Incremental Costs and Benefits of Window Replacement for Lead Hazard Control

This analysis estimates incremental costs, benefits and net benefits of replacing all original windows (i.e., single-pane windows not already replaced since the 1978 lead paint ban), relative to the costs and benefits of repairing some windows to satisfy HUD regulations related to friction and impact surfaces. The 1999 HUD regulation on lead paint hazard evaluation and control in federally-assisted housing requires that rehab work in pre-1978 units receiving more than $5,000 of federal assistance be done with lead safe work practices, plus stabilization of any deteriorated lead paint, friction and impact work as needed, cleanup and clearance tests for lead in dust. Friction and impact work often involves window work and/or window replacement.

Incremental Lifetime Earnings Benefits of Window Replacement vs. Window Work

Extensive research documents the societal benefit of lead paint hazard reduction based on the present value of increased average lifetime earnings associated with avoided preschool lead exposure. This benefit reflects the average loss of IQ due to lead exposure, and associated losses in education attainment and earnings. On average, the lifetime earnings value to every child who avoids a one ug/dL increase in preschool blood lead is $8,741 (in 2005 $).[1] The brain is especially vulnerable to elevated blood lead before the age of three, and the most common exposure pathway for young children is lead-contaminated dust ingested via normal hand to mouth activity when children crawl and play on floors. Therefore, the societal value of window replacement relative to window work can be estimated based on the difference in dust lead associated with window replacement versus window repair, and the impact of this difference on blood lead for young resident children. Table 1 presents available data on the difference in floor dust and sill dust lead over 12 years in units with window work versus window replacement.

Table 1: Adjusted Geometric Mean Dust Lead (µg/ft^2) by Window Replacement Group

Years Post-Intervention	*Floor, All Replacement*	*Floor, Non-Replacement*	*Sill, All Replacement*	*Sill, Non-Replacement*	*Floor Difference*	*Sill Difference*
0.5	9.9	16.9	65	134	7.0	69
1	7.9	13.5	52	107	5.6	55
2	11.0	18.8	46	93	7.8	47
3	7.9	13.5	34	70	5.6	36
4	6.1	10.4	36	74	4.3	38
5	4.3	7.3	38	78	3.0	40
6	2.5	4.3	40	82	1.8	42
7	2.4	4.1	38	78	1.7	40
8	2.2	3.8	36	75	1.6	39
9	2.1	3.6	35	71	1.5	36
10	2.0	3.4	33	68	1.4	35
11	1.8	3.1	31	64	1.3	33
12	1.7	2.9	29	61	1.2	32
Average	**4.8**	**8.1**	**39**	**81**	**3.3**	**42**

[1] Nevin et al., 2008, Monetary benefits of preventing childhood lead poisoning with lead-safe window replacement, *Environmental Research* 106, 410–419

The data in Table 1 reflect small sample sizes for some years and interpolation estimates for other years. Therefore, the 12-year average values (bottom row of Table 1) for sill and floor dust lead loadings are used to predict the average difference in dust lead exposure for young children in window replacement versus non-replacement units.

Table 2 presents predicted blood lead levels for children living in pre-1950 homes with specific floor and sill dust lead levels, based on the blood lead model developed from analysis of NHANES 1999-2004[2] data for pre-1950 homes. This NHANES analysis shows:

- The Geometric Mean (GM) dust lead levels were: floors 0.89 µg/ft^2 and sills 19.35 µg/ft^2
- The GM blood lead was 2.57 µg/dL
- Only 7.7% of floor loadings were above 4.8 µg/ft^2 and 5.4% were above 8.1 µg/ft^2
- 31% sill loadings were above 39 µg/ft^2 and 22% were above 81 µg/ft^2

Table 2: Predicted Blood Lead for Specific Floor and Sill Dust lead Values

Floor Dust (µg/ft^2)	Sill Dust (µg/ft^2)	Predicted Blood Lead (µg/dL)
0.89	19.35	2.4
0.89	39.00	2.5
0.89	81.00	4.2
4.80	19.35	3.6
4.80	***39.00***	***3.7***
8.10	19.35	4.0
8.10	***81.00***	***4.2***

Comparing the results in Tables 1 and 2 shows:

- Predicted blood lead is 3.7 µg/dL for young children in pre-1950 homes with window replacement, based on the 12-year average floor dust lead of 4.8 µg/ft^2 and sill dust lead of 39 µg/ft^2 for homes with all original windows replaced in Table 1.
- Predicted blood lead is 4.2 µg/dL with no windows replaced, based on the average floor dust lead of 8.1 µg/ft^2 and sill dust of 81 µg/ft^2 in Table 1 for non-replacement homes.
- Predicted blood lead is 0.5 µg/dL lower, on average, for children in homes with all original windows replaced relative to those in homes with non-replacement window work.

Table 3 calculates the incremental average lifetime earnings benefit of window replacement based on the value of every avoided one ug/dL increase in blood lead ($8,741), the predicted difference in blood lead with window replacement versus window work (0.5 ug/dL); the fraction of units with children ages 6 to 30 months, and the fraction with children ages 6 to 18 months. The calculations in Table 3 assume that lead hazard reduction with either window replacement or window work yields lifetime earnings benefits for resident children ages 6 to 30 months in the first year, and for new birth cohorts of children ages 6 to 18 months every year for another 11 years. This yields a 12-year present value of incremental lifetime earnings benefit of $1,671 for children in homes with original windows replaced relative to those in homes with window work.

[2] Dixon et al., 2009, Exposure of U.S. Children to Residential Dust Lead, 199-2004: II. The Contribution of Lead-Contaminated Dust to Children's Blood Lead Levels, *Environmental Health Perspectives* 117, 468–474

Table 3: Lifetime Earnings Benefit from Window Replacement vs. Window Repair

Value per avoided 1 ug/dL (A)	$8,741
Avoided ug/dL for Window Replacement vs. Repair (B)	0.50
Average benefit per resident child (C = A x B)	$4,370
Number of Children ages 6-30 months per unit (D)	0.07
Number of Children ages children ages 6-18 months per unit (E)	0.035
Year 1 Average Benefit per unit (C x D)	$306
Years 2-12 Average Benefits per unit (C x E)	$153
Present Value of Lifetime Earnings Benefits per unit over 12 years	$1,671

Incremental Costs and Market Benefits of Window Replacement

In units where all original windows are replaced for lead hazard reduction, the average cost per window replaced was $360. In non-replacement units with window friction and impact work for lead hazard reduction, the average window work cost (spread over all the windows in the unit) was $81. Based on these data, Table 4 shows the window replacement costs, avoided window repair costs, and net replacement costs (in 2005 $) associated with an intervention strategy that targets all single-pane (original) window for replacement in homes with 7, 10, or 16 windows.

Table 4: Window Replacement vs. Repair Costs

	800 ft^2 Attached 7 Windows	**1200 ft^2 Detached 10 Windows**	**2000 ft^2 Detached 16 Windows**
Window Replacement Costs	$2,520	$3,600	$5,760
Avoided Window Repair Costs Stabilization	$567	$810	$1,296
Net Window Replacement Cost	$1,953	$2,790	$4,464

Academic research shows that higher home market value is associated with new windows, due to an average increase in home value of $20 for every dollar per year in energy bill savings, plus an appearance value of about $100 per window.[3] A separate analysis of 93 different cities, estimates that replacing single-pane windows with Energy Star windows yields average energy bill savings of $304 per year in a 2000 square foot home, and replacing clear glass double-pane windows with Energy Star windows yields average savings of $141 per year.[4] By subtraction, this indicates that replacing single-pane windows with clear glass double-pane windows yields average savings of $163 per year in a 2000 square foot home. Table 5 shows these estimates for energy savings in a 2000 square foot home, and estimated energy savings in smaller homes (1200 and 800 square feet), assuming that the energy savings from window replacement is proportionate to square feet of living area.

[3] Nevin, R. and G. Watson (1998), Evidence of rational market valuations for home energy efficiency, *Appraisal Journal*; Nevin, R., H. Gazan, C. Bender (1999), More evidence of rational market values for home energy efficiency, *Appraisal Journal*

[4] **http://www.energystar.gov/ia/products/windows_doors/CitySavingsEstimates.pdf**

Table 5: Window Replacement Average Annual Energy Savings

	800 ft^2 Attached 7 Windows	1200 ft^2 Detached 10 Windows	2000 ft^2 Detached 16 Windows
Energy Star Window vs. Single-Pane	$122	$182	$304
Energy Star Window vs. Double-Pane	$56	$85	$141
Double Pane (Clear Glass) vs. Single-Pane	$65	$98	$163

Table 6 shows net costs for window replacement (from Table 4) and lifetime earnings benefits (from Table 3), relative to window work for lead hazard reduction, plus the market value benefit of clear glass double-pane windows versus single-pane windows. The market value includes an appearance value of $100 per window plus the value of energy efficiency equal to 20 times the annual energy savings from replacing single-pane windows with clear glass double-pane windows (from the last row of Table 5). Table 6 reflects the market benefit of clear glass double-pane versus single-pane windows because the average cost of $360 per window replaced reported for lead hazard reduction suggests that these interventions are using clear glass double-pane windows rather than more expensive Energy Star windows.

Table 6: Window Replacement vs. Window Work Costs, Benefits, and Net Benefits

	800 ft^2 Attached 7 Windows	1200 ft^2 Detached 10 Windows	1800 ft^2 Detached 16 Windows
Net Window Replacement Cost	($1,953)	($2,790)	($4,464)
Lifetime Earnings Benefits per unit	$1,671	$1,671	$1,671
Appearance Value	$700	$1,000	$1600
Energy Efficiency Value	$1,301	$1,951	$3,250
Net Economic Benefit	**$1,719**	**$1,832**	**$2,057**

The net economic benefit of replacing all single-pane windows with clear glass double-pane windows, versus window work for lead hazard reduction is $1,719 to $2,057, depending on home size and number of windows replaced. This net benefit reflects lifetime earnings benefits, plus appearance value, plus energy efficiency value, minus net window replacement costs.

Table 7 shows the additional energy savings that can be realized by replacing old windows with Energy Star windows (from Table 5, Energy Star Window vs. Double-Pane). Multiplying this additional annual savings by 20 yields increased energy efficient home value of $1,120 to $2,820, depending on the home size and number of windows. Dividing by the number of windows in each home shows that choosing Energy Star windows rather than clear glass double-pane windows yields additional net benefits if the incremental cost of the Energy Star windows is no more than $160 to $176 more than the clear glass double-pane cost per window. This means the upgrade to Energy Star windows is cost-effective unless the cost per Energy Star window is more than 44% to 49% higher than the $360 average cost per window replaced reported in units with all original windows replaced for lead hazard reduction.

Table 7: Additional Benefit of Energy Star Windows and Break-Even Incremental Cost per Energy Star Window

	800 ft^2 Attached 7 Windows	1200 ft^2 Detached 10 Windows	1800 ft^2 Detached 16 Windows
Additional Energy Savings	$56	$85	$141
Additional Energy Efficiency Market Value	$1,120	$1,700	$2,820
Break-Even Incremental Cost per Window	$160	$170	$176
Break-Even % Higher Price Per Window	44%	47%	49%

On average, the price premium for Energy Star windows is only about 15%,[5] so choosing Energy Star replacement windows over clear glass double-pane windows further increases the net benefits of window replacement.

[5] **http://www.energystar.gov/ia/partners/manuf_res/downloads/PartnerResourceGuide-LowRes.pdf**