# Window Attachments: The Next Big Energy-Savings Measure?

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## ABSTRACT

Windows in residential buildings are estimated to generate 29% of all HVAC heating and cooling load, approximately 2.67 quadrillion Btu (Apte and Arasteh 2006). Although more than a third of residential windows are single pane, very few utility programs offer incentives for installation of energy-efficient windows (Bickel et al. 2013). The reason is simple: unless someone is already planning to replace their windows, the payback can often take a decade, if not longer.

Preliminary data indicates that some energy-efficient window attachments, such as low-emissivity (low-e) storm windows and interior panels, cellular shades, interior and exterior roller shades and shutters, window films, solar screens, window quilts, and awnings, can deliver cost-effective energy savings. Additionally, the means to reliably identify and compare energy-efficient window attachment products will soon be available through the Attachment Energy Rating Council (AERC), a public interest energy performance rating and certification organization co-funded by the U.S. Department of Energy (DOE) and the window attachment industry.

This paper presents, for the first time, national and regional energy savings estimates for cellular shades and low-emissivity storm windows and panels using existing data on household energy savings potential. This paper is an early step in the process of determining the cost-effectiveness of window attachments for utility programs. The next step is for utilities to develop pilot programs to conduct field tests of these products, which will generate the energy savings data to determine if full-scale programs are cost-effective.

## Introduction

Preliminary research sponsored by the Department of Energy (DOE) and the National Trust for Historic Preservation (NTHP) suggests that energy-efficient window attachments, including low-e storm windows, interior panels, and cellular shades, offer a new source of significant cost-effective residential energy savings. If these savings are realized, program administrators (PAs) for energy efficiency programs will have a cost-effective solution to fix the "windows gap" they experience in their efforts to improve the thermal envelope of many homes. DOE and the window attachment industry are co-funding the development of the Attachments Energy Rating Council (AERC) to make these products readily identifiable and accessible to PAs through independent rating, labeling, and certification. Labeled and rated products are scheduled to be available by January 1, 2017.

The current research, sponsored by the AERC, quantifies this energy-savings potential by calculating the technical potential of this product category at the national and regional levels. These estimates are a first step in determining the cost-effectiveness of window attachments for utility incentive programs. Two additional pieces of information are necessary: field-verified household-level energy savings and the costs of capturing the associated energy savings under one or more program implementation models.

## What Are Window Attachments?

Energy-efficient window attachments include low-e storm windows and interior panels, cellular shades, interior and exterior roller shades and shutters, window films, solar screens, window quilts, and awnings. Figure 1 illustrates a few different types of window attachment products found in the market today.

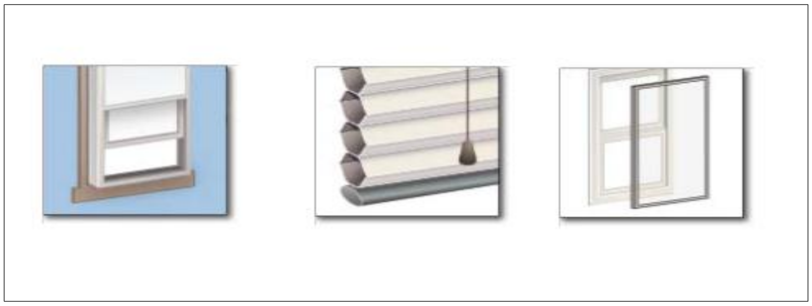

**Figure 1.** Examples of Window Attachments - Exterior Storm Window, Cellular Shade, and Interior Window Panel (Lawrence Berkeley National Laboratory)

## Why Should Program Administrators Care about Energy Efficient Window Attachments?

Some utility programs have included fenestration as a measure to improve the efficiency of the building envelope, but replacing windows is generally expensive and their long lifetimes mean replacements occur infrequently. The ENERGY STAR Windows, Doors, and Skylights program calculated mean and median payback for ENERGY STAR certified windows at 13 and 11 years, respectively, excluding installation costs (U.S. Environmental Protection Agency 2012). The high cost and long product lifetimes make it difficult for windows to pass utilities' cost-effectiveness tests and be included in energy-efficiency prescriptive program portfolios.

In contrast, the relatively low cost and shorter lifetimes of window attachments make them a viable measure for utilities seeking new efficiency measures to address energy loss through the building envelope. Average lifetime estimates for metal or vinyl horizontal blinds are slightly over four years, so consumers are more likely to replace them with energy-efficient window attachments than replace their entire home's windows before the end of the window's useful life (Bickel et al. 2013). Window attachments are also fairly easy for a consumer or professional to install, which keeps installation costs low.

Despite this, energy-efficient window attachments have received limited attention from the energy-efficiency community. Some utilities, like Austin Energy, have offered rebates on solar screens or window films. These rebates range from $0.60/square foot to $1.00/square foot, depending on the attachment's ability to block the sun's rays (Austin Energy 2015). However, these programs have not been widely adopted and have not been extended to all attachment types, due largely to the lack of a standardized way to measure, rate, and certify product performance. Utilities and PAs also need data on real-world energy savings and a proven, cost-effective program delivery model to implement energy efficiency programs.

## Do Energy Efficient Window Attachments Really Deliver Savings?

A growing body of evidence indicates that energy-efficient window attachments have significant energy-saving potential at the individual window and household levels. Laboratory measurements, building energy modeling, and field tests indicate that energy-efficient window attachments can deliver heating energy savings of 10-20% and cooling energy savings of 8-10%.

For example, Pacific Northwest National Laboratory (PNNL) measured energy savings in Oregon of 10.5% during the heating season, 8% during cooling season, and estimated annual energy savings of 10.1% or 2,216 kilowatt hours per year in two electrically heated and cooled lab homes with and without exterior low-e storm windows (Know et al. 2014). An LBNL in-situ field study in six Chicago homes measured a larger heating benefit, with low-e storm windows reducing heating load by 21%, more than double the improvement from clear glass storm windows (Drumheller et al. 2007). A PNNL field study of low-e storm windows on 10 homes in Atlanta calculated savings similar to those in the Oregon lab homes, with 10% heating savings and 8% cooling reduction (Cort 2013).

## How Can Programs Identify Truly Energy-Efficient Window Attachments?

Energy-efficient window attachments and their savings potential are mostly unknown in the energy efficiency community. Even if there were broader knowledge of the savings potential, widespread adoption of programs would not be possible because there are no certified energy performance ratings or labeling. The new Attachments Energy Rating Council (AERC) will soon eliminate this barrier.

Established by DOE and the window attachment industry in November 2014, AERC will issue ratings for low-e storm windows, cellular shades, slat shades, and roller shades in late 2016, and for additional product categories in the following years. The ratings will give PAs, homeowners, retailers, architects, contractors, designers, and others quantitative and qualitative energy performance ratings. Figure 2 below presents the timeline for the development of AERC and ratings for window attachment products.

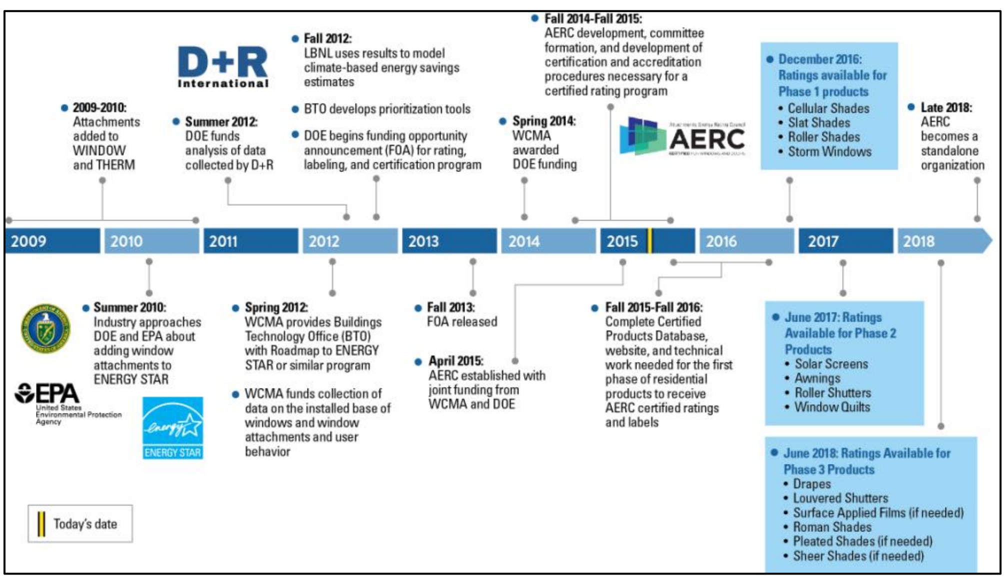


**Figure 2.** Timeline of AERC Development

### What Else Do Program Administrators Need to Know?

Energy performance ratings alone will not be sufficient to tell PAs whether window attachments truly offer the opportunity the preliminary data suggests. They also need data on energy savings demonstrated in the real world and proven cost-effective program delivery models.

## Method

To provide an initial estimate of the national energy-savings potential and energy savings of energy-efficient window attachments by climate zone, D+R focused on low-e storm windows/panels and cellular shades, two product categories for which AERC ratings will be available the soonest. The estimates build on two energy modeling studies conducted by LBNL and the National Trust for Historic Preservation (NTHP) that calculated energy savings at the city level but did not estimate savings at the national level or by climate.

### Baseline Assumptions of LBNL and NTHP Studies

LBNL's *Energy Savings from Window Attachments* provided a broad characterization of the energy performance and savings of a wide variety of window attachments under normal and energy-optimal use cases. LBNL calculated energy consumption estimates for a large number of windows, window attachments, and deployment position conditions in different types of residential buildings. Study outputs included household annual energy-savings estimates for combinations of base windows (single pane, double pane, etc.) and window attachment types (cellular shades, storm windows, etc.) for 13 U.S. cities (see Table 1).

The NTHP study, *Saving Windows, Saving Money: Evaluating the Energy Performance of Window Retrofit and Replacement*, evaluated the energy performance of non-destructive window energy upgrades compared to complete window replacements in residences with historical significance and included several of the same cities studied in the LBNL research.

**Table 1.** LBNL Modeled Cities by Climate Zone

| **Northern** | **Central** | **Southern** |
|---|---|---|
| Boston* | Atlanta* | New Orleans/Lake Charles |
| Chicago* | Fort Worth | Phoenix* |
| Denver | San Francisco | San Antonio |
| Minneapolis | Washington, DC | Tampa |
| Portland* | | |

* Denotes cities modeled by NTHP

D+R reviewed assumptions for each study to assess whether they were reasonable and comparable. While reasonable for their respective purposes, the two studies' assumptions were sufficiently divergent that they could not be combined (see Table 2). Noteworthy differences include the following:

- Home size–the home LBNL used was significantly larger than the NTHP home
- Heating and cooling–LBNL used central air conditioning while NTHP used window air conditioning units and allowed for the possibility of a heat pump

- Energy efficiency–the LBNL baseline home met the 2012 International Energy Conservation Code (IECC), making it much more efficient than the installed base of homes likely to qualify for historic preservation
- Operation schedules–LBNL and NTHP used different assumptions about when shades were open and closed

**Table 2.** Assumptions for LBNL and NTHP

| **Baseline Category** | **LBNL** | **NTHP** |
|---|---|---|
| House Type | 2-story - one core and four perimeter zones | 2-story plus basement |
| Square Footage | 2,400 | 1,579 |
| Foundation | Basement or slab-on-grade | Basement |
| Year Built/Year Renovated | Mix proportional to population | 1896/2009 |
| Occupancy | Not provided | 3 |
| Window Type | All double hung vertical sliding windows with single clear glazing and aluminum alloy frame, double clear glazing and wood frame, or double low-e glazing and vinyl frame | Double hung, single pane wood windows, no storm windows or panels |
| Heating System Type | Gas furnace or heat pump | Gas furnace |
| Heating System Sizing | For each climate, system was sized for the base window option | 62 KBTUH |
| Heating Efficiency (Higher Performance/Lower Performance) in AFUE | Gas furnace (0.78)<br>Heat pump (1) | 0.92/0.78 |
| Cooling System Type | Central air conditioning | Window air conditioning units |
| Cooling Efficiency (SEER) | 13 | 9.4 |
| Thermostat Settings (Heating/Cooling) | 72°F/ 75°F | Not provided |
| Calculation Tool | EnergyPlus version 8.1 | SEEM (Simple Energy and Enthalpy Model) program |
| Energy Code | IECC 2012 | N/A |
| Deployment Schedule (Cellular Shades) | Based on Bickel et al. 2013, schedule of open, half-open, and closed for morning, afternoon, and evening/night | Assumed closed during daytime and 70% closed during nighttime hours, averaged with and without side tracks |
| Climate Data | TMY3 | TMY3 |

**Calculation Method**

Given the differences in the assumptions used by LBNL and NTHP, D+R calculated energy-savings figures for each attachment type separately, using the savings figures from each study to calculate aggregate energy savings. LBNL generated data for single and double pane windows, so D+R calculated savings potential for cellular shades, exterior storms, and interior panels for the following scenarios:

- LBNL Single Pane: Aggregate savings based on LBNL savings for attachments over a single pane window.
- LBNL Double Pane: Aggregate savings based on LBNL savings for attachments over a double pane window.
- LBNL Weighted Pane: Aggregate savings based on LBNL savings for attachments, weighted by pane type by climate zone using data from Bickel et al. 2013.
- NTHP: Aggregate savings based on NTHP savings for attachments over a single pane window. Uses LBNL savings figures for cities that were not modeled by NTHP.

D+R used the LBNL and NTHP data to develop aggregate energy-savings potential estimates for cellular shades, storm windows, and interior panels using the following process:

1. Organized cities with data available into the ENERGY STAR Climate Zone regions.[1] D+R combined the North-Central and South-Central zones into one Central Zone so each zone had the same number of cities (New Orleans and Lake Charles were treated as one city because of their geographic proximity).
2. Calculated total population modeled for each climate zone by adding the population of each city in this study within the zone. Table 3 shows the share of the actual U.S. population captured in this data.

**Table 3.** LBNL Modeled Households vs. U.S. Households

| Climate Zone | LBNL Modeled Households | U.S. Households | % of U.S. Households |
|---|---|---|---|
| Northern | 18,665,250 | 112,923,402 | 16.5% |
| Central | 22,117,068 | 152,040,731 | 14.5% |
| Southern | 10,489,493 | 46,300,493 | 22.7% |
| Total | 51,271,811 | 311,264,626 | 16.5% |

3. Calculated the proportion of each city's population in its climate zone and each climate zone's share of the nation.
4. Determined the number of households per city by dividing the population of each city by the average U.S. household size of 2.63 people (U.S. Census Bureau 2015).
5. Using the average household potential energy savings from each study, calculated the weighted average annual household energy savings of each city by multiplying the city average annual household energy savings (from LBNL and NTHP) by the city's households' share of its climate zone.
6. Calculated the average annual household energy savings of the climate zone by adding the weighted average annual household energy savings of each city within the given climate zone. This process is outlined in Table 4.

[1] U.S. Environmental Protection Agency. ENERGY STAR for Windows, Doors, and Skylights Climate Zone Map https://www.energystar.gov/ia/products/windows_doors/Promotional_Map.pdf?c073-dd50

**Table 4.** Weighted Average Energy Savings by Climate Zone for Cellular Shades on Double Pane Windows

| Climate Zone | City | City Average Annual Household Energy Savings (kWh) | City % of Climate Zone's Population | Weighted Average Annual Household Energy Savings of City (kWh) | Average Annual Household Energy Savings of Climate Zone (kWh) |
|---|---|---|---|---|---|
| Northern | Boston | 1,076 | 22.4% | 241.3 | 1,375.6 |
| | Chicago | 1,389 | 46.2% | 641.0 | |
| | Denver | 1,639 | 13.9% | 228.4 | |
| | Minneapolis | 1,514 | 17.5% | 264.8 | |
| Central | Atlanta | 1,292 | 24.3% | 314.2 | 1,335.0 |
| | Fort Worth | 1,528 | 29.7% | 454.2 | |
| | San Francisco | 1,347 | 19.9% | 268.2 | |
| | Washington, DC | 1,146 | 26.0% | 298.4 | |
| Southern | New Orleans | 1,222 | 11.5% | 140.9 | 1,655.8 |
| | Phoenix | 1,986 | 40.7% | 808.2 | |
| | San Antonio | 1,542 | 20.9% | 322.3 | |
| | Tampa | 1,431 | 26.9% | 384.5 | |

7. Calculated the city total annual energy savings by multiplying the city's average annual household energy savings by the number of households in that city.
8. Calculated the climate zone total annual energy savings by adding the city total annual energy savings of each city within the climate zone.
9. Calculated the weighted average annual household energy savings of each climate zone by multiplying the average annual household energy savings of the climate zone by the city's percentage of the total population accounted for in this study.
10. Calculated the national average annual household energy savings by adding the weighted average annual household energy savings of the Northern, Central, and Southern zones.
11. Repeated steps 6-10 separately for LBNL and NTHP data on cellular shades, storm windows, and interior panels.

## Findings

The figures in this section illustrate the aggregate energy-savings potential from each attachment type, scenario, and climate zone. These estimates represent technical rather than the actual savings potential, because in this study we did not project how many households would install energy-efficient attachments.

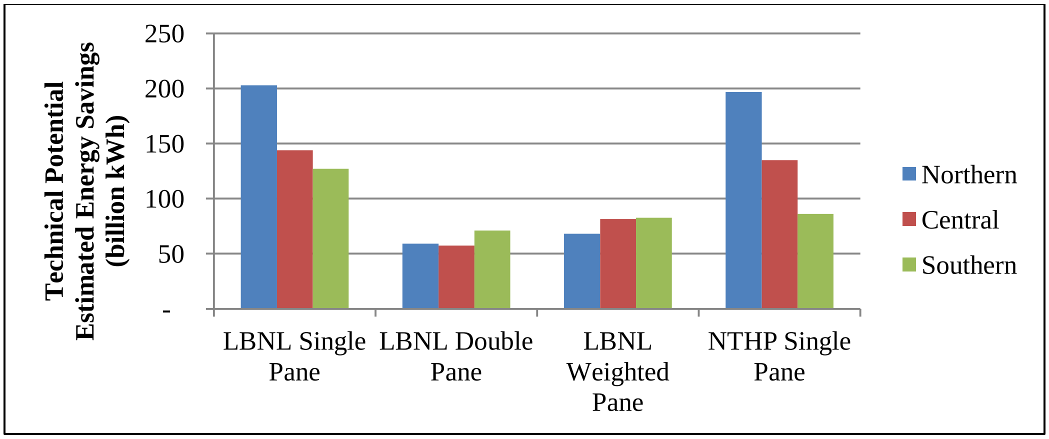


**Figure 3.** Cellular Shades Aggregate Savings by Climate Zone

Figure 3 compares the calculated aggregate energy-savings estimates of cellular shades based on the LBNL and NTHP reports by climate zone. The Northern climate zone has the highest per-household savings when cellular shades are installed with single pane windows (approximately 4,727 kWh/year in the LBNL scenario), while the Southern zone has the highest savings when installed over double pane windows (1,656 kWh/year). It is also notable that the LBNL single pane scenario and the NTHP scenario have very similar aggregate savings numbers (202 billion kWh and 196 billion kWh, respectively), as the cities used in those scenarios overlapped the most.

When weighted by pane type, the Southern and Central zones have higher aggregate savings (81 and 82 billion kWh, respectively) than the Northern zone (68 billion kWh), because double pane windows make up almost 91% of windows in the Northern zone, compared to approximately 75% of the installed base of windows in the Central and Southern zones (Bickel et al. 2013).The LBNL Weighted Pane scenario is the most realistic in terms of technical potential based on currently installed residential windows.

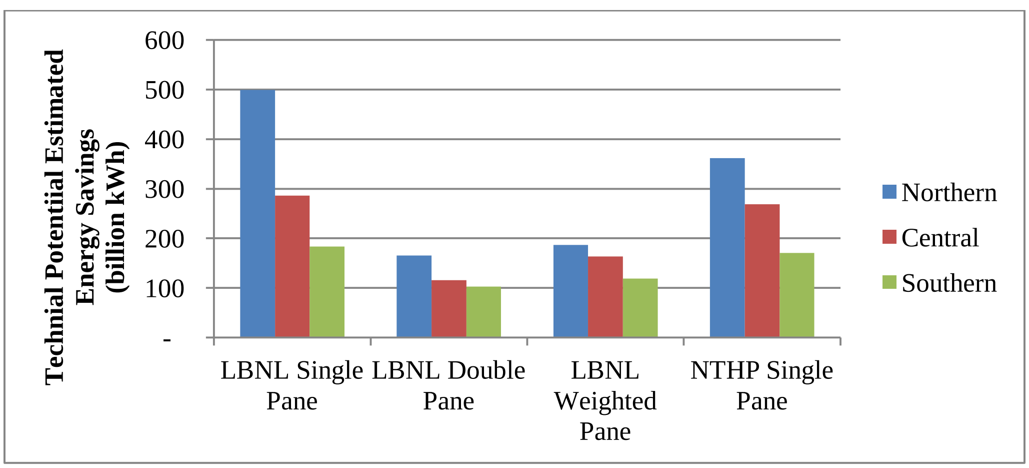


**Figure 4.** Exterior Storm Windows Aggregate Savings by Climate Zone

As shown in Figure 4, in all scenarios, energy savings from exterior storm windows are greatest in the Northern climate zone, followed by the Central zone; the smallest energy savings (which were still larger than the savings from cellular shades) are in the Southern zone. In the LBNL Weighted Pane scenario, the weighted average household savings are 2,771 kWh in the Southern zone, 3,812 kWh in the Central zone, and 4,344 in the Northern zone. Additional analysis shows that for exterior storm windows, the LBNL Single Pane and NTHP Single Pane scenarios do not align as closely as they do for cellular shades. There is a 3% difference between the cellular shade single pane scenarios in the Northern zone, and a 38% difference for exterior storm window single pane scenarios.

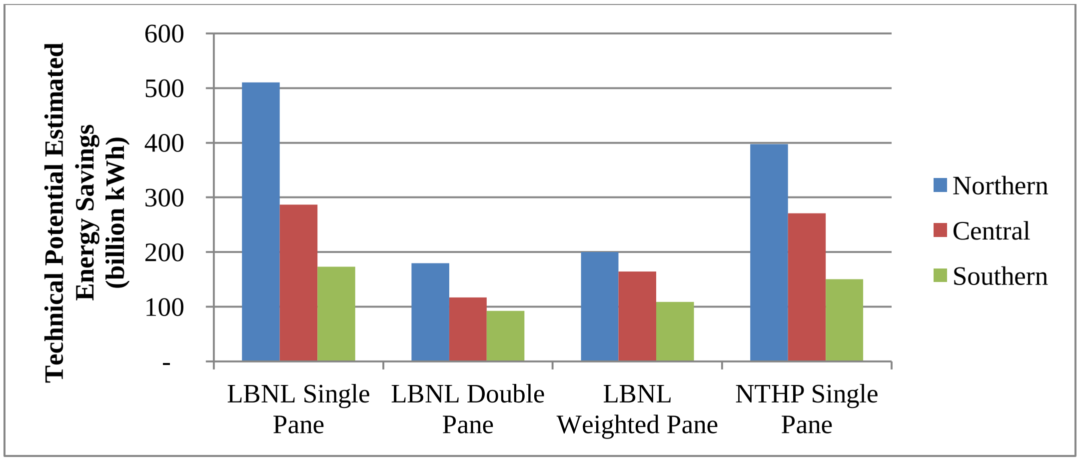


**Figure 5.** Interior Panels Aggregate Savings by Climate Zone

Because interior panels are similar to exterior storm windows, their energy-savings potential is comparable, with interior panels estimated to have slightly higher energy-savings potential than storm windows, as shown in Figure 5. Like exterior storm windows, savings are estimated to be greatest in the Northern climate zone, followed by the Central zone and the Southern zone. The LBNL Weighted Pane scenario shows that savings range from 108 billion kWh in the Southern zone to 200 billion kWh in the Northern zone.

Based on D+R's calculations of the aggregate savings for each product type across each climate zone, shown in Figures 3-5, cellular shades have roughly half the energy-savings potential of exterior storm windows and interior panels. However, the aggregate savings for cellular shades are still large across all three climate zones, as shown in Figure 3.

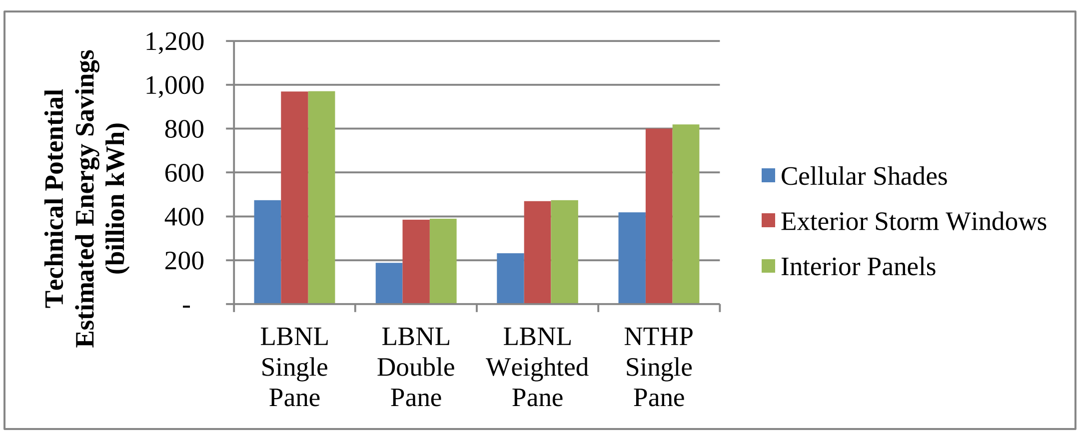


**Figure 6.** National Savings by Product Type

Figure 6 compares national savings for cellular shades, exterior storm windows, and interior panels. Aggregate national savings are 232 billion kWh for cellular shades, 469 billion kWh for exterior storm windows, and 473 billion kWh for interior panels. Figure 6 shows that the savings potential of exterior storm windows and interior panels is almost identical across all scenarios, while cellular shade savings are roughly half that of storm windows and interior panels.

**Achievable Savings**

As noted in the introduction, the rate of turnover for most window coverings is high, especially for vinyl miniblinds, the least-efficient window covering. Therefore, it is possible that a meaningful fraction of the technical potential can be realized within 10 or 15 years. Figure 7 illustrates the energy savings of U.S. households installing energy-efficient cellular shades, storm windows, or interior panels, using the LBNL Weighted Pane Scenario and assuming different conversion rates. For example, if 5% of U.S. households upgraded to cellular shades, they would save 11 billion kWh, and if they upgraded to low-e storm windows or interior panels they would save 23 billion kWh.

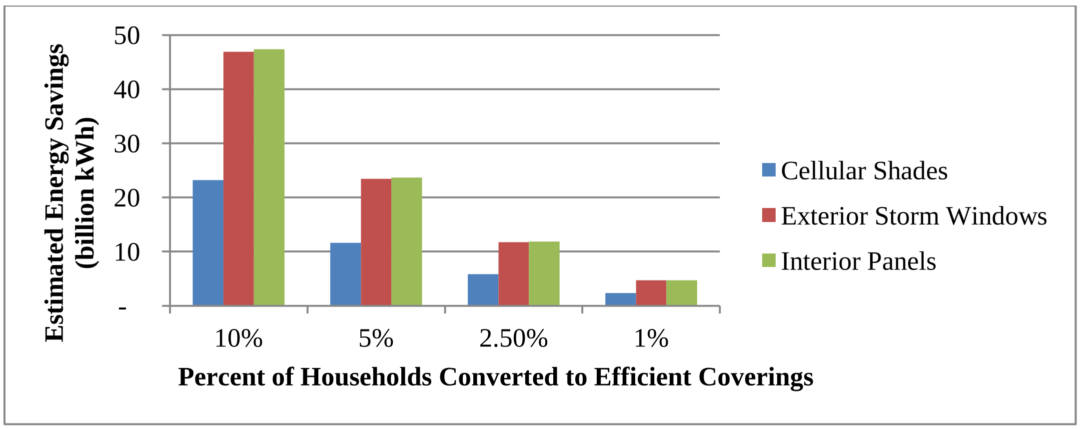


**Figure 7.** National Savings Assuming Different Conversion Rates Using LBNL Weighted Pane Scenario

## The Next Steps Toward Incentive Programs

The analysis presented in this paper demonstrates that the technical potential of energy savings from efficient window attachments is substantial at the household, regional, and aggregate levels. Overall, interior panels and storm windows have twice the savings of cellular shades, but cellular shades still offer significant energy-savings potential. This study estimates that if 5% of households upgraded to efficient attachments, 11-23 billion kWh in energy savings could be realized, depending on the attachment product type. Additional research is needed to generate real-world savings figures to position utilities to capture those energy savings.

Window attachments' relatively low cost and moderate lifetimes make them a viable option for utilities seeking new efficiency measures to address energy loss through the building envelope. This study provided the first step toward determining the cost-effectiveness of efficient attachments by estimating the technical potential of these products at the regional and national levels. However, program administrators need more data on the actual energy performance of these products before developing incentive programs for window attachments. Prescriptive programs will be possible once the AERC launches its standardized rating and certification program. While AERC works to develop ratings, utilities and other stakeholders should consider running pilot incentive programs and collecting additional field data on the energy-savings performance of a variety of attachments to get tested models and field data to justify incorporating a full-scale window attachment incentive program into their portfolios.

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