Selecting Replacement Window Types for Residential Facilities in Various Climates

James P. Miller

US Army ERDC/CERL

(217) 373-4566

James.P.Miller@usace.army.mil

Windows in residential facilities waste BIG ENERGY

- Windows conforming to earlier energy standards (e.g. ASHRAE Std 90-1989) less efficient than current technologies
  - Higher U-values, higher solar gain, higher air leakage, etc.
  - Lack of maintenance, wear and tear, further decrease performance

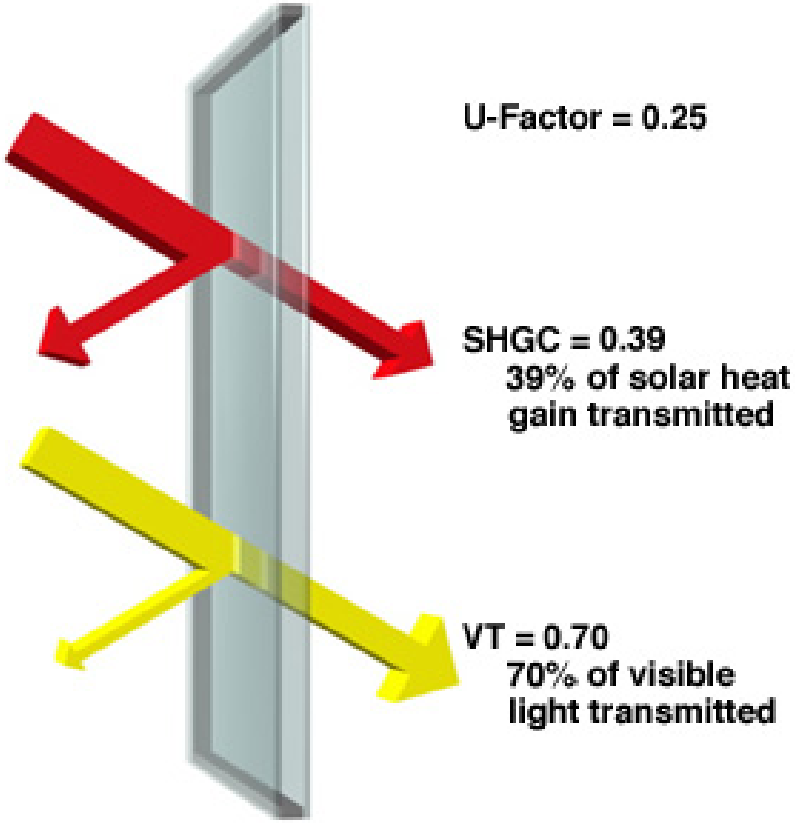
Potential benefits of replacing inefficient windows

- Improved visual and thermal comfort
- Reduced energy costs
- Reduced potential of mold/mildew formation

Challenge – selecting the right type of replacement window

- What's the best window choice for my location?
  - Cold climates – solar gain and ability to minimize heat losses
  - Hot climates – minimize solar gain with good visual characteristics
- "Conventional" vs "premium" replacement windows?
- First cost and payback?

Critical window performance parameters



U-Factor - a measure of the rate of non-solar heat loss or gain through a material or assembly W/m2 °C (Btu/hr-sq ft °F)

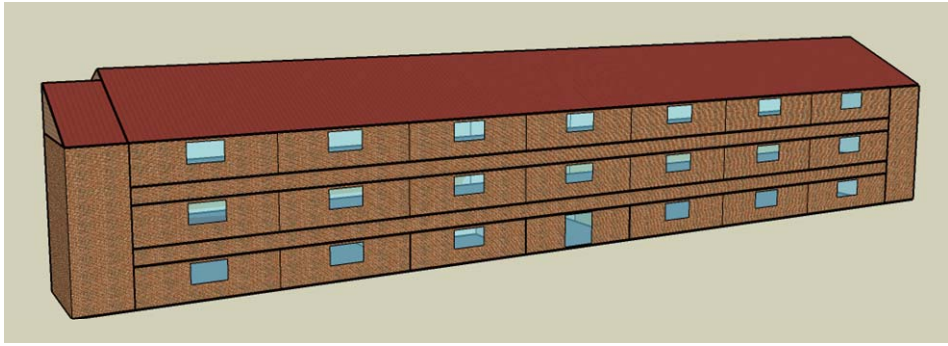
Solar Heat Gain Coefficient - The fraction of external solar radiation that is admitted through a window or skylight, both directly transmitted, and absorbed and subsequently released inward

Visible Transmittance - a measure of the ratio of visible light transmitted through a glazing fixture

Other important parameters

- Air tightness
- Framing materials

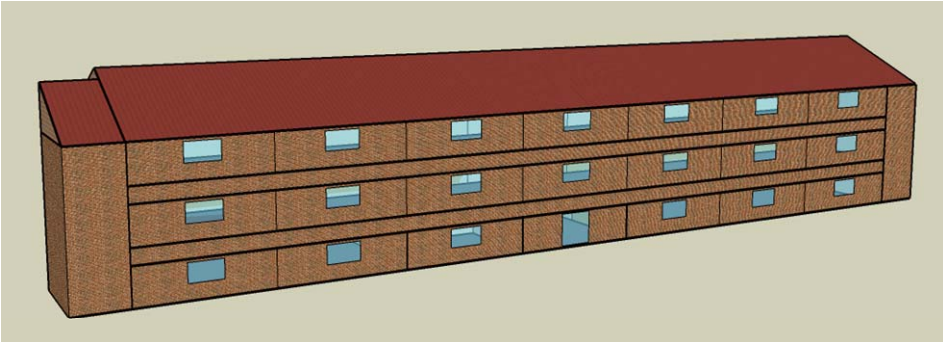
Window Replacement Study



Study conducted to identify best window replacement options

- Sponsored by IEA ECBCS Annex 46, conducted by NREL
- Modeled using EnergyPlus
- Baseline barracks facility model's envelope thermal criteria compliant with ASHRAE Std 90-1989
- Fifteen locations selected to represent fifteen US climate zones

Window Replacement Study



- Project considered replacement of existing ASHRAE Std 90-1989 windows with currently available “conventional” replacement windows and several “premium” replacement window options
- Flat utility rates assumed for each location
  - No energy demand charges
  - Based on Energy Information Administration (EIA) 2007 average data for commercial rates in each state.
- Interest rates and maintenance costs not considered

Performance parameters and installed costs of modeled window retrofits

Window Options with Default Performance Values								
Window #	Glazing Type	Frame Type	U-Factor (imp./metric)	SHGC	VT	Air Leakage (imp./metric)	Installed Cost*	Marginal Cost*
I	2-pane, tinted	Aluminum	0.76/4.3	0.56	0.51	0.2/0.06	$300	Baseline
II	2-pane, uncoated	Non-metal	0.49/2.8	0.56	0.59	0.2/0.06	$350	Baseline
A	2-pane, low-solar-gain, low-E	Aluminum, thermal break	0.47/2.7	0.33	0.55	0.2/0.06	$325	$25
B	2-pane, low-solar-gain, low-E	Non-metal	0.34/1.9	0.30	0.51	0.2/0.06	$375	$25
C	2-pane, low-solar-gain, low-E	Non-metal	0.36/2.0	0.49	0.54	0.2/0.06	$375	$25
D	3-pane, low-solar-gain, low-E	Non-metal	0.26/1.4	0.25	0.40	0.1/0.03	$450	$100
E	3-pane, high-solar-gain, low-E	Non-metal	0.27/1.5	0.38	0.47	0.1/0.03	$450	$100
F	3-pane, high-solar-gain, low-E	Non-metal, insulated	0.18/1.0	0.40	0.50	0.1/0.03	$500	$150

- Installed Cost and Marginal Cost based on a 1.1 m^2 (12 ft^2) window
- Marginal Cost compares installed cost of currently available premium efficiency window options with that of currently available “conventional” replacement window options (I & II) of equivalent frame material (e.g., aluminum or non-metal)

“Conventional” retrofit options

Zone	Climate	Representative U.S. City	Conventional Options		Zone	Climate	Representative U.S. City	Conventional Options
1A	Very hot – humid	Miami, FL	Window I		4C	Mixed – marine	Seattle, WA	Window II
2A	Hot – humid	Houston, TX	Window I		5A	Cool – humid	Chicago, IL	Window II
2B	Hot – dry	Phoenix, AZ	Window I		5B	Cool – dry	Boise, ID	Window II
3A	Warm – humid	Memphis, TN	Window I		6A	Cold – humid	Burlington, VT	Window II
3B	Warm – dry	El Paso, TX	Window II		6B	Cold – dry	Helena, MT	Window II
3C	Warm – marine	San Francisco, CA	Window II		7A	Very cold	Duluth, MN	Window II
4A	Mixed – humid	Baltimore, MD	Window II		8A	Subarctic	Fairbanks, AK	Window C
4B	Mixed – dry	Albuquerque, NM	Window II					

Site energy use intensities for modeled barracks facilities

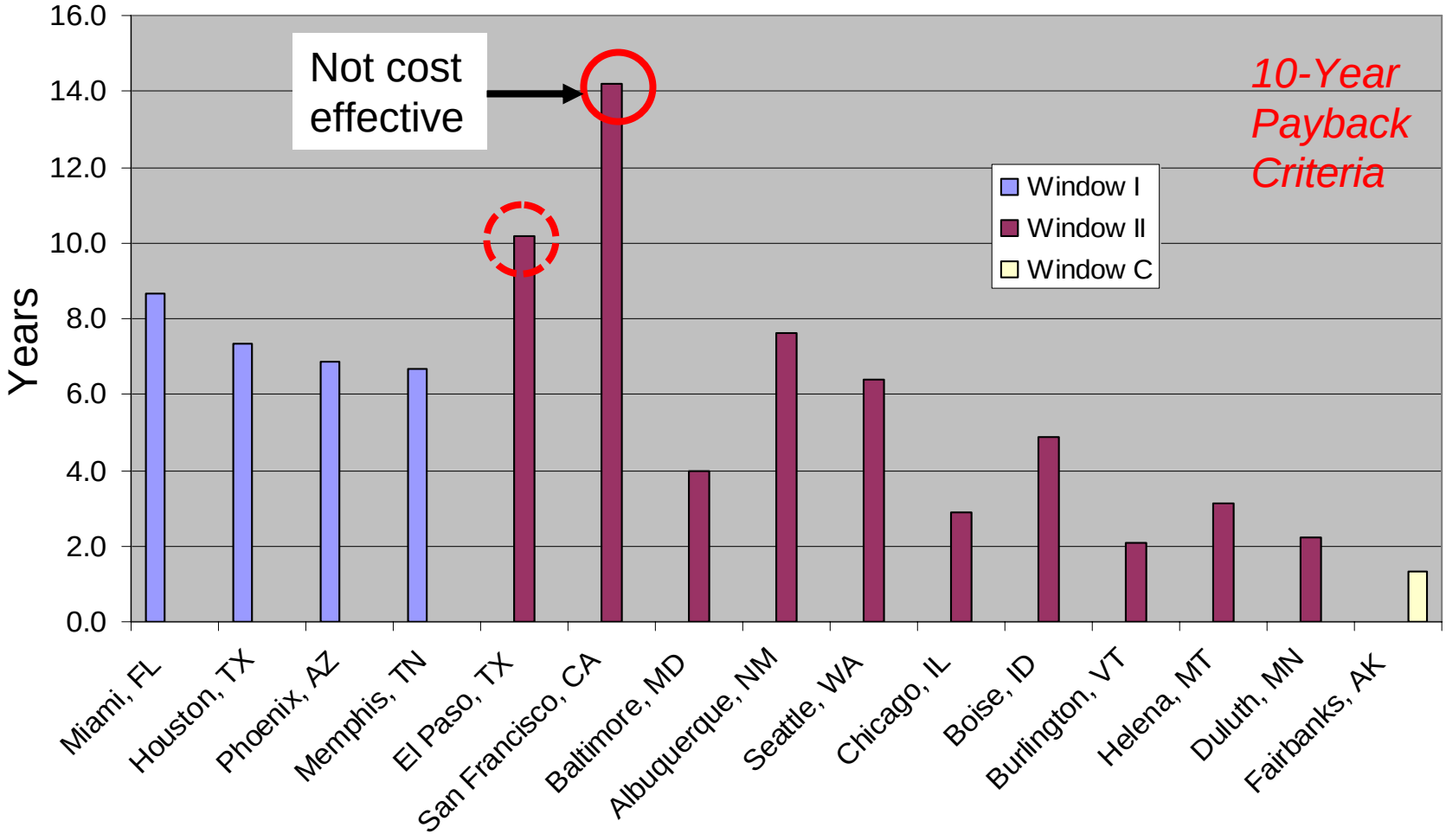
		Base	Window I		Window II		Window A		Window B	
Zone	City	kWh/m2/yr	kWh/m2/yr	Savings	kWh/m2/yr	Savings	kWh/m2/yr	Savings	kWh/m2/yr	Savings
1A	Miami, FL	346.6	341.5	1.47%	341.2	1.56%	339.7	1.99%	338.9	2.22%
2A	Houston, TX	345.2	335.2	2.90%	334.3	3.16%	333.5	3.39%	332.5	3.68%
2B	Phoenix, AZ	338.9	329.6	2.74%	328.7	3.01%	327.5	3.36%	326.1	3.78%
3A	Memphis, TN	367.1	354.6	3.41%	352.8	3.90%	352.9	3.87%	351.7	4.20%
3B	El Paso, TX	314.4	304.2	3.24%	302.8	3.69%	302.7	3.72%	301.9	3.98%
3C	San Francisco, CA	286.8	277.7	3.17%	276.3	3.66%	276.9	3.45%	276.1	3.73%
4A	Baltimore, MD	417	397.1	4.77%	394.4	5.42%	395	5.28%	393.6	5.61%
4B	Albuquerque, NM	362.6	349.2	3.70%	346.6	4.41%	347.6	4.14%	346.5	4.44%
4C	Seattle, WA	340.3	324.4	4.67%	322.3	5.29%	322.8	5.14%	321.3	5.58%
5A	Chicago, IL	501.8	472	5.94%	467.8	6.78%	468.7	6.60%	466.6	7.01%
5B	Boise, ID	425.5	403.5	5.17%	400.1	5.97%	401.2	5.71%	399.4	6.13%
6A	Burlington, VT	553.1	519.1	6.15%	514.3	7.02%	515.4	6.82%	513	7.25%
6B	Helena, MT	496.9	468.9	5.63%	464.1	6.60%	465.3	6.36%	462.9	6.84%
7A	Duluth, MN	666.6	621.8	6.72%	615.4	7.68%	617	7.44%	614	7.89%
8A	Fairbanks, AK	956.8	885.4	7.46%	876.3	8.41%	877.3	8.31%	873.1	8.75%

Site energy use intensities for modeled barracks facilities

		Base	Window C		Window D		Window E		Window F	
Zone	City	kWh/m2/yr	kWh/m2/yr	Savings	kWh/m2/yr	Savings	kWh/m2/yr	Savings	kWh/m2/yr	Savings
1A	Miami, FL	346.6	340.4	1.79%	338.7	2.28%	339.7	1.99%	340.5	1.76%
2A	Houston, TX	345.2	333.3	3.45%	332	3.82%	332.4	3.71%	332.5	3.68%
2B	Phoenix, AZ	338.9	327.3	3.42%	325.5	3.95%	326.1	3.78%	326.2	3.75%
3A	Memphis, TN	367.1	351.7	4.20%	350.9	4.41%	350.6	4.49%	349.7	4.74%
3B	El Paso, TX	314.4	302	3.94%	301.3	4.17%	301.2	4.20%	300.8	4.33%
3C	San Francisco, CA	286.8	275.5	3.94%	275.4	3.97%	274.7	4.22%	273.6	4.60%
4A	Baltimore, MD	417	392.9	5.78%	392.3	5.92%	391.5	6.12%	389.8	6.52%
4B	Albuquerque, NM	362.6	345.7	4.66%	345.6	4.69%	344.7	4.94%	343.1	5.38%
4C	Seattle, WA	340.3	320.9	5.70%	320	5.97%	319.3	6.17%	317.9	6.58%
5A	Chicago, IL	501.8	465.7	7.19%	464.9	7.35%	463.7	7.59%	461.4	8.05%
5B	Boise, ID	425.5	398.4	6.37%	397.9	6.49%	396.7	6.77%	394.4	7.31%
6A	Burlington, VT	553.1	512.1	7.41%	511.2	7.58%	509.8	7.83%	507.1	8.32%
6B	Helena, MT	496.9	461.9	7.04%	461.1	7.20%	459.7	7.49%	456.9	8.05%
7A	Duluth, MN	666.6	612.6	8.10%	611.8	8.22%	609.9	8.51%	606.3	9.05%
8A	Fairbanks, AK	956.8	872.3	8.83%	870.4	9.03%	868.6	9.22%	864.3	9.67%

Energy Conservation Project

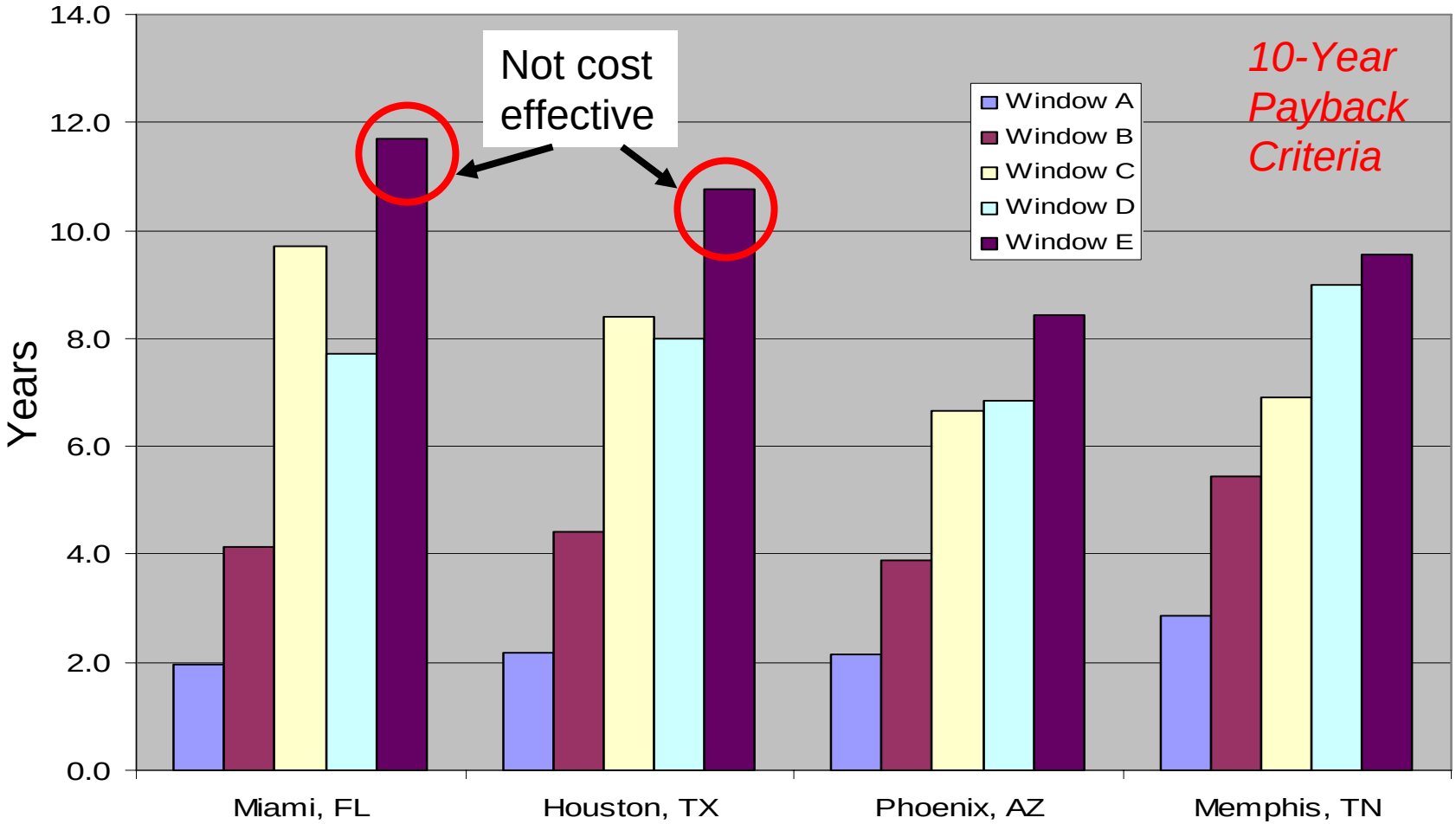
Modeled payback results – Replacing ASHRAE Std 90-1989 windows with current baseline quality replacement windows



Major Renovation or Repair Project

Modeled payback results - upgrading to premium quality replacement windows vs current baseline quality replacement windows

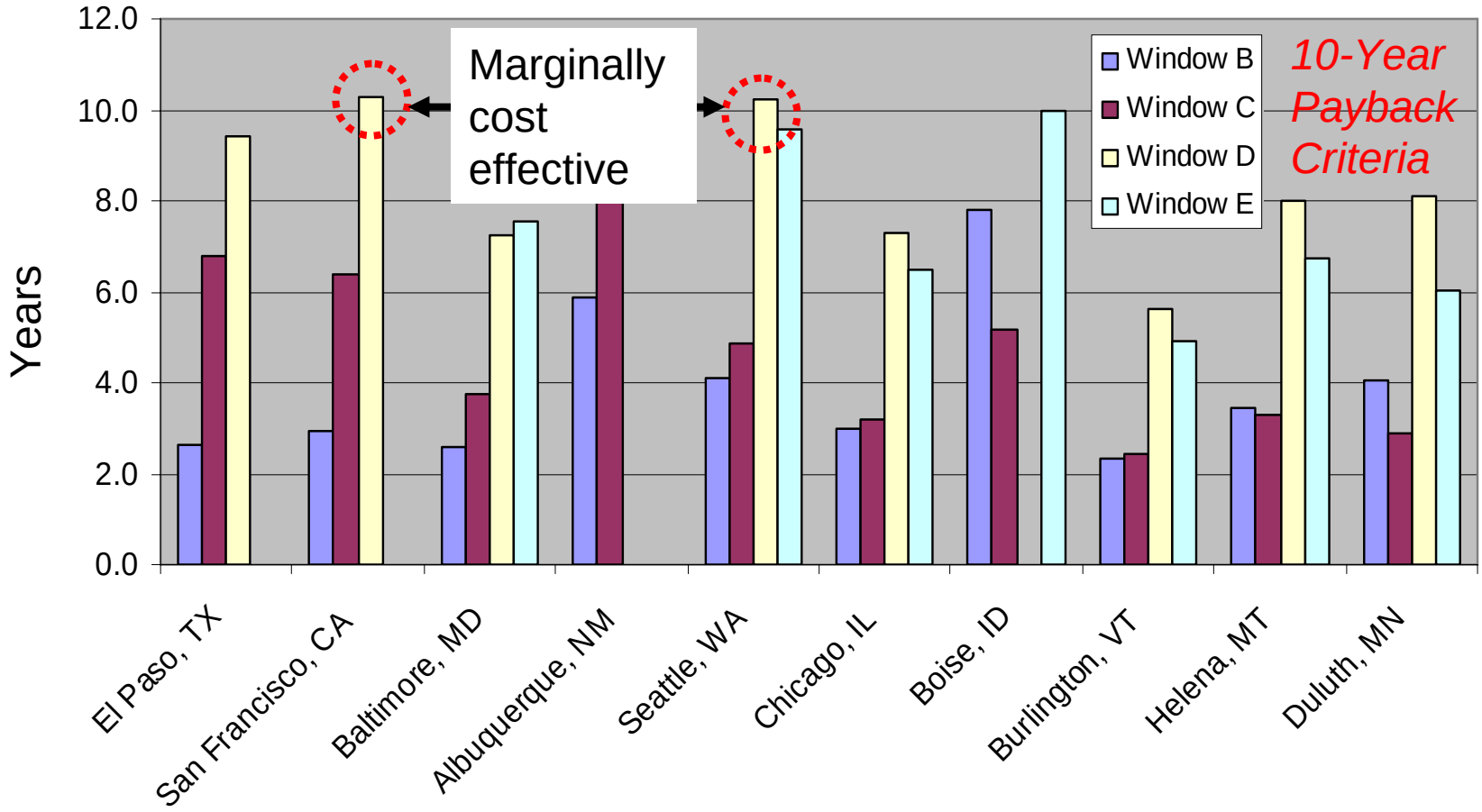
(Zones 1A, 2A, 2B, and 3A)



Major Renovation or Repair Project

Modeled payback results - upgrading to premium quality replacement windows vs current baseline quality replacement windows

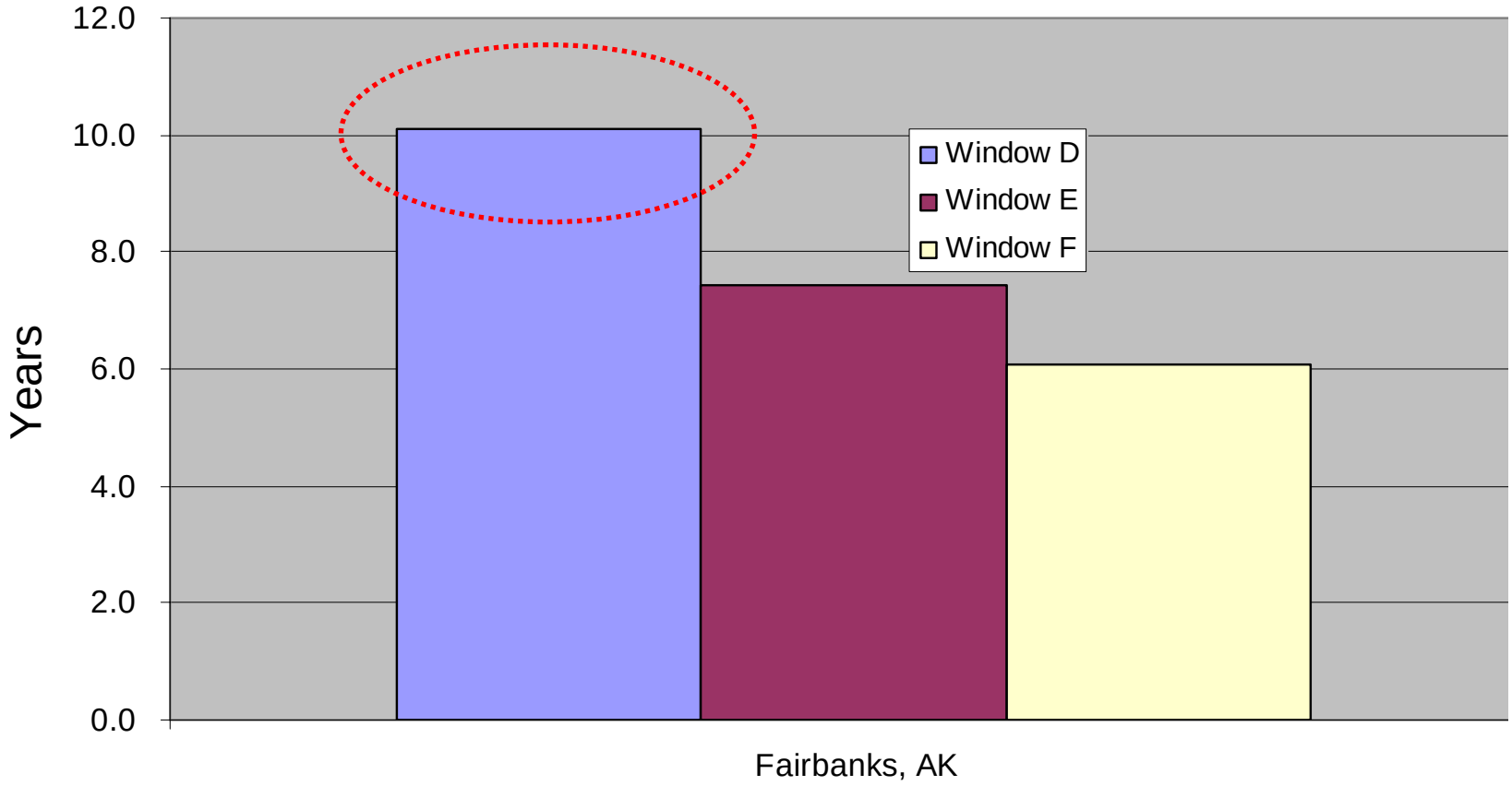
(Zones 3B, 4A, 4B, 4C, 5A, 5B, 6A, 6B and 7A)



Major Renovation or Repair Project

Modeled payback results - upgrading to premium quality replacement windows vs current baseline quality replacement windows

(Zone 8)



Recommended Premium Retrofit Window Options

Renovation/Repair Projects, 10-Year Payback Criteria

Zone	Climate	Representative U.S. City	Conventional Selections	Premium Options
1A	Very hot – humid	Miami, FL	Window I	A,B,C,D
2A	Hot – humid	Houston, TX	Window I	A,B,C,D
2B	Hot – dry	Phoenix, AZ	Window I	A,B,C,D
3A	Warm – humid	Memphis, TN	Window I	A,B,C,D,E
3B	Warm – dry	El Paso, TX	Window II	B,C,D
3C	Warm – marine	San Francisco, CA	Window II	B,C
4A	Mixed – humid	Baltimore, MD	Window II	B,C,D,E
4B	Mixed – dry	Albuquerque, NM	Window II	B,C
4C	Mixed – marine	Seattle, WA	Window II	B,C,E
5A	Cool – humid	Chicago, IL	Window II	B,C,D,E
5B	Cool – dry	Boise, ID	Window II	B,C,E
6A	Cold – humid	Burlington, VT	Window II	B,C,D,E
6B	Cold – dry	Helena, MT	Window II	B,C,D,E
7	Very cold	Duluth, MN	Window II	B,C,D,E
8	Subarctic	Fairbanks, AK	Window C	E,F

Conclusions

Energy Conservation Projects

- ASHRAE Std 90-1989 windows can be cost effectively replaced with current conventional replacement technologies in most climate zones
- Premium replacement windows *not cost effective* for energy conservation projects

Major Renovation/Repair Projects

- Considering “sunk costs” of installing conventional replacement windows, the small marginal cost to install premium replacement windows and resulting marginal energy savings makes premium replacement windows cost effective in all climate zones