ENERGY STAR WINDOWS' PERFORMANCE AND ORIENTATION

Authors:

Maral Jalili, Colorado State University, USA

Caroline M. Clevenger, University of Colorado at Denver, USA

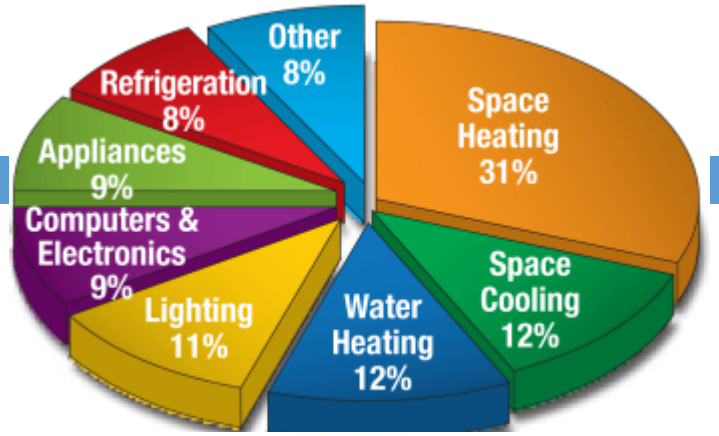
Mehmet E. Ozbek, Colorado State University, USA

Moatassem A. Abdallah, University of Colorado at Denver, USA

Outline

- Introduction
- Methodology
- Analysis & Discussion
- Future Research
- Conclusions

Introduction



(chromasun.com)

- In United states in 2010, residential and commercial building sectors use 41% of nation's primary energy
- Residential buildings use 43% for space heating and cooling.
- Building Energy Data Book states - 25% to 35% energy loss through inefficient windows.

(ecocel.ie)

ENERGY STAR Federal Tax Credits

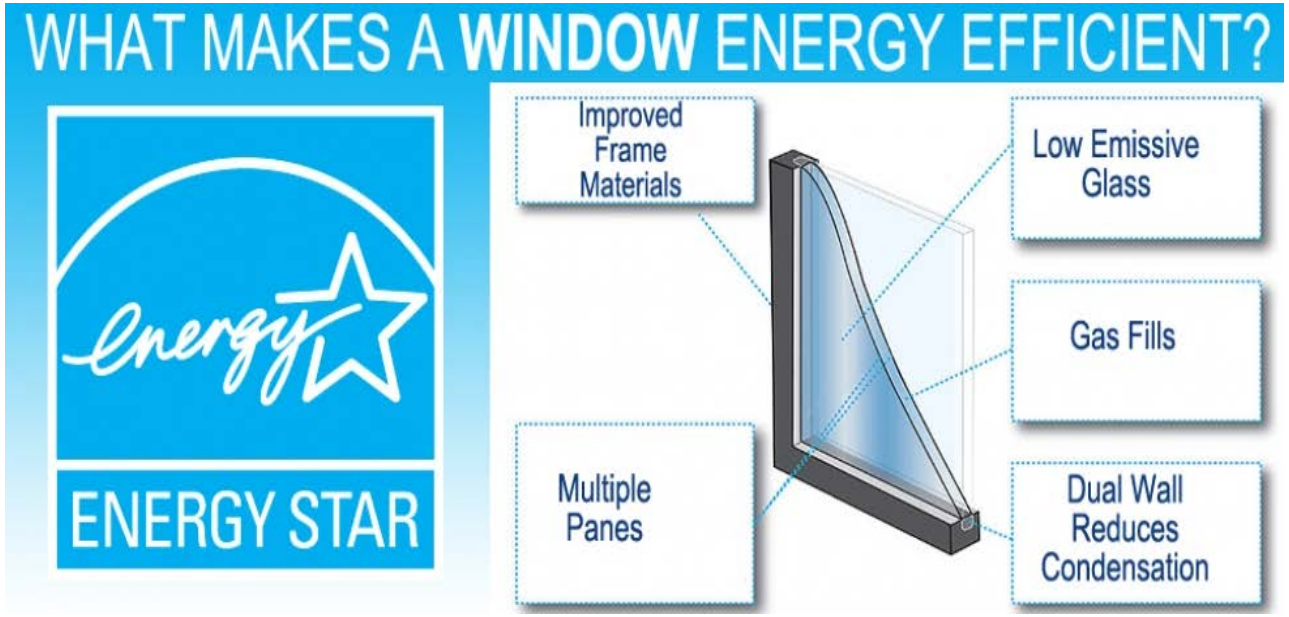
ENERGY STAR provides incentives for technologies that lower energy bills.

- Biomass stoves
- Heating, Ventilation, Air Conditioning (HVAC)
- Insulation
- Roofs
- Water Heaters
- Windows and Doors
- Geothermal Heat pumps
- Small Wind Turbines
- Solar Energy Systems
- Fuel cells

ENERGY STAR Tax Credits for Windows

Windows to qualify as ENERGY STAR certified, should meet three criteria:

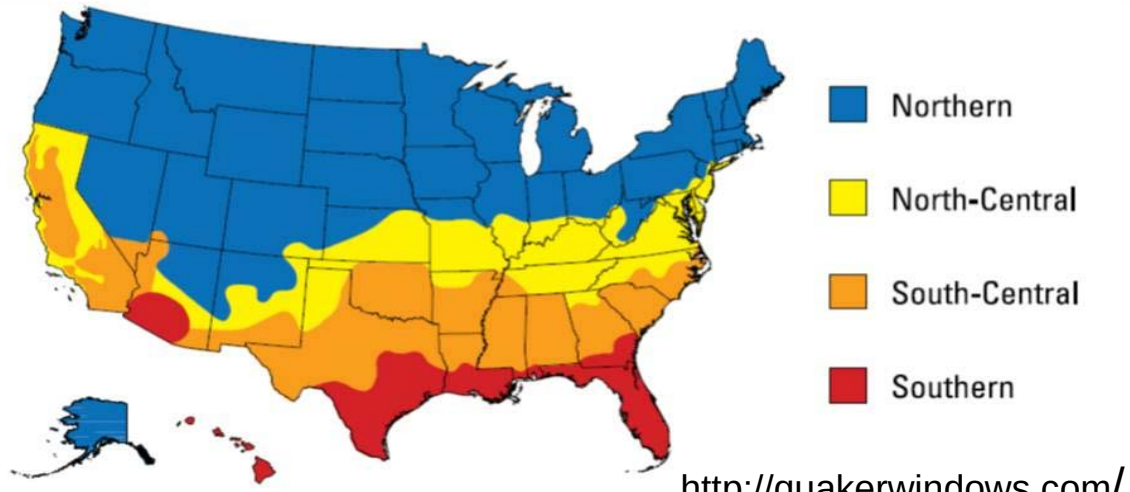
- Manufactured by an ENERGY STAR partner
- Tested and certified by National Fenestration Rating Council (NFRC)
- Meets US DOE guidelines
- Credit: **10% of the cost, up to $200**



airtightsidingandwindows.com

ENERGY STAR Climate Zones

- U-Factor – Heat transfer per unit of time per area and per degree of temperature difference.
- Solar Heat Gain Coefficient (SHGC) – The fraction of incident solar radiation entering the space through window.



http://quakerwindows.com/

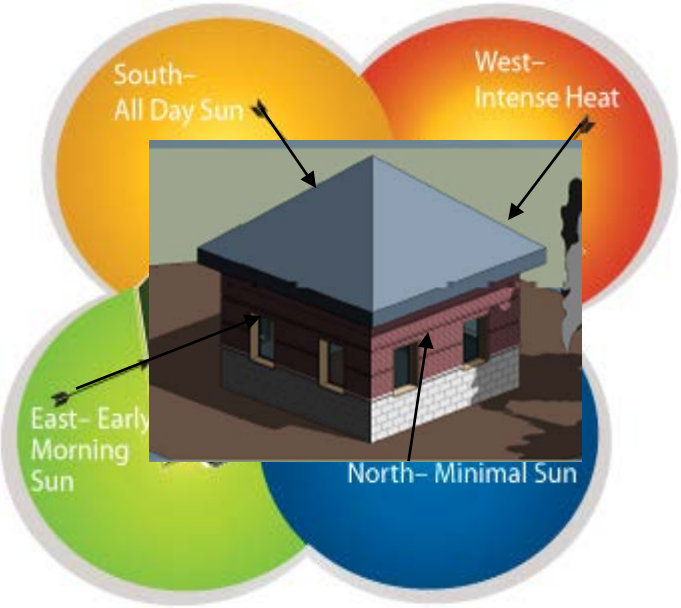
Energy Star ® Performance Levels		
Climate Zone	U-Value	SHGC
N=Northern	0.30 and below	any
Northern alternative criteria #1	0.31	0.35 and below
Northern alternative criteria #2	0.32	0.40 and below
NC=North/Central	0.32 and below	0.40 and below
SC=South/Central	0.35 and below	0.30 and below
S=Sourthern	0.60 and below	0.27 and below

ENERGY STAR qualification criteria for residential windows (EnergyStar, 2014c)

Energy Model

Square single story 25 m^2 (269 SF) model with total 15 m^2 (161 SF) glazing was simulated for the four ENERGY STAR climate zones.

- In baseline model glazing distributed equally on all facades.
- Four alternative models glazing placed exclusively on North, South, East or West facades



Inputs

- TRNSYS energy modeling software
- Assumptions
  - Existing Energy Modeling research
  - ASHARE 2010
  - One year simulation set time
- Windows library Creation
  - Lawrence Berkeley National Labs
  - ASHARE 90.1.99
  - ASHARE Standard 140
  - Building Energy Simulation Test (BESTEST) Standard

Climate Zone	Representative City	Window Type	U-value	SHGC
Northern	Denver, CO	A	0.32	0.614
North-Central	Albuquerque, NM	B	0.28	0.392
South-Central	Atlanta, GA	C	0.17	0.230
Southern	Miami, FL	D	0.44	0.196

Selected (ENERGY STAR eligible) window performance criteria per climate zone

Potential Cost Impacts

Climate Zone	City, State	Average Annual Electricity Bill by State	Potential Cost Variation per year (Electricity only)
Northern	Denver, CO	$971	$87 (9%)
North-Central	Albuquerque, NM	$895	$125 (14%)
South-Central	Atlanta, GA	$1473	$132 (9%)
Southern	Miami, FL	$1481	$15 (1%)

Potential cost Impacts of energy performance differences by climate zone

Performance Analysis

Location		Baseline		South		West		North		East		
Climate	City	Energy ($\frac{kWh}{m^2}$)	% Diff	Energy ($\frac{kWh}{m^2}$)	% Diff	Energy ($\frac{kWh}{m^2}$)	% Diff	Energy ($\frac{kWh}{m^2}$)	% Diff	Energy ($\frac{kWh}{m^2}$)	% Diff	Total Delta
Northern	**Denver, CO**	479	**N/A**	468	**2%**	510	**-7%**	505	**-5%**	498	**-4%**	**9%**
North-Central	**Albuquerque, NM**	388	**N/A**	362	**7%**	413	**-7%**	406	**-5%**	413	**-7%**	**14%**
South-Central	**Atlanta, GA**	304	**N/A**	289	**5%**	316	**-4%**	305	**0**	306	**-1%**	**9%**
Southern	**Miami, FL**	198	**N/A**	197	**1%**	198	**0**	173	**13%**	197	**1%**	**1%**

Estimated energy consumption ($\frac{kWh}{m^2}$) and percentage differences by orientations

Solar Irradiance

Location	Average Vertical Surface Irradiance ($\frac{kWh}{m^2}$)	South ($\frac{kWh}{m^2}$)	% Diff	West ($\frac{kWh}{m^2}$)	% Diff	North ($\frac{kWh}{m^2}$)	% Diff	East ($\frac{kWh}{m^2}$)	% Diff
Denver, CO	971.35	1331	**37%**	1064	**10%**	426	**-56%**	1064	**10%**
Albuquerque, NM	994.93	1354	**36%**	1083	**9%**	460	**-54%**	1083	**9%**
Atlanta, GA	805.34	1062	**32%**	850	**6%**	459	**-43%**	850	**6%**
Miami, FL	813.64	1061	**30%**	849	**4%**	495	**-39%**	849	**4%**

Average annual solar irradiance (kWh/m^2) on vertical surfaces

Energy vs. Irradiance

Location	South		West		North		East	
City	Energy ($\frac{\text{kWh}}{\text{m}^2}$)	Average Vertical Surface Irradiance ($\frac{kWh}{m^2}$)	Energy ($\frac{\text{kWh}}{\text{m}^2}$)	Average Vertical Surface Irradiance ($\frac{kWh}{m^2}$)	Energy ($\frac{\text{kWh}}{\text{m}^2}$)	Average Vertical Surface Irradiance ($\frac{kWh}{m^2}$)	Energy ($\frac{\text{kWh}}{\text{m}^2}$)	Average Vertical Surface Irradiance ($\frac{kWh}{m^2}$)
Denver, CO	2%	37%	-7%	10%	-5%	-56%	-4%	10%
Albuquerque, NM	7%	36%	-7%	9%	-5%	-54%	-7%	9%
Atlanta, GA	5%	32%	-4%	6%	0	-43%	-1%	6%
Miami, FL	1%	30%	0	4%	13%	-39%	1%	4%

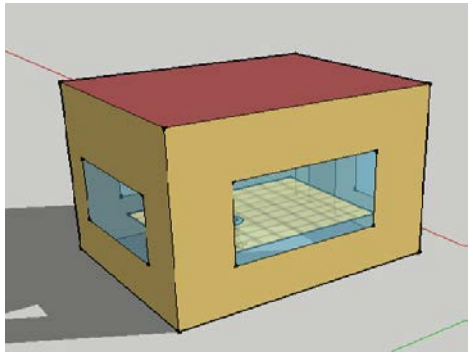
Observations & Recommendations

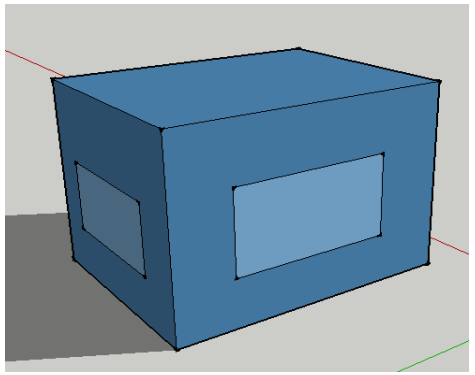
- Annual energy consumption of buildings could vary up to 14% depending on placement of Energy STAR windows.
- Annual cost impact can vary from $15 (Southern) to $132 (South-Central) annually.
- Placement of ENERGY STAR windows on the south façade improves performance in all climate zones.
- Placement of ENERGY STAR windows on all other orientations worsens building energy performance on all other orientation except in the Southern climate.

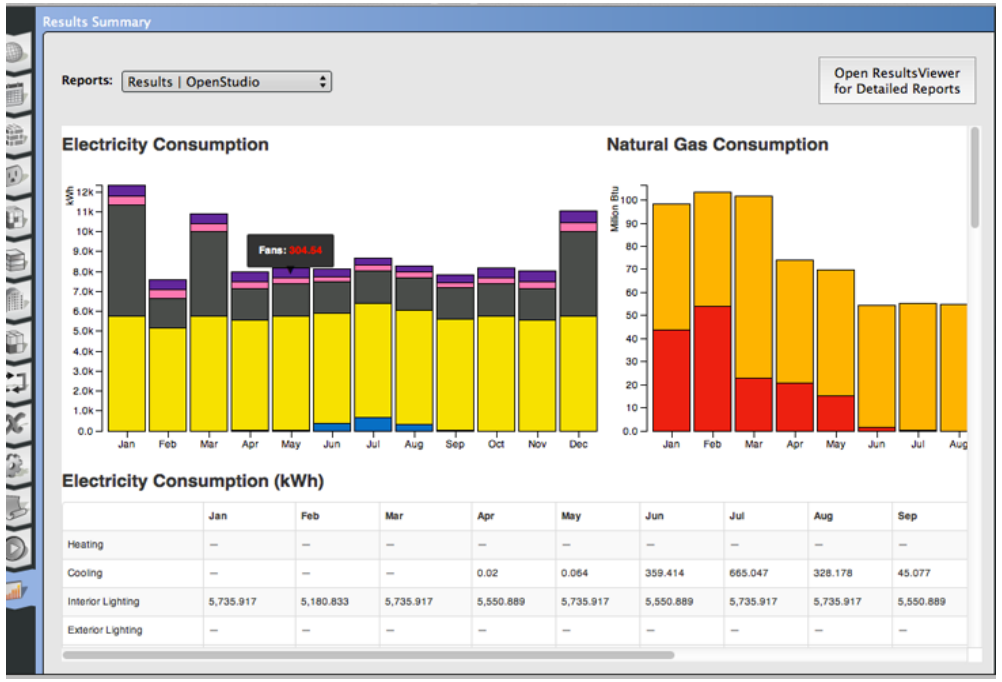
OpenStudio

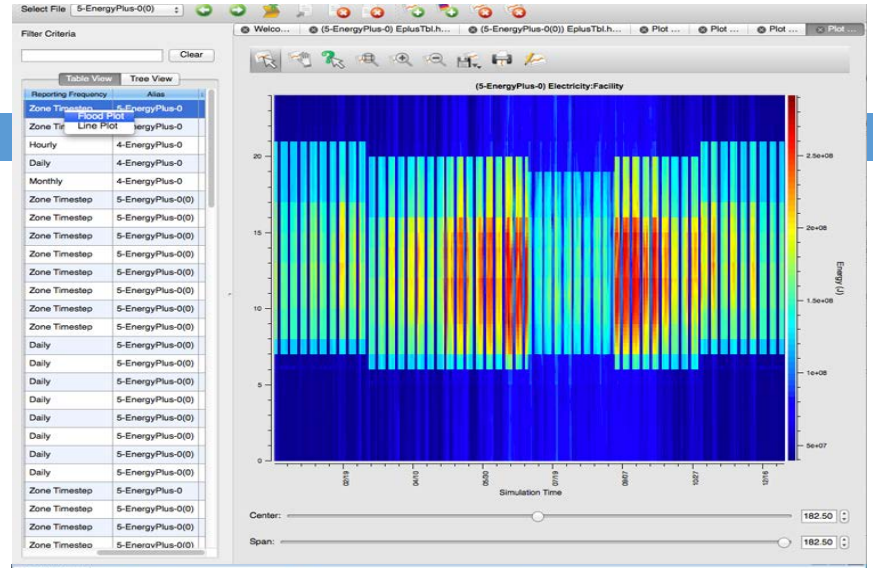
- OpenStudio is a cross platform collection of software tools developed by National Renewable Energy Laboratory (NREL).
- It is a whole building energy modeling software using EnergyPlus and advanced daylight analysis using Radiance.
- The software handles the building geometry, building envelope, plug loads, people and daylighting, along with many other inputs.

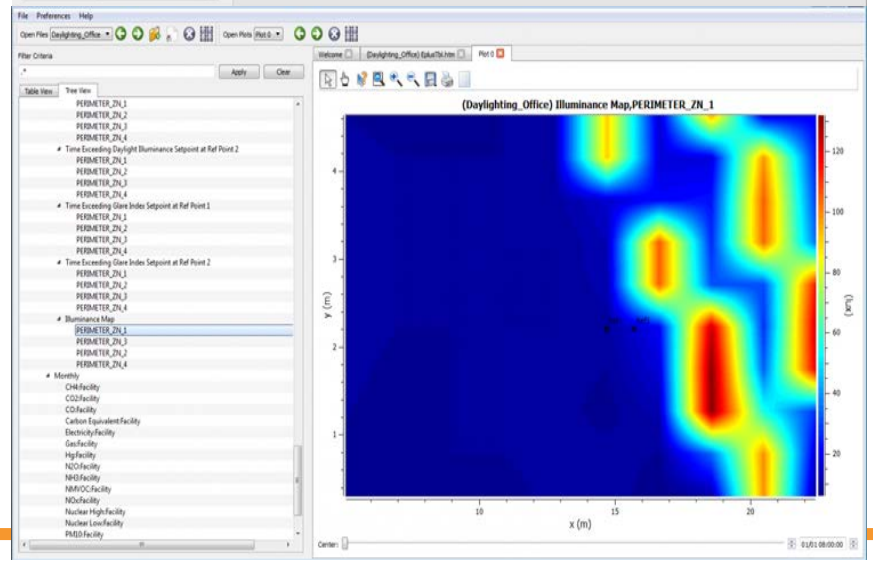
Optimization Studies











Conclusions and Policy Implications

- The cost effectiveness of the ENERGY STAR Tax Credit program for windows will vary based on the performance characteristics of products, and orientation of installation.
- The energy usage performance varies up to 14%, although accurate estimates require detailed, custom energy modeling.
- Complex energy modeling is required to assess the impact of window orientation

References

- ASHRAE. (2010). Energy standard for buildings except low-rise residential buildings 90.1 Building Envelope.
- BEDB. (2012). 2011 Building Energy Data Book Building Technologies Program, Energy Efficiency and Renewable Energy, US Department of Energy: D&R International. Ltd.
- Clevenger, C. M., Haymaker, J. R., & Jalili, M. (2014). Demonstrating the impact of the occupant on building performance. Journal of Computing in Civil Engineering, 28(1), 99-102.
- DOE. (2014b). 179D DOE Tax Calculator Retrieved April 4th, 2014
- EERE. (2014a). Windows and building envelope research and development: Roadmap for emerging technologies Windows and Building Envelope Research and Development Emerging Technologies Program: Building Technologies Office, Office of Energy Efficiency and Renewable Energy, US Department of Energy.
- EERE. (2014b). Summary of 179D Tax Deductions Retrieved April 4th, 2014
- EnergyStar. (2013). Is there tax credit for windows, doors and skylights? Retrieved April 7th, 2014
- EnergyStar. (2014a). Federal tax credits for consumer energy efficiency Retrieved April 4th, 2014,
- EnergyStar. (2014b). About Energy Star Retrieved May 2nd, 2014
- EnergyStar. (2014c). What makes it ENERGY STAR? Retrieved April 7th, 2014
- EnergyStar. (2014d). Climate Zone Map Retrieved April 7th, 2014
- Eskin, N., & Türkmen, H. (2008). Analysis of annual heating and cooling energy requirements for office buildins in different climates in Turkey. Energy and Buildings, 40(5), 763-773.
- Gasparella, A., Pernigotto, G., Cappelletti, F., Romagnoni, P., & Baggio, P. (2011). Analysis and modelling of window and glazing systems energy performance for a well insulated residential building. Energy and Buildings, 43(4), 1030-1037.
- Greenstream. (2014). Solar Irradiance Handbook 2014 Edition Retrieved April 7th, 2014
- Hassouneh, K., Alshboul, A., & Al-Salaymeh, A. (2010). Influence of windows on the energy balance of apartment buildings in Amman. Energy Conversion and Management, 51(8), 1583-1591.
- Johnson, R., Selkowitz, S., & Sullivan, R. (1984, March 19-21). How fenestration can significantly affect energy use in commercial buildings. Paper presented at the Proceedings of the 11th Energy Technology Conference, Washington, DC.
- Morrissey, J., Moore, T., & Horne, R. E. (2011). Affordable passive solar design in a temperate climate: An experiment in residential building orientation. Renewable Energy, 36(2), 568-577.
- NREL. (2014). Solar Radiation Data Manual for Buildings Retrieved April 30th, 2014
- Persson, M. L., Roos, A., & Wall, M. (2006). Influence of window size on the energy balance of low energy houses. Energy and Buildings, 38(3), 181-188.
- Poirazis, H., Blomsterberg, Å., & Wall, M. (2008). Energy simulations for glazed office buildings in Sweden. Energy and Buildings, 40(7), 1161-1170.
- Saeli, M., Piccirillo, C., Parkin, I. P., Binions, R., & Ridley, I. (2010). Energy modelling studies of thermochromic glazing. Energy and Buildings, 42(10), 1666-1673.
- Tahmasebi, M., Banihashemi, S., & Shakourihassanabadi, M. (2011). Assessment of the variation impacts of window on energy consumption and carbon footprint. Procedia Engineering, 2011 International Conference on Green Buildings and Sustainable Cities, 21(2011), 820-828. doi: 10.1016/j.proeng.2011.11.2083
- TRNSYS. (2013). A TRaNsient SYstems Simulation Program Retrieved May 7th, 2014
- Wall, M. (2006). Energy-efficient terrace houses in Sweden: Simulations and measurements. Energy and Buildings, 38(6), 627-634.

Thank You

.