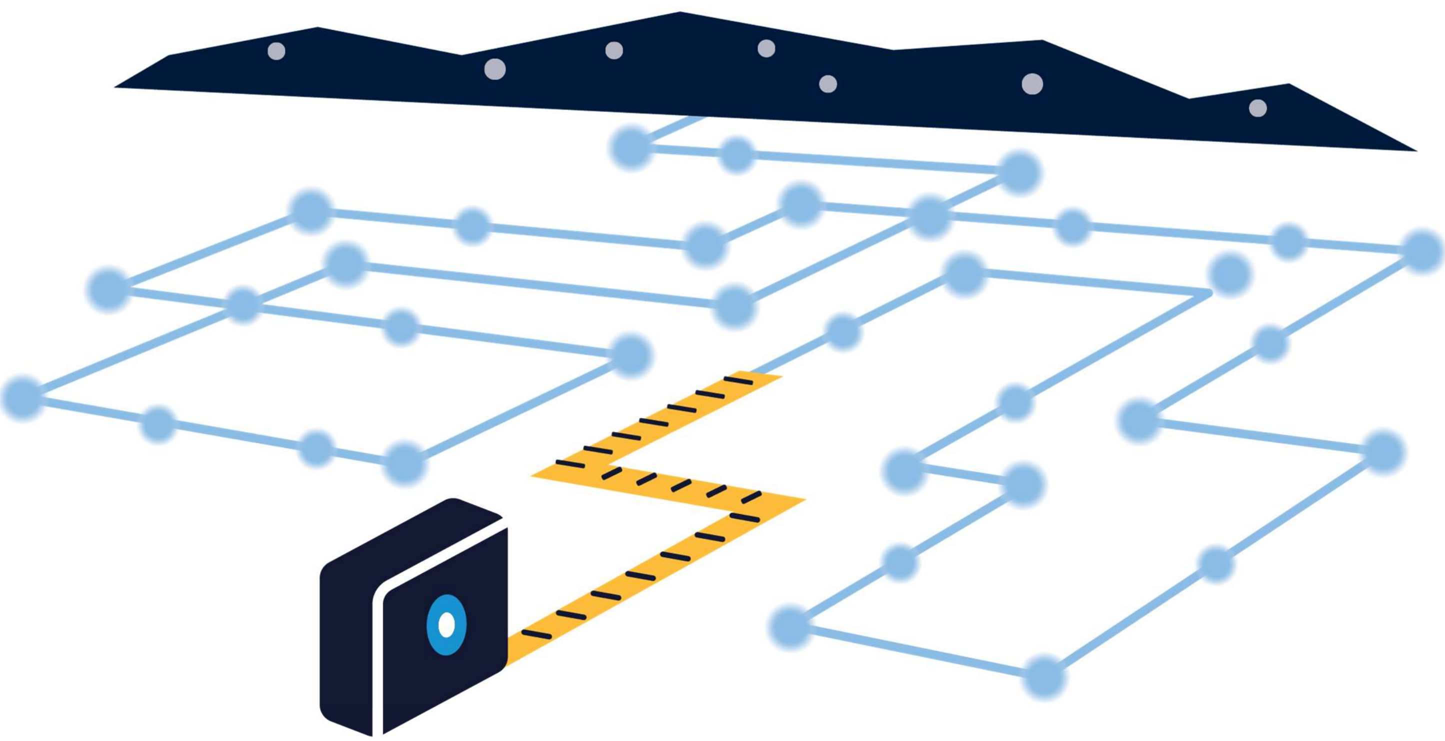
# Residential Exterior Window Shading Deemed Measure Assessment Study



October 10, 2022
CALMAC Study ID: CPU0347.01

This study is covered under CPUC Contract 17PS5017 between Opinion Dynamics and the California Public Utilities Commission (CPUC).

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# Table of Contents

# Executive Summary

The California Public Utility Commission (CPUC) requested that Opinion Dynamics research the market and energy savings potential of external window shading (EWS) technologies for single-family residences in California. EWS devices are mounted outside the home and save energy by completely blocking or drastically reducing the solar radiation through the window before it enters the home to become heat, versus inside window coverings which block the sun but inside the space where it contributes to overheating. The CPUC requested a short-term two-month study with the primary goal of determining if development of a deemed California electronic Technical Reference Manual (eTRM) *measure package* for residential external window shading (EWS) measures is warranted. Deemed measures use a prescriptive average-participant savings approach for energy efficiency measures, the *measure package* documents the information and requirements needed to claim savings for each measure, and the eTRM is the repository for the measure packages.

The primary elements of the research included characterization of the EWS device types, a literature review to identify existing EWS market information and energy impact studies, manufacturer interviews to establish existing market size and barriers, estimates of potential EWS device savings, and items to be considered for development of a deemed measure. Although this work was originally tasked as a feasibility assessment, the findings are sufficient to support immediate, active development of an EWS measure, although some elements will require additional data development. Highlights of the assessment and findings include:

- Existing studies show that adjustable awning EWS devices can provide average cooling energy savings of 39%, though savings vary significantly by climate zone.
- Controllable rolling shutters, although rarely used now on homes and not included in the studies we found, can block 100% of the solar gain so could be actively used to reduce cooling loads leading up to and during peak demand periods, and potentially even used as a demand response measure.
- Exterior window shading devices are currently only 1% of the combined interior/exterior window covering market, offering a huge potential opportunity.
- EWS devices are not currently offered by the IOUs nor included in the California eTRM.
- Currently EWS devices are rarely used for residential homes due to a number of barriers including alteration of a home’s exterior façade, applicability and optimal operation varies significantly by window orientation, under-appreciation for the thermal impact of blocking solar insolation before it enters the home, the diversity of device types and design approaches (active versus passive), and shading requirements which differ significantly by climate type. In developing the deemed measure package, these barriers would need to be considered and addressed, and energy impacts should be developed for all climate zones using the latest CPUC residential building simulation prototypes.

# 1. Introduction and Background

According to the Department of Energy, about "76% of the sunlight that falls on standard double-pane windows enters a building to become heat,"[1] driving the need for air conditioning and increased grid resources in the summer. External window shading devices save energy in homes by reducing the amount of solar radiation that enters through the windows to become heat. Interior window coverings are fairly common for residences; however, external window shading devices are rare even though they may offer higher energy savings and peak demand reduction benefits by blocking solar gain *before* it enters the home.

External window shading devices are typically added on to a home and are either attached to the outside of the window frame or to the building walls, typically above the window. These devices can be attached in temporary ways such as snaps and clips, or more permanent ways such as screws, adhesives, and in some cases, as an expansion of the building structure itself. For this study, we assessed a variety of external shading devices (e.g., awnings, canopies, projecting horizontal and vertical fins) and their potential energy savings in California for single family homes.

## Research Objectives

The California Public Utility Commission (CPUC) requested that Opinion Dynamics research the market and energy savings potential of external window shading (EWS) technologies for single-family residences in California. The CPUC requested a short-term two-month study with the primary goal to determine whether development of a deemed eTRM *measure package*[2] for residential external window shading (EWS) measures is warranted. The primary elements of this research were:

- Characterize EWS Device Types: Identify and describe the types of external window shading devices that are commonly used in California for single-family residential homes.
- Literature Review: Conduct a comprehensive search for existing and emerging EWS technologies; identify key studies on energy savings potential and occupant behaviors in operating EWS devices; identify potential market barriers and drivers to adoption of EWS devices; and identify common methods for assessing energy savings of EWS devices for potential future study.
- Manufacturer Interviews: Identify top manufacturers and retailers of EWS devices that supply the California market; develop questions on market share, perceived barriers, and drivers to adoption of EWS in homes; conduct outreach to identified companies, conduct up to eight interviews with manufacturers or retailers.
- Potential Energy and Demand Savings: Combine findings from literature review and market interviews to create energy savings estimates by technology; review current and past EWS measures in California, such as those offered in the Database for Energy Efficient Resources (DEER)[3]; and develop energy savings estimates for California regions or climate zones.
- eTRM Measure Package Assessment. Based on the study findings, discuss the feasibility and recommendations to be considered for development of an EWS measure package.

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[1] Department of Energy (2022). "Energy Efficient Window Coverings." Retrieved from https://www.energy.gov/energysaver/energy-efficient-window-coverings

[2] Formerly referred to as "workpapers", a "measure package" is the new term for a deemed measure in the California eTRM.

[3] California Public Utilities Commission (2022). "DEER Database." Retrieved from https://cedars.sound-data.com/deer-resources/deer-database/

Research findings and recommendations are discussed in the following sections and appendices.

### Types of Exterior Window Shading Devices

The nine external window shading device types identified by our research are presented in Table 1, along with some of the key features that characterize each type. A majority of these devices are manufactured units that are add-on installations to a home. These devices are the focus of this study. The last three EWS types are home design and construction features which are not compatible with a deemed measure approach so were excluded from the study. Vertical/horizontal fins are also not very common in single family residences, though are sometimes used in multifamily applications.

Table 1. Summary of EWS Devices Identified Through Secondary Research

<table>
<tr><th>EWS Device</th><th>Fixed</th><th>Adjustable/ Operable</th><th>Attachment Point</th><th>Construction Type</th></tr>
<tr><td>Awnings</td><td>✓</td><td>✓</td><td>Above and Side of window</td><td rowspan="6">Manufactured</td></tr>
<tr><td>Blinds</td><td>✓</td><td>✓</td><td>Above window, with blinds overlaying window</td></tr>
<tr><td>Canopies</td><td>✓</td><td>✓</td><td>Above window</td></tr>
<tr><td>Rolling Shutters</td><td>✓</td><td>✓</td><td>Above and Side of window</td></tr>
<tr><td>Solar Screens</td><td>✓</td><td></td><td>Overlaying window</td></tr>
<tr><td>Solar Shades</td><td></td><td>✓</td><td>Above window</td></tr>
<tr><td>Patio covers</td><td>✓</td><td>✓</td><td>Above window</td><td>Site-built</td></tr>
<tr><td>Vertical/Horizontal Fins</td><td>✓</td><td>Potential</td><td rowspan="2">Above and Side of window</td><td rowspan="2">Architectural features</td></tr>
<tr><td>Overhangs/Sidefins</td><td>✓</td><td></td></tr>
</table>

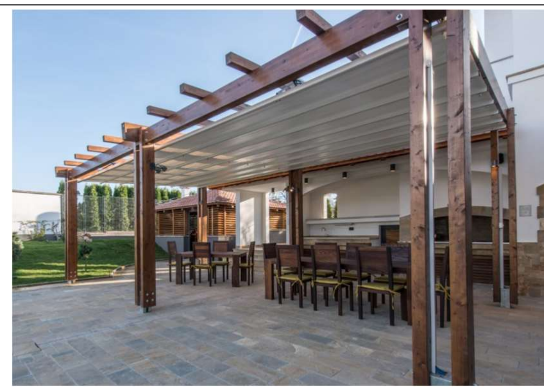
As indicated in Table 1, many of these EWS devices also have both fixed and adjustable options. A fixed EWS device means that it cannot be adjusted to different positions to actively block the sunlight. An example of a fixed EWS is a solar screen. Fixed EWS devices are not ideal because the sun's path changes dramatically throughout the year. Fixed awnings are typically designed to reduce solar insolation during the summer but allow sunlight penetration during the winter, though design and effectiveness varies significantly by window orientation with the most benefit gained for South-facing windows and little to no benefit for north-facing windows.

Adjustable EWS devices can be adjusted manually or remotely to reduce sunlight penetration and address glare issues. An example of an adjustable EWS are blinds, which can be rotated along a horizontal axis to increase or decrease the amount of daylight admitted into a space. Another variation is operable EWS devices, which incorporate a motor that also enables remote control adjustments. Typical remote control approaches would be a direct-wired wall switch or a smart phone application. Adjustable and operable versions of EWS devices are also more expensive than their fixed counterparts.

Detailed descriptions and an image of each EWS device are provided in Table 2.

Table 2. Common EWS Device Types Used in Residential Applications

| EWS Device | Description | Reference Image |
|---|---|---|
| Awnings | This device consists of a fabric cover stretched over a rigid frame made from a lightweight material that extends from the building over the window, shading the entire window. The fabric is usually treated to be UV-resistant and waterproof. Awnings can be fixed arm (pictured) or adjustable arm types. The drop arm awning is a common adjustable awning type. It consists of a roll of fabric that on one end retracts into a housing above the window and on the other end is suspended away from the building facade on a hinged frame. |  |
| Blinds | This device covers the entire window and is comprised of horizontal slats made from a hard material like metal, wood, or plastic. These slats can be rotated on their horizontal axis to let in more or less light. Similar to common interior blinds, exterior blinds are made of more durable materials to withstand the elements. |  |
| Canopies | This device is constructed using a fabric cover supported by a frame that is attached to the main building, as well as at least one stanchion at the outer end. This type of EWS can be very minimal, not needing a frame or substantial mounting. The canopy is a strong, cloth material that can be pulled taught to support itself. |  |
| Rolling Shutters | This type of device is made from interlocking metal slats. The slats cover the entire window and cannot be tilted on their horizontal axis. Similar to solar shades, a rolling shutter can be retracted into a housing above the window. |  |

| EWS Device | Description | Reference Image |
|---|---|---|
| Solar Screens | This device is a single piece of shade cloth constructed similar to standard bug screens but designed to cover the entire window and block a large portion of the sun's heat and visible light, while still allowing a filtered view of the outdoors. This material is usually UV-resistant as well. This screen is mounted to the window frame and is fixed in place. Solar screens can also be removed in the winter, if desired. |  |
| Solar Shades | This device uses a similar material to that of the solar screen, but rather than being fixed the shade cloth is on vertical sidetracks and can be rolled up into a housing above the window, extended to completely shade the entire window, or adjusted to any setting in between. |  |
| Patio Covers | These site-built units are constructed as first-floor roof extensions of a home and are attached to the home. The patio cover can be closed/solid or open-framed/roofless and/or might use a solar cloth much like a canopy to block the sun. A pergola is a free-standing (i.e., not physically attached to the home) equivalent of the patio cover. |  |

In addition to these established devices, we identified three emerging window and shading technologies that are currently being developed for residential and commercial, retrofit, and new construction applications. They are mentioned here as potential alternatives to EWS devices but were not explored in this study. The technologies are:

- **Photovoltaic windows** that produce energy from the sun. External window shading would not be beneficial for these window types.
- **Electrochromic/Chromogenic windows** have a layer of polymer dispersed liquid crystal that can be switched from clear to frosted via electrical current. The 2019[4] and 2022[5] Title 24 standards describe

[4] EnergyCode ACE (2019). "FENESTRATION." Retrieved from https://energycodeace.com/site/custom/public/reference-ace-2019/index.html#!Documents/gloss_fenestration.htm

[5] EnergyCode ACE (2022). "FENESTRATION." Retrieved from https://energycodeace.com/content/reference-ace-2022-tool

this technology as chromogenic glazing whose "primary function is to switch reversibly from a high transmission state to a low transmission state with associated changes in VT [visible transmittance] and SHGC [solar heat gain coefficient]."

- **Integrated shading systems** are described in the 2022 Title 24 standards as, "a class of fenestration products including an active layer: e.g., shades, louvers, blinds or other materials permanently integrated between two or more glazing layers." Adjusting the position of the enclosed EWS device changes the SHGC and VT of the window like chromogenic windows but mechanically instead of electronically.

### Title 24 Characterization of Exterior Shading Devices

It is important to also understand how EWS devices are treated under the California Energy Commission (CEC) Title 24 Building Energy Efficiency Standards.[6] Title 24 takes both a prescriptive and a performance (building simulation modeling) approach to EWS devices. The 2019 Standards includes the prescriptive list of exterior shading devices and their solar heat gain coefficient (SHGC) values shown in Table 3.[7]

Table 3. 2019 Title 24 Exterior Shading Devices and Corresponding Solar Heat Gain Coefficient (SHGC)

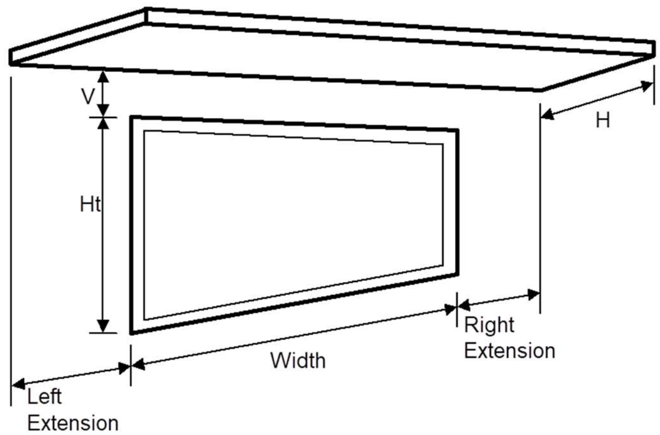
| Exterior Shading Device | SHGC |
|---|---|
| Standard Bug (insect) Screen (default for windows) | 0.76 |
| Exterior Sunscreens with Weave 53 x 16/inch | 0.30 |
| Louvered Sunscreens w/Louvers as Wide as Window Openings | 0.27 |
| Low-Sun-Angle Louvered Sunscreen | 0.13 |
| Vertical Roller Shades or Retractable/Drop Arm/ Combination/Marquisette and Operable Awnings | 0.13 |
| Roll Down Blinds or Slats | 0.13 |
| None (for skylights only) | 1.00 |

The 2022 Title 24 standards transitioned to building SHGC as a whole. The standards maintain a prescriptive requirement to not exceed a 0.23 SHGC for climate zones 2, 4, and 6-15, and also requires that EWS devices "must be permanently secured with attachments or fasteners that are not intended for removal" to receive the prescriptive credit. The energy impact of overhangs and side fin architectural features, shown in Figure 1. Overhang Dimensioning Approach for Title 24, is modeled via the Performance approach. Overhangs and sidefins are designed to provide shade during the summer to reduce cooling loads while allowing solar gains during the winter for space heating.

[6] California Energy Commission (2021). "Express Terms for the Proposed Revisions to 2022 Title 24, Part 1 and Part 6." 2022 Energy Code Update Rulemaking. 21-BSTD-01

[7] SHGC is a measure of the amount of solar radiation that is able to enter a building through a window. The lower the SHGC the better the device is at stopping solar insolation from entering.

Figure 1. Overhang Dimensioning Approach for Title 24[8]




## 2. Literature Review

We conducted a targeted review of existing literature on EWS devices and technologies and their potential for energy savings in residential single-family homes in California. Upon discovering that existing literature focused on California was limited, we expanded our search to national studies and studies focused on human behavior and interactions with the EWS devices. Table 4 summarizes the most applicable reference sources, their methods, and the exterior window shading technology covered in the report. These studies are discussed in detail in the next two sections. We discuss the key technologies and studies that were most useful in contextualizing the findings relevant to California. A complete list of sources is provided in Appendix A.

Table 4. Key Studies on Energy Savings and Market Potentials of EWS Devices

| Study Team | Study Year | Methods | Exterior Window Shading Devices in Study |
|---|---|---|---|
| Lawrence Berkeley National Laboratory (LBL) | 2013 | Energy Modeling | Fixed and adjustable awnings, solar screens, exterior storm panels |
| Pacific Northwest National Laboratory (PNNL) | 2020 | Lab Homes and Field Testing | Solar shades |
| Professional Awning Manufacturers Association (PAMA) | 2012 | Energy Modeling | Adjustable awnings and solar shades |
| University of Texas at Austin (UTA) | 1987 | Energy Modeling | Fixed awnings with and without sidewalls, overhangs, and solar screens |
| Department of Energy (DOE) | 2013 | Customer and Manufacturer Survey | Adjustable and fixed awnings, solar shades, and rolling shutters |
| Department of Energy (DOE) | 2014 | Research and Development Workshop | Emerging technologies of dynamic windows, e.g., thermochromic glass |

[8] Title 24 2016 ACM Reference Manual, https://energycodeace.com/site/custom/public/reference-ace-2016/Documents/25conditionedzones.htm, Figure 7 Overhang Dimensions

## Market Penetration of Exterior Window Shading Devices

Exterior shading strategies have a significantly smaller share of the combined interior/exterior window covering market.[9] Exterior window shading devices (specifically rolling shutters, solar shades and awnings) represent only 1% of installed residential window coverings nationally. The DOE market assessment study surveyed Window Covering Manufacturers Association (WCMA) members to estimate shipment volumes of residential exterior window coverings across four ENERGY STAR climate zones for windows.[10] For those climate zones that include California, exterior rolling shutters account for the majority of exterior product shipments (~60%), followed by awnings (~39%) and exterior solar shades (~1%). While the climate zones cover large swaths of the continental United States and may not be representative of California's unique climate and housing characteristics, the distribution of shipments by product is similar across the other climate zones.

While the lack of homeowner adoption is not directly connected to specific reasons in the DOE study, it can be inferred that cost may be a significant driver for adopting interior window coverings over exterior. Exterior products, namely awnings, solar shades and rolling shutters, can cost upwards of two to three times as much as interior treatments, ranging between $300 and $600 on average per covering, in comparison to $20 for interior vinyl blinds or $100 for interior solar shades.[11] Moreover, motorization and automation of exterior window coverings, a preferable feature in exterior solar shades and roller shutters, can increase the cost of window coverings by as much as 20%.

Another report published by the DOE assessed the market potential and market barriers of dynamic windows, i.e., windows capable of sensing solar heat and light intensity and respond by automatically adjusting window tint or integrated shading device to minimize heat gain.[12] While dynamic windows are outside the scope of this exterior window shading study, several findings are relevant. First, the DOE study included a research and development workshop of industry and subject matter experts. These workshop attendees concluded that dynamic windows in existing residential buildings held the highest market potential in terms of energy savings in comparison to other window and envelope improvements. Second, the observed market barriers for dynamic windows include: (1) architect, fabricator, and consumer *acceptance of the technology, further noting the importance of remote control and operation; (2) product standardization* to assist consumers in making informed decisions; and (3) manufacturers high upfront costs for materials. Manufacturers and consumers of EWS devices may experience similar barriers to broader market adoption.

## Energy Savings Estimates from EWS Studies

The literature review uncovered several useful studies. A summary of the detailed savings estimates from these studies is presented in three tables that represent different views of the data. Table 5 summarizes the original values and their study sources, Table 6 is organized by technology and percent savings, and Table 7 is a high-level summary of the percent savings ranges by EWS device. Impact values are presented as a percent of cooling energy savings or peak demand reduction per home. We were unable to locate any studies that included rolling shutters, although this EWS type is likely the most expensive and least popular for residential applications. This could be an area for future primary research.

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[9] Department of Energy (2013). "Residential Windows and Window Coverings: A Detailed View of the Installed Base and User Behavior."
[10] The DOE market study used the ENERGY STAR window climate zones, where California is included in the North-Central climate zone, which includes California's mountain and coastal regions, predominately associated with 2012 IECC climate zones 3 and 4, and the South-Central climate zone, covering the remainder of California, and associated with 2012 IECC climate zones 2 and 3. See Appendix B for maps illustrating the International Code Council (ICC), ENERGY STAR, and Title 24 climate zones.
[11] Department of Energy (2013). "Residential Windows and Window Coverings: A Detailed View of the Installed Base and User Behavior."
[12] Department of Energy (2014). "Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies."

A prominent study is Lawrence Berkeley Laboratory's (LBL) 2013 study, which assessed the performance of fixed awnings, drop-arm awnings (referred to as adjustable awnings), solar screens, and exterior storm windows (which are not used in California).[13] Percent of cooling load reduced was developed following the method described in Appendix C.

Table 5. Estimated Cooling Energy Savings per from Home from Literature Review Reference Sources

| City | Climate Zone | Exterior Window Shading Device Type | Interior Treatment Included | Percent of Cooling Load Reduction | | Reference Source |
|---|---|---|---|---|---|---|
| | | | | Energy | Peak Demand | |
| Phoenix, AZ | IECC – 2B (Dry) | Adjustable Awning | Yes | 28% | N/A | LBL 2013 |
| | | Adjustable Solar Screen | | 27% | N/A | |
| | | Fixed Awning | | 27% | N/A | |
| Richland, WA | IECC – 5B (Dry) | Adjustable Solar Screen | No | 20% | N/A | PNNL 2020 |
| | | | Yes | 10% | N/A | |
| San Francisco, CA | T24 – 3 | Adjustable Awning | Yes | 72% | 30% | PAMA 2012 |
| | | Solar Shades | | 16% | 0% | |
| San Diego, CA | T24 – 7 | Adjustable Awning | Yes | 46% | 26% | |
| | | Solar Shades | | 28% | 8% | |
| Sacramento, CA | T24 – 12 | Adjustable Awning | Yes | 36% | 13% | |
| | | Solar Shades | | 27% | 13% | |
| Burbank, CA | T24 – 9 | Adjustable Awning | Yes | 32% | 16% | |
| | | Solar Shades | | 22% | 7% | |
| Fresno, CA | T24 – 13 | Adjustable Awning | Yes | 24% | 14% | |
| | | Solar Shades | | 22% | 2% | |
| Palm Springs, CA | T24 – 15 | Adjustable Awning | Yes | 18% | 8% | |
| | | Solar Shades | | 17% | 7% | |
| Austin, TX | IECC – 2A (Moist) | Solar Screen | No | 27% | 5% | UTA 1987 |
| | | | Yes | 17% | 12% | |
| | | Fixed Awning | No | 6% | -1% | |
| | | | Yes | 2% | 0% | |
| | | Overhang | No | 2% | 0% | |
| | | | Yes | 1% | 0% | |

Table 6. Summary of Reported Estimated Cooling Energy Savings per Home by EWS Device

| Exterior Window Shading Device Type | Climate Zone | Interior Treatment Included | Percent of Cooling Load Reduction | | References Sources |
|---|---|---|---|---|---|
| | | | Energy | Peak Demand | |
| Adjustable Awnings | T24 – 15 | Yes | 18% | 8% | LBL 2013 and PAMA 2012 |
| | T24 – 13 | | 24% | 14% | |

[13] Lawrence Berkeley National Laboratory (2013). "Energy Savings from Window Attachments." DOE/EE-0969.

| Exterior Window Shading Device Type | Climate Zone | Interior Treatment Included | Percent of Cooling Load Reduction | | References Sources |
|---|---|---|---|---|---|
| | | | Energy | Peak Demand | |
| | IECC – 2B (Dry) | | 28% | N/A | |
| | T24 – 9 | | 32% | 16% | |
| | T24 – 12 | | 36% | 13% | |
| | T24 – 7 | | 46% | 26% | |
| | T24 – 3 | | 72% | 30% | |
| Solar Shades | IECC – 5B (Dry) | Yes | 10% | N/A | PAMA 2012 and PNNL 2020 |
| | T24 – 3 | | 16% | 0% | |
| | T24 – 15 | | 17% | 7% | |
| | IECC – 5B (Dry) | No | 20% | N/A | |
| | T24 – 9 | Yes | 22% | 7% | |
| | T24 – 13 | | 22% | 2% | |
| | T24 – 12 | | 27% | 13% | |
| | T24 – 7 | | 28% | 8% | |
| Fixed Awning | IECC –2A (Moist) | Yes | 2% | 0% | LBL 2013 and UTA 1987 |
| | | No | 6% | -1% | |
| | IECC – 2B (Dry) | Yes | 27% | N/A | |
| Overhangs | IECC – 2A (Moist) | Yes | 1% | 0% | UTA 1987 |
| | | No | 2% | 0% | |
| Solar Screens | IECC – 2A (Moist) | Yes | 17% | 12% | LBL 2013 and UTA 1987 |
| | IECC – 2B (Dry) | | 27% | N/A | |
| | IECC – 2A (Moist) | No | 27% | 5% | |

Table 7. Range of Reported Cooling Energy and Peak Demand Savings by External Shading Device

| Exterior Window Shading Device Type | Percent Cooling Load Reduction | | Reference Sources |
|---|---|---|---|
| | Energy | Peak Demand | |
| Adjustable Awnings | 18% to 72% | 8% to 30% | LBL 2013 and PAMA 2012 |
| Solar Shades | 10% to 28% | 0% to 13% | PAMA 2012 and PNNL 2020 |
| Fixed Awnings | 2% to 27% | -1% to 0% | LBL 2013 and UTA 1987 |
| Overhangs | 1% to 2% | 0% | UTA 1987 |
| Solar Screens | 17% to 27% | 5% to 12% | LBL 2013 and UTA 1987 |

We cannot draw definitive conclusions from these studies to develop savings for an EWS deemed measure offering but can make several general observations to guide that work:

1. **Impacts vary significantly by climate zone.** The energy savings potential of an exterior window shading device varies significantly by climate zone and geography. The PAMA study illustrates this point.[14] For the California cities included in the study, the percentage of cooling energy use that an EWS device will save is largest where the cooling energy use is smallest (San Francisco) and is smallest where cooling load is largest (Palm Springs). However, the savings potential for San Francisco, as reported in the PAMA study, is a mere 86 kWh for awnings and 19 kWh for solar shades, in comparison to 1,690 kWh and 1,587 kWh for those respective devices in Palm Springs. The percent of peak summer cooling savings follows a similar

[14] Professional Awning Manufacturers Association (2012). "The Impact on Energy Use and Peak Demand of Awnings and Roller Shades in Residential Buildings."

pattern but exhibits some variability by device. One reason for this occurrence, is that outside air temperature in Palm Springs is much higher in summer, routinely above 100°F, than in San Francisco, and has a significant impact on a home's ability to maintain indoor conditioned temperatures.

2. Savings are heavily influenced by the presence of interior window treatments. The PNNL study draws a direct correlation between energy savings resulting from solar screens where interior window treatments are absent versus when they are present. The study showed a 20% reduction when no indoor blinds were present and only a 10% reduction when interior treatments were present.[15] The University of Texas at Austin (UTA) study observed a similar decrease in energy savings of 10% for solar screens, aligning with the PNNL study, and also 4% for awnings, and 1% for overhangs.[16] The reduction in energy savings when interior treatments are present is partially due to decreased solar heat gain coefficients stemming from the added layers of shading. However, the more significant benefit of exterior window coverings over interior is that they prevent solar heat gain from ever entering the building, being absorbed by interior coverings, and then radiated into the interior space.[17]

3. Adjustable devices provide better performance than fixed devices. Adjustable shading devices slightly outperform fixed devices in summer cooling energy savings. Table 6 shows that adjustable exterior coverings in the LBL and UTA studies have slightly higher percent cooling savings values than the fixed coverings.[18,19] Fixed coverings are typically designed to provide window shading for specific sun positions (summer) and window orientations, which limits their performance while minimizing installation and maintenance. Conversely, adjustable coverings allow the homeowner to better manage their comfort and adapt to the changing positions of the sun, which can lead to increased savings. Automated control of adjustable EWS devices can further increase savings: One study estimated an additional 14.9% of peak summer cooling savings with the introduction of a movable window shading device capable of tracking the sun's path.[20] While this technology is likely years away from being viable for single family homes, it could be one element of a smart home control system. It is also worth noting that heating savings in the winter may be available via adjustable coverings, which can be raised, removed, or fully retracted to allow for beneficial solar heat gain in the winter. Winter impacts of window coverings are outside the scope of this study but could be easily assessed as part of a follow-up building energy modeling (BEM) analysis.

### Assessment of California EE Program EWS Measure Offerings

External shading device measures are not currently being offered by any of the investor-owned utilities (IOUs). However, we found that eight municipalities and publicly-owned utilities (POUs) have offered or are actively offering some exterior shading devices as deemed measures, as summarized in Table 8. These programs offer rebates to their customers or residents for solar shades and solar screens.

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15 Pacific Northwest National Laboratory (2020). "Evaluation of Exterior Shades at PNNL Lab Homes and Occupied Field Sites." PNNL-30536.

16 University of Texas at Austin (1987). "Energy Savings Resulting from Shading Devices on Single Family Residences in Austin, Texas."

17 Kim, Gon, Lim H.S., Lim T.S., Schaefer, L., Kim, J., (2012). "Comparative Advantage of an Exterior Shading Device in Thermal Performance for Residential Buildings." Energy and Buildings, vol. 46, 2012, pp. 105–111., https://doi.org/10.1016/j.enbuild.2011.10.040.

18 Lawrence Berkeley National Laboratory (2013). "Energy Savings from Window Attachments." DOE/EE-0969.

19 University of Texas at Austin (1987). "Energy Savings Resulting from Shading Devices on Single Family Residences in Austin, Texas."

20 Dutta, Arindam, Samanta, A., and Neogi, S. (2017). "Influence of orientation and the impact of external window shading on building thermal performance in tropical climate." Energy and Buildings, vol. 139, 2017. Pp. 680-689., https://doi.org/10.1016/j.enbuild.2017.01.018.

The programs are not targeted at specific building-types or customer segments. For most programs, the eligibility requirements specify that the installation must be on a window for an air-conditioned space and the window cannot be north-facing, as solar radiation is negligible for north-facing windows.

Table 8. Status of California Utility Offerings of Exterior Window Shading Measures

| Program Name | Program Sponsor | Entity Type | Title 24 Climate Zone | Current/ Expired |
|---|---|---|---|---|
| Residential Home Efficiency Rebate Program | City of Azusa | City | 9 | Current |
| Residential Home Efficiency Rebate Program | Hercules Municipal Utility | Utility | 3 | Expired |
| Residential Rebate Program | City of Lodi Electric Utility | Utility | 12 | Current |
| Residential Rebate Program | Modesto Irrigation District | Utility | 12 | Current |
| Residential Weatherization Rebate Program | City of Redding Electric Utility | Utility | 11 | Expired |
| Residential Rebate Program | Roseville Electric Utility | Utility | 11 | Current |
| Residential Rebates | City of Pasadena | City | 9 | Expired |
| Sunscreens Rebate | Turlock Irrigation District | Utility | 12 | Current |

[a] Refer to Appendix D for links to each rebate program.

### CMUA Technical Reference Manual EWS Deemed Measures

We also found that the California Municipal Utilities Association's (CMUA) 2017 Technical Reference Manual (TRM) included deemed savings estimates for solar screens.[21] The savings estimates refer to the 2008 DEER, suggesting that IOUs previously offered solar screen measures as well but discontinued the offering. The CMUA 2017 TRM estimates annual electric energy savings in units of kWh per square foot ($ft^2$) of window area. As a rough estimate of actual kWh cooling energy savings per home, we assumed eight, 3' by 5' windows for a total 120 $ft^2$ of window area per home.[22] Table 9 summarizes the calculated savings per home for fixed solar screens. The CMUA values apply to all windows that are not north-facing.

Table 9. Energy Savings Potential for EWS Devices Found in the 2017 CMUA TRM

| Title 24 Climate Zone | Fixed Solar Screens | |
|---|---|---|
| | Annual kWh Savings per sqft of window | Total Annual kWh Savings per Home for 120 $ft^2$ of windows |
| CZ02 | 0.81 | 97 |
| CZ03 | 0.3 | 36 |
| CZ04 | 0.75 | 90 |
| CZ05 | 0.44 | 53 |
| CZ08 | 1.04 | 125 |
| CZ09 | 1.1 | 132 |
| CZ10 | 0.93 | 112 |

21 California Municipal Utilities Association (2017). "Savings Estimation Technical Reference Manual 2017." Third Edition.

22 The assumption of eight windows per home is estimated from 2015 residential energy consumption survey data published by the Energy Information Administration at https://www.eia.gov/consumption/residential/.

| Title 24 Climate Zone | Fixed Solar Screens | |
|---|---|---|
| | Annual kWh Savings per sqft of window | Total Annual kWh Savings per Home for 120 ft$^2$ of windows |
| CZ11 | 0.82 | 98 |
| CZ12 | 0.81 | 97 |
| CZ14 | 1.05 | 126 |
| CZ15 | 1.45 | 174 |
| CZ16 | 0.51 | 61 |

The solar screen savings estimated using the CMUA TRM are comparable to those from the EWS studies we found. The household savings potential of a solar screen in Title 24 climate zone 15 (Palm Springs) calculated through the CMUA TRM is 174 kWh, representing an approximate 13% reduction in home cooling energy use.[23] In comparison, the range of household energy savings from solar screens is between 17% and 27% for similar climates (Phoenix, AZ and Austin, TX), with the lower end savings estimate including interior treatment.

# 3. Manufacturer Research and Interviews

We targeted interviews with EWS manufacturers and retailers to better understand the California residential EWS market as well as the claimed savings on their websites. We created a list of research objectives to guide the interview questions. Focusing on the EWS market, we wanted to determine the company's share of the California residential EWS market and more specifically, what their share by specific EWS device type is. We also asked about the company's current drivers and barriers to increased adoption of their product and how the adoption rate could be increased. Finally, we tried to identify the regions, and if possible, the California Title 24 climate zones where most of their products were sold. To assess potential savings for these devices, we also asked about their projections for energy savings for the products and tried to determine the source of those estimates.

## Manufacturer Identification and Savings Claims

We conducted an internet search for exterior window shading manufacturers and retailers to identify those that sell the targeted EWS devices in the California residential market. Once potential companies were identified, we searched their website for advertised energy savings and contact information. We were able to identify 16 different residential-serving EWS manufacturers and retailers located throughout California, with a majority serving the large coastal cities in Northern and Southern California. Table 10 provides a summary of the details gathered from company websites including their products, their sales region, and savings claims from their websites. Links to the company websites and claims are provided in Appendix E.

Table 10. Summary of EWS Manufacturer and Retailer Energy Savings Projections

| Company | Products | Region | Energy Savings Projections |
|---|---|---|---|
| Insolroll | Solar shades | Nation | 97 percent of the sun's heat is blocked |
| EZ Snap | Solar shades | SoCal | 90 percent of the sun's heat is blocked |
| | | | 15 degree Fahrenheit cooler indoor temperatures |
| The Awning Company | | SoCal | 77 percent interior heat reduction |

[23] Household energy consumption is derived from the 2019 California Residential Appliance Saturation Study (RASS) and discussed in Assessing EWS Energy Savings Potential.

| Company | Products | Region | Energy Savings Projections |
|---|---|---|---|
| | Awnings, solar shades, solar screens | | 25 percent reduced A/C load and energy |
| Sun Control Products | Awnings, solar shades, solar screens | San Diego | 25 percent reduction to room temperature |
| | | | 60 percent reduced A/C load |
| Accent Awning Company | Awnings | SoCal | 20 degree Fahrenheit cooler indoor temperatures |
| | | | 77 percent reduced solar heat gain |
| Enviroblind | Solar shades, rolling shutters | CA | Only qualitative claim |
| Hartley | Awnings, solar shades, solar screens | NorCal | 22 degree Fahrenheit cooler indoor temperatures |
| | | | 50 percent reduced A/C load |
| European Rolling Shutters | Awning, rolling shutters, solar screen, canopy | NorCal | 86 percent reduced cooling costs in San Francisco Homes |
| Diversified | Solar shades | SoCal | Only qualitative claims |
| Blinds & Designs | Solar shades | NorCal | |
| Master Blinds | Blinds, solar shades | SoCal | |
| JustBlinds | Solar shades | Nation | |
| Intertrade | Awning, rolling shutter, canopy | State | |
| Goodwin | Awning, solar shades, canopy | State | 60 percent reduced cooling costs |
| | | | 50 percent reduced energy bills |
| Screens of Norcal | Awnings | NorCal | No claim made |
| High Desert Mobile Screens | Solar screens | EastCal | |

As part of our literature review research, we also identified two EWS trade organizations which were already mentioned, the Window Covering Manufacturers Association (WCMA, https://windowcoverings.org/) and Professional Awning Manufacturers Association (PAMA, https://awnings.textiles.org/). We focused our initial manufacturer outreach efforts to actual manufacturers and did not contact these organizations due to the short timeline of this study. However, any future EWS efforts should work with these organizations to obtain market data and potentially enlist their help with recruiting survey participants.

### Interview Outreach and Survey Questions

We attempted to recruit EWS manufacturers who served the California residential market. We used contact information obtained from company websites and attempted outreach via both email and phone over the span of three weeks. We requested interviews of no-longer than 30 minutes. The interview questions we prepared are provided in Appendix F. The questions were designed to target key EWS device types, establish current market characteristics for the manufacturer and each device, determine general EWS adoption barriers and drivers and the potential for improving adoption and uptake, and investigate estimated savings claimed (if made) and the source and/or substantiation of those claims if available.

### Interview Results

Of the 16 companies we contacted, we were only able to complete an interview with one of them due to the limited timeframe for this study. However, the interview offered valuable insights and confirmed general characterizations of the market and EWS devices. The company interviewed sells statewide with 90% of their sales coming from single family homes. The company's sales are distributed evenly across the state, and their share of the California residential EWS market was estimated to be about 5%. The main barrier to adoption was reported to be a general lack of knowledge about external window shading devices, and specifically for their product: the low cost and energy savings benefits it offers. This company also shared their opinion that in at least one area where these barriers have been overcome (Arizona) the presence of EWS devices on many homes can begin to act as a market driver and actually motivate potential customer purchases. This company also claims quantitative savings on their website, but we were not able to substantiate a reference source with the contact.

As part of our literature review research, we also reached out to other subject matter experts including Title 24 residential software tool developers and a passive home design consultant, to determine if they were aware of any previous EWS studies. They could not identify previous studies but provided additional thoughts and comments. One noted that rolling shutter devices are already common throughout Northern Europe where they are used in lieu of air conditioning and could serve other resiliency functions. Another recalled development of residential prescriptive Standard requirements for solar shades and solar screens in California's more arid climate zones such as Palm Springs. Another observed that the reason EWS devices have likely not caught on is because they can be unattractive and may require more maintenance than the underlying windows, but then also noted that EWS devices should be considered a low-hanging fruit for energy conservation.

# 4. Assessing EWS Energy Savings Potential

To assess the energy savings potential of exterior window shading devices, we gathered and summarized savings claims from two sources: studies from the literature review and values from manufacturers' websites. We assessed the validity of these sources to identify the best savings estimates for use in quantifying the energy savings potential in California.

The percent cooling energy savings claimed by manufacturers and retailers (Table 10) are not always easily translatable to quantifiable energy savings, and often do not make a distinction between technology in cases where the manufacturer makes more than one device. Of the list of manufacturers identified in this study, three manufacturers claim a percent reduction in home cooling energy use ranging from 25 to 60%. Without the underlying study used to develop these claims, we cannot know whether the savings are reasonable and appropriate for this study.

As a result, we decided not to include the manufacturer's claims in our potential savings analysis. We instead relied completely on the savings estimates from the research studies. The methods used in the literature are scientific, transparent, and utilize energy models to quantify the impact of exterior shading on a home's energy use. We reviewed the study methods and modeling assumptions to verify that resulting savings estimates are reasonable. However, we excluded studies from Texas and Washington as their climates are too dissimilar to California. The climate of Phoenix, AZ is similar to Palm Springs' (Title 24 climate zone 15) so is included in the savings analysis. Exclusion of some studies limited the literature-claimed savings to awnings (fixed and adjustable), solar screens, and solar shades, which we averaged across the studies and climate zones.

The results of these studies used for our energy savings potential analysis are summarized in Table 11. This table also includes the Title 24 climate zones and the utilities serving those climate zones as determined from a review of the California Energy Commission (CEC) 2019 RASS study.

Table 11. Summary of Household Cooling Percentage Reduction Used in the Savings Potential Analysis

| Exterior Window Shading Technology | T24 Climate Zone | Utilities Serving T24 Climate Zone | Percent of Cooling Energy Reduced per Home |
|---|---|---|---|
| Adjustable Awnings | T24 – 3 | PG&E | 72% |
| | T24 – 7 | SDG&E | 46% |
| | T24 – 9 | LADWP/SCE | 32% |
| | T24 – 12 | SMUD | 36% |
| | T24 – 13 | PG&E | 24% |
| | T24 – 15 | SCE | 23% |
| Solar Shades | T24 – 3 | PG&E | 16% |
| | T24 – 7 | SDG&E | 28% |
| | T24 – 9 | LADWP/SCE | 22% |
| | T24 – 12 | SMUD | 27% |
| | T24 – 13 | PG&E | 22% |
| | T24 – 15 | SCE | 17% |
| Fixed Awnings | T24 – 15 | SCE | 27% |
| Solar Screens | T24 – 15 | SCE | 27% |

## Energy Use and Savings from 2019 RASS

The recently completed California 2019 Residential Appliance Saturation Study (2019 RASS) was used as our primary source for estimates of household annual cooling energy use, referred to as unit energy consumption (UEC).[24] Unfortunately, CEC Forecasting Zones[25] – rather than Title 24 climate zones – were the basis for the study sample and end-use energy consumption results. RASS results were also available at a utility level. Although this zone difference by utility makes application of the RASS results difficult to apply for this EWS study, it is still the best available source for average cooling energy savings estimates. Table 12 provides annual cooling energy use for the RASS Central Air Conditioning (CAC) end use by utility service area and includes the Title 24 climate zones served by each utility. There are two other RASS cooling end uses – Room Air Conditioning and Evaporative Cooling – but CAC is the most typical single-family HVAC system type. The equipment saturations also shown in Table 12 are relevant because they show the fraction of homes that have CAC systems and on which the average UEC is based. This is especially relevant for EWS measures since they can only be applied to air conditioned homes (cooling savings require a cooling system) and because the average UEC for <u>all</u> households is slightly lower than it would be for a home that has a CAC. For example, for

[24] DNV (2021). "2019 California Residential Appliance Saturation Study (RASS)." CEC-200-2021-005-PO. Table 1, "Central Air Conditioning" unit energy consumption (UEC) and equipment saturation values.

[25] See full discussion of relevant regions and climate zones in Appendix B

PG&E with a saturation of 51%, the UEC for homes that have CAC equipment would be 1,132/0.51 = 2,219 kWh per year.

Table 12. RASS 2019 Central Air Conditioning Energy Consumption by Electric Utility and Title 24 Climate Zones Served

| Forecasting Zone Utility | Title 24 Climate Zones Served[26] | Average Household Central Air Conditioning Annual Unit Energy Consumption (kWh) | Central Air Conditioning Equipment Saturation |
|---|---|---|---|
| LADWP/SCE | 6, 8, 9, 16 | 1,021 | 52% |
| PG&E | 1, 2, 3, 4, 5, 11, 12, 13, 16 | 1,132 | 51% |
| SCE | 6, 8, 9, 10, 14, 15, 16 | 1,344 | 68% |
| SDG&E | 7, 10, 14 | 599 | 54% |
| SMUD | 12 | 1,194 | 89% |

Average EWS measure energy savings are estimated from the average cooling reduction percentages in Table 11 and the RASS CAC UEC values in Table 12. Calculation results are discussed in Appendix C.

# 5. Savings Analysis Results & Recommendations

Table 13 present the final average savings values developed from the research studies. Adjustable awnings have the highest cooling energy savings potential (39%), followed by fixed awning and solar screens (27%), and finally the solar shades (22%). To estimate the total annual energy savings in units of kWh, the average EWS household cooling savings are multiplied against the average household central air conditioning annual unit energy consumption. The resulting average household annual energy savings are presented in Table 14.

Table 13. Average EWS Annual Cooling Energy Reductions

| | Adjustable Awnings | Fixed Awnings | Solar Screens | Solar Shades |
|---|---|---|---|---|
| Average % of Homes Cooling Energy Reduced | 39% | 27% | 27% | 22% |

Table 14. Average Household Annual Cooling Energy Savings

| Forecasting Zone Utility | Average Household CAC Annual UEC (kWh) | Adjustable Awnings | Fixed Awnings | Solar Shades | Solar Screens |
|---|---|---|---|---|---|
| LADWP/SCE | 1,021 | 396 | 276 | 225 | 276 |
| PG&E | 1,132 | 440 | 306 | 249 | 306 |
| SCE | 1,344 | 522 | 363 | 296 | 363 |
| SDG&E | 599 | 233 | 162 | 132 | 162 |
| SMUD | 1,194 | 464 | 322 | 263 | 322 |

These results align with general expectations that the highest savings occurs in the SCE service area which includes the T24 climate zones (Table 12) with the highest cooling degree days (CDD) – specifically CZs 9, 14,

[26] DNV (2021). "2019 California Residential Appliance Saturation Study (RASS)." CEC-200-2021-005-MTHLGY.pdf. Page 88, Table 36, tabulation of T24 climate zones covered by sample for each utility.

and 15 - as shown in the Appendix B climate zone discussion. Conversely, the lowest savings potential is for the SDG&E forecasting zone, which predominately covers the city of San Diego (CZ 7) where the CDD reflects more moderate cooling requirements.

A limitation of this study is the use of simple averages in estimating energy savings across forecasting zones that cover a range of geographies and climate zones. For example, the PAMA study estimates a 72% reduction in household cooling energy use for adjustable awnings in climate zone 3 (represented by San Francisco), which is based on an estimated 119 kWh of energy use for cooling, annually.[27] Averaging the savings potential of a technology results in an equal weighting, and potentially inflates savings for other regions. A comprehensive study is needed to develop a refined potential savings for EWS devices across California's climate zones.

## Recommendations

Based on the results of the literature review and energy savings analysis, we recommend continued research into the savings potential for the technologies summarized and discussed in Table 15.

Table 15. Exterior Window Shading Devices Recommended

| Recommend | EWS Device Type | Justification |
|---|---|---|
| Yes | Adjustable Awnings | Recommendable features include adjustability, potential to cover the entire window, can install post-construction, and more accessible price points for residents. Adjustable EWS devices cost more than fixed devices. |
| | Solar Shades | |
| No | Solar Screens | While saving estimates from literature are high, these are not recommended due to being fixed devices. |
| | Fixed awnings | Not recommended due to being non-adjustable. |
| | Canopies | Not recommended due to anticipated high cost of a site-built structure, especially adjustable versions. |
| | Patio covers | |
| | Rolling Shutters | Not recommend since we did not locate any comprehensive studies covering these devices and their potential savings. |
| | Blinds | |
| | Vertical/Horizontal Fins | Not recommended due to high cost, lack of ability to be installed post-construction, and being a fixed device. Additionally, low savings estimates from literature were found for overhangs. |
| | Overhangs/Sidefins | |

The recommended EWS devices with the highest potential energy savings are adjustable drop-arm awnings and solar shades. Within the adjustable awning category, there are many different types such as drop arm, retractable, and marquisette. The studies in our literature review modeled drop arm awnings, so that is the adjustable awning variety that we recommend be pursued for deemed measure development.

These two devices are recommended because they are adjustable and completely cover or expose a window. The market and literature review indicated a strong trend in consumers' preference for controlled EWS devices, that is, those EWS devices that can be operated manually, through remote controls, or even via phone apps or smart home controls. Both adjustable awnings and solar screens come in operable versions. Finally,

[27] Professional Awning Manufacturers Association (2012). "The Impact on Energy Use and Peak Demand of Awnings and Roller Shades in Residential Buildings."

both devices can be installed post-construction though adjustable EWS devices are typically much more expensive than their fixed counterparts.

Solar screens and fixed awnings are not recommended because they are fixed devices. A fixed device may make sense in one of California's arid climate zones with high CDDs but is not a recommended statewide approach. Canopies and patio covers are not recommended due to their high cost. The price does not make sense for a statewide approach especially when compared against our recommended EWS devices. We cannot speak to rolling shutters and blinds since we did not locate any comprehensive studies covering these devices and their potential savings. In addition to their high cost, vertical and horizontal fins as well as overhangs and sidefins can only be added during construction so they are not viable options for existing homes in California.

# 6. EWS Measure Package Development

The original objective of this assessment was to determine if a larger study to inform deemed measure package (work paper) development for EWS measures was warranted. However, our conclusion is that the savings and potential from this assessment are sufficient to support development of an EWS measure, although there are some elements as identified below that will require additional data development. Due to the DEER Update process moving to a two-year cycle, the earliest an EWS measure could likely be implemented is the 2026-2027 program cycle.

Some of the external studies we leveraged used building simulation modeling of energy performance for exterior window shading devices based on the device's unique passive or dynamic characteristics and operation. The methodology used in these studies can serve as a roadmap for a more comprehensive study for California. The study could use either the latest DEER residential EnergyPlus-based prototypes being developed[28], or the CEC's CBECC-Res software tool and building prototypes.

While we were only able to conduct a single market interview due to the short timeframe for this study, it confirmed a key point and common observations by anyone who lives in California. There is currently limited use of EWS devices by California homeowners, and when they are used, it is more to address non-energy issues such as esthetics, glare, and spaces overheating from solar exposure. This situation offers a potentially huge opportunity for EWS measures, if the right device or devices and approach can be developed.

Development of a deemed EWS measure package should consider and include these key elements:

- Develop Adjustable Awnings and/or Solar Screens for deemed measure. From our limited research, these two EWS devices show the most potential for energy savings, and because they are adjustable, it may be possible to also use them for peak demand reduction. However, a more extensive, detailed and robust cost assessment and savings analysis using building simulation tools would better inform this decision. Conversations with the IOUs and California Technical Forum (Cal TF), the primary entities responsible for the eTRM and new measure development, and other stakeholders would help determine the receptivity to EWS measures and also leverage any past experience with these or similar measures.
- EWS device savings are orientation-limited and customized for each home. As demonstrated by other exterior-applied window shading measures like window film and solar screens, applying these devices as energy efficiency or peak demand measures is limited to specific orientations, and the devices need to be custom-sized for each home and location. For example, savings can typically only be claimed for

[28] California Public Utilities Commission (2022). "DEER 2020." Retrieved from https://cedars.sound-data.com/deer-resources/deer-versions/2020/

specific window orientations (S, W, E), but windows are oriented in a range of actual orientations (NW, SSW, SE, etc.). In addition, the actual EWS device performance can vary significantly based on the home design and features of the EWS device, especially how it is controlled and operated by the occupants. A house on the coast with West-facing windows would not likely want to obstruct their view of the sunset in exchange for reduced energy consumption, though if controllable it could also be programmed to shield from the sun until just before sunset satisfying both objectives.

- Response to more heat waves and electrification of space heating. Although EWS measures are much more applicable and effective for high-cooling climate zones, climate change and increasing summer heat waves across *all* climate zones could make them effective for low and moderate cooling climate zones as well, which is an important consideration as heat pump electrification adds cooling capability to all homes in California. With the statewide push for electrification via heat pumps, EWS impacts on space heating should also be considered, though adjustable EWS devices can eliminate that concern.

- Use building simulation prototypes to assess energy and peak demand impacts. This initial high-level assessment supports EWS deemed measure development but using a building energy modeling (BEM) prototype approach to model the desired EWS measures and scenarios with the latest California TMY weather (CZ2022), and for all Title 24 climate zones will better estimate potential cooling energy *and peak demand* impacts. Space heating impacts (typically increased heating use) can also be assessed which will be more important as electrification occurs. Since deemed measures typically use the DEER prototypes, it would be best to use the updated residential models when they are publicly available. However, if there is a delay in availability of the DEER prototypes, then CEC CBECC-Res prototypes could be used instead.

- Investigate climate change weather impacts. Every year since 2016, the annual average temperature has been warmer, there have been more and longer heat waves, and the heat waves are extending from traditional summer months into the fall. Given these conditions, it may be worthwhile to look at cooling savings for actual year weather data in addition to normal year (CZ2022) weather data, especially now that actual year weather data is readily available from the California Measurement Advisory Council (www.calmac.org). However, current, official DEER policy is to use savings for normal year weather data (CZ2022).

- Conduct more manufacturer interviews to better characterize the EWS market. A more complete characterization of the targeted EWS measures in California could be obtained by enlisting the assistance of the Window Covering Manufacturers Association (WCMA) and other groups such as the Professional Awning Manufacturers Association (PAMA). The survey form developed for this study can be used as-is or further refined to focus on EWS measures with the best potential.

- Develop measure costs and cost-effectiveness. This study primarily focused on characterizing the EWS device types and energy savings potential, so only rough, relative estimates of costs were obtained by that process. However, cost effectiveness is a key element of deemed measures, so a more extensive, robust, and citable source of costs would need to be developed for the measure package development. An explicit description of each EWS measure's features and characteristics are also needed so that it can be used as a consistent cost basis for EWS costs. The measure description is also a key element of the measure package and would also be used for measure eligibility requirements.

- Establish existing EWS baselines in target Title 24 CZs. Our initial assessment and general intuition indicate that EWS measures will be more effective in regions with higher temperatures and clear skies during the Summer and Fall. A survey of market actors on-the-ground in these regions – such as building departments, contractors, home builders, etc. - could help establish how often these devices are already being used, as well as reveal some useful application and operation insights for developing a deemed measure. In addition, EWS devices may already be required in some areas by local energy code requirements or practice.

- Consider Rolling Shutters for energy and as a Demand Response (DR) option. Although rarely used now, controllable rolling shutters which offer maximum solar control and the bonus of privacy as home density continues to increase, should also be explored as a deemed measure. Operable rolling shutters applied to West and South-facing windows were not one of our recommended options because they were not included in any of the studies found by the literature review. However, they can 100% block the solar gains and could be used to *actively* reduce cooling energy use during summer peak demand periods and could possibly even be used as a demand response option.

# Appendix A. Literature Review Sources

Pacific Northwest National Laboratory (2020). “Evaluation of Exterior Shades at PNNL Lab Homes and Occupied Field Sites.” PNNL-30536. Retrieved from https://www.osti.gov/biblio/1785962-evaluation-exterior-shades-pnnl-lab-homes-occupied-field-sites-final-report

Department of Energy (2013). “Residential Windows and Window Coverings: A Detailed View of the Installed Base and User Behavior.” Retrieved from https://www.energy.gov/eere/buildings/downloads/residential-windows-and-window-coverings-detailed-view-installed-base-and

Department of Energy (2014). “Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies.” Retrieved from https://www.energy.gov/eere/buildings/articles/research-and-development-roadmap-windows-and-building-envelope

Lawrence Berkeley National Laboratory (2013). “Energy Savings from Window Attachments.” DOE/EE-0969. Retrieved from https://www.energy.gov/eere/buildings/downloads/energy-savings-window-attachments

Professional Awning Manufacturers Association (2012). “The Impact on Energy Use and Peak Demand of Awnings and Roller Shades in Residential Buildings.” Retrieved from https://www.retractableawnings.com/retractableawnings/university/energy-studies/PAMA_Energy_Study_August_2012.pdf

University of Texas at Austin (1987). “Energy Savings Resulting from Shading Devices on Single Family Residences in Austin, Texas.” Proceedings of the Fourth Symposium on Improving Building Systems in Hot and Humid Climates, Houston, TX, September 15-16, 1987

Kim, Gon, Lim H.S., Lim T.S., Schaefer, L., Kim, J., (2012). “Comparative Advantage of an Exterior Shading Device in Thermal Performance for Residential Buildings.” Energy and Buildings, vol. 46, 2012, pp. 105–111., https://doi.org/10.1016/j.enbuild.2011.10.040.

Dutta, Arindam, Samanta, A., and Neogi, S. (2017). “Influence of orientation and the impact of external window shading on building thermal performance in tropical climate.” Energy and Buildings, vol. 139, 2017. Pp. 680-689., https://doi.org/10.1016/j.enbuild.2017.01.018.

# Appendix B. Climate Zones and Regions

This appendix provides a description and maps for the multiple California-specific and national climate zones, weather stations, and regions referenced in this study.

California's sixteen Title 24 climate zones used for energy efficient building code compliance are presented in Figure 2.[29] Table 16 summarizes the representative cities and heating and cooling degree days for each climate zone.

Figure 2. Title 24 Standards Building Climate Zones


*Source: Pacific Gas and Electric "Guide to California Climate Zones."*

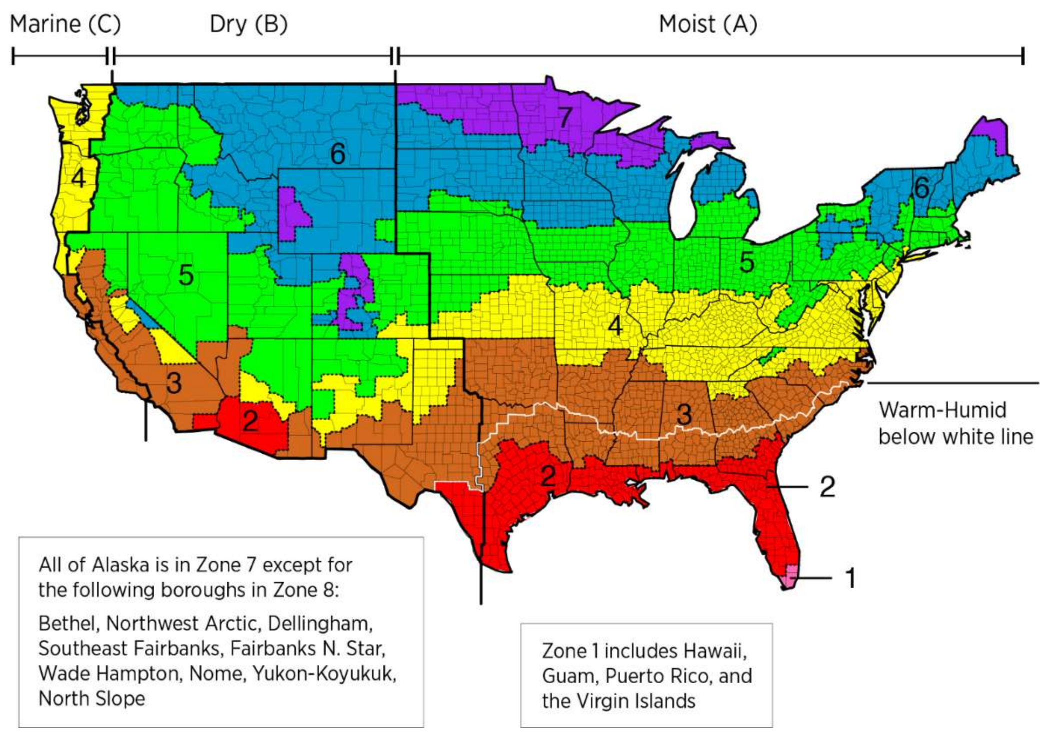
Table 16. Title 24 Climate Zone Representative Cities and Heating and Cooling Degree Days [29]

| Zone – Representative City | HDD | CDD | Zone – Representative City | HDD | CDD |
|---|---|---|---|---|---|
| 1 – Eureka | 4469 | 0 | 9 – Los Angeles (Civic Center) | 1154 | 1398 |
| 2 – Napa | 2844 | 456 | 10 – Riverside | 1678 | 1456 |
| 3 – San Francisco | 3042 | 108 | 11 – Red Bluff | 2688 | 1904 |
| 4 – San Jose | 2335 | 574 | 12 – Stockton | 2702 | 1470 |
| 5 – Santa Maria | 2844 | 456 | 13 – Fresno | 2702 | 1470 |
| 6 – Los Angeles | 1458 | 727 | 14 – Barstow | 2581 | 4239 |
| 7 – San Diego | 1256 | 984 | 15 – Brawley | 1106 | 6565 |
| 8 – Long Beach | 1430 | 1201 | 16 – Bishop | 4313 | 1037 |

[29] Pacific Gas and Electric (2022). "Guide to California Climate Zones." Retrieved from https://www.pge.com/myhome/edusafety/workshopstraining/pec/toolbox/arch/climate/index.shtml

The International Energy Conservation Code (IECC) defines the climate zones widely used in national appliance and non-California building energy standards.[30] The U.S. IECC climate zones are illustrated in Figure 3. This climate zone definitions were used in several of the national studies found in our literature review.

Figure 3. IECC 2012 Climate Zones[31]




*Source: International Code Council "2012 International Energy Conservation Code."*

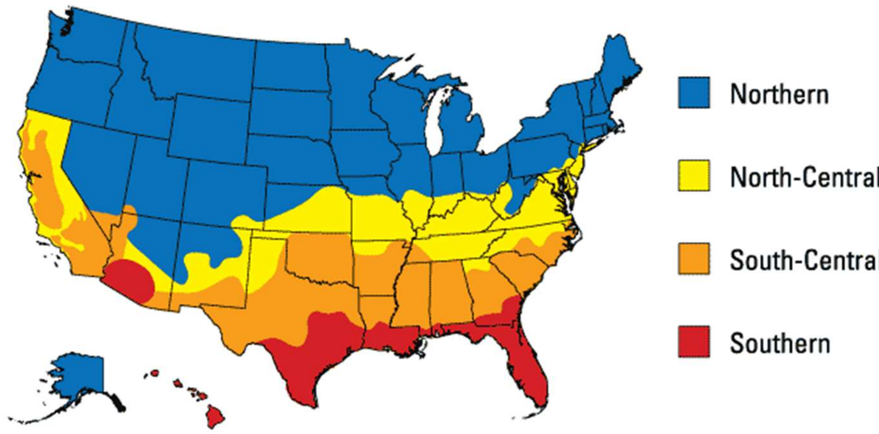
ENERGY STAR developed climate zones specifically for use in defining energy performance standards for windows, doors, and skylights.[32] The four climate zones are developed in part from IECC 2012 climate zones, and include the Northern, North-Central, South-Central, and Southern regions illustrated in Figure 4.

[30] International Code Council (2011). "2012 International Energy Conservation Code." ISBN: 978-1-60983-058-8

[31] Image retrieved from PNNL website at https://basc.pnnl.gov/images/iecc-climate-zone-map

[32] Environmental Protection Agency (2015). "ENERGY STAR Product Specification for Residential Windows, Doors, and Skylights Eligibility Criteria." Version 6.0

Figure 4. ENERGY STAR Climate Zones for Windows, Doors, and Skylights[33]




*Source: ENERGY STAR website at www.energystar.gov*

The California Forecasting Climate Zones are illustrated in Figure 5 and summarized in Table 17.

Figure 5. Map of California 2021 Forecasting Climate Zones[34]


*Source: CEC GIS tool at www.cecgis-caenergy.opendata.arcgis.com*

[33] Image retrieved from ENERGY STAR website at www.energystar.gov/sites/default/files/asset/document/Promotional_Map.pdf
[34] Forecasting zone map created from California Energy Commission data at www.cecgis-caenergy.opendata.arcgis.com

Table 17. List of California Forecasting Climate Zones and the Utility Planning Area[35]

| FZ # | FZ Name | Utility | FZ # | FZ Name | Utility |
|---|---|---|---|---|---|
| 1 | Greater Bay Area | PG&E | 11 | Eastern | SCE |
| 2 | North Coast | PG&E | 12 | SDG&E | SDG&E |
| 3 | North Valley | PG&E | 13 | SMUD Service Territory | SMUD |
| 4 | Central Valley | PG&E | 14 | Turlock Irrigation District | NCNC |
| 5 | Southern Valley | PG&E | 15 | Rest of BANC Control Area | NCNC |
| 6 | Central Coast | PG&E | 16 | LADWP Coastal | LADWP |
| 7 | LA Metro | SCE | 17 | LADWP Inland | LADWP |
| 8 | Big Creek West | SCE | 18 | Burbank/Glendale | Burbank/Glendale District |
| 9 | Big Creek East | SCE | 19 | Imperial Irrigation District | Imperial Irrigation District |
| 10 | Northeast | SCE | 20 | Valley Electric | Valley Electric |

[35] Data sourced from the California Energy Commission geographic information system at www.cecgis-caenergy.opendata.arcgis.com

# Appendix C. Percent Cooling Savings Method – LBL 2013 Study

Our goal was to create a percent annual cooling savings in kWh estimate from the data available in the LBL 2013 study. To do this, we used, Figure 6 (Figure 23 from the study) which depicts the annual heating and cooling energy end-uses by EWS type (including a control with no EWS installed) for the modeled prototype home they created. The units of the bar graph is gigajoules (GJ).

We then created a scale in inches to accurately pull values from this bar graph that enabled us to create a ratio of GJ to inches. We could then measure the portion of the bar graph colored for cooling end-use to get the value of cooling end-use in GJ. This method was verified against the values in Figure 7 (table 30 of the LBL 2013 study).With our verified method, we subtracted from one the quotient of the measured GJ for the EWS device type by the measured GJ for the control situation with no EWS installed to yield a percent savings of the EWS device type. Please see below for the equation described above:

$$PercentCoolingSavings_{EWS\ Device} = 1 - (Cooling\ Energy_{Ews\ Device} / Cooling\ Energy_{Control})$$

Figure 6. LBL Study 2013 – Cooling Enduse by EWS Device

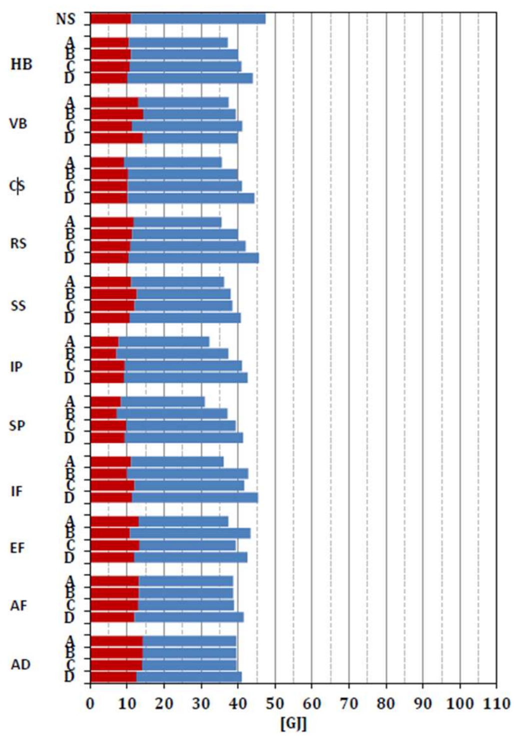



Figure 23. South Zone Weighted Deployment Schedule Grouped by Shade Category

| | | | |
|---|---|---|---|
| HB | Horizontal Louvered Blind | IP | Interior Window Panel |
| VB | Vertical Louvered Blind | SP | Storm Panel |
| CS | Cellular Shade | IF | Interior Applied Film |
| RS | Roller Shade | EF | Exterior Applied Film |
| SS | Solar Screen | AF | Fixed Awning |
| | | AD | Drop-arm Awning |

Heating
Cooling

Figure 7. LBL Study 2013 – Total Energy Savings by EWS Type

Table 30. Double Clear Glazing -Total Energy Savings [GJ] Compared to an Un-Shaded Baseline for All Attachment Types in a House With Slab, Gas Heating, and Electric A/C, for Four Attachment Qualities (A, B, C, D).

| Location | Attachment Type | A | B | C | D |
|---|---|---|---|---|---|
| Phoenix | HB | 10.2 | 7.4 | 6.5 | 3.4 |
| Phoenix | Vertical Blind | 10.0 | 8.0 | 6.2 | 7.5 |
| Phoenix | Cellular Shade | 11.8 | 7.6 | 6.3 | 2.9 |
| Phoenix | Roller Shade | 11.8 | 7.5 | 5.4 | 1.8 |
| Phoenix | Solar Screen | 11.2 | 9.4 | 8.9 | 6.6 |
| Phoenix | Interior Window Panel | 15.1 | 10.0 | 6.3 | 4.8 |
| Phoenix | Storm Window | 16.4 | 10.2 | 8.1 | 6.0 |
| Phoenix | Interior Applied Film | 11.3 | 4.6 | 5.7 | 2.0 |
| Phoenix | Exterior Applied Film | 10.0 | 4.0 | 8.0 | 4.8 |
| Phoenix | Fixed Awning | 8.7 | 8.7 | 8.5 | 5.8 |
| Phoenix | Droparm Awning | 7.8 | 7.8 | 7.8 | 6.4 |

# Appendix D. Links to Municipal and Publicly-Owned Utility Rebate Programs

Pro Replacement Windows. "California Rebates 2022." Retrieved from https://www.proreplacementwindows.com/california-window-rebates/

Campbell Window Film. "Top 21 Energy Efficient Window Rebates in California." Retrieved from https://campbellwindowfilm.com/energy-efficient-window-rebates-california/

City of Azusa. "Residential." Retrieved from https://www.ci.azusa.ca.us/519/Residential

City of Lodi. "Residential Rebates." Retrieved from https://www.lodi.gov/909/Residential-Rebates

Modesto Irrigation District. "MID Home Rebates." Retrieved from https://www.mid.org/rebates/home/default.html

City of Roseville. "Sunscreen Rebates." Retrieved from https://www.roseville.ca.us/cms/one.aspx?portalId=7964922&pageId=8894884

Turlock Irrigation District. "Heating, Cooling & Sun Screens." Retrieved from https://www.tid.org/customer-service/save-energy-money/heating-cooling-sunscreens-rebates/

# Appendix E. Manufacturer and Retailer Website Links

Insoroll. “Exterior Sun Shades for Windows and Doors.” Retrieved from https://insolroll.com/exterior-sun-shades/

EZ Snap. “Exterior Window Sun Shades – DIY Kits.” Retrieved from https://ezsnapdirect.com/products/exterior-window-shades/

The Awning Company. “About Us.” Retrieved from https://theawningcompanyca.com/awning-company-awnings-awnings-orange-county-awnings-san-diego/

Sun Control Products. “SOLAR SUN SCREENS AND SHADES | SAN DIEGO.” Retrieved from https://suncontrolproducts.com/solar-sun-screens-and-shades-san-diego/

Accent Awning Company. “CALIFORNIA ENERGY STUDY.” Retrieved from https://www.accentawnings.com/ca-energy-study/

Enviroblind. “Exterior Solar Shades Shade Screens.” Retrieved from https://www.enviroblind.com/exterior-solar-shades/

Hartley Window Coverings. “Exterior vs. Interior Window Coverings: Which Is More Effective to Reduce Heat?” Retrieved from https://www.hartleywindowcoverings.com/blog/effective-reduce-heat-exterior-or-interior-window-coverings

European Rolling Shutters. “Retractable Solar Screens.” Retrieved from https://www.ersshading.com/retractable-solar-screens

Diversified. “EXTERIOR SHADING - Window Treatment Services for Restaurants, Businesses, and Homes in Southern California.” Retrieved from https://www.divwin.com/exterior-shading/

Blinds & Designs. “Outdoor Exterior Shades - Roller Shades.” Retrieved from https://blindsdesigns.com/outdoor-exterior-shades/

Master Blinds. “EXTERIOR SHADES.” Retrieved from https://www.master-blinds.com/exterior-shades

JustBlinds. “Outdoor Shades.” Retrieved from https://www.justblinds.com/outdoor-shades

Intertrade. “Welcome to Inter Trade Inc.” Retrieved from https://www.intertradeincorporated.com/

Goodwin. “Outdoor Roller Shades.” Retrieved from https://www.goodwincole.com/residential/outdoor_shade_residential/outdoor_roller_shades_residential/

Goodwin. “Energy Efficiency.” Retrieved from https://www.goodwincole.com/energy_efficiency/

Screens of Norcal. “Transform your home.” Retrieved from https://www.screensofnorcal.com/

High Desert Mobile Screens. “High Desert Mobile Screens.” Retrieved from https://hdmobilescreens.com/

<u>Window Manufacturer Trade Organizations:</u>

Window Covering Manufacturers Association (WCMA). https://windowcoverings.org/

Professional Awning Manufacturers Association (PAMA). https://awnings.textiles.org/

# Appendix F. Manufacturer and Retailer Interview Guide

Q1. Does your company sell residential EWS devices in California?

Q2. From reviewing your website, I noted that your company sells [PRODUCTS]. Can you confirm my list includes all exterior window shading devices your company sells within California?

Q3. What is your position within the company?

Q4. Who would you describe as your typical residential customer? IF UNCLEAR, OFFER EXAMPLES

1. Single-family?
2. Multifamily customers?
3. Homeowner/renter
4. Landlord?
5. Homebuilder?

Q5. Does your company sell to retailers like Home Depot, Lowe's, etc?

## Market Assessment

Q6. Regionally, what is your market or markets?

Q7. Which regions buy the most? Buy the least?

Q8. Are there any region-specific issues your company faces?

Q9. What percentage of your company sales does each EWS device make up?

1. What percent split do you see between operable/smart and fixed options?

Q10. What is your company's share of the total CA residential EWS market?

1. Could you specify CA residential EWS market by each specific EWS device?

## Barriers & Drivers

Q11. What market barriers does your company face?

Q12. How does your company overcome these barriers?

Q13. What motivates customers to buy your products?

Q14. How could homeowners be more motivated to adopting products like yours?

Q15. What company strategies are currently driving your market?

Q16. Are there common strategies applied industry-wide?

## Energy Savings

Q17. Are you familiar with the energy savings claimed on your company's website?

Q18. Does your company have any California-specific savings estimations? Percent of cooling/heating reduction due to your product installed?

1. Your company claims ________. Could you share how your company arrived at that figure?

Q19. Are there any key studies your company contributed or relies on to substantiate claimed savings in your marketing materials?

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