19 from R-10)
- 37% of heat lost through windows (U=0.35 from 0.50)
- 10% of heat lost through ceiling (R-40)
- 12% of heat lost through basement floor (R-30)

Heat loss in terms of fuel units

	Duluth	Minneapolis
Heating Degree Days	9,724	7,876
Energy per sq ft of window area (Double clear, u = 0.50)	1.30 Th	1.05 Th
Cooling Degree Days	225	700
Energy (source) per sq ft of window area (Double clear, u = 0.50)	0.06 Th	0.19 Th

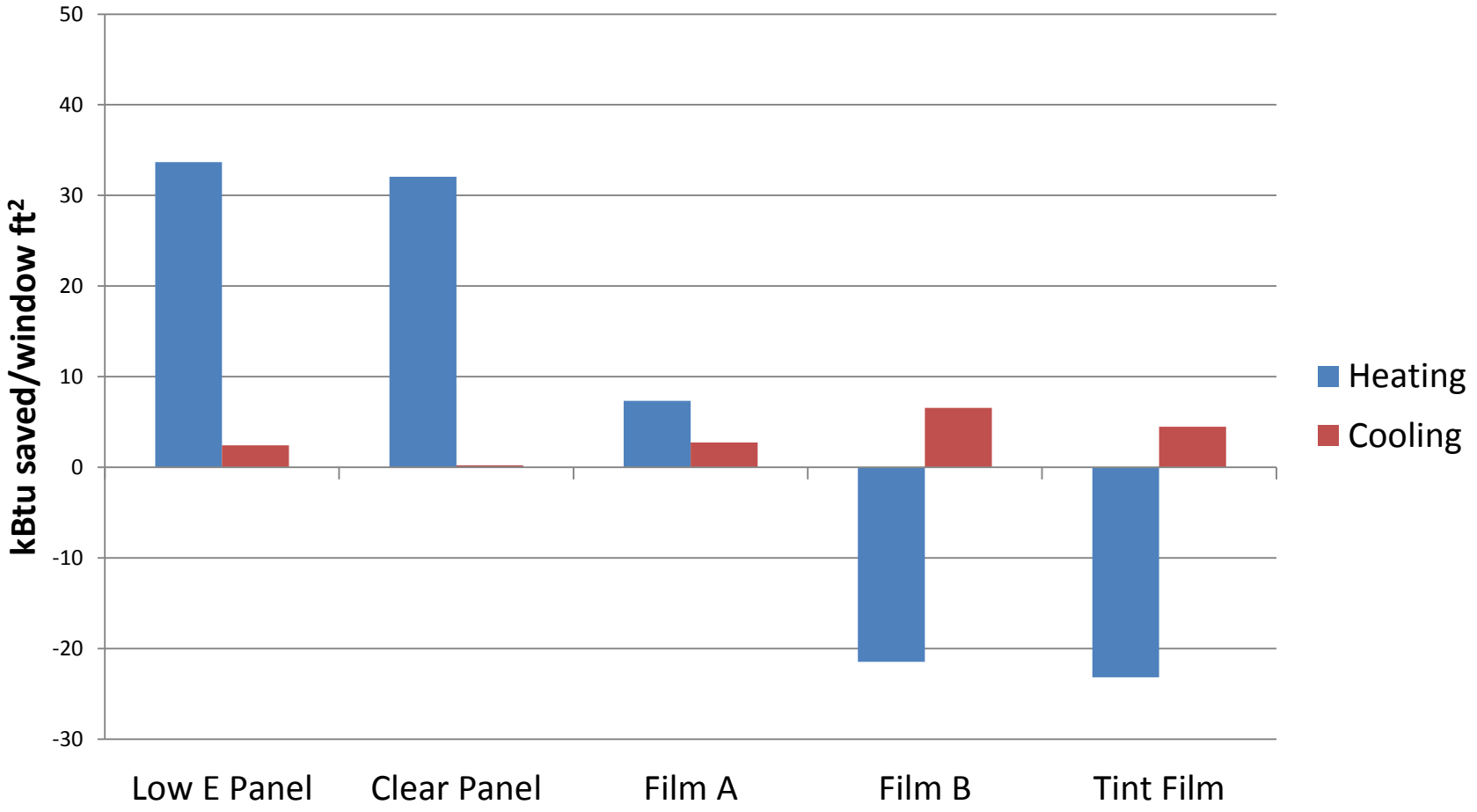
HDD*24 hrs/day*U/(100,000btu/Th*0.90) with 90% furnace efficiency

Residential building results

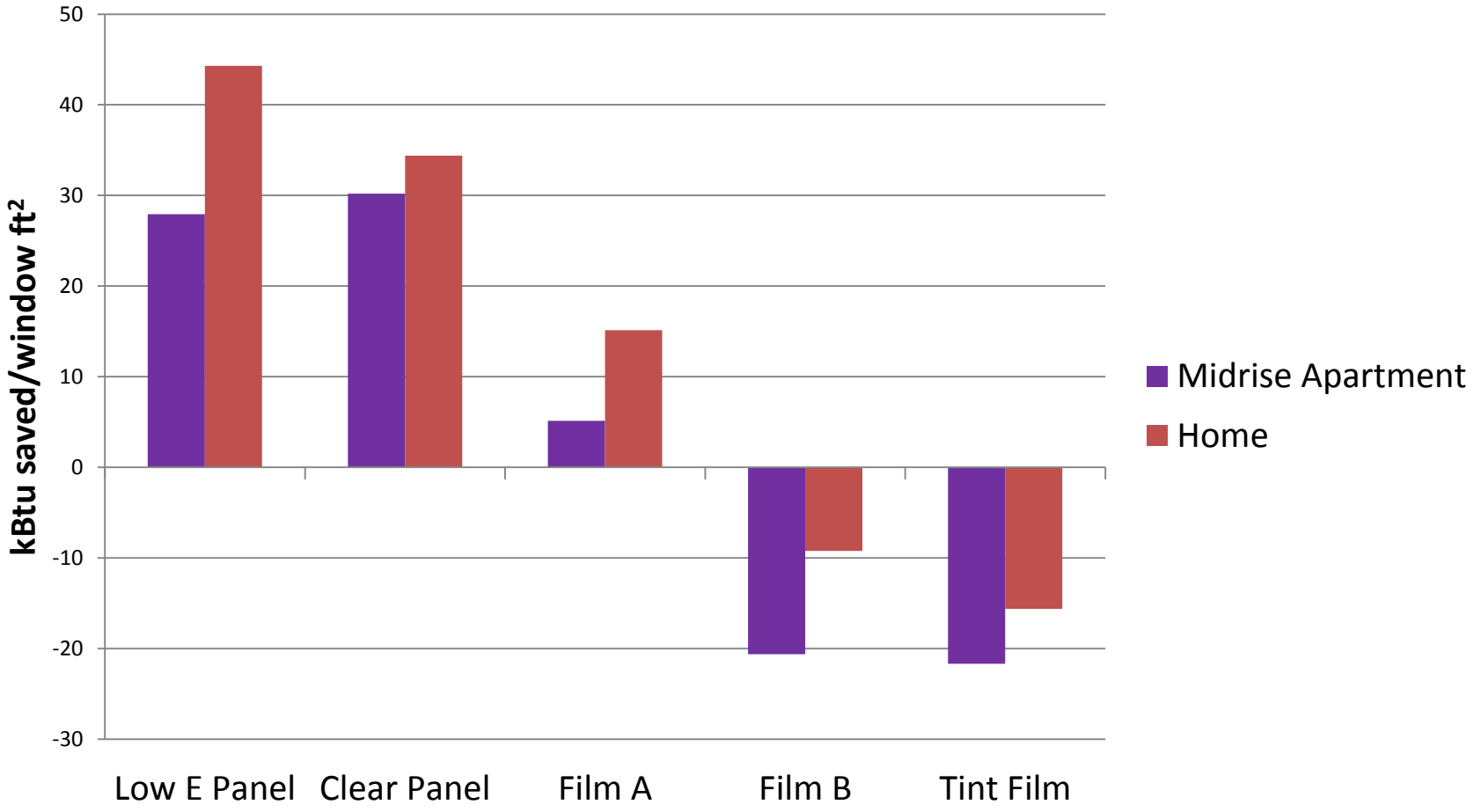


Courtesy: Lawrence Berkeley National Laboratory

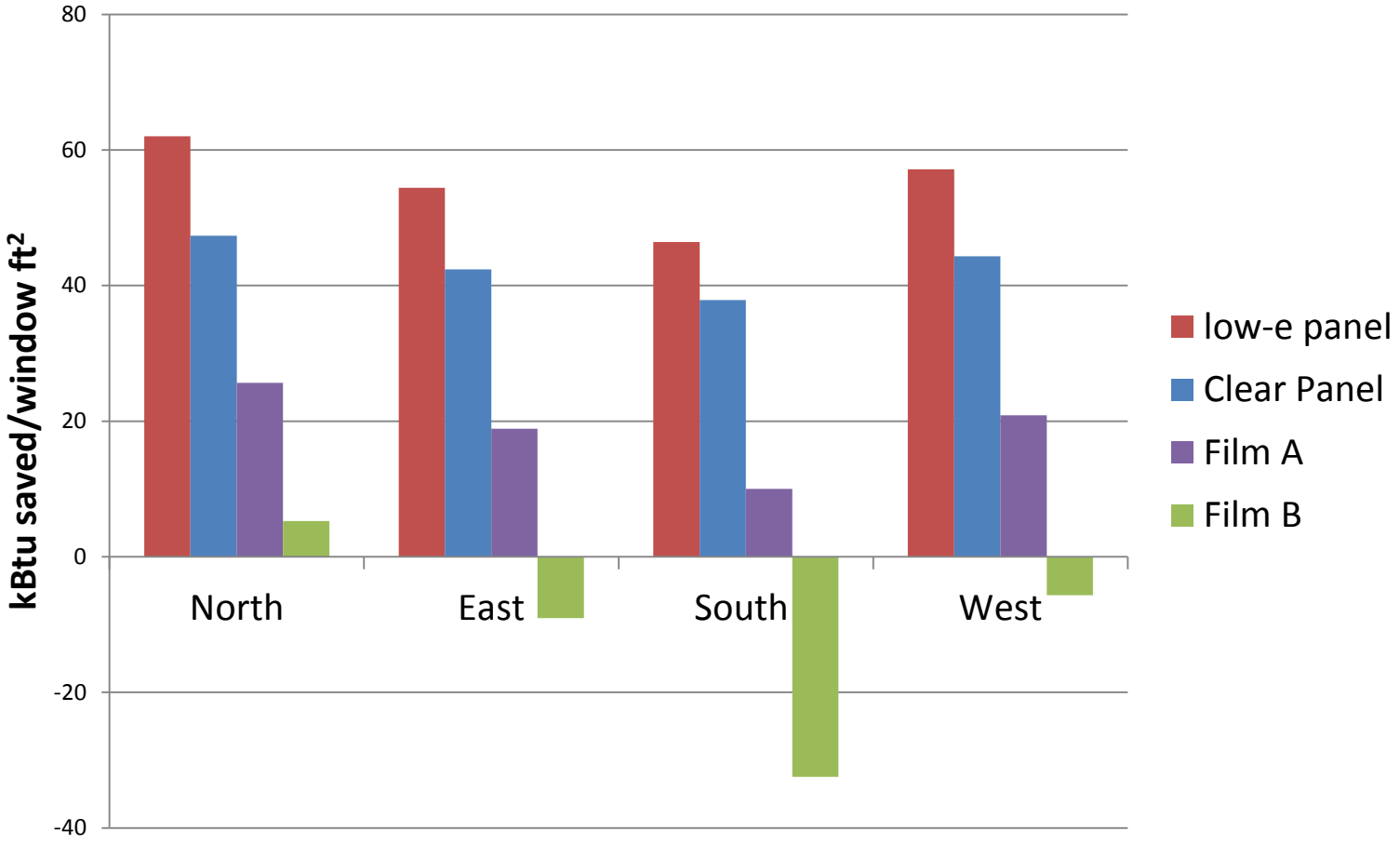
Window retrofit savings in residential buildings



Savings are larger in houses than apartments



Savings depends on orientation



House in Duluth

Value of the savings in a house

Retrofit	Location	Total Energy Saved, %	$ Savings (natural gas heat)	Annual $ Savings (electric)
Panel, clear	Zone 6	6.2%	$ 64	$ 146
Panel, Low-e	Zone 6	8.1%	$ 84	$ 191
Film A	Zone 6	3.2%	$ 33	$ 75
Panel, clear	Zone 7	6.5%	$ 82	$ 189
Panel, Low-e	Zone 7	8.4%	$ 102	$ 244
Film A	Zone 7	2.9%	$ 35	$ 84

Low-e window panels save the most money, although they are also the most expensive product

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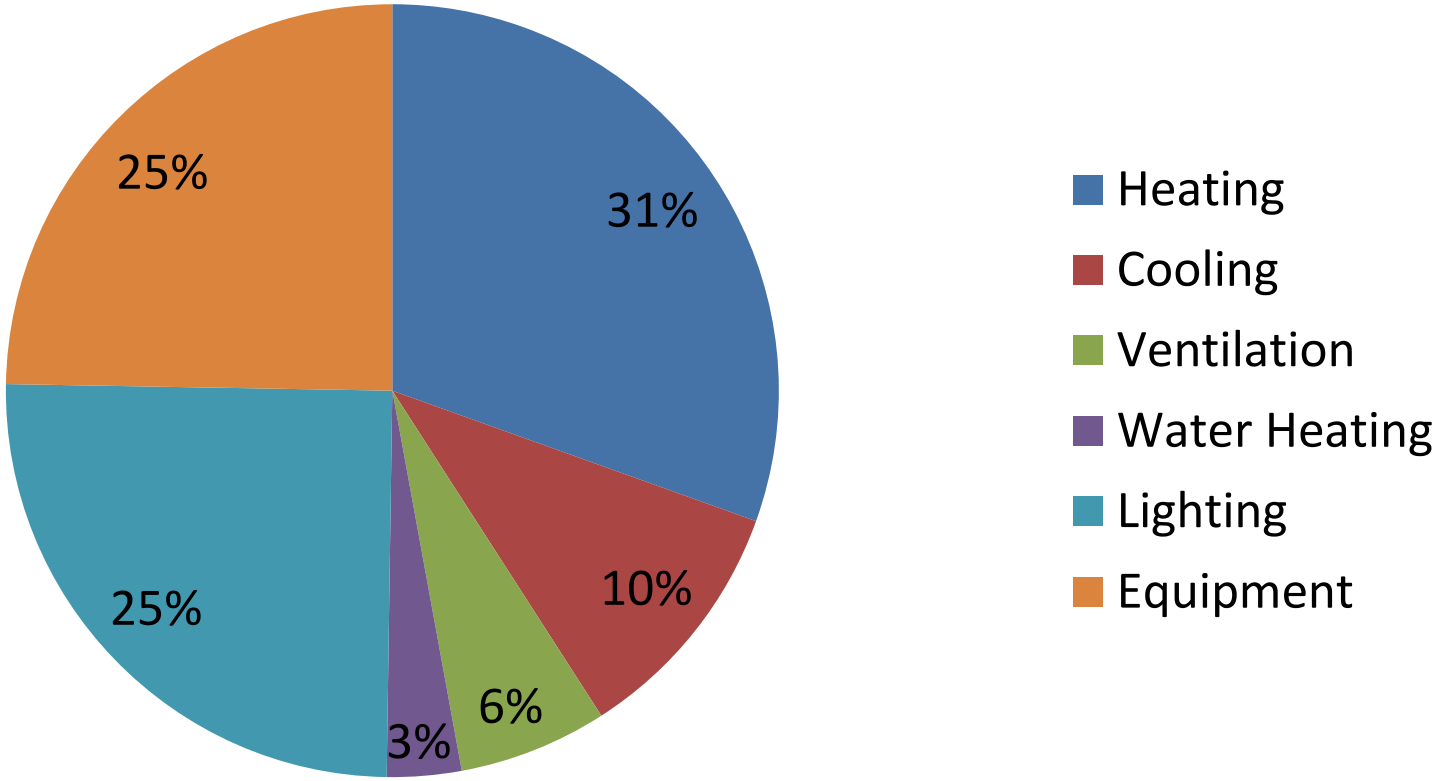
Commercial building results

- Savings depends on building type
  - Defined by primary activity
  - Typical construction
  - Operations
  - Maintenance
- Location
- Orientation
- Design

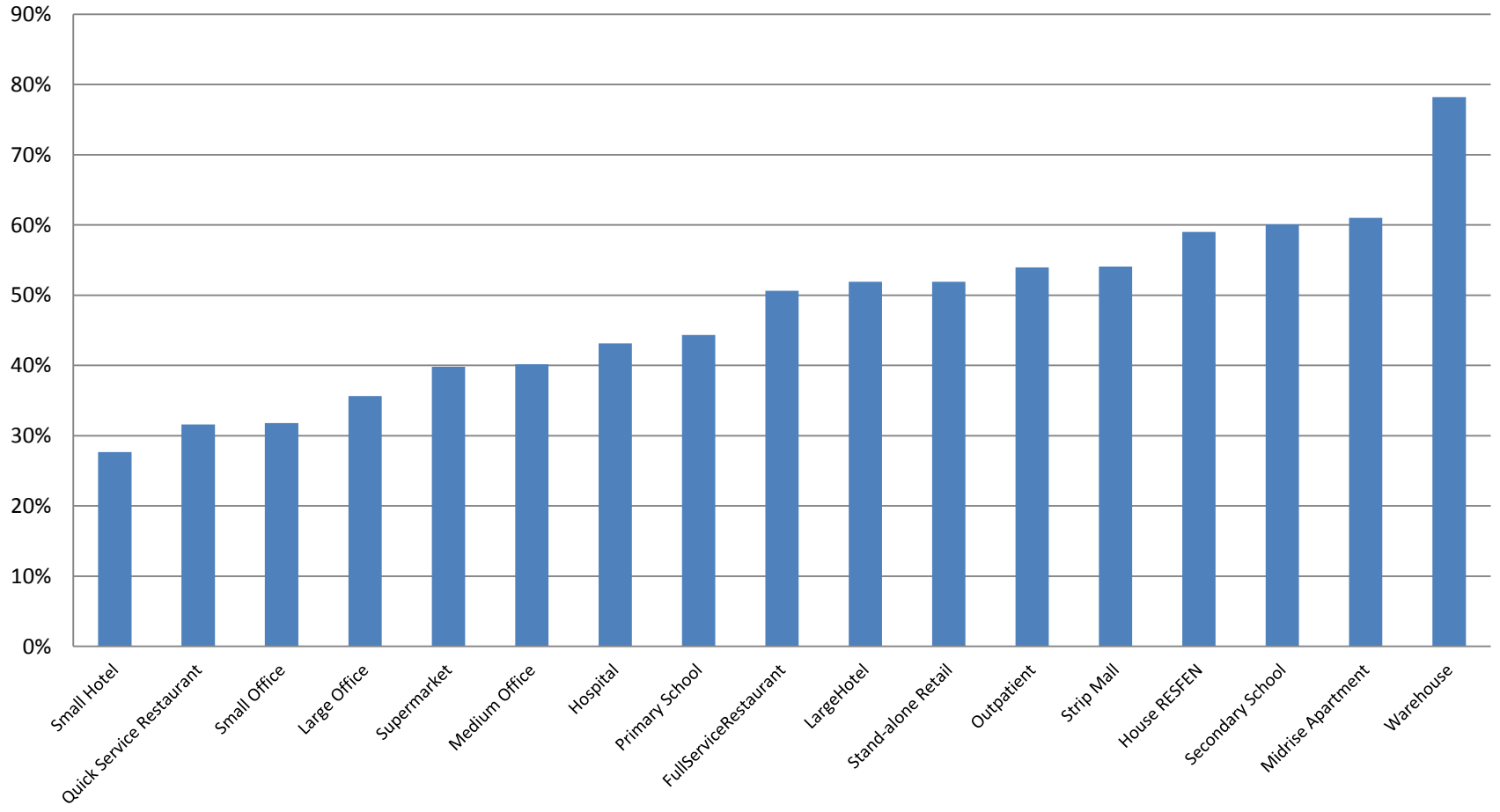
Commercial buildings in Minnesota

Building Size (ft^2)	# of Buildings	% of Buildings	Total Area (sq.ft.)	% of Area	Building Types
5,001 to 10,000	17,090	20%	126,785,374	10%	Small Office, Restaurant
10,001 to 25,000	14,602	17%	228,206,463	18%	Strip Mall, Standalone Retail, Mid-rise Apartment
25,001 to 50,000	4,705	5%	169,131,293	13%	Small Hotel, Outpatient Healthcare, Supermarket
50,001 to 100,000	2,650	3%	185,518,027	14%	Medium Office, Primary and Secondary School, Warehouse
100,001 to 200,000	1,334	2%	184,184,014	14%	
200,001 to 500,000	469	1%	135,095,918	10%	Large Office, Hospital, High Rise Apartment
Over 500,000	144	0%	138,088,435	11%	

MN Commercial Building Site Energy Use

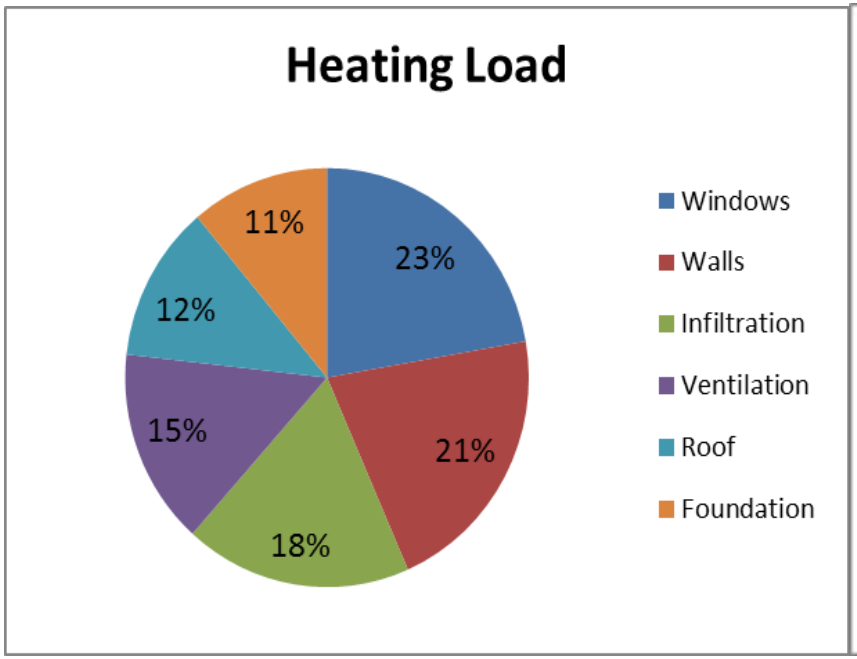


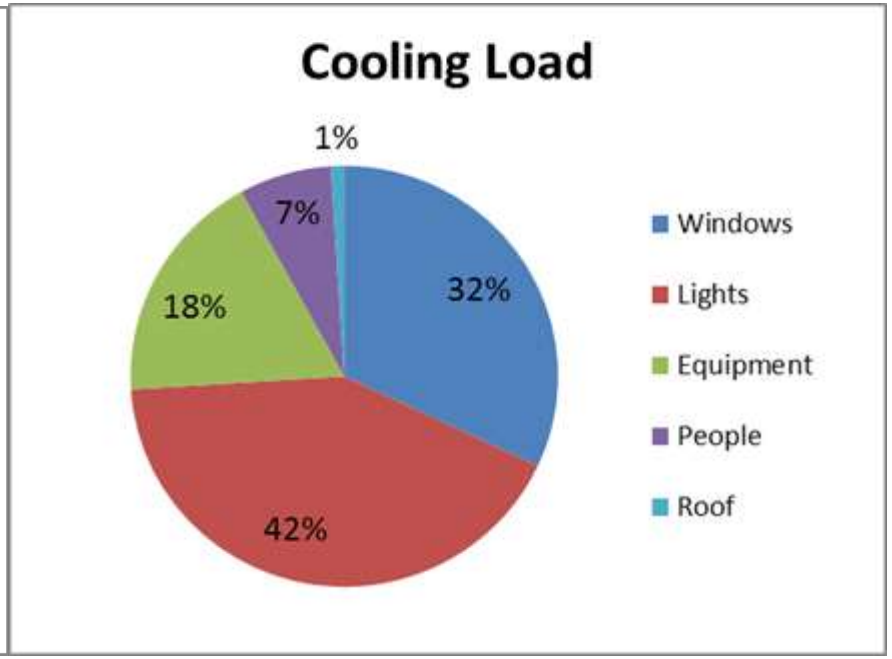
Heating and cooling energy varies by building type



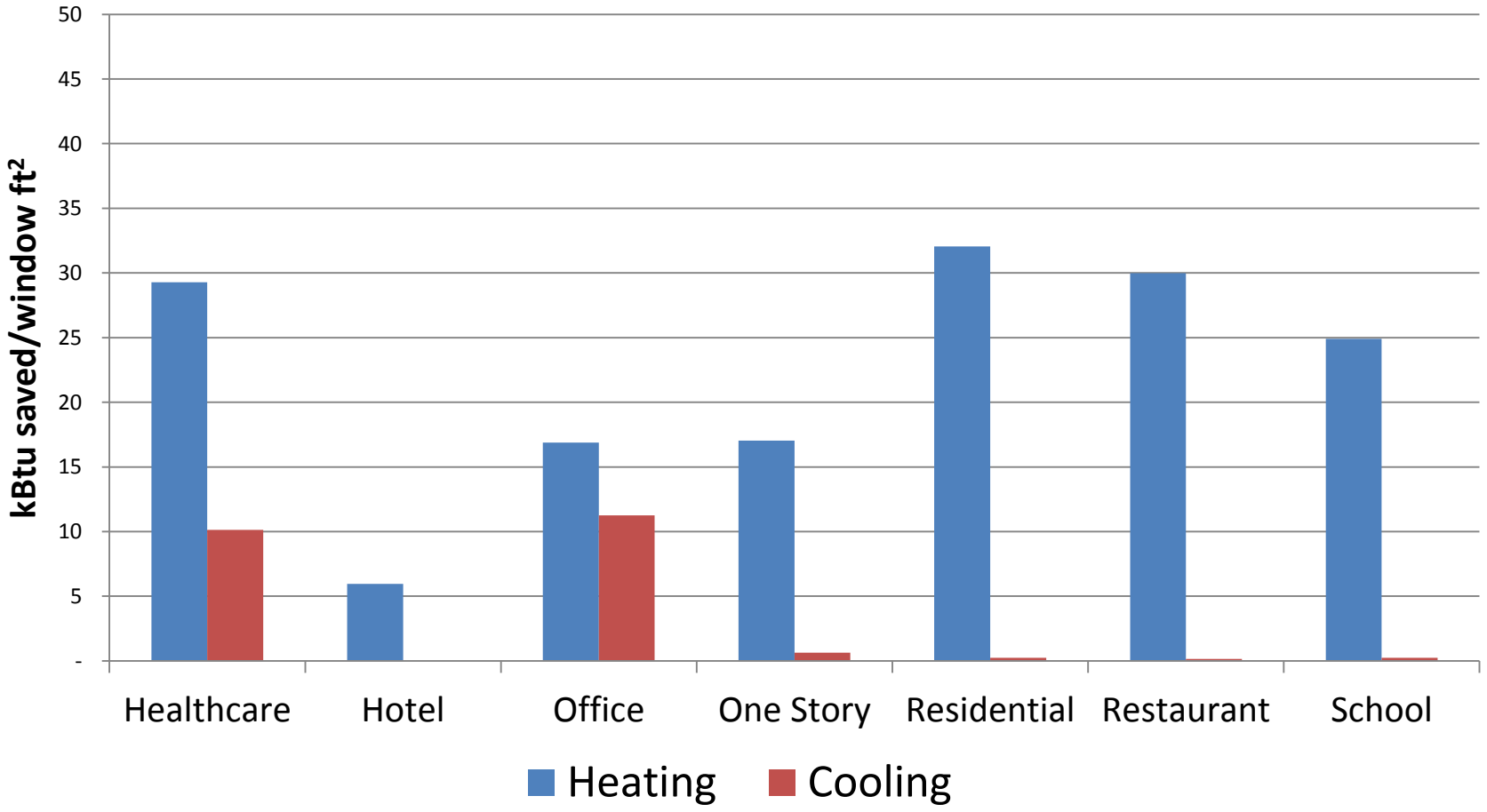
Center for Energy and Environment

Windows are a major source of heating and cooling load in commercial buildings

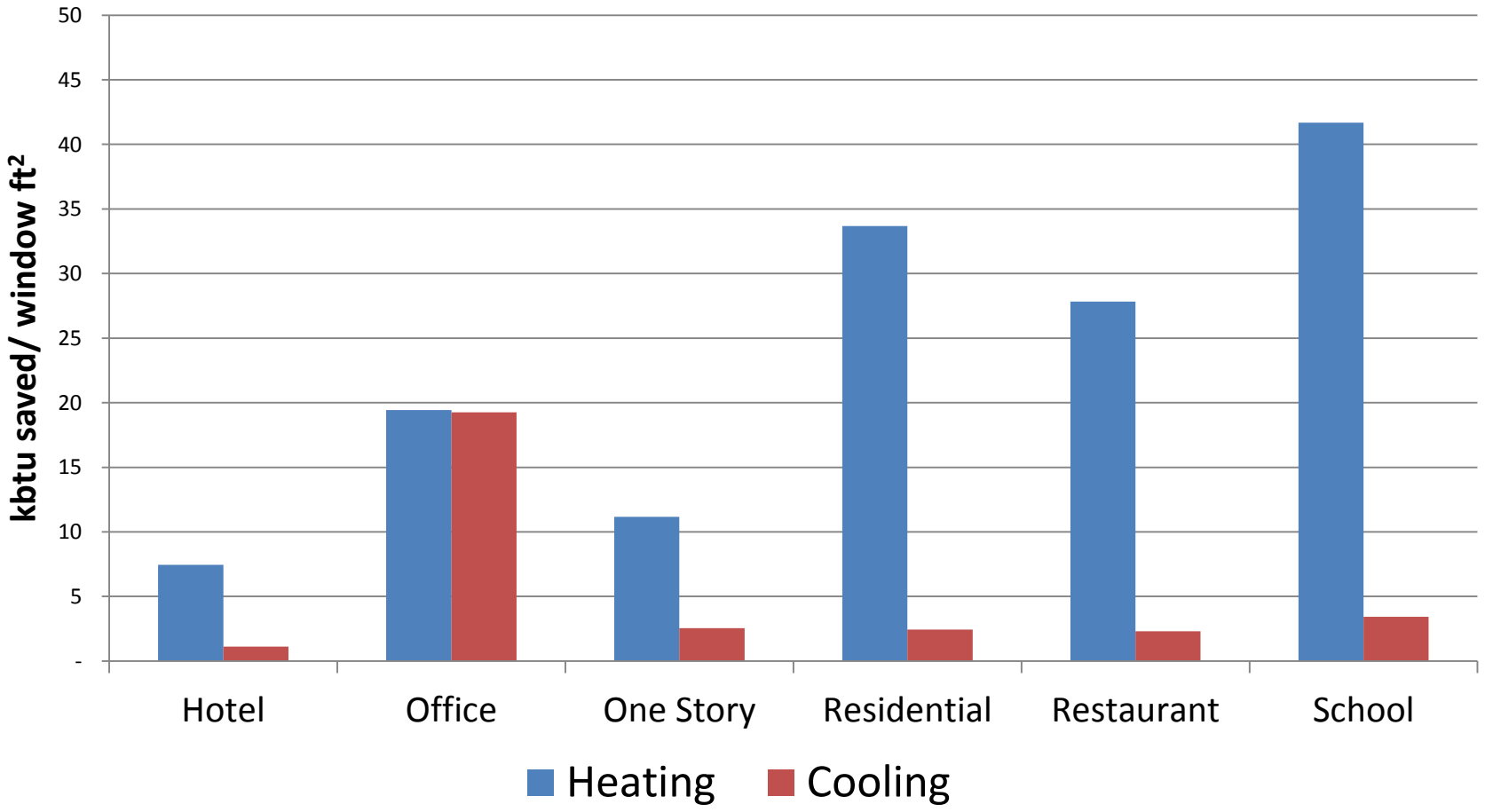




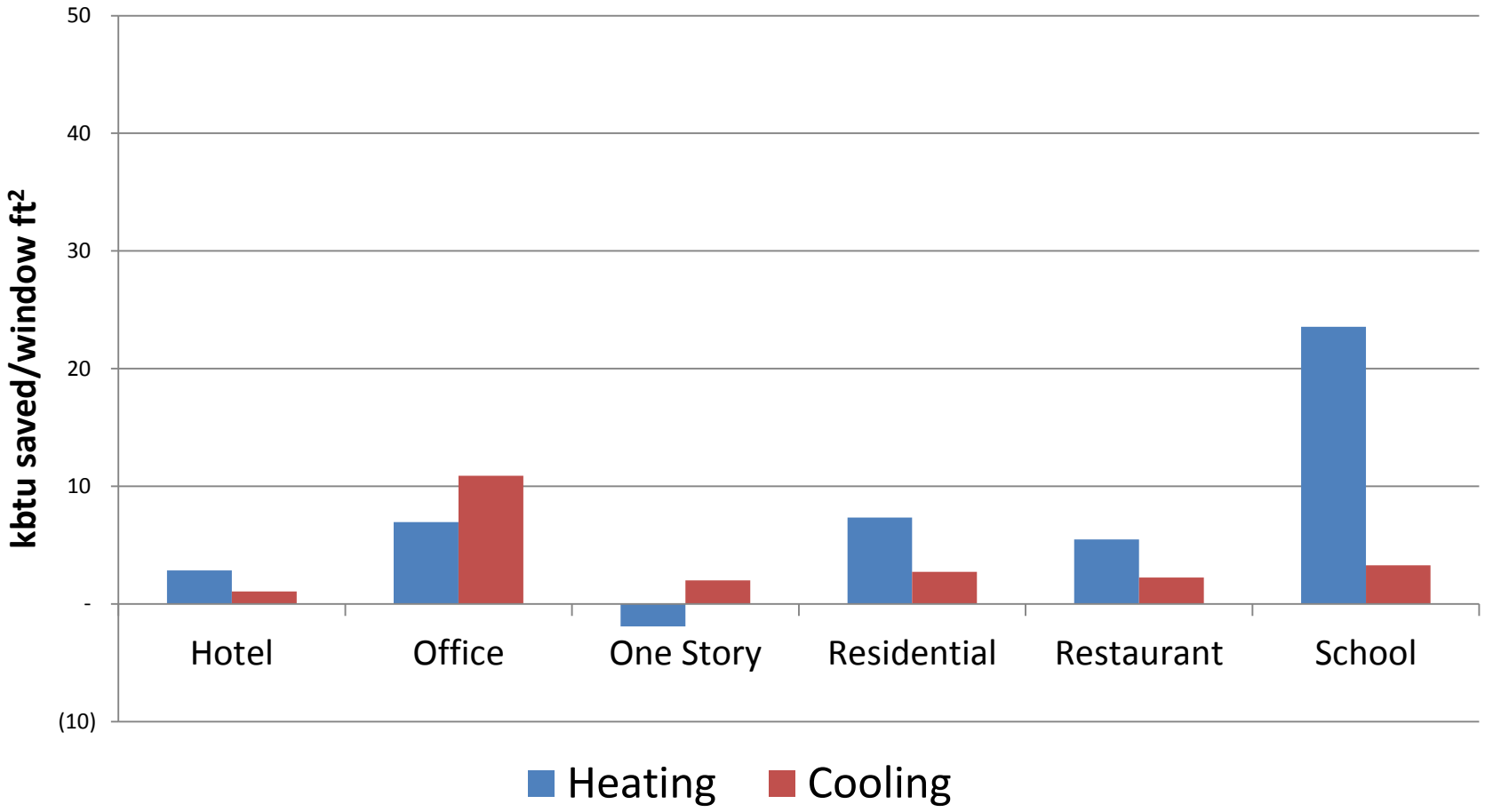
Clear window panels (Zone 6)



Low-e panels (Zone 6)



Window Film A (Zone 6)



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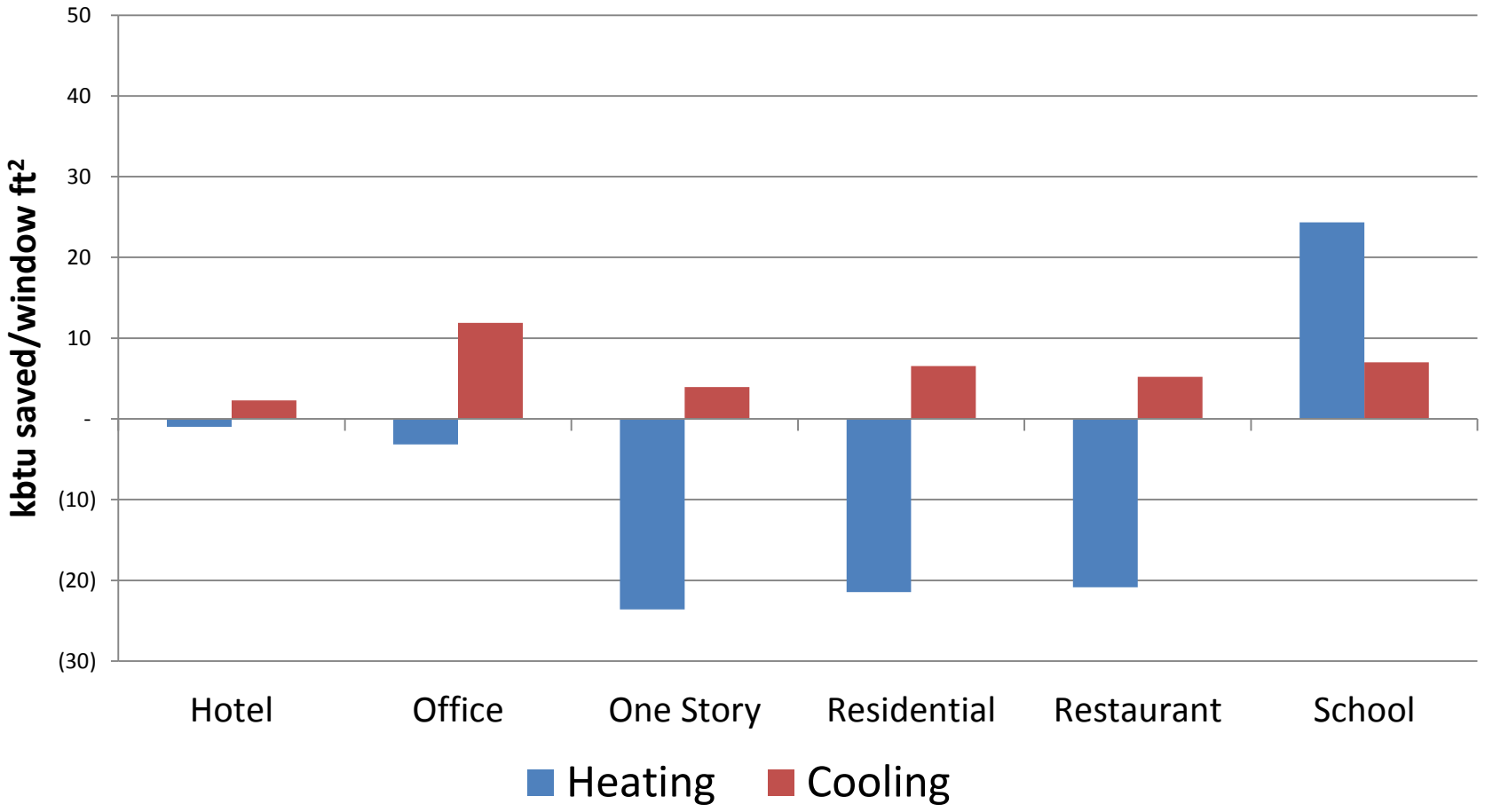
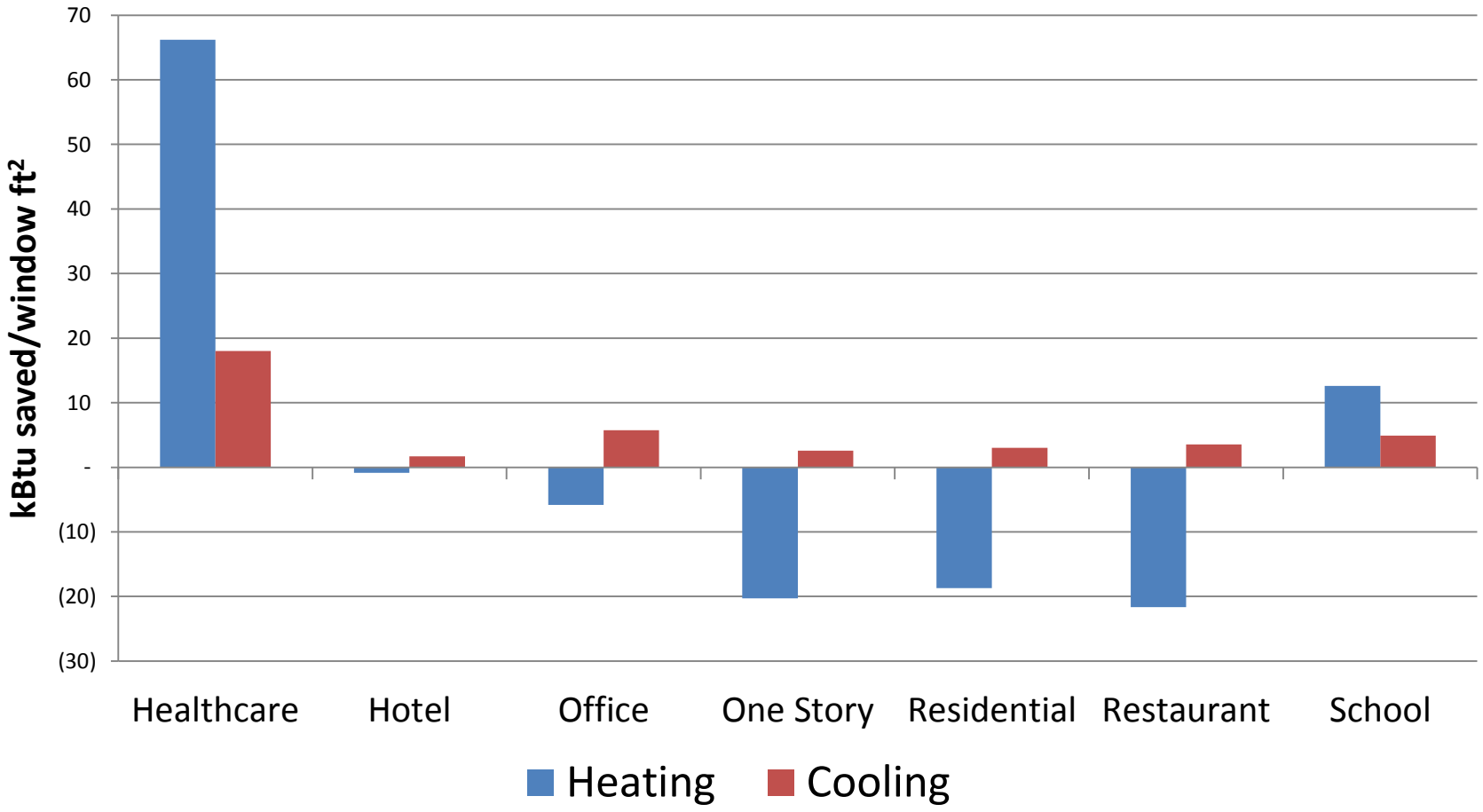
Ener-Logic Film

Window Film B (Zone 6)

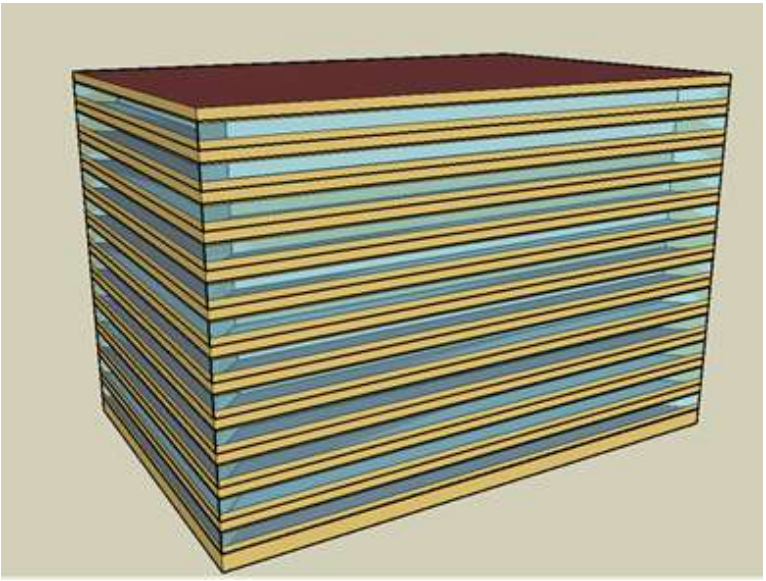


3M Amber Low-e

Effect of tinted window films

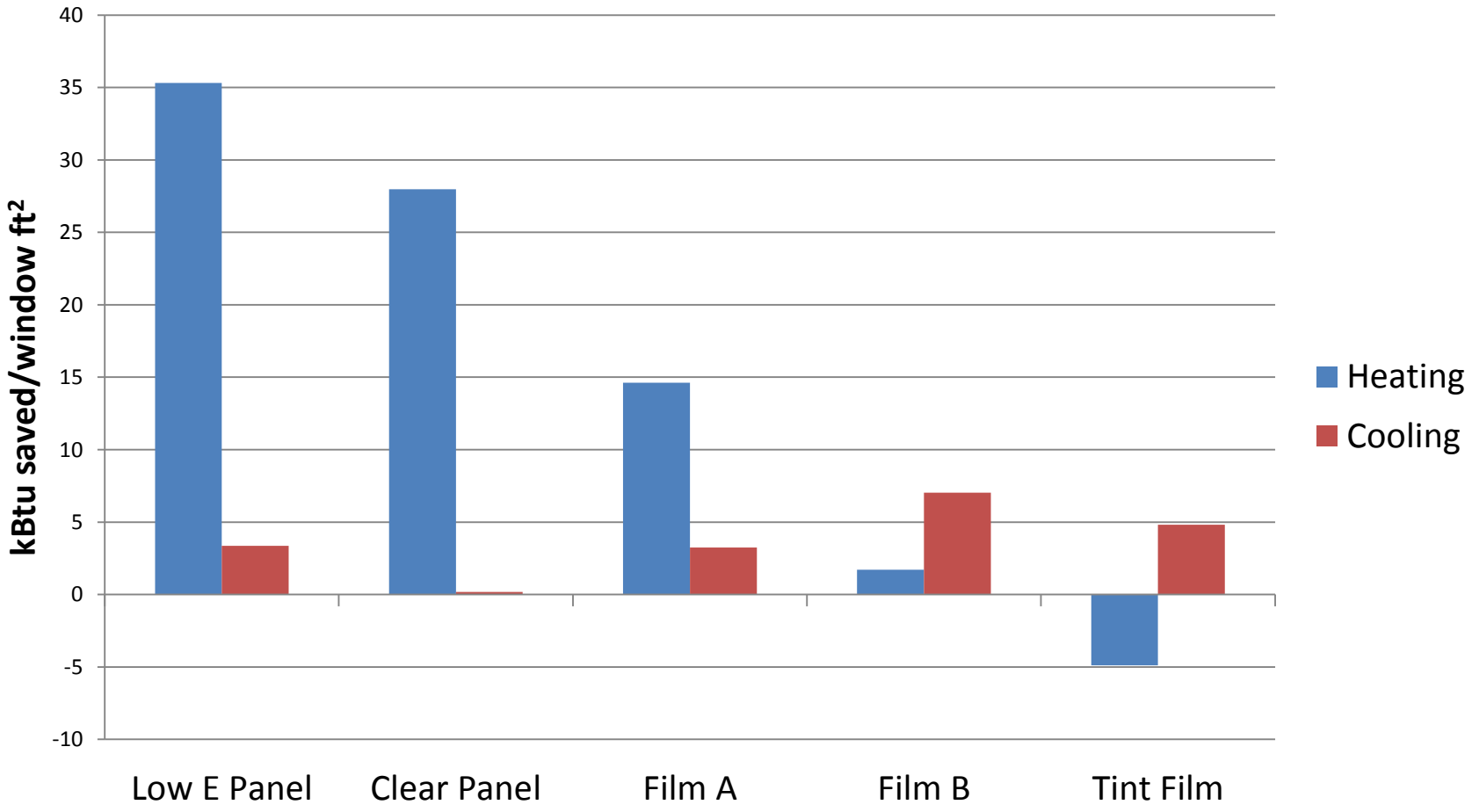


Office Buildings

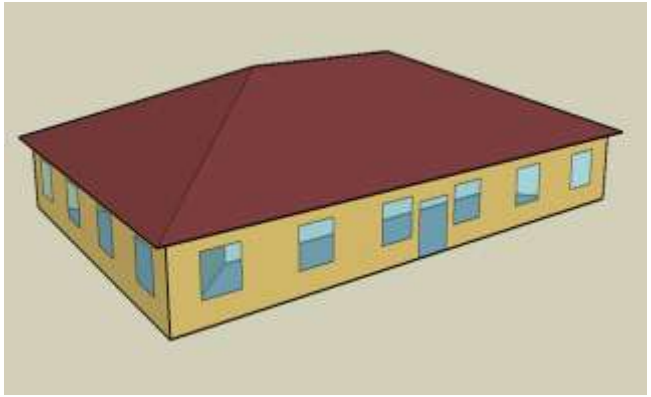


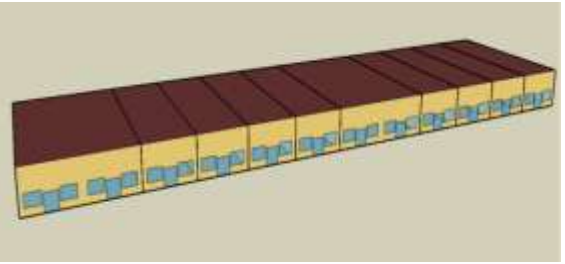
Comparing a multistory large office building to the DOE reference building

Comparison of window retrofits on office buildings



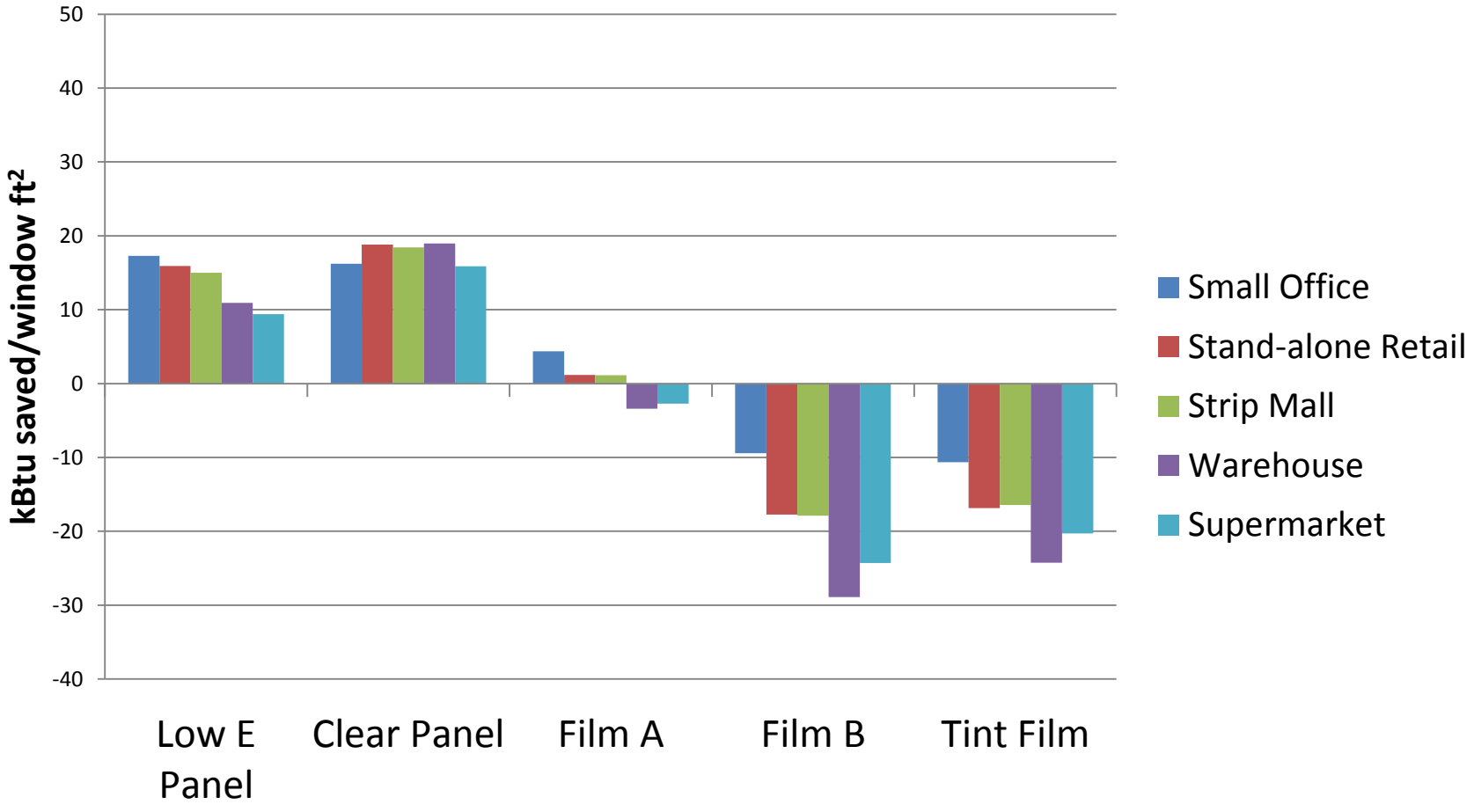
One-story commercial buildings



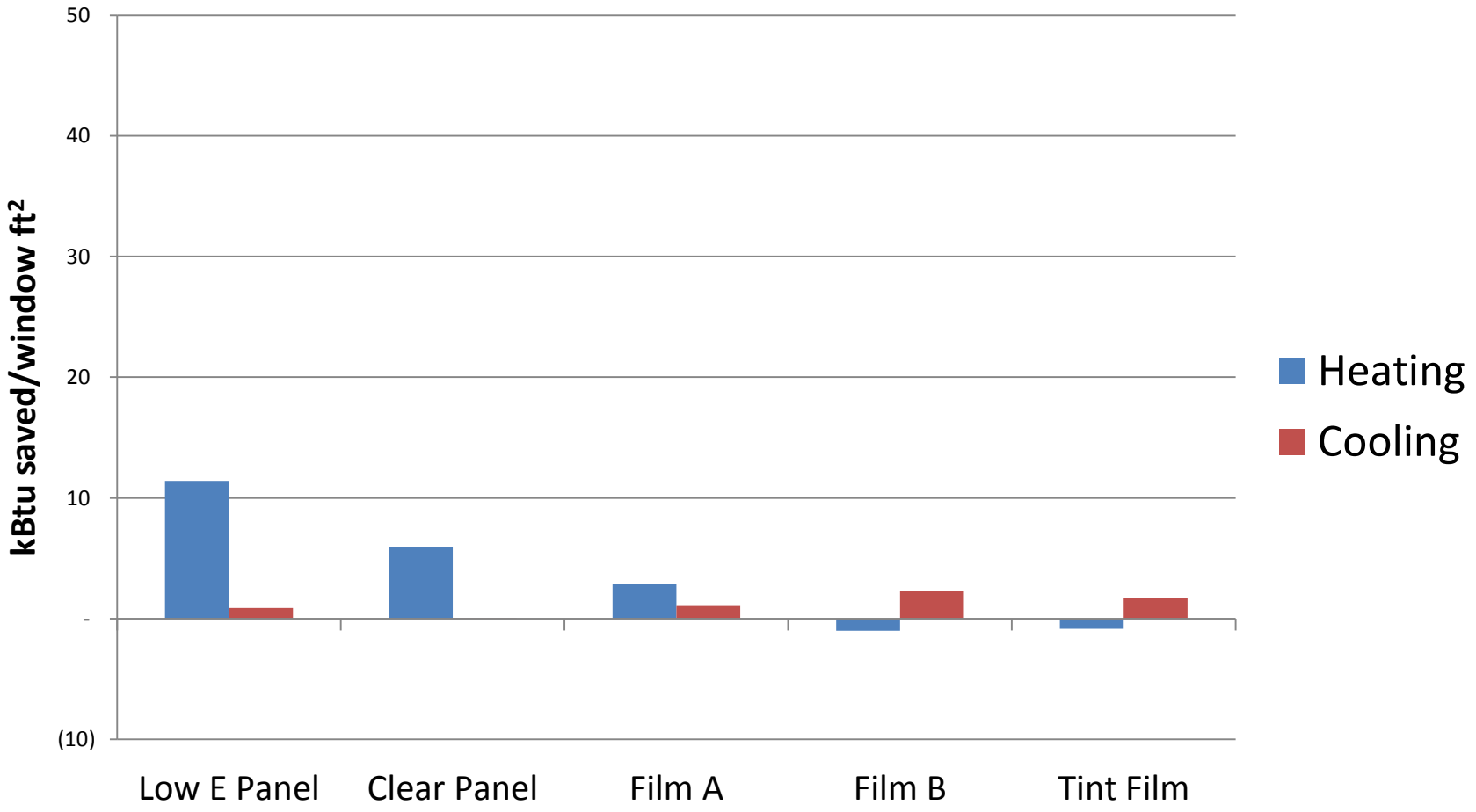


Includes small offices, standalone retail, strip malls, supermarkets and warehouses

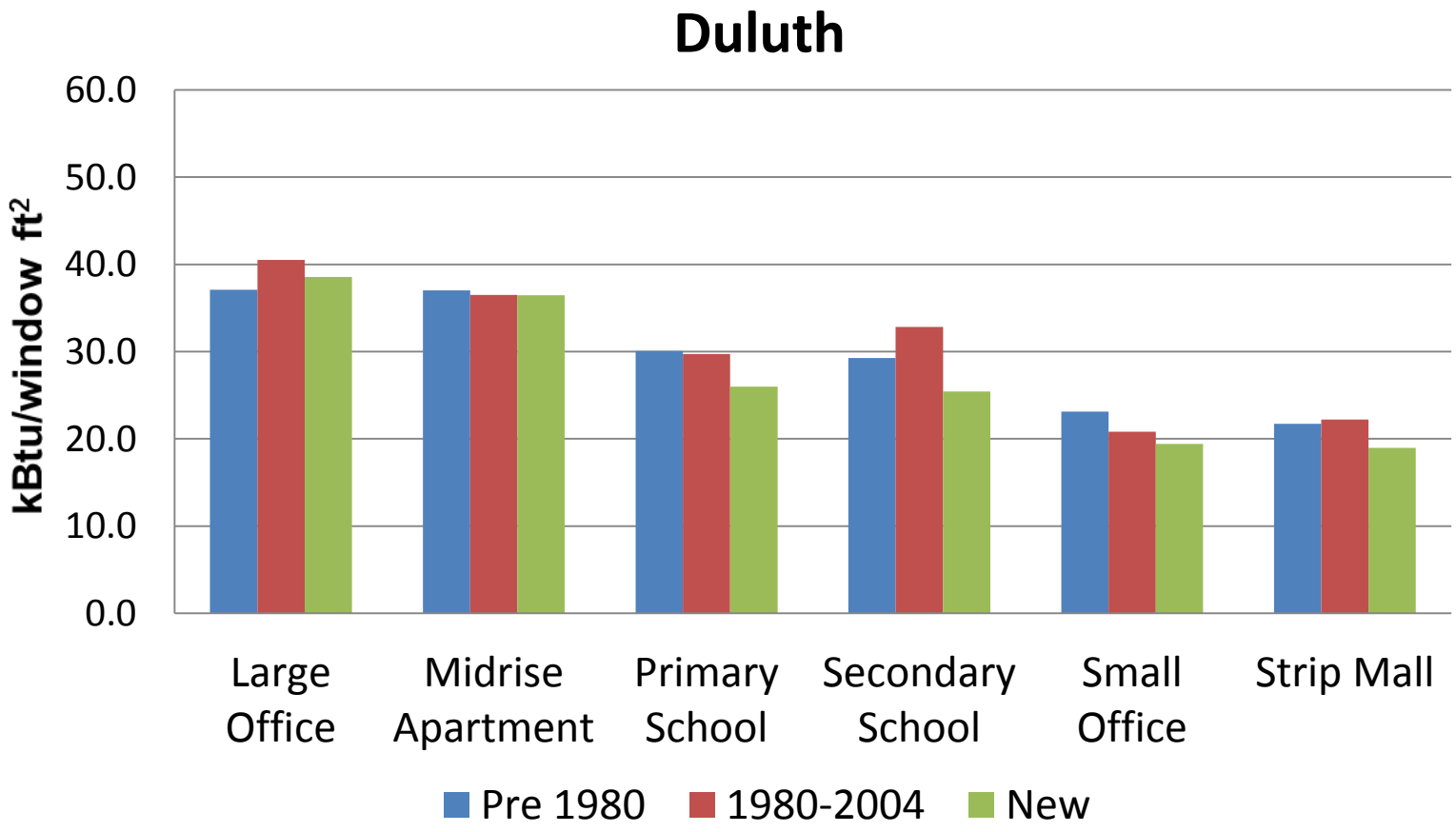
Energy savings in single story buildings



Hotels had smaller than average savings



Date of construction has a minor impact (Clear panel)



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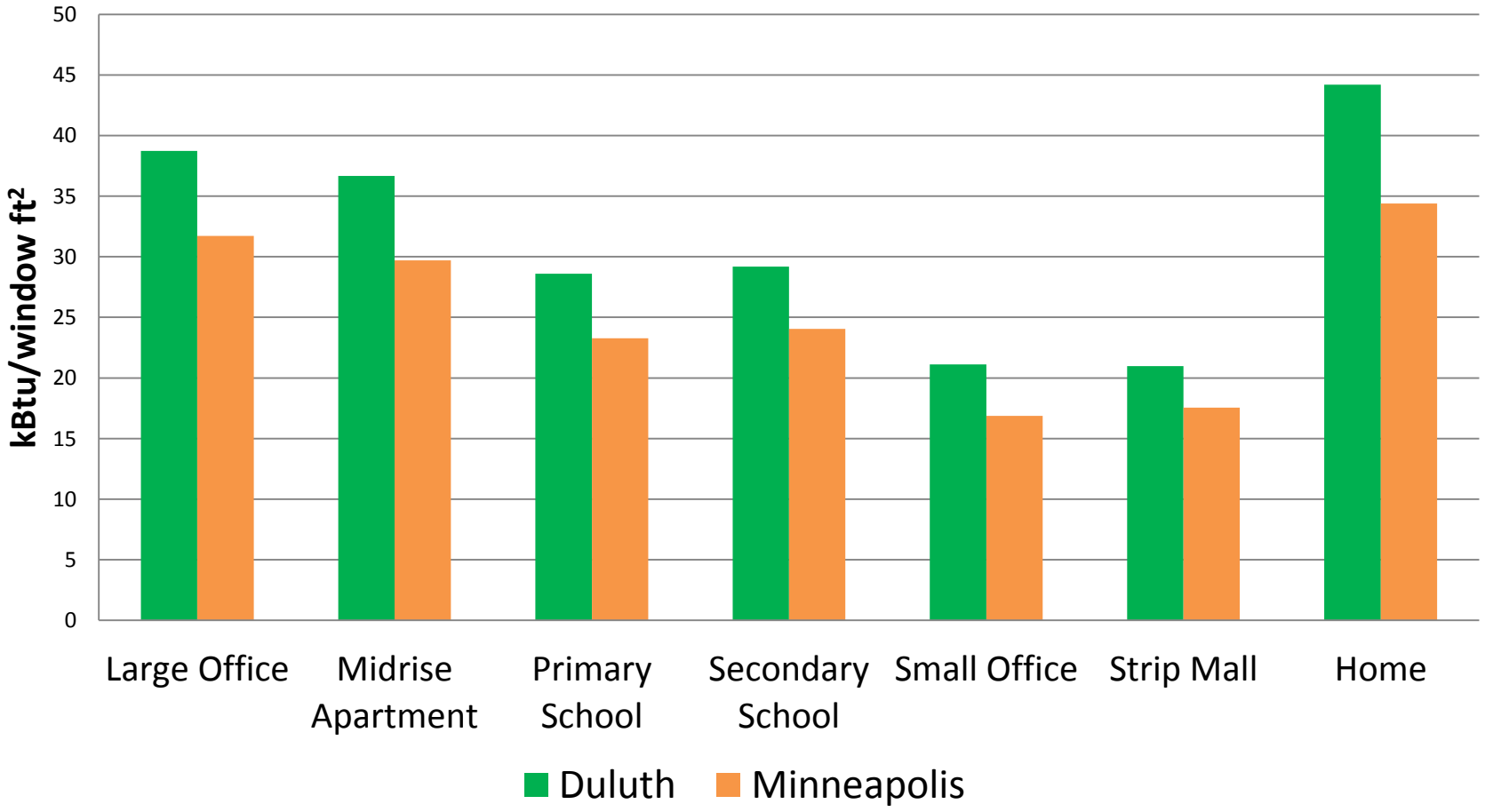
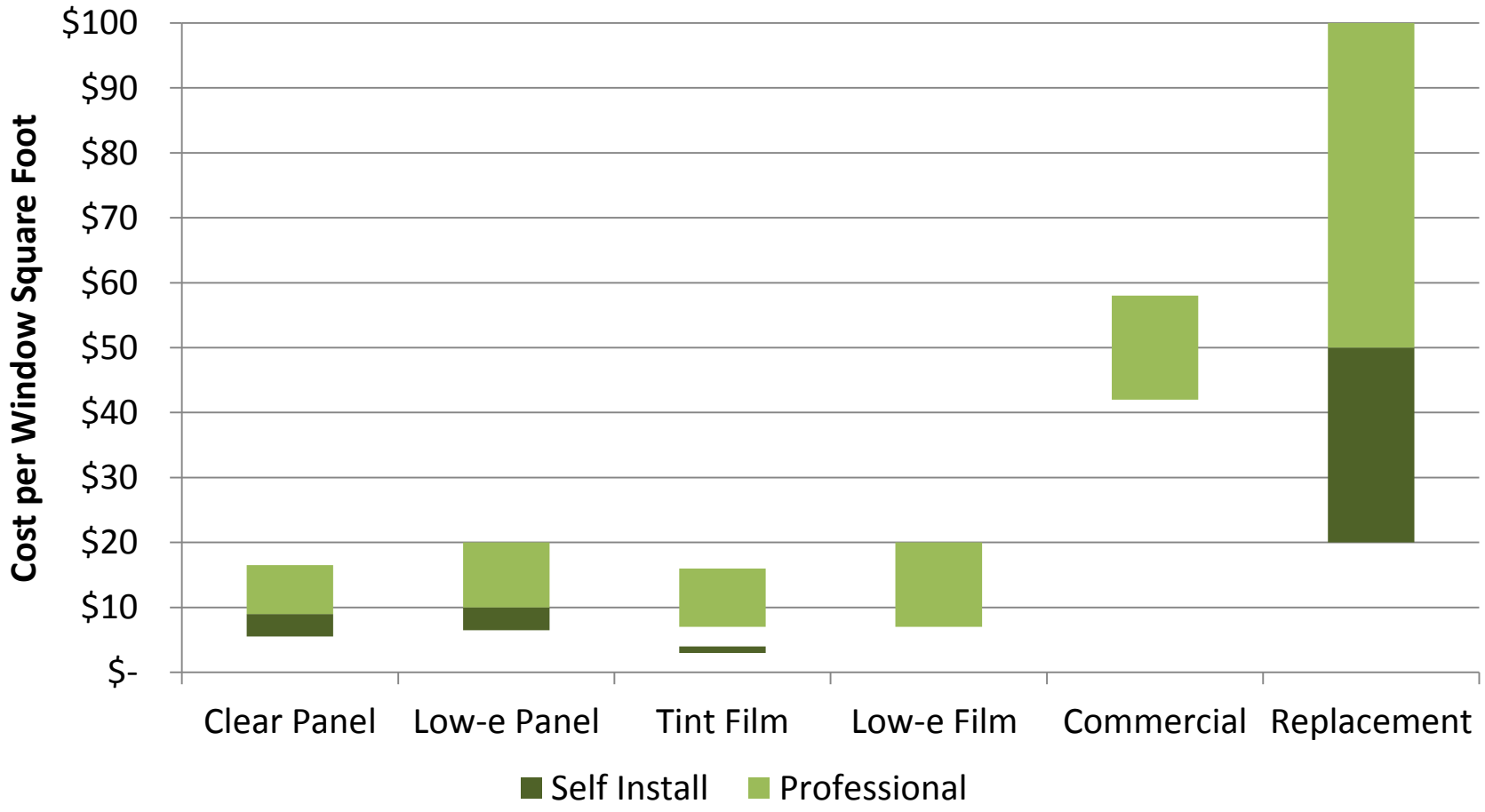
Window retrofits save energy in buildings of all ages

Zone 7 savings are always higher than Zone 6

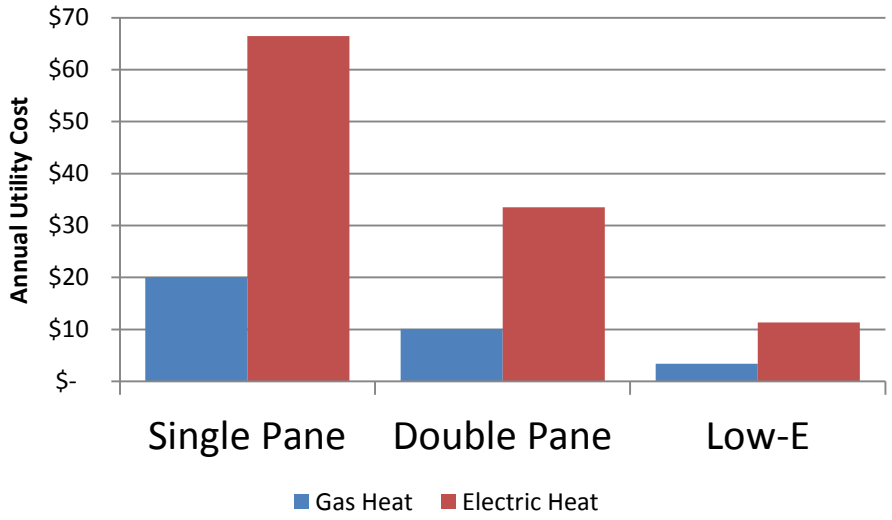


Product costs



Effect of fuel prices

Fuel	Market Cost	Unit Cost ($/100 kbtu)	Annual Savings for a home in Zone 7 with Low-e window panels	Payback of $2,500 Investment (years)
Natural gas	$0.92/therm	$ 0.92	$ 78	19
Electricity	$0.11/kWh	$ 3.31	$ 283	5
Propane	$2.06/gal	$ 2.24	$ 191	8
Fuel Oil	$3.87/gal	$ 2.78	$ 238	6



cee
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Panel paybacks with natural gas heat

Retrofit	Type of Building	% of Total Energy Saved	Payback
Clear Panel	Outpatient	1.1%	6.7
Clear Panel	Medium Office	3.9%	7.3
Clear Panel	Hospital	1.1%	9.8
Low E Panel	Hospital	3.0%	3.5
Low E Panel	Outpatient	2.7%	3.6
Low E Panel	Medium Office	5.1%	6.4
Low E Panel	Secondary School	4.4%	12.5
Low E Panel	Large Office	6.6%	13.5
Low E Panel	Primary School	5.8%	13.7
Low E Panel	House	7.6%	14.9

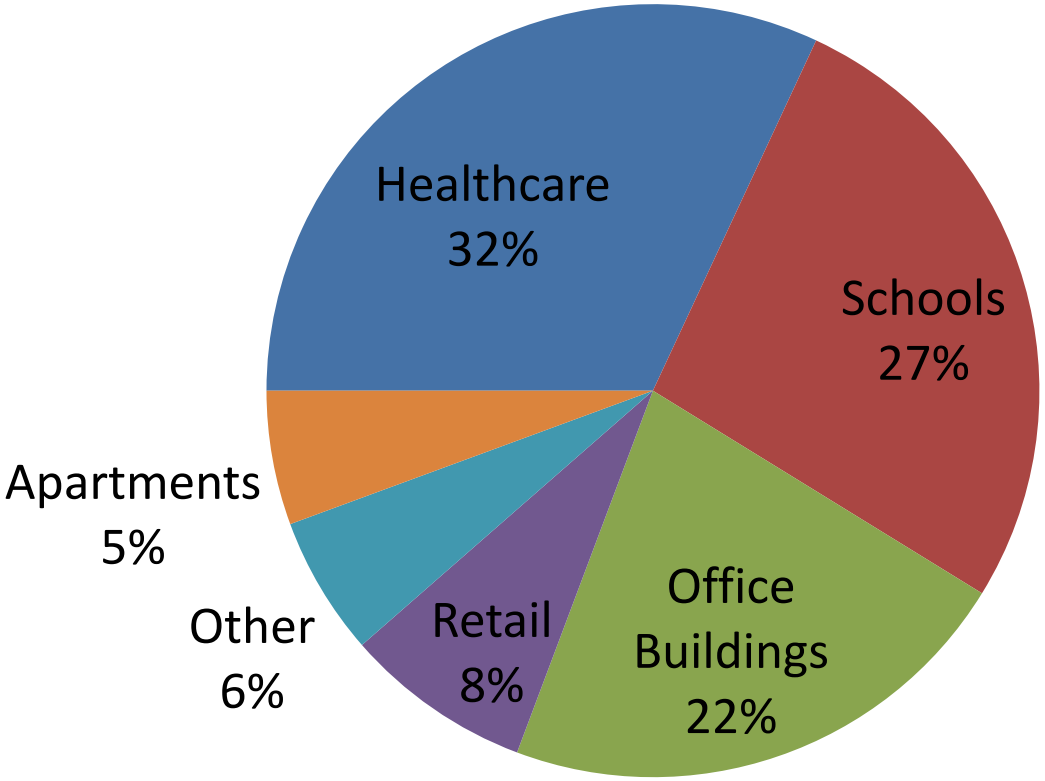
Film paybacks with natural gas heat

Retrofit	Type of Building	% of Total Energy Saved	Payback
Film A	Hospital	2.3%	8
Film A	Outpatient	1.9%	10
Film B	Hospital	3.5%	3
Film B	Outpatient	3.1%	4
Film B	Medium Office	1.1%	14
Film B	Secondary School	2.8%	15

Maximum impact: Low-e panel and electric heat

Building	Savings (%)	# Buildings	Payback (years)	Saving Potential (Billion Btu)
House	7.6%	1,290,000	4	12,848
Outpatient	2.7%	2,353	2	621
Secondary School	4.4%	474	4	459
Hospital	3.0%	269	1	392
Medium Office	5.1%	1,557	6	334
Primary School	5.8%	547	4	228
Large Office	6.6%	64	4	160
Midrise Apartment	2.3%	2,233	7	155
Stand-alone Retail	0.4%	10,694	12	152
Small Office	2.5%	10,543	11	117
Large Hotel	0.6%	561	13	114

Commercial building savings potential



Agenda

- Background
- What are window retrofits?
- Summary of the results
- Determining energy savings
- Residential building results
- Commercial building results
- Opportunities for market transformation

Opportunities for market transformation

- Increase awareness of window retrofits
  - Consumer energy guides
  - Conferences like this
  - Division of Energy Resources newsletter
  - CERTS programs
- Include in approved energy efficiency product inventory for loan and weatherization programs

Opportunities for market transformation

- Offer prescriptive rebates
  - $5/ Dt saved is about $50 for an average home
  - $0.045/kWh saved for electric heat
- Custom rebates for large projects (over 500 Dt)

THANK you!

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