


Single-pane window efficiency

Eric Schiff, Program Director

ARPA-E Workshop
Philadelphia, PA
November 6-7, 2014



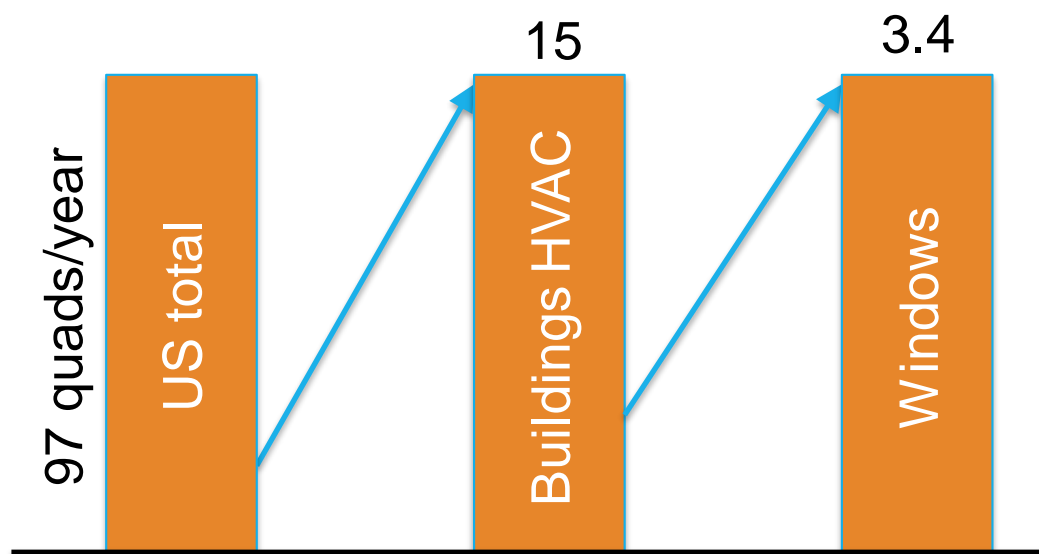
The US has a great many windows ...

- 43×10^9 square feet ($4 \times 10^9 \text{ m}^2$) in the US
- 140 square feet (13 m^2) per person



... with substantial energy costs in quads and cash

- Heat flow through windows (mainly winter):
 - 3.4 quads/year (primary “thermal load”)
 - \$34 billion/year (@\$10 /MBtu)

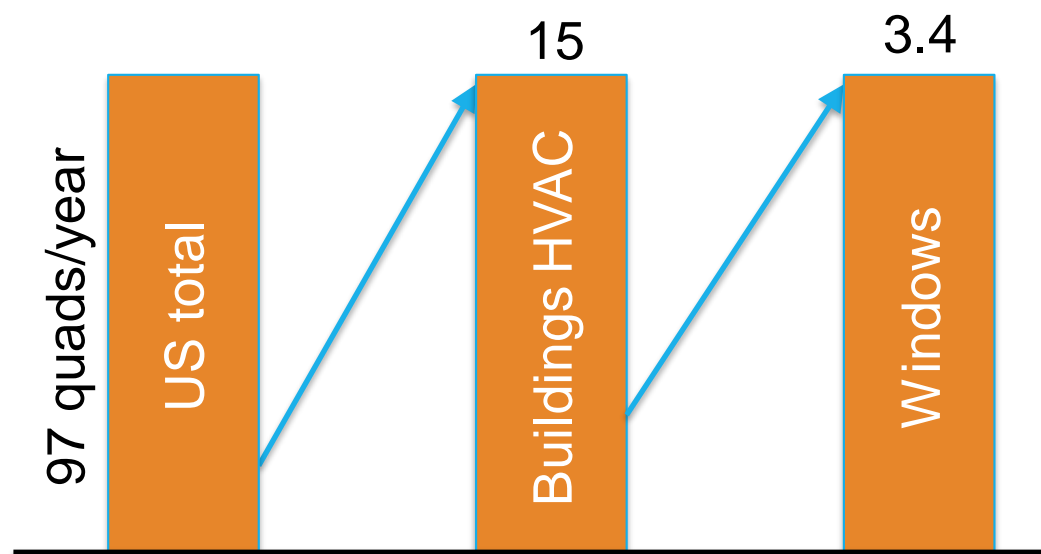


Solar heat gain is not included in this figure.
BTO workshop report (2014) Table 2. Edited by K. Sawyer.

1 quad $\equiv 10^{15}$ Btu = 1.06×10^{18} J

... with substantial energy costs in quads and cash

- 3.4 quads is certainly significant
- Costs are very diffused: \$100 /person/year
- Is there a sweet spot to improve windows & reduce usage?



A windows glossary

single pane

$U \approx 0.7 - 1.1$ Btu/sf/hr/F

33% (res) 40% (com)

often has a storm window, screen or combination



double pane

0.3 - 0.7

66% (res) 59% (com)



space between glass may be gas-filled; glass may be low-E type



triple pane

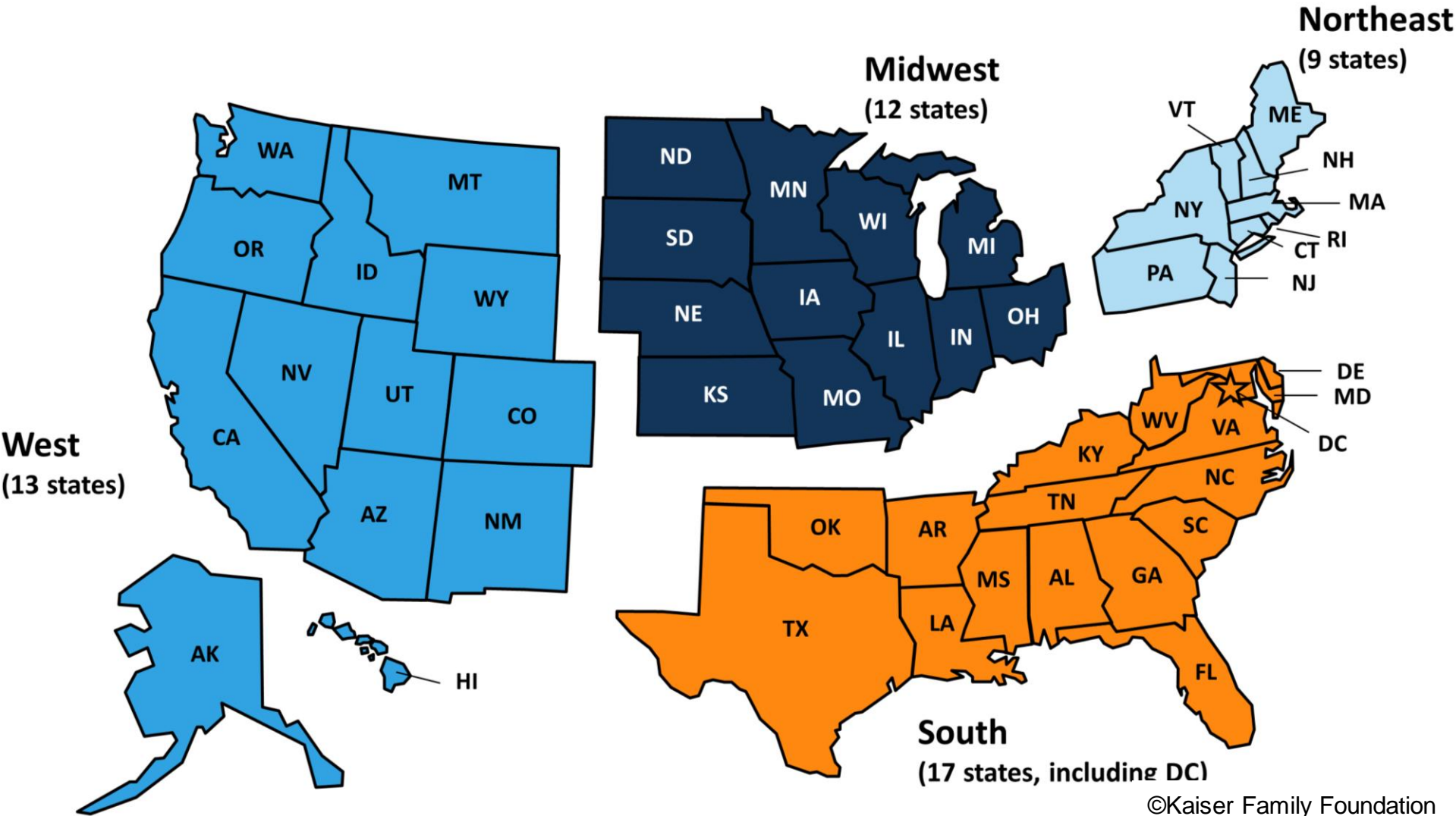
0.2 - 0.3

small

©Hearst Connecticut Media Group

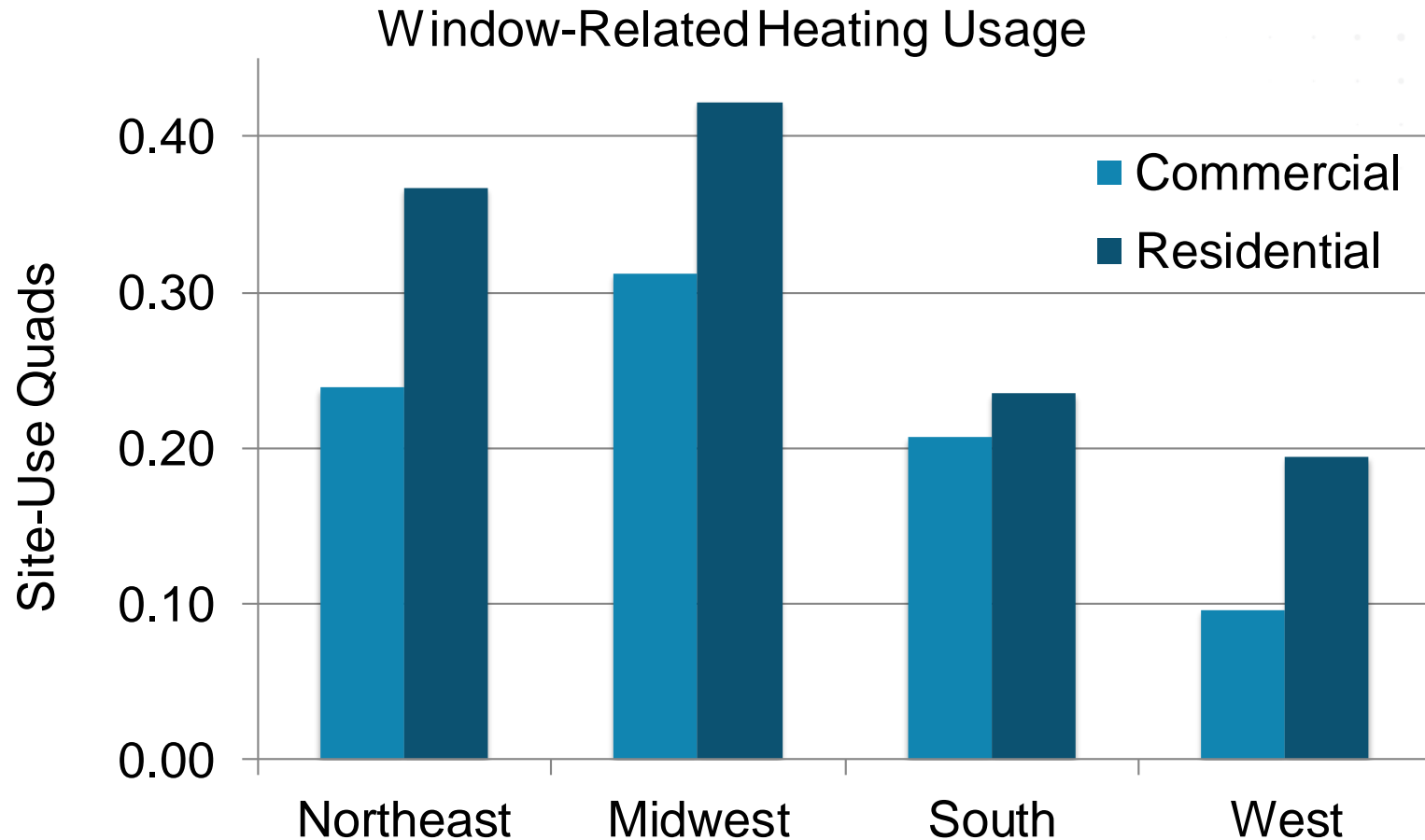
units: $1 \text{ Btu/sf/hr/F} \cong 5.7 \text{ W/m}^2/\text{C}$

Census regions of the United States



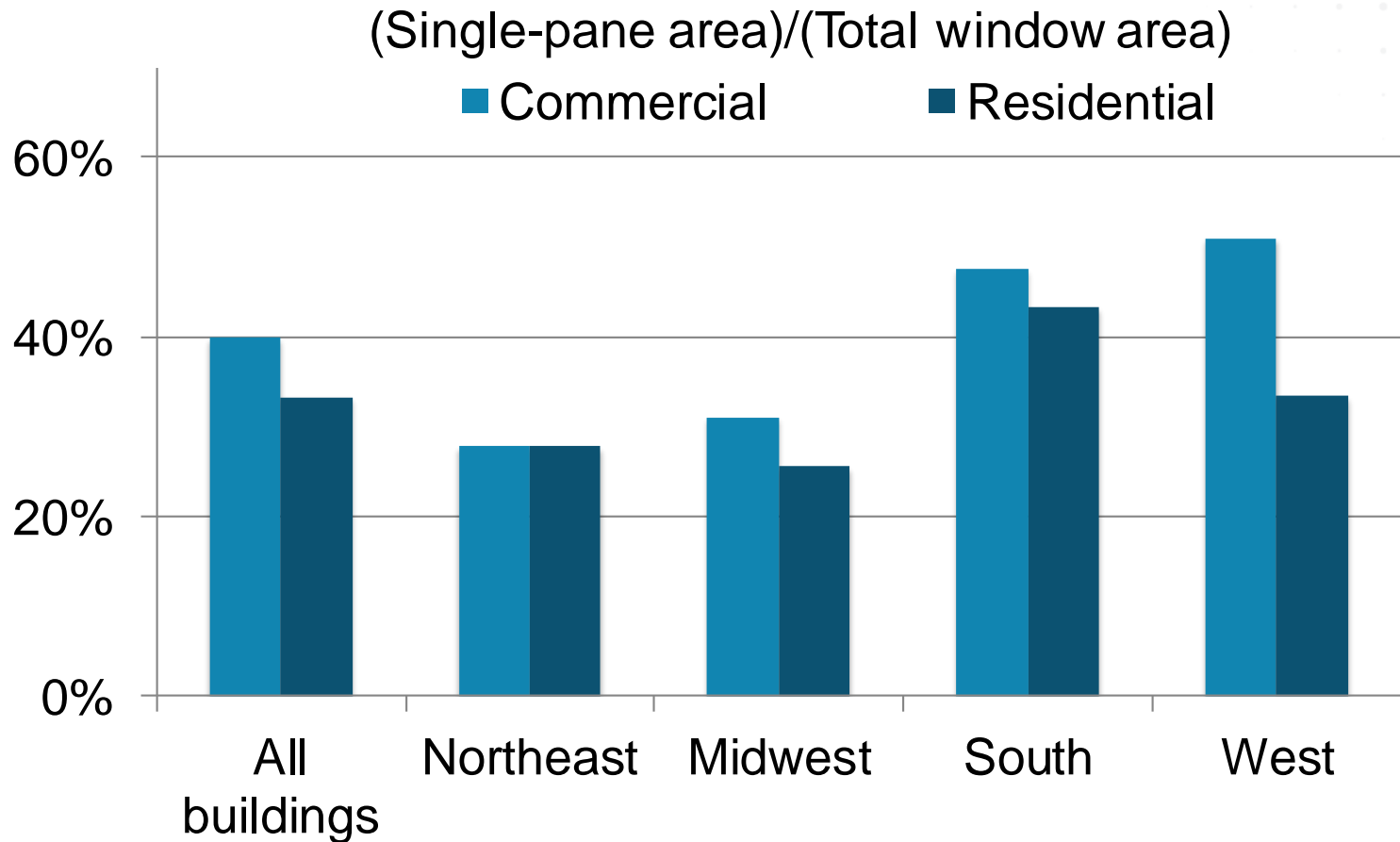
©Kaiser Family Foundation

Site use of energy by windows



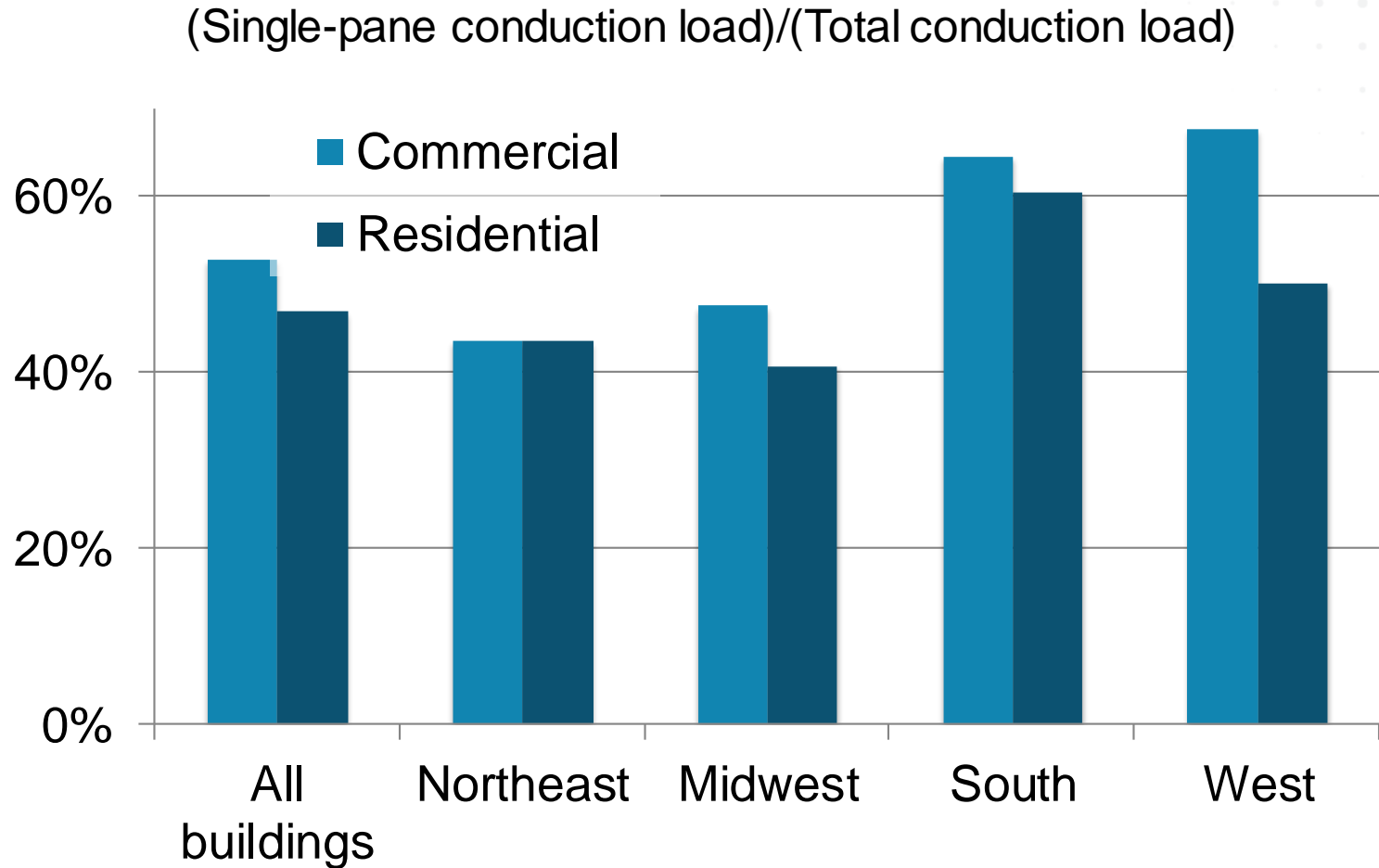
Dan Matuszak, unpublished [1].

Area fraction of single pane windows



Dan Matuszak, unpublished [2].

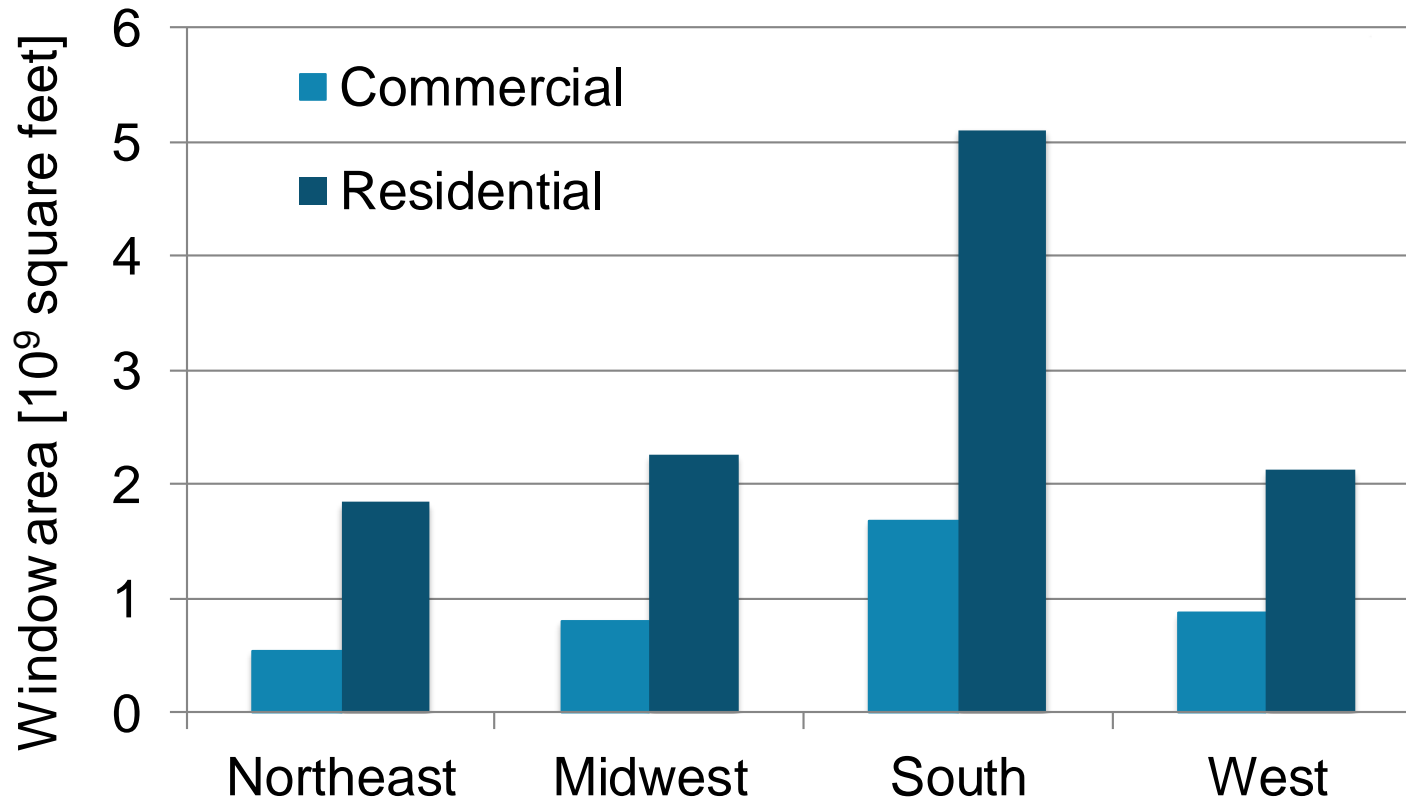
Thermal load fraction of single pane windows



Dan Matuszak, unpublished [3]

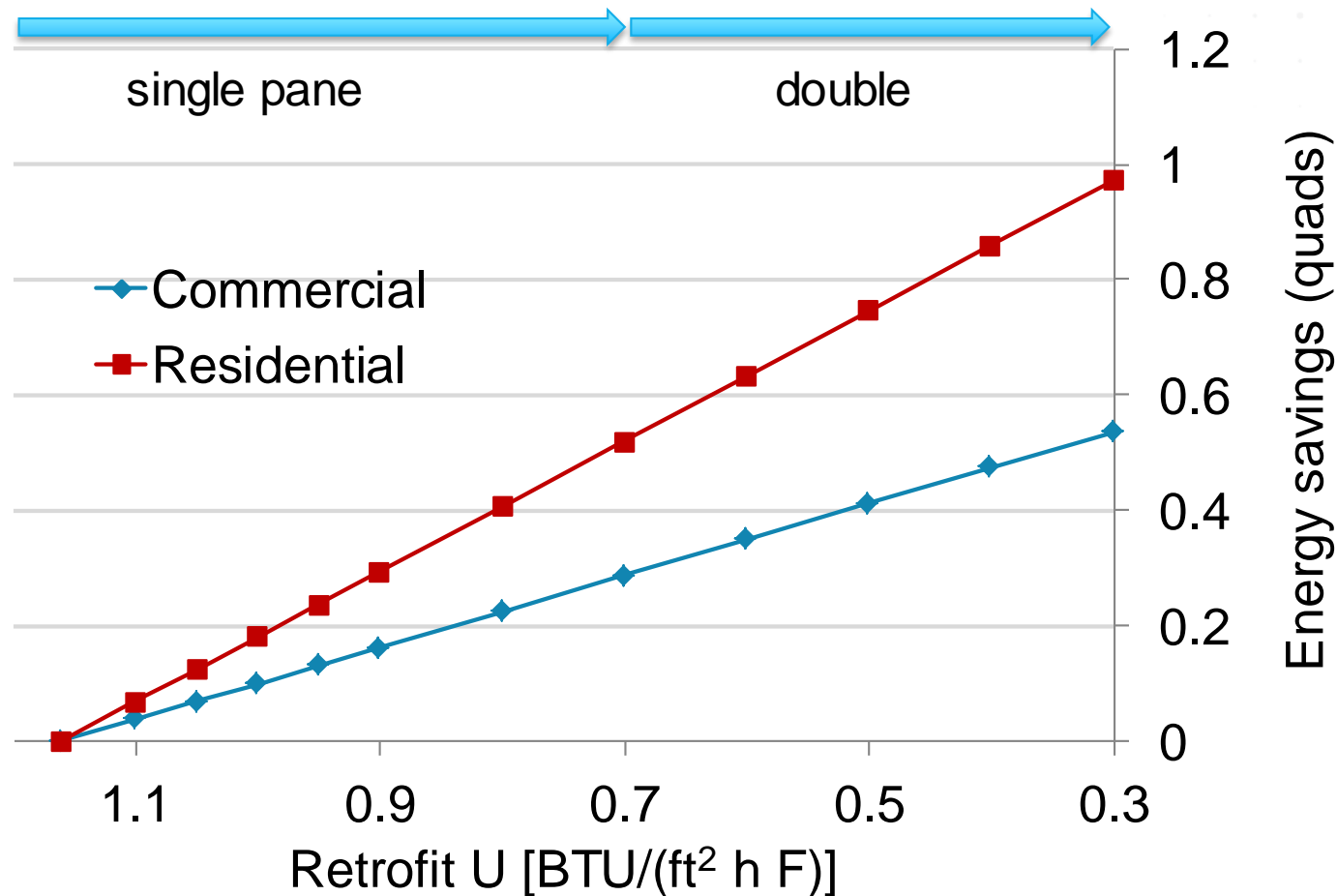
Single panes: billions and billions of square feet

Single-pane window stock by region



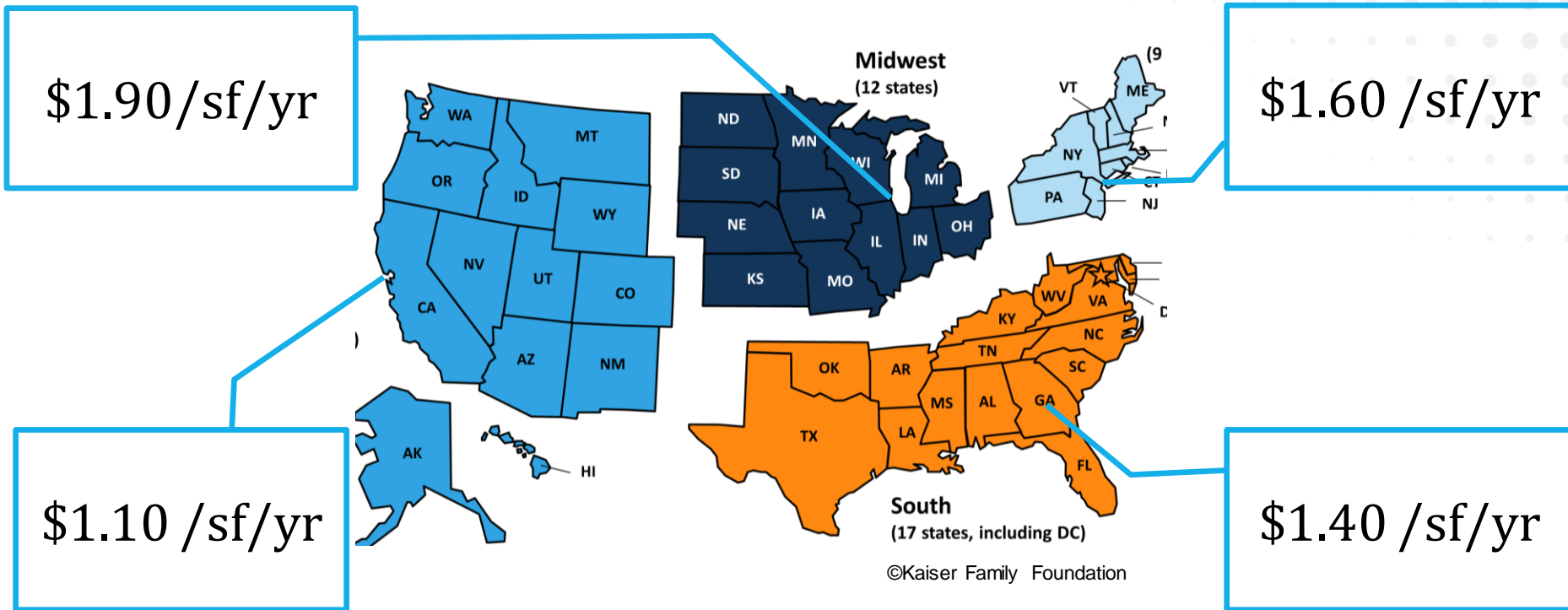
Dan Matuszak, unpublished [4]

Primary energy savings from single pane retrofitting



Dan Matuszak, unpublished [5], [6]

Heating cost savings from single pane retrofits



Improve single pane $U = 1.15 \rightarrow 0.30$ Btu/sf/hr/F
Change in \$ using 2014 local NG prices & degree days (20 C interior)
Note: exterior low-e storm window @ retail: ~\$8/sf (+installation)

Present technologies for single-pane retrofits

- Full replacement with modern, insulated glazing units
 - Low-e, double/triple pane, argon/krypton fill
- Add exterior storm windows (low-e)
- Add interior panels (low-e pane)
- Affix window films (solar control &/or low-e)
- Replace panes with low-e panes
- Shrink-film & tape window insulation kits
- ...others

All have limitations.

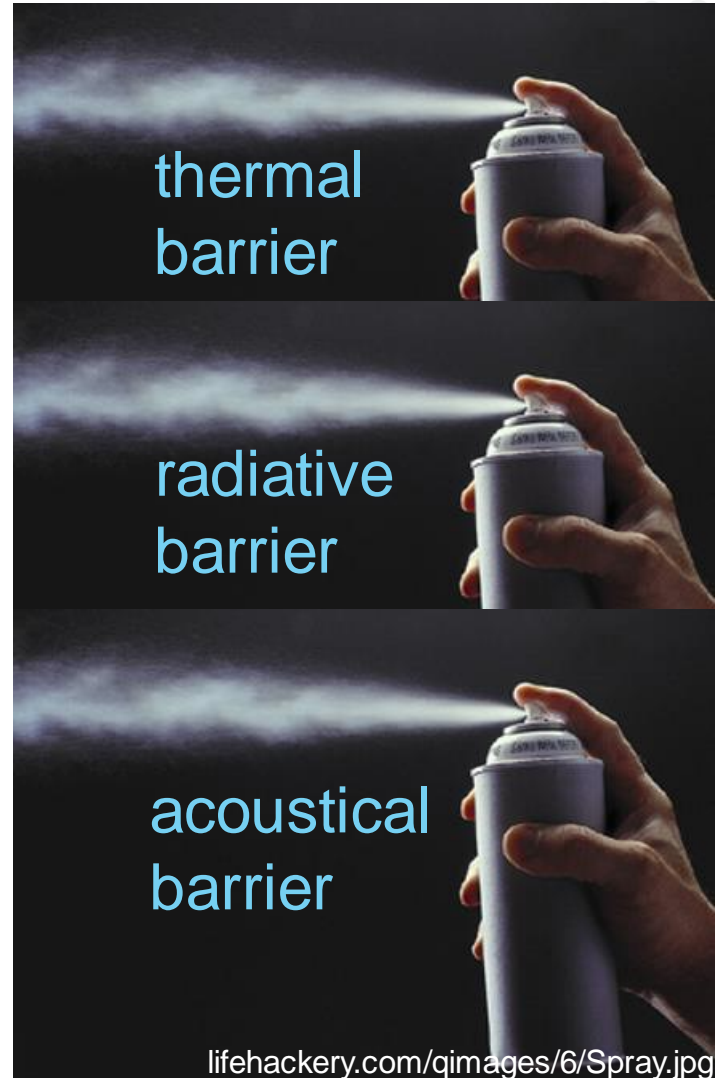
Single pane fraction >35% after decades of retrofits



The single pane window: a canvas for creativity



thumbs.dreamstime.com/x/hair-spray-8717489.jpg



lifehackery.com/qimages/6/Spray.jpg

Research goals for single pane window retrofitting

Reduce payback times

- Increase efficiencies of retrofitted windows
- Reduce installed price of retrofits
- Increase attractiveness of a capital investment

Add value beyond energy performance

- Condensation resistance & humidity control
- Noise dampening
- Clarity or other optical properties
- Comfort & security
- Service lifetime
- Form factor (thinness, ease of installation)
- Dynamic elements (cf. electrochromic or thermochromic)

ARPA-E program criteria

Challenge what's possible

- EnergyStar U-values with only a thin coating on the single pane?
- Higher clarity and transparency for low-e surfaces?
- 20-year service lifetime for applied films?
- Inexpensive dynamic performance for panels and films?

Credible path to market

- 1 billion sf/year (retrofit most single panes in 10 years)
- \$10/sf installed (at scale)

The workshop: ARPA-E needs your help

- Are there research paths that, if successful, would significantly affect the industry?
 - Can there be a substantial (>1%) impact on US energy?
 - What are the price points to get a new technology adopted?
 - What are the other criteria to get energy-efficient technologies adopted?
- Is an ARPA-E *focused research program* the right choice?
 - ARPA-E programs can be as large as \$30 M over 3 years
 - We don't renew programs. We expect successful projects to find new support after 3 years.
 - We don't compete with other funders.
 - We're seeking breakthrough technologies.
 - We tolerate high risk. We manage projects actively.

Workshop organization

- Informational talks & panel discussion
 - Engineering and science of windows (Selkowitz, Wright)
 - Getting window retrofits adopted (Krug, Rose, Sawyer, Tegan)
- 3 Breakout sessions – 3 groups for each. Assignment sheets.
 1. Identify what's needed to get retrofit technologies adopted. Payback period? Perceived risks? Value-added opportunities?
 2. Identify research areas with breakthrough possibilities that could move ahead with ARPA-E support.
 3. Develop technology-agnostic metrics for selecting and managing a program for energy efficiency and commercial success.

Endnotes

- [1] Residential (Commercial) data are based on end-use consumption information within EIA RECS 2009 (CBECS 2003) and the building ensembles constructed by J. Apte and D. Arasteh in “Window-Related Energy Consumption in the US Residential and Commercial Building Stock”, LBNL-60146.
- [2] Approximates the single-pane fraction of the national window stock as the single-pane fraction of the national floorspace. Floorspace information was obtained from RECS 2009 and CBECS 2003.
- [3] The fractional energy usage associated with window conduction is approximated as $f_s * U_s / (f_s * U_s + (1 - f_s) * U_m) = f_s / [f_s + (1 - f_s) * (U_m / U_s)]$, where f_s is the fraction of single pane area to total window area in a region, U_s is the average U-value for single pane window, and U_m is the average U-value for multi-pane windows. The approximation $U_m / U_s = 0.5$ was used. Fractional areas from [2].
- [4] Assumes an aggregate window area to floorspace ratio of 15%. Floorspace information obtained from EIA RECS 2009 and CBECS 2003.
- [5] The U-factor was changed at a constant solar heat gain coefficient, using the methodology described in J. Apte and D. Arasteh in “Window-Related Energy Consumption in the US Residential and Commercial Building Stock”, LBNL-60146. The regional residential window stock was segmented according to BEDB 2011 Table 5.2.6.
- [6] Specific questions may be directed to daniel.matuszak@hq.doe.gov