Commercial Windows Market Study and Measure Package Development

Final Report

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Executive Summary

The Commercial Windows Market Study and Measure Package Development project seeks to characterize the California commercial windows market, understand the barriers to the widespread use of high-performance windows in commercial buildings, and draft a deemed savings measure package for California's electronic Technical Resource Manual (eTRM). The study will include primary research through market interviews and analyses of secondary sources to generate actionable recommendations for increasing the number of high-efficiency window projects in California's investor-owned utility (IOU) service area. In addition, this market study will model savings potential for California's 16 climate zones and address commercial barriers for new construction, retrofits, and secondary window projects.

There are currently no incentivized deemed savings measure packages for high-performance windows in commercial buildings in California. The first step towards assessing the potential for a deemed measure for high-performance commercial windows is to understand the market potential for such a measure. The market study portion of this project seeks to develop a deeper understanding of the commercial buildings market for high-efficiency window products and illuminate the reasons for the low adoption levels of high-performance windows in the commercial sector. The report provides an estimate total market size and percent of market sales for each type of commercial window measure as well as an economic analysis of window measures available to each commercial building participant in all California IOU service areas. Lastly, this report details a draft measure package to be submitted to the California Technical Forum (Cal TF) along with an overview on Energy Solutions' considerations for a commercial windows incentive program design that includes education components and hard- to-reach customers and disadvantaged community (HTR/DAC) considerations.

Summary of Key Market Study Findings

1. Cost, education, a lack of incentive programs, and code flexibility and enforcement are major barriers to the adoption of high-performance windows.
2. Full commercial window replacements are rare. Secondary window attachments are a more feasible retrofit option for commercial buildings.
3. Technology advancements in the commercial window industry have primarily been on the window glass and not on the window frame.
4. Windows are not viewed by customers or policymakers as an important source of a building's energy savings.

Abbreviations and Acronyms

Acronym	Meaning
CA	California
CBO	Community Based Organization
DAC	Disadvantaged Communities
EE	Energy Efficiency
GHG	Greenhouse Gas
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor-Owned Utility
kWh	Kilowatt-hour
PG&E	Pacific Gas & Electric
SCE	Southern California Edison
Therms	Gas (often in the context of savings)
TPM	Technology Priority Map

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Introduction

Commercial windows cover a large swath of nonresidential buildings such as offices, retail, stores, hotels, and more. Windows serve multiple non-energy and energy purposes in nonresidential applications. Non-energy benefits can include aesthetics, natural light, ventilation, and noise control. Energy benefits of windows can include improved heating and cooling efficiency which impact overall building energy performance. Commercial windows are available in a variety of styles, materials, and systems to meet the architects' design of the building.

This report presents findings from a commercial windows market study conducted by Energy Solutions. Energy Solutions interviewed regional, California statewide, and national market actors to understand high-performance window sales trends, new and emerging technologies, and barriers to adoption. Additionally, this report contains an overview of the total market size of commercial windows, an economic analysis of window measures available in California investor-owned utilities' (IOU) service areas, recommendations for a program delivery model and finally, details on the windows measure package Energy Solutions plans to submit to the California Technical Forum ("CalTF").

Common window systems and frame options are listed below.

Common Window System Terms

Operable – Windows that can be opened and closed mechanically.

Fixed – Windows set in the closed position that cannot be opened.

Curtain Wall – A thin nonstructural wall that is attached to the exterior of the building and supports only its own weight. Often, curtain walls are made of glass but not always.

Window Wall – A large section of glass installed between floors, typically used in large areas, to maximize sunlight.

Panes of Glass – "Pane" refers to the sheets of glass in the window system and can be single, double, or triple. If more than one pane exists, it can be filled with a gas to increase overall efficiency of the window.

Window Films and Coatings- Coatings are an extremely thin clear film that is added to the glass' surface to achieve desired operational outcomes. These outcomes range from energy savings to security to glare reduction.

Secondary Windows – A window attachment fitted to the interior or exterior of an existing, primary window for quick installation, often resulting in improved occupant comfort, health, and wellness, while reducing heating and cooling energy use.

Thermally Broken Window– A window where the interior and exterior sides are joined by an insulated barrier (or "break") that is designed to inhibit conductive thermal energy loss.

Common Window Frames

Aluminum – Widely used for their durability, strength, weather resistance and design flexibility. The most common material used for commercial window frames despite its high thermal conductance.

Vinyl – Low maintenance, cost-effective and high thermal performance.

Wood – Traditional look, with natural insulation properties.

Deliverables of this report include the following:

1. **Market Overview:** Energy Solutions interviewed market actors and industry experts to gain an understanding of commercial window sales trends, emerging technologies, supply chain, key drivers and decision-makers, and barriers to adoption of high-efficiency windows. These interviews fill in data gaps in industry and secondary data sources. Additionally, the Energy Solutions team conducted detailed research into the market and policy landscape. Through this research, the team developed an understanding of the distinct interests, motivations, and positions of various groups in the commercial window sector.
2. **Customer Journey and Value Chain:** Using the data collected from the market actor interviews, the project team created a supply chain map and incentive layering strategies. The supply chain map details the journey from manufacturer to customer, customer journey maps for new construction, retrofit, and secondary window projects. The incentive layering strategies detail complementary existing and future funding sources for commercial windows. The project team also provides a methodology for analyzing window projects in combination with mechanical and electrical upgrades used for electrification projects.
3. **Market Sizing and Potential** - Energy Solutions requested detailed sales and shipment data from window distributors and manufacturers supplying building projects. Energy Solutions also reviewed the statewide construction forecast from the California Energy Commission. This data was analyzed to estimate total market size and percent of market sales for each type of window measure.
4. **Economic Analysis** - Working with the data collected, Energy Solutions performed a detailed cost analysis for window measures available to each commercial building participant in all California IOU service areas.
5. **Program Delivery Model** - Energy Solutions developed recommendations for a practical program delivery model for primary and secondary high-performance commercial windows that aligns with and incorporates California IOU's goals.
6. **Measure Package Development** – Energy Solutions is compiling a draft measure package to submit to the California Technical Forum (Cal TF) for approval. The market characterization provides some of the information required for measure package development, such as baseline efficiency, measure efficiency, incremental measure cost, and savings. The measure package development also includes all required measure package information, such as eligibility requirements, measure application types, applicable program delivery models, and data collection requirements. Energy modeling software was utilized as part of

the energy savings analysis, and the DEER Commercial Building Prototypes will be utilized once they are approved by the California Public Utility Commission.

Summary of Key Findings

- Cost, education, a lack of incentive programs, and code compliance are major barriers to the adoption of high-performance windows.
- Full commercial window replacements are rare. Secondary window attachments are a more feasible retrofit option for commercial buildings.
- Technology advancements in the commercial window industry have primarily been on the window glass and not on the window frame.
- Windows are not valued by customers or policymakers as a viable source of generating building energy savings.

Background

Windows can be a significant source of heat gain and loss. Research estimates windows account for 30 to 45 percent of envelope heat transfer. The good news is, the commercial windows market has experienced tremendous growth due to market emphasis on energy efficiency and sustainability coupled with an increase in commercial building remodeling and renovations. Due to this increased demand, there have been technological advancements with the development of high-efficient windows, glazing systems, thermal performance, sound insulation and enhanced visual appeal.

However, even with an uptick in demand, the adoption of these new technologies is slow and there are currently no deemed savings for high-performance windows for commercial buildings in California. Energy Solutions conducted a market study to develop a deeper understanding of the commercial buildings market for high-efficiency window products. The information gathered in this study will allow our team to develop a deemed measure package for consideration. The outcome will help provide guidance to California IOUs and hopefully spur greater adoption of high-performance windows.

Objectives

The main objectives of this study are to understand the market for high-performance windows in California, design a program delivery model that meets California IOU's goals, and provide the relevant information for a high-performance window deemed measure package.

"High-performance" is a broad term in the commercial windows industry. A standardized metric for commercial windows to be deemed highly efficient does not yet exist. As a first step, the study aims to define a maximum U-factor and Solar Heat Gain Coefficient ("SHGC") that classifies a window as high-performance. Once defined, the study attempts to chart product availability, existing incentives for these established high-performance windows and barriers to widespread market adoption through supply chain and customer journey mapping. By describing key-decision makers and their motivations, these maps strive to highlight the variability in purchasing high-efficiency windows between new construction, window replacement, and secondary windows. The study then provides

an overview of the total market size and an economic analysis for high-performance commercial windows. The study concludes with recommendations for a commercial windows program delivery model and an overview on relevant data for a high-performance commercial windows measure package.

Methodology & Approach

Leveraging relationships with trade associations such as the National Glass Association (NGA) and Partnership for Advanced Windows Solutions (PAWS), Energy Solutions gathered insight from industry experts. Through outreach to architectural firms, glass manufacturers, windows fabricators, glazers, and consultants, Energy Solutions solicited a wide array of market actors and industry experts to participate in interviews. With input from players across the supply chain, the market study provides an inclusive perspective on a complex industry.

To calculate market size and potential, Energy Solutions developed a preliminary market size utilizing data from the 2025 Nonresidential Envelope Codes and Standards Enhancement (CASE) Report developed by the California Statewide Codes and Standards Team. For the window measure cost analysis, Energy Solutions gathered cost data on multiple different product types and calculated the incremental measure cost by subtracting baseline efficiency cost from the measure case efficiency cost. For more information on the market size estimates and cost analysis methodologies, please refer to the respective sections.

Energy Solutions has experience developing practical program delivery models and utilized this experience, along with data collected from the market characterization, to create a program delivery model that incorporates the goals of the California IOUs. Likewise, for the measure package development, Energy Solutions drew upon experience as well as guidance from CalTF on obtaining the relevant information for a successful commercial windows measure package. For more information on the program delivery model and measure package methodologies, please refer to the respective sections.

Market Characterization Findings

This section features overviews of the commercial window industry including key market actors, the commercial windows supply chain, the customer journeys for new construction, retrofit replacement, and secondary window projects, as well as incentive pathways for commercial windows.

Market Actors and Key Decision-Makers

Typically, the key decision-makers in commercial window projects are the project owner (or customer), the architect, and the general contractor. A glazing consultant's involvement will depend on the size and scope of a project.

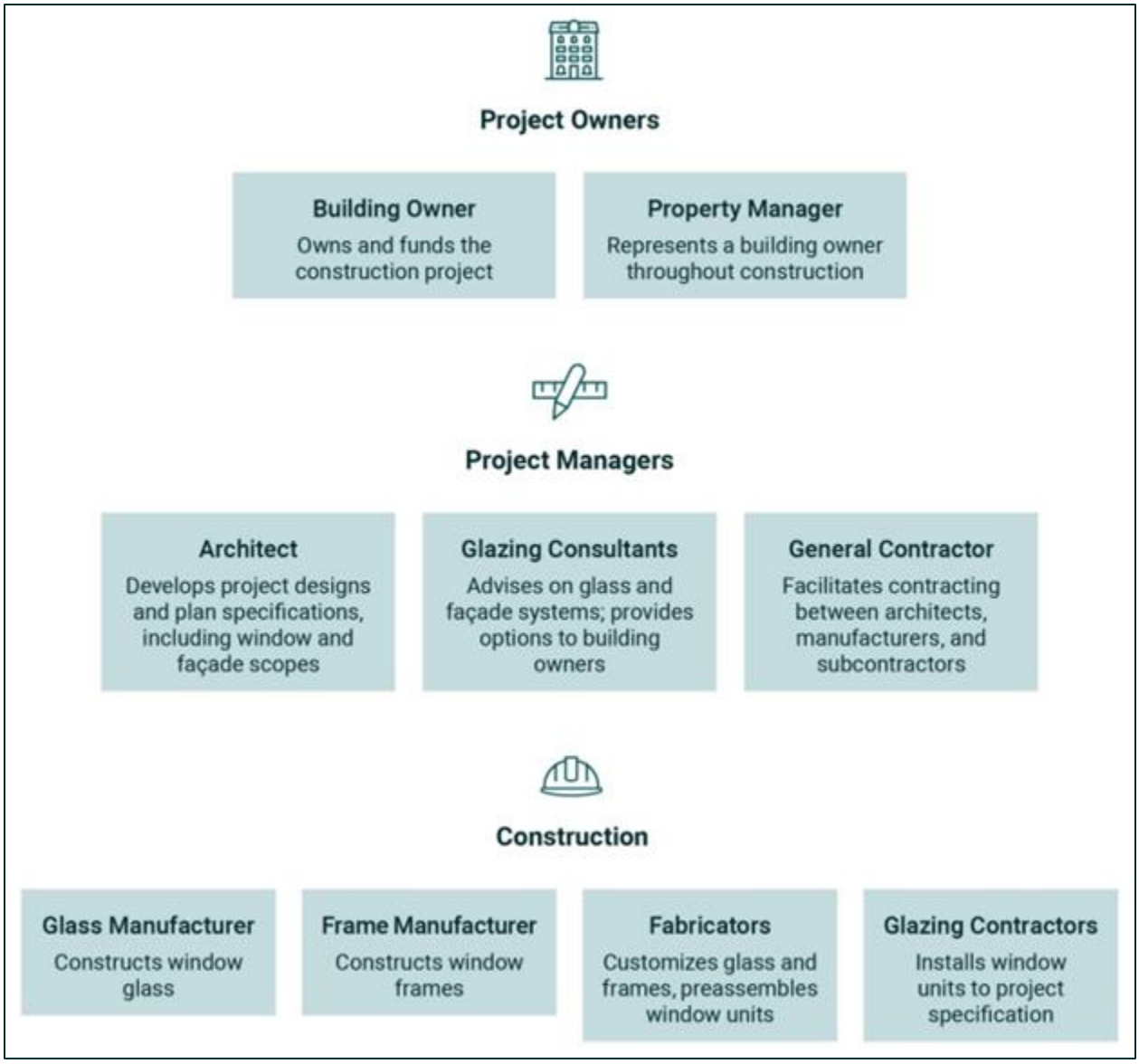


Figure 1: Market Actors and Key Decision-Makers

Supply Chain Map

The supply chain for high-performance commercial windows has great variability depending on the scope of the project. Factors impacting the supply chain process and timeline include building type, window design, location, and labor costs. As depicted in Figure 2, some glass manufacturers will cut and fabricate the window glass while others only cut the glass and then send it to a glass fabricator for customization. Sometimes the window glass and frame are assembled by the glazing contractor at the project site and other times, the window is assembled by window fabricators and shipped to the job site.

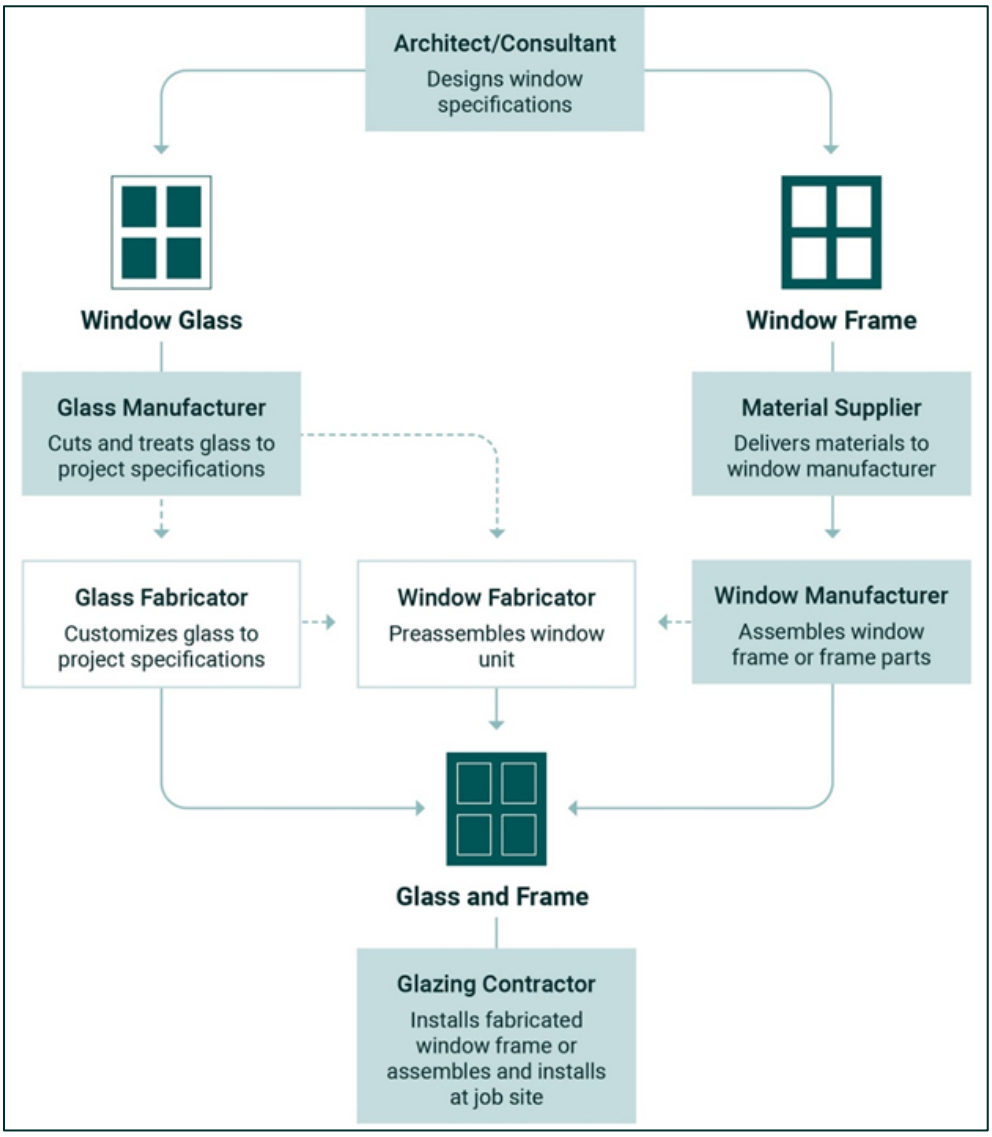


Figure 2: Commercial Window Supply Chain

Customer Journey Mapping

New Construction

Much like the supply chain, the customer journey is impacted by building type, window design, location, and labor costs.

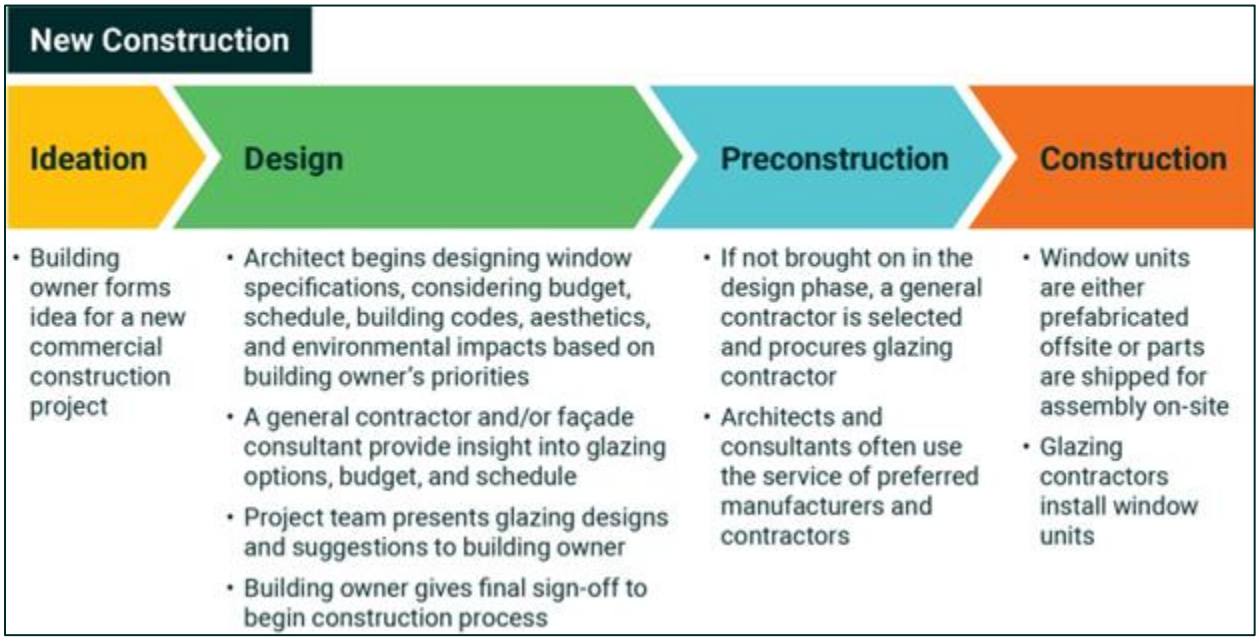


Figure 3: Customer Journey Map for New Construction Projects

Retrofit Replacement Window

Retrofit replacement windows are uncommon on a large scale due to the price and occupant disruption during installation. Energy savings from replacement windows rarely outweigh the costs.

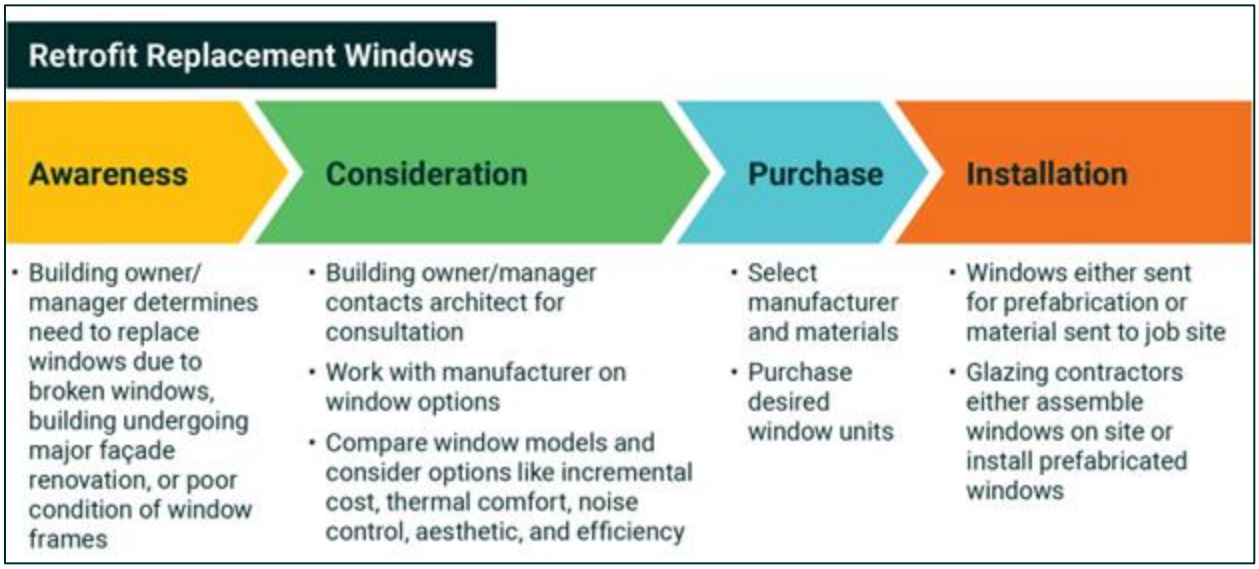


Figure 4: Customer Journey Map for Retrofit Replacement Window Projects

Secondary Windows

Retrofit secondary windows are gaining popularity as awareness of the benefits increases. The lower cost, energy savings, ease of installation, and reduced occupant disruption all make secondary windows appealing to building owners.

Figure 5: Customer Journey Map for Retrofit Secondary Window Projects

Window Project Timeline

New Construction and Retrofit Replacements

The sales timeline for high-efficiency commercial windows has a great degree of variability. The planning process for a new building typically takes between one and three years but can extend beyond that range by several years. The timeline of a project depends greatly on financing and permitting for the commercial building. This timeline includes budgeting, window design, and construction plan development. Typically, a greater project scale will translate to a longer timeline. After the window is commissioned, the manufacturer procurement process typically takes about one month. Then, the window is either prefabricated or materials are shipped to the site. This fabrication process can take two to six months. Finally, shipping and installation can take a couple of weeks or a few months depending on the size of the project and shipping delays.

The process for retrofitting replacement windows can look relatively similar but this will depend heavily on the size, type, and location of a building. Additionally, replacement window projects also tend to be building façade projects that include major renovations which will also impact the project timeline.

Secondary Windows

For secondary window projects, the timeline is significantly truncated compared to new construction or replacement projects. In total, secondary window projects are estimated to take around one year from start to finish. This one-year estimation includes the discovery phase in which a building owner will take two to three months to rule out alternative options such as a full window retrofit replacement and then an additional two to three months to research secondary window options. Once the pre-work has been completed and the secondary window order is in place, the process will move relatively

quickly depending on the building type and size. For a building owner who is already knowledgeable about secondary windows, the project timeline can be cut down by sixty to seventy percent.

Added-Value Opportunities

This section explores a building owner's opportunity to take advantage of multiple incentive pathways to reduce the overall cost of a commercial windows project. There are two potential opportunities to layer funding sources.

1. **179D energy-efficient commercial building deduction**. Currently the federal government offers a tax deduction for energy efficient commercial buildings up to $5/ft^2$. This deduction is offered for both new and existing buildings and can include installed projects such as lighting, HVAC, or building envelope (windows and roofs). For non-profit or state-owned buildings, the tax deduction can go to the design professional. For illustrative purposes it is assumed the buildings' deduction amount will be $0.63/ ft^2$. for a window replacement or retrofit, although this deduction could be significantly higher. The tax deduction is based on the total square footage of the building. The additional $5/ft^2$ deduction can be obtained depending on the modeled savings for the overall project.
2. **California IOU Incentives**. In anticipation of the deemed measure package being accepted into the eTRM, Energy Solutions expects the California IOUs will adopt a commercial windows incentive program for new construction, retrofits, and secondary windows. The recommended incentives for new construction, replacement and secondary windows are $4/ft^2$. $5/ft^2$ and $10/ft^2$, respectively. The proposed incentive amount is based off product economics and utility benchmarking. This is described in section Methodology. Incentive Levels.

Table 1 depicts potential overall benefit when incentives are layered together for secondary window installations, new construction or retrofit replacements. The following assumptions were made: a commercial building is 50,000 ft^2 and has a total of 7,500 ft^2 of window product installed. The building owner can receive both 179D tax deduction for the total building square footage and a California IOU sponsored incentive for square footage of windows installed.

Table 1: Commercial Windows Incentive Stacking

Measure Type	Utility Incentive	Tax Deduction	Total Incentives
New Construction	$30,000	**$31,500**	$61,500
Window Retrofit	$37,500	**$31,500**	$69,000
Secondary Windows	$75,000	**$31,500**	$106,500

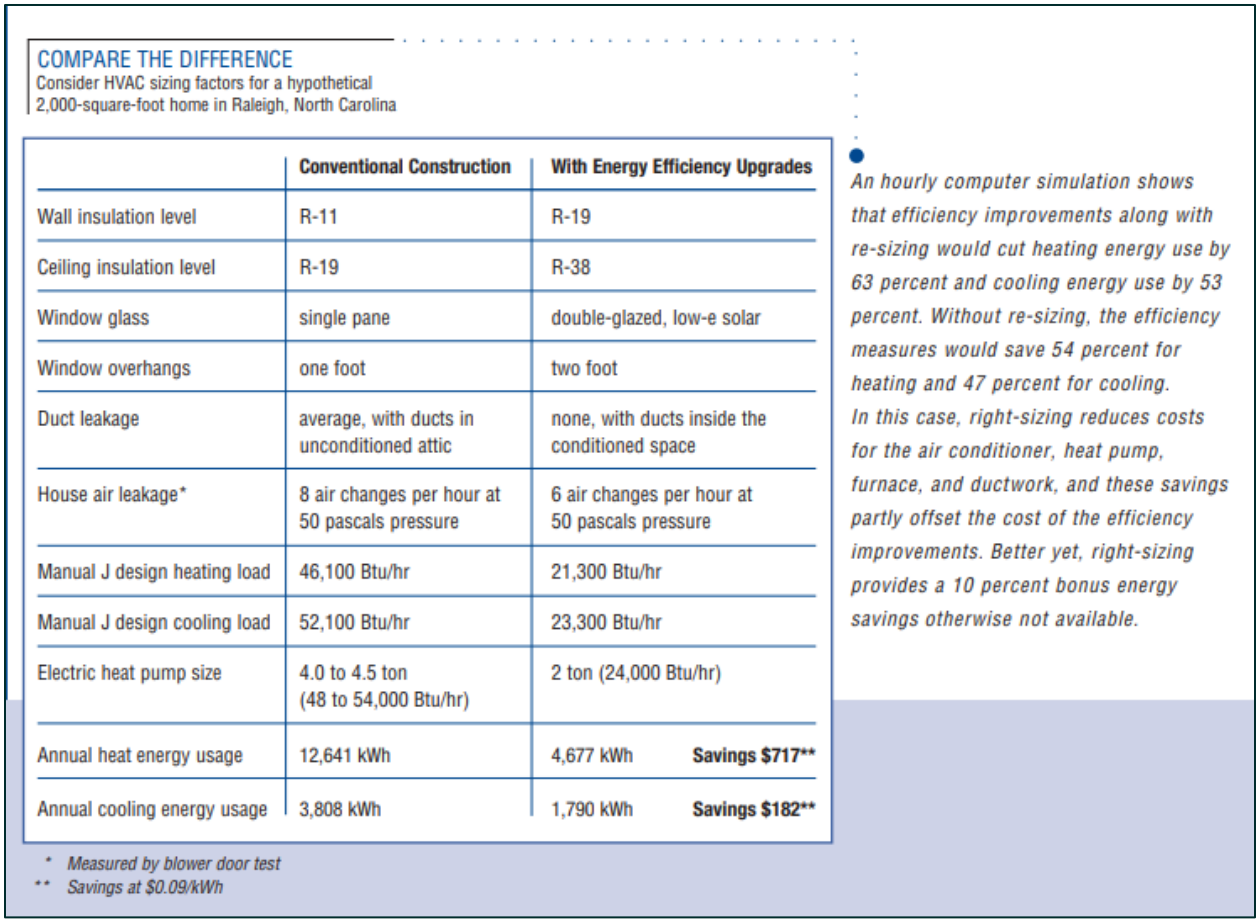
Total project costs are estimated and summarized in **Error! Reference source not found.** for a commercial building that has 7,500 ft^2 of window fenestration. These costs are generalized due to varying technology types and existing conditions. It was noted that installation costs for secondary

windows were not readily available. However, during interviews, industry partners noted that secondary window installation costs are significantly lower because they do not require a major building renovation or disposal of materials. Secondary windows are installed on the interior side of the window which eliminates the need for a specialized general contractor, scaffolding, cranes, faced replacement and other materials/equipment. While material for replacement windows could be potentially less as shown below, labor and installation costs are significantly higher in a replacement window project. It was noted by many stakeholders during our final review process that the costs of secondary windows could be anywhere from 20-50 percent lower than retrofits. Our research did not lead to that conclusion, which demonstrates the lack of information in the market regarding secondary windows.

Table 2: Estimated Project Costs

Construction Type	Material Cost	Labor Cost	Total Cost	Total Project Cost offset by incentive layering
Replacement Windows	$123,075	$175,000	$298,075	23%
Secondary Windows	$187,500	$75,000	$262,500	41%

Improvements to building envelopes such as high-performance windows or secondary windows help to reduce heating and cooling loads. This reduction in load can translate to a reduction in cooling equipment sizing, and a reduction in heating equipment sizing, both of which have potential to impact electrical panel sizing. The National Renewable Energy Laboratory (NREL) published a Technology Fact Sheet on right-sizing HVAC systems with building envelope. The figure below outlines the HVAC tonnage needed for a conventional and high-performance building envelope. The high-performance building envelope requires approximately half the HVAC tonnage needed for the conventional building envelope.



COMPARE THE DIFFERENCE

Consider HVAC sizing factors for a hypothetical 2,000-square-foot home in Raleigh, North Carolina

	Conventional Construction	With Energy Efficiency Upgrades	
Wall insulation level	R-11	R-19	
Ceiling insulation level	R-19	R-38	
Window glass	single pane	double-glazed, low-e solar	
Window overhangs	one foot	two foot	
Duct leakage	average, with ducts in unconditioned attic	none, with ducts inside the conditioned space	
House air leakage*	8 air changes per hour at 50 pascals pressure	6 air changes per hour at 50 pascals pressure	
Manual J design heating load	46,100 Btu/hr	21,300 Btu/hr	
Manual J design cooling load	52,100 Btu/hr	23,300 Btu/hr	
Electric heat pump size	4.0 to 4.5 ton (48 to 54,000 Btu/hr)	2 ton (24,000 Btu/hr)	
Annual heat energy usage	12,641 kWh	4,677 kWh	**Savings $717****
Annual cooling energy usage	3,808 kWh	1,790 kWh	**Savings $182****

* *Measured by blower door test*

** *Savings at $0.09/kWh*

An hourly computer simulation shows that efficiency improvements along with re-sizing would cut heating energy use by 63 percent and cooling energy use by 53 percent. Without re-sizing, the efficiency measures would save 54 percent for heating and 47 percent for cooling. In this case, right-sizing reduces costs for the air conditioner, heat pump, furnace, and ductwork, and these savings partly offset the cost of the efficiency improvements. Better yet, right-sizing provides a 10 percent bonus energy savings otherwise not available.

Figure 6: HVAC Sizing for Building Envelope Performance

Source: NREL Technology Fact Sheet

Energy Solutions analyzed the large office building prototype for average demand reduction to approximate HVAC system size reduction and found an average of 5.82 kW demand reduction due to high efficiency windows. There is wide variation in demand savings across the 16 California climate zones, and Energy Solutions observed a range of 0.65-12.98 kW demand reduction across the climate zones. Using an average full load efficiency of 12 EER, this would equate to a range of 0.5-13 tons for HVAC tonnage reduction, with an average system size reduction of 6 tons.

Survey Results

Industry Partners

The following is a sample of organizations in the commercial windows market that were engaged with for this survey:

- Birch Point Consulting LLC
- Northwest Energy Efficiency Alliance
- Vitro Architectural Glass
- Alpen HPP

- Archila Group LLC
- Indow Window
- Edify Studios Inc.
- Technoform Glass Insulation, Inc
- National Glass Association Conference

Key Findings: Interviews, Conference & Secondary Sources

The following is a list of some of the key topics covered in market interviews and secondary sources. For the full questionnaire, please see Appendix A:

- Commercial Windows Supply Chain
- Key decision-makers for commercial window projects
- Ranking of customer awareness
- The barriers to scaling the deployment of high-performance windows.
- Feedback to help advance the deployment of high-performance windows.

Defining High-Efficiency Windows: U-Factor and Solar Heat Gain Coefficient (SHGC)

What is the U-factor used to define a high-efficiency window? What is the SHGC used to define a high-efficiency window?

The first question Energy Solutions asked in the market actor survey was to define a high-efficiency window by thermal efficiency (U-factor and SHGC)[1]. Out of our eight survey respondents, six reported that the U-factor for a high-efficiency window is between 0.20 –0.25. The remaining two market actors defined U-factor levels for high-efficiency windows as 0.29 and 0.32. It should be noted that several interviewees specified that U-factors will vary depending on the type of window. For instance, one respondent stated that the U-factor for a high-performance operable window is 0.40.

In a similar vein, when asked about SHGC ratings for high-performance windows, the overwhelming response was that the appropriate SHGC rating requirement for a window is largely determined by a region's climate. According to two market actors, the highest performing windows will typically have an SHGC rating between 0.20 and 0.23, however these models tend to be quite expensive. More affordable high-performance window options are often around 0.27 SHGC rating, while off-the-shelf window models generally land around a 0.35-0.38 SHGC rating.

The Commercial Window Market: Secondary Windows

Is the commercial building window business dominated by new construction, replacements, or secondary window products?

Early in the data collection process for this market study, Energy Solutions concluded that commercial window replacements are far less common than new construction or window insert projects. Window replacements in commercial buildings often require an entire building façade

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[1] U-Factor – the measurement of a window's insulation. The lower a window's U-Factor, the better the window insulates. Solar Heat Gain Coefficient – the measurement of solar radiation admitted through a window, door, or skylight. The lower a window's SHGC, the less solar heat it transmits and the greater its shading ability.

Source: Department of Energy: Guide to Energy Efficient Windows

renovation, which is costly, time consuming, burdensome for building occupants, and does not provide a return on investment ("ROI") for customers. One survey respondent stated that "less than one percent of [commercial] windows get replaced per year." Secondary windows for commercial buildings are the common choice for customers looking to improve their window performance without requiring significant structural renovations. For historic buildings that are protected by regulations that forbid façade alterations, secondary windows are especially practical as they can be installed on the interior of the window. With the rarity of window replacement projects, it seems apparent that the high-efficiency window market is dominated by new construction projects. Often, customers are compelled to pursue higher efficiency windows to meet certain building code requirements or to qualify for a certain energy efficiency rating for their building performance. Ultimately, high-efficiency windows are not the default option for most customers due to several factors discussed below.

Margins for High-Efficiency Windows Compared to Standard Windows

Are there larger margins for the sale of high-efficiency windows compared to standard windows?

Market actors varied in their assessments of the margins for the sale of high-efficiency windows compared to standard window sales. One market actor compared the sale of high-performance windows to automobiles in that high-efficiency windows are sold with a bundle of other performance enhancements that will increase overall cost for the customer. Several survey respondents pointed to the fact that high-performance windows are more costly to produce than standard windows which contributes to the cost differential between the two. Despite the price disparity, several survey respondents stated that the margins are similar between standard windows and high-performance windows. One interviewee explained that in some instances the margins are less for high-performance windows because the labor required to achieve certain thermal efficiency levels. Another market actor noted that commercial window sales are often a "competition for who can provide the cheapest windows," resulting in similar margins for standard and high-performance windows. However, it should be noted that while the overall margins for high-performance windows may be similar to the margins for standard windows, high-performance windows sell for more than standard windows and as such, manufacturers receive more from high-performance window sales than standard window sales.

Window Certifications

What percentage of the Commercial windows sold are certified and labeled in accordance with NFRC 100 or NFRC 200? For window assemblies that are not National Fenestration Rating Council's (NFRC) *labeled, are the code-required default values being met?*

For the residential window sector, the NFRC 100 or 200 certification labels are important markers of window performance. In the commercial window sector, however, "less than one percent are NFRC labeled" according to a study cited by one survey respondent. The explanation for the lack of window certification adoption in the commercial sector is two-fold. Historically, the NFRC's commercial window certifications were a duplication of the code requirements that architects were already adhering to, which rendered window certifications moot for window manufacturers. Furthermore, with the strict nature of building codes today, architects are very careful when designing a building to ensure they comply with all building codes otherwise they risk serious legal ramifications. For instance, if a customer finds an issue with their building's temperature control or humidity levels due

to non-code compliant windows, a customer may take legal action which could result in the architect having to redo the installation. Between the NFRC's historic duplication of building codes, and the legal risks associated with installing non-code compliant windows, the NFRC certification has not taken root in the commercial windows sector. The fourth iteration of the NFRC's commercial window certification is currently in development and, according to one market actor, there is hope that the certification will hit the mark this time around.

According to the survey data collected, NFRC certifications do not currently cover secondary windows. Rather, the Attachment Energy Rating Council (AERC) has a certified product list for commercial secondary windows featured on their website. With secondary windows being a relatively new technology in the windows market, it stands to reason that there are limited resources on secondary window certifications.

Market Evolution in the Last Five to Ten Years

How has the commercial window market evolved over the last decade?

Window glass has undergone several iterations of improvements over the past decade while window frames have remained relatively the same for several decades. Market actors reported that the advancements in window glass have enabled improved thermal comfort, noise control, and more dynamic glass configuration options. One market actor went so far as to state that window glass advancements have led to an oversaturation of options such that customers and architects have difficulty determining which window is best suited to their needs. The emergence of secondary windows as a feasible, cost-effective option for window retrofits is as significant as the evolution of primary glass technology.

In contrast to the advances in window glass technology, aluminum window frames have dominated the commercial window market for several decades. Advances in aluminum frame technology include the advent of thermally broken frames which can significantly impact the thermal performance of a window unit. However, adoption levels of thermally broken frames are low and aluminum frame technology has otherwise seen relatively few modifications. As it pertains to energy efficiency, one survey respondent stipulated that "glass has done the heavy lifting." Since the COVID-19 pandemic, the window industry has started to shift towards other framing materials such as composite, but movement has been slow.

Window Frames

It is important to note that even though window frame technology has not advanced like window glass in recent history, frames are a key aspect of a window's performance. For a high-performance window to achieve the thermal performance levels discussed throughout this report, the glass must be outfitted with the appropriate frame. For instance, windows with thermally broken frames will be far more effective at reducing the transfer of heat or cold air through the window unit than a standard grade frame. Though window frames are not heavily emphasized in this report, through the finalization process of this report it became clear to the team that window frames require proper acknowledgement when discussing high-performance windows.

Lifespan of Commercial Windows

What is the typical lifespan of a commercial window?

Despite the propagation of high-efficiency windows and the advent of secondary windows, adoption levels remain low. One such explanation for these low adoption levels is the lifespan of a commercial window. Among survey respondents, the life of a commercial window was estimated to be anywhere from 40 to 70 years, depending on upkeep and frame material. While there are some who placed the average closer to 25 to 30 years, the reality is that unless there is a window failure, such as water or air intrusions, window replacements are rare. According to one market actor, "about 40 percent of all commercial buildings still have the original single pane glass with aluminum frames." Interestingly, the typical warranty for a commercial window is 10 years but there are very few instances where a customer will replace their window within the warranty period.

Customer Awareness

On a scale from one to five, how would you rank customer awareness of the benefits of high-performance windows?

One of the key aspects of understanding the high-performance commercial window market is assessing customer and market awareness of the importance of windows in building envelope performance. The Energy Solutions team asked survey respondents to rank customer awareness on a scale from one to five (one being the lowest and five the highest). Out of the eight respondents, five of them ranked awareness between one and two. A commonly held belief among respondents is that customers and developers do not view windows as an opportunity to improve the overall building envelope. For most customers, the primary motivations for purchasing a high-efficiency window, or installing a secondary window attachment, are non-energy benefits such as thermal comfort and noise control. In addition to a lack of awareness among customers, one survey respondent stipulated that government stakeholders are also unaware of the impact that high-performance windows can have on building performance. There were two survey respondents who ranked customer awareness between three and four. The prevailing sentiment among all survey respondents was that customers do not understand the potential for energy savings that windows can produce.[2]

Scaling Deployment

What barriers will affect the ability to scale the deployment of high-efficiency windows?

A common theme throughout this market study is that high-performance windows are expensive. Market actors were unanimous in identifying cost as one of the major barriers to scaling the deployment of high-performance windows. If a customer and architect do not factor in high-efficiency windows during the initial design stages of a project, they can incur up to a 40 percent budget increase if added later in the project. As it stands, there are alternative building design options beyond windows (such as, lighting and HVAC upgrades) that achieve the same building performance targets, require less labor, and are more cost-effective. In addition to prohibitive costs, survey respondents identified the prevalence of old building envelope codes across the country as another major barrier. The technology for high-performance windows exists, but adoption remains low because the mechanisms in place that require states to adopt updated building codes are lacking. Between high costs and flexible building performance codes, the need for impactful window incentive programs is apparent. The final barrier identified was a lack of customer awareness

[2] Note: The commercial market includes an array of different customers and building types. As such, the market should not be treated as a unified body. The data presented in this section reflect the experiences and perceptions of windows industry professionals surveyed in this market study.

surrounding the value of high-efficiency windows. This is most apparent in the secondary window market, where adoption remains low despite a relatively easy installation process and cost-effectiveness when compared to whole window replacement.

Quality Installation

When discussing thermal performance of a window, one must consider window installation. Much like a window frame, where the thermal performance rating of the glass does not amount to much if not supported by an appropriate frame, a window that is poorly installed will experience similar performance issues. In other words, resulting in greater air leakage and a lower performance than the rated window performance. It should be noted that it was only after Energy Solutions surveyed market actors for this study, and received additional feedback, that the team came to appreciate the importance of quality installation on window performance. As such, this was not a topic covered in the survey but nonetheless, merits acknowledgement.

An area for further study would be the impacts on air infiltration associated with a high efficiency window with quality installation. Air infiltration reduction is currently not part of the energy model savings, and there may be additional savings associated with air infiltration. A study focusing on testing air infiltration reduction associated with quality window installations could provide data on additional savings related to windows.

Incentive Price Point

What do you see as a price point for an incentive that will promote sales of high-efficiency windows?

Cost is a major barrier to the adoption of high-performance windows. As such, the Energy Solutions team surveyed market actors for their thoughts on a window incentive price point that would help move the market towards adoption of higher-efficiency windows. Overall, the survey responses did not provide an exact price point or incentive amount; however, the question did prompt interesting insights into important considerations for how to design a window incentive program. One such example is an incentive program that measures savings by the total calculated kWh savings of a high-performance window compared to a standard window model. Other survey respondents pointed to state or federal programs, such as the Inflation Reduction Act ("IRA"), which includes language that will provide tax credits for dynamic glazing on curtain wall window projects. A common thread among all responses is that there is stagnation in the high-efficiency window market. To increase adoption, there needs to be a mechanism for creating urgency among developers and manufactures to invest in a portfolio of higher efficiency windows, as well as a source of funding to support this transition.

Feedback to Increase Adoption of High-efficiency Windows and Secondary Windows

What feedback do you have to help advance the deployment of high-efficiency windows?

The feedback received from market actors to help advance the deployment of high-efficiency windows can be distilled into three major takeaways: 1) code amendments and enforcement, 2) education, and 3) improved incentive programs. The code provisions that exist regarding windows and building performance are enforced on a state-by-state basis and in several states, the minimum enforced building codes are from the 2013 cycle. It should be noted that in states like California, Massachusetts, and New York, this is not the case; however, for these states the challenge is that

building codes are flexible such that a lighting or HVAC upgrade can be substituted for higher performing windows. The Title 24 2025 Draft Case Report includes a mandatory requirement for window performance that does not allow for substitutions; however, previous code cycles only feature prescriptive requirements. The key takeaway is that flexible building codes coupled with a lack of a nationally enforced code cycle for building performance has resulted in a slow uptick in high-performance window adoption. In a similar vein, survey respondents pointed to a lack of industry advocacy among the federal government as one of the reasons for the disparity in state code compliance. There is a lack of awareness among government actors as to the importance of windows in overall building performance. One survey respondent stipulated that the window industry needs to engage in the same level of advocacy as the heat pump industry to drive meaningful shifts in the market.

Beyond the lack of government awareness, there is also a customer education gap on the value of improving window performance. This is particularly true of secondary windows which are severely underutilized. In most cases, barring a complete window failure, customers are unlikely to engage in a full window replacement due to the time and cost that such a project incurs. If a commercial building owner is looking to improve their window performance, secondary windows are the most cost-effective and efficient means to do so. And yet, customers are largely unaware of secondary windows as a retrofit option.

Finally, given the obstacle that the price of high-performance windows presents to customers, market actors stipulated that an incentive program supported by stricter codes and education would increase adoption of both high-performance primary windows and secondary windows. The prevailing sentiment among all survey respondents was that a mixture of education, incentives, and codes are the pathway to transforming the commercial windows market.

Market Sizing and Potential

Methodology

Energy Solutions developed a preliminary market size utilizing data from the 2025 Nonresidential Envelope Codes and Standards Enhancement (CASE) Report developed by the California Statewide Codes and Standards Team. The team utilized the California Energy Commission's 2026 Statewide Construction Forecast for nonresidential buildings along with CBECC-Com compliance software to estimate the square footage of windows in both new construction and existing buildings.

Sales and Shipment Data

Energy Solutions obtained sales and shipment data from a large commercial window manufacturer. This data was used to inform the market size estimates below.

Table 3: Total 2022 Industry Sales and Forecast for 2026

Market	2022 Sales	2026 Forecast
Commercial	$ 14,675,510	$ 16,519,020
Institutional	$ 17,927,620	$ 22,210,490
Industrial	$ 2,498,390	$ 3,552,490
Total Market Sales	**$ 35,101,520**	**$ 42,282,000**

Market Size Information

Table 4 provides estimates of window market size for each major nonresidential building type in California. Existing and new construction areas are both shown and are based on the 2026 Statewide Construction Forecast from the California Energy Commission and the CBECC-Com prototype buildings using window to wall ratio for each building type to calculate window square footage.

Table 4: California Commercial Window Market Size by Building Type

Building Type	Window Area Existing Building Stock (Square Feet)	Window Area New Construction (Square Feet)	Window Area Combined New and Existing Building (Square Feet)
Assembly	137,119,219	2,085,074	139,204,293
Hospital	15,146,384	220,504	15,366,889
Hotel	17,498,202	326,944	17,825,146
Office - Large	99,773,625	1,284,861	101,058,485
Office - Medium	84,390,302	2,026,952	86,417,254
Office Medium Laboratory	21,716,742	713,374	22,430,116
Office - Small	26,619,546	375,171	26,994,717
Restaurant	21,470,850	402,330	21,873,180

Building Type	Window Area Existing Building Stock (Square Feet)	Window Area New Construction (Square Feet)	Window Area Combined New and Existing Building (Square Feet)
Retail - Large	10,674,897	204,256	10,879,153
Retail - Medium	19,697,432	268,339	19,965,772
Retail - Strip Mall	27,520,858	405,291	27,926,149
School- Large	41,643,731	769,593	42,413,324
School - Small	63,650,749	914,248	64,564,997
Warehouse	4,262,549	63,666	4,326,215
Total	591,185,088	10,060,602	601,245,691

Economic and Savings Analysis

Methodology

Energy Solutions gathered cost data on multiple different product types, ranging from single-pane windows to triple-pane windows, along with multiple material and coating options. Products were then mapped to baseline and measure case efficiency based on area-weighted U-factor for each product type. Incremental measure cost was then determined by subtracting baseline efficiency cost from the measure case efficiency cost.

Cost Analysis for Window Measures

Table 5: Measure Offering Cost Basis

Measure Offering	Baseline Product (U-factor)	Measure Efficiency Product (U-factor)	Baseline Cost ($/ft²)	Measure Cost ($/ft²)	Incremental Measure Cost ($/ft²)	Cost Source
New Construction	0.58	0.29	$9.06	$16.41	$7.34	2025 NR Envelope CASE Report (Supporting Data)

Measure Offering	Baseline Product (U-factor)	Measure Efficiency Product (U-factor)	Baseline Cost ($/ft²)	Measure Cost ($/ft²)	Incremental Measure Cost ($/ft²)	Cost Source
Existing Window Replacement	0.86	0.29	$4.45	$16.41	$11.96	2025 NR Envelope CASE Report (Supporting Data)
Secondary Window Insert	0.86	0.45	$0.00	$25.00	$25.00	Regional Technical Forum (Supporting Data)

The window cost data used in this report is based on detailed data from surveys researching commercial building construction costs. Pricing for multiple window types, efficiencies, and quantities was provided directly from multiple leading window manufacturers and includes pricing for actual building projects. The price indexes were adjusted for January 2023 based on Bureau of Labor Statistics Construction Industry Data.

Energy Savings Methodology

Energy Solutions will be utilizing the DEER Commercial Building Prototypes for EnergyPlus building energy modeling to calculate energy savings for the measure. Details of the assumptions utilized in the modeling are included in the Program Delivery Model Recommendations

The Energy Solutions team recommends implementing the following model to measure program delivery model:

1. Distinct incentive program designs for new construction/retrofit replacements and secondary windows.
2. Incentives amounts that covers between 75 to-100 percent of high-performance window incremental measure cost.
3. The development and delivery of a joint training session with window manufacturers design for architects.
4. The development of a high-performance windows buyer's guide.
5. Incorporation of the HTR/DAC considerations as detailed above.

Measure Package Development section.

Program Delivery Model

In this section, Energy Solutions provides considerations for a program delivery model that aims to increase the adoption of high-performance windows in new construction, window replacements, and secondary windows projects. The program delivery model considerations attempt to address the

barriers to high-performance window adoption that were identified in the market study and provide strategies to overcome those challenges through incentives and education.

Through careful consideration and discussion, Energy Solutions determined a two-pronged program model that includes incentives and education would be the most effective means of influencing the commercial windows market. Additionally, Energy Solutions recommends two distinct program models: one for new construction and replacement window projects, and the other for secondary window projects. The sections below detail the various actors along the supply chain that the team considered for an incentive program design.

Program design

Initially, the Energy Solutions team considered an incentive program design in which rebates would be calculated based on the kWh and therm savings of a building's windows. Several benchmarked utilities use this methodology for providing incentives. However, the team determined that a program based on electrical and gas savings would pose a barrier to industry actors who do not have the resources necessary to forecast savings estimates for their projects. Rather, the team opted for an incentive program based on square footage of the window unit as a more practical go-to-market design. Using this methodology speaks the language of the industry.

Incentive Model Considerations: New Construction and Replacement Windows

The team identified numerous segments of the commercial windows supply chain that would be well positioned to receive incentives. The team's evaluation process for which party should receive incentives is detailed below as well as a finalized program delivery model recommendation.

Installers

The sales process for commercial windows is variable but, in some cases, especially small window replacement projects, the installers are the ones placing the orders with window fabricators. Additionally, an important consideration when evaluating the performance of a commercial building's windows is the quality of the window installation. For these reasons, Energy Solutions considered a program model in which window installers are required to participate in a training on quality window installation to receive incentives on high-performance window projects. However, according to the data collected from the commercial windows market study, installers are typically not the ones driving the customer's window purchasing decisions and, therefore, may not be the most effective market actor at increasing the adoption of high-performance windows.

General Contractors

In most commercial window projects, the general contractors are the ones who facilitate the pricing and purchasing of the window frames and glass. General contractors will handle bidding to subcontractors as well as any preliminary pricing for the building's windows. Given that cost is one of the major barriers to high-performance window adoption, it would stand to reason that an incentive program focused on general contractors could help address this barrier. However, a general contractor's focus is on maintaining the project budget, meeting deadlines, and wrangling subcontractors, and not on deciding which type of window frames and glass to purchase. As such, the team determined that the scope of a general contractor is likely to impact their interest and availability in engaging with an incentive program. In other words, as one of the primary drivers in a

commercial building project, general contractors are unlikely to spend the time and energy learning about, and engaging with, a high-performance window incentive program.

Manufacturers

Finally, the team considered an incentive program design centered around manufacturers. Manufacturers, while not directly involved with customer decision-making, can influence market adoption through the products they offer. When compared to architects, the network of window manufacturers servicing the California commercial market is far smaller and tight knit such that communication about the program to industry players does not present an obstacle. Energy Solutions has existing relationships with window manufacturers which could be utilized to help increase awareness of the incentive program and allow for partnerships on market education efforts. However, after further consideration and input from industry partners, the team learned that many commercial window manufacturers are already incentivized to produce high-performance windows due to the higher margins they receive when compared to standard window margins. Additionally, customer awareness remains a barrier to adoption of high-performance windows and manufacturers may not be the best leverage point to increase customer awareness.

Incentive Model Recommendation: Architects

New Construction

When the team considered its goal of increasing the adoption of high-performance commercial window adoption, naturally our search led us to consider an incentive program for architects. Early in the scoping process of a commercial building project, the customer will hire an architect to coordinate and ultimately execute the construction of the building. The architect is involved in the whole building design and will work directly with the customer to guide them through the planning and design of the project. Put simply, architects have a great degree of influence on the customer's purchasing decisions. **As such, Energy Solutions recommends an incentive program design centered around architects.** Architects are well-positioned to engage in an incentive program because of the influence they have on customer decision-making as well as their involvement in the entire building project. As a liaison to the customer and a project supervisor, architects are more attuned to the value of an incentive on the overall project costs and thus, more likely to take the time to engage in an incentive program. Furthermore, from a design perspective, architects are well-equipped to navigate the market of high-performance windows and advocate accordingly for the best options.

The team considered the potential challenges an architect-based program might present. Most notable, the ubiquity of architects throughout California and the reality of their de-centralization may hinder engagement efforts with the architect network. Ultimately, this would lead to low levels of market engagement in the program. To account for this potential barrier, Energy Solutions would utilize its relationships with the American Institute of Architects, California ("AIA CA") to foster communication with California's architect community. In collaboration with AIA CA, Energy Solutions would conduct informational sessions for architects to educate them about the program and the benefits of high-performance windows.

Replacement Windows

In contrast to new construction projects, smaller window replacement projects do not always require the use of an architect. For window replacement projects that do include an architect, Energy

Solutions recommends an incentive program design centered around architects, as detailed above in the New Construction section. However, for replacement projects that do not include an architect, the team recommends a more flexible program design that allows contractors to apply for incentives in lieu of an architect. These projects will be evaluated on a case-by-case basis to ensure the rules of program engagement are met.

Incentive Disbursement

In this incentive program design, there are two distinct incentives for building projects. The first is a stipend that the market actor will receive for each high-performance window claim they submit to the program implementor to cover the administrative burden of submitting the claim. The second incentive will go to the customer and will be calculated based on the dollar per square foot of the window. This incentive will be deducted from the total cost of the window invoice sent to the customer. Please note that this is only a preliminary design of the incentive program delivery model. Details and program specifications will be determined prior to program implementation.

Incentive Model: Secondary Windows

For secondary windows, Energy Solutions recommends an incentive model that allows anyone who sells secondary windows to qualify for incentives. Given the variability of commercial building types that would benefit from secondary windows, and subsequently, variety of market actors who will get involved in different secondary windows projects, a broad approach to a secondary windows incentive program would be the best method for increasing adoption. The only exception to incentive-eligible actors along the supply chain are manufacturers. The reason for this exclusion is to account for any "double-dipping" that might occur if a manufacturer and a contractor both claim incentives for the same sale. Over time, manufacturers could be phased into the program.

Methodology

Incentive Levels

The team referenced primary and secondary window incentive programs as a benchmarking exercise (Table 7), then researched incremental measure cost and collected data from market actors to formulate the incentive recommendation (**Error! Reference source not found.**). Energy Solutions understands cost effectiveness will play a primary role in deciding the final incentive amount. Therefore, each California IOU may need to adjust incentive levels to fit their portfolio needs.

To spur market adoption, it is recommended for incentives to pay 40 to 50 percent of the incremental cost. The incremental cost for a high-performance window is dependent on code baselines in a particular region. For the state of California, the code baseline is U-factor of 0.58 for new construction and 0.86 for existing buildings. For secondary windows the incremental measure cost is higher than a new construction project or a window replacement, however most of the cost savings for secondary windows is attributed to installation costs. After tailoring a projects economics to the California region, the following incentives are recommended:

Table 6: Recommended Incentives

Measure Offering	Incentive
New Construction	$4.00/ ft^2
Window Replacement	$5.00/ ft^2
Secondary Windows	$10.00/ ft^2

Table 7: Benchmark analysis for incentive levels for Replacement/Secondary windows

Replacement/Secondary	Utility	Incentive Level
Window Replacement	Utility A (Puget Sound Energy)	$9/ft^2
Window Replacement	Utility B (Efficiency Manitoba)	$50/window
Window Replacement	Utility C (Elmhurst Mutual Power & Light)	$3.00/ ft^2
Window Replacement	Utility D (OUC)	$1.50/ ft^2
Secondary Window	Utility D (Austin Energy)	$1.00/ ft^2
Secondary Window	Utility E (Consumers Energy)	$15/window

Education and Market Awareness

In addition to incentives, the Energy Solutions team feels strongly that educating the market on the benefits of high-performance commercial windows is essential to achieving market transformation and will ultimately foster an increase in high-performance window utilization. As such, the team developed recommendations for education and market awareness to include in the program delivery model.

New Construction and Window Replacements

To increase market awareness and education about the benefits of high-performance windows, the team recommends partnering with window manufacturers for joint training sessions. Training materials would be geared towards educating architects on the importance of high-performing windows, highlighting energy and non-energy benefits, and providing an overview on the product catalogue of high-performance window models. The training would also highlight the importance of quality installations as a strategy to ensure windows increase energy and gas savings. Energy Solutions has experience of successfully conducting similar trainings in other market sectors such as HVAC and heat pumps.

Beyond training sessions, the team recommends developing a high-performance commercial windows buyer's guide for primary and secondary windows. The buyers guide will provide window market actors with a reference manual on the array of high-performance window technologies on the market with details on the manufacturer, applications, performance, and relative cost. To ensure the buyer's guide serves its purpose, the team would utilize the training sessions, manufacturers contact networks, and architect/contractor channels to circulate the guide to the relevant market actors.

Secondary Windows

For secondary windows, Energy Solutions recommends training for building owners and management, and building engineering groups (such as the Building Owner and Managers Association (BOMA) and the International Facility Management Association (IFMA)). The trainings would focus on spreading awareness of secondary windows as a quick, non-invasive, and effective window retrofit solution The training would also highlight the energy and non-energy benefits of secondary windows, as well as their availability in the market. Energy Solutions would partner with secondary window manufacturers to develop and deliver the training to building owners and managers.

DAC/HTR Considerations

Hard-to-reach (HTR) and disadvantage customers (DAC) communities often face disparities in access to energy-efficient technologies and programs. These communities may have limited resources, information, or awareness about the benefits of energy-efficient technologies, such as high-performance windows. The project team acknowledges these challenges and seeks to address them by tailoring recommendations to make high-performance windows more accessible to HTR and DAC customers.

Definition of HTR and DAC:

- Hard-to-reach (HTR): HTR communities refer to areas or groups that are challenging to engage with or serve due to various barriers. These barriers can be geographical, linguistic, cultural, economic, or a combination of factors. HTR communities are often underserved when it comes to energy efficiency programs. (S. Rotmann 2020)
- Disadvantaged customers/communities (DAC): DAC communities encompass individuals or groups facing economic, social, or environmental hardships that hinder their access to essential resources, including energy-efficient technologies. DAC communities are vulnerable to energy cost burdens and may lack the means to adopt energy efficient technology without support (California Public Utilities Commission n.d.).

Recommendations

To ensure proper coverage of California's IOU service area, Energy Solutions provided recommendations for a program delivery model that includes HTR/DAC customers.

High-performance windows are a costly investment and as the study has demonstrated, cost is one of the primary barriers to scaling the deployment of high-performance windows. For HTR/DAC customers, the prohibitive cost of high-performance window technology is especially prevalent. As such, Energy Solutions recommends a program design that provides market actors with 150 percent of the prescribed incentives for any high-performance windows that are sold to HTR/DAC customers. The additional incentives are intended to motivate market actors to engage in windows projects in specifically with these customers. Additionally, the added incentives can also be used by market

actors to lighten the financial burden on these customers for expensive window projects. Beyond incentives, the team recommends partnerships with community-based organizations (CBOs) for trainings geared towards architects who work with primarily with these customer groups to ensure they have the tools to educate them on the value of high-performance windows. Lastly, the team recommends investment in local workforce development that trains hard-to-reach customers and disadvantaged community members on quality installation of windows projects.

Beyond incentives, education, and workforce development, the Energy Solutions team recommends that any program materials for HTR/DAC customers are tailored accordingly. It is essential that all program materials, communication, and interactions are culturally competent and respectful of the diverse backgrounds and languages within the communities we are trying to reach. In that vein, the team recommends partnerships with community members as energy efficient ambassadors and/or advisors who can provide guidance and cater program communications to suit the preferences and challenges of their community.

There are several potential benefits of high-performance window technology to HTR/DAC customers. Energy Solutions feels there is need for further research into the potential impacts of lower cost window improvements, such as secondary windows.,. This could include models that educate and promote secondary windows for this sector, potential community-based education programs and delivery models, and crossovers with other building envelope improvement programs that might help with outreach and delivery, as well as audience and market understanding.

Program Delivery Model Recommendations

The Energy Solutions team recommends incorporating the following into a future program delivery model:

6. Distinct incentive program designs for new construction/retrofit replacements and secondary windows.
7. Incentives amounts that covers between 75 to-100 percent of high-performance window incremental measure cost.
8. The development and delivery of a joint training session with window manufacturers design for architects.
9. The development of a high-performance windows buyer's guide.
10. Incorporation of the HTR/DAC considerations as detailed above.

Measure Package Development

The text below will serve as a framework for the measure package characterization. Many sections are copied directly from the eTRM Measure Characterization Template v5.0, provided by CalTF. https://www.caltf.org/tools

Technology Summary

This measure covers the installation of high-efficiency windows in new construction and retrofit applications of commercial buildings with reduced thermal conductance and solar heat gain coefficient and secondary windows in retrofit applications. Secondary windows are window attachments fitted to the interior or exterior of an existing, primary window for quick installation that improve the insulating characteristics of the window assembly. This measure is only applicable to

windows that serve as a barrier between conditioned spaces and outside air. Energy is saved by reducing cooling and heating loads due to reduced energy loss between the building interior and exterior.

Southern California Edison (SCE) sponsored a project in the Emerging Technology Program to evaluate the energy performance of High-Performance Commercial Windows, as indicated in **Error! Reference source not found.**.

Table 8: Energy Performance of High-Performance Commercial Windows

Project Number	Program Funding Year	Year Introduced to Programs
ET23SWE0018	2023-2024	

Measure Case Description

The measure case is defined as the installation of windows that have a U-factor of 0.29 or less and a SHGC of 0.36 or less for climate zones 1, 3-5, and 16 and a SHGC of 0.23 or less for all other climate zones. These values were determined from the market characterization interviews with market actors. For secondary windows, a combined window U-factor of 0.45 is used based on the Regional Technical Forum's Commercial Secondary Glazing measure.

Table 9: Measure Case Description

Equipment Type	Statewide Measure Offering ID	Measure Offering Description
High Efficiency Window, New Construction	A	Window with low U-factor and SHGC
High Efficiency Window, Retrofit	B	Window with low U-factor and SHGC
Secondary Window	C	Secondary Window

Baseline Efficiency

The base case is defined as a window with a U-factor of 0.58 for new construction and a U-factor of 0.86 for existing buildings using the 2025 Nonresidential Envelope CASE Report as a source for baseline efficiency. There are no requirements for SHGC, so DEER Commercial Building Prototype default values will be utilized for baseline SHGC.

Table 10: Baseline Efficiency

Equipment Type	Existing Description	Measure Offering Description
High Efficiency Window, New Construction	Code Compliant Window	Code Compliant Window
High Efficiency Window, Retrofit	Single Pane Window	Single Pane Window
Secondary Window	Single Pane Window	Single Pane Window

Code Requirements

The 2022 California Building Energy Efficiency Standards (Title 24) specifies U-factor requirements for fenestration products including windows. The requirements for fenestration products are listed in Section 110.6. There are currently no mandatory efficiency requirements for non-residential windows outside of the fenestration product requirements in Section 110.6.

The CEC is currently reviewing a proposal to include mandatory requirements for non-residential window assemblies in the 2025 California Building Energy Efficiency Standards.

Table 11: Code Requirements

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	N/A	N/A
CA Building Energy Efficiency Standards – Title 24	Section 110.6	1/1/2023
Federal Standards	N/A	N/A

Program Requirements

Measure Implementation Eligibility

All measure application type, delivery type, and sector combinations established for this measure are specified in Table 12. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial

incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

The AOE measure application type will be used for the secondary window measure and the NC and NR measure application types will be used for the primary window measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Table 12: Measure Implementation Eligibility

Measure Application Type	Delivery Type	Sector
AOE	DnDeemed	Com
AOE	UpDeemed	Com
NC	DnDeemed	Com
NC	UpDeemed	Com
NR	DnDeemed	Com
NR	UpDeemed	Com

Eligible Products

Primary and secondary windows that meet the criteria specified in the Measure Case Description Section are eligible for this measure.

Primary windows must be certified by the National Fenestration Rating Council (NFRC).

Secondary windows must be added to an existing window.

Eligible Building Types and Vintages

This measure is applicable for all nonresidential building types. The Existing Building vintage is eligible for NR and AOE MATs. The NC MAT shall use the New Building vintage.

Eligible Climate Zones

This measure is applicable in all California climate zones.

Program Exclusions

Window films or specialty window treatments are not eligible for this measure.

Data Collection Requirements

Data Collection requirements are described in DEER Resolutions E-5152 and E-5221 with the objectives of:

1. Better tracking of the installed equipment that received a rebate,
2. Ensuring that eligible measures are submitted in applications,
3. Proper evaluation and application of savings are performed per California EM&V Protocols,
4. Cost effectiveness values are properly/correctly applied for each application/project.

Table 13: Data Collection Requirements

Data Collection Requirements	Required for Upstream	Required for Downstream
Site ID - unique identifier for the shipping destination (upstream) or installed location (Midstream/Downstream/DI) of the incentivized equipment (e.g., site address)	Yes	Yes
Quantity per Site – Total units of incentivized equipment located at the site or project	Yes	Yes
Measure equipment ID[3] - unique identifier for each unit of incentivized equipment (e.g., serial number)	Yes	Yes
Measure equipment model number	Yes	Yes
Measure equipment manufacturer	Yes	Yes
Measure equipment U-factor	Yes	Yes
Measure equipment SHGC	Yes	Yes
Measure equipment type (primary window, secondary window)	Yes	Yes
Existing window type (secondary windows only)	Yes	Yes
Climate Zone	Yes	Yes
Building Type[4]	Yes	Yes

[3] Exemptions to the equipment identifier requirement will be made for measure package offerings where leveraging a serial number or other practical unique identifier is infeasible. Exemptions will need to be approved by the CPUC in advance.

[4] Refer to guidance below for obtaining existing equipment type and building type for upstream and midstream.

For upstream/midstream delivery types, the participant baselines and measure equipment installation details may be unknown. The manufacturer or distributor may not be aware of the following information:

- The building type of the measure equipment location

If baseline or measure equipment data cannot be provided for each application for Upstream delivery type, an alternative method to collect data may be used if approved by the CPUC and Program Administrator.

If baseline or measure equipment data cannot be provided for each application for the Midstream delivery type, the following solutions may be implemented:

- The implementer shall survey at least 10 percent of the midstream installations to determine the actual baseline equipment types, baseline and measure equipment system configurations, baseline and measure equipment operating parameters, and measure equipment installation location. The program administrator shall adjust claimed savings based upon the survey results. This survey will be conducted monthly, by e-mail or some other trackable digital means. Sample survey questions are as follows:
    - "What is the building type of the location that the measure equipment will be installed at?" (Residential/Multifamily/Single Family/Mobile Home/I'm not sure)
- An alternative method to collect data requirements such as equipment type and/or installation location may be used if approved by the CPUC and Program Administrator.

Electric Savings (kWh)

The electric unit energy savings (UES) of this measure were derived from building energy use simulation results and were calculated as the difference between the baseline and measure building unit energy consumption (UEC). Building energy use and demand were estimated using EnergyPlus 9.4.

Table 14: Electric Savings with EnergyPlus 9.4

Platform	EnergyPlus
Model Type	IOU Modelled
Energy Modeling Engine	EnergyPlus Version 9.4
Energy Modeling Interface	Text Editor for Raw Input Files
Batch Processor	T24 Modelkit and Pyscript
Weather Files	CBECC 2025

Platform	EnergyPlus
Prototype Source	CBECC 2025

UEC values are expected to change with climate zone, building type, and vintage. Modelling was performed using 2022 Title 24 Prototypes for the OfficeLarge, OfficeSmall, RetailLarge, and SchoolSmall building types and the 2022 vintage. Modelling was conducted for all climate zones. Other building types and vintages are excluded due to the expected upcoming release of DEER Commercial Building Prototypes. When the DEER prototypes are released, all commercial building types will be modelled with new and existing vintages.

Baseline Energy Use Simulation

Modelling was performed using 2022 Title 24 Prototypes for the OfficeLarge, OfficeSmall, RetailLarge, and SchoolSmall building types. The U-factors and SHGC values were modified per the table below and all other values were unchanged:

Table 15: Baseline Energy Use Simulation

Parameter	Parameter Description	Modified Baseline Value/Assumption
U-factor	Thermal Conductance of the Window	0.86 Retrofit, 0.58 New Construction
SHGC	Solar Heat Gain Coefficient	CZ01, 3-5, 16 – 0.43 CZ02, 6-15, 0.34

Measure Case Energy Use Simulation

Modelling was performed using 2022 Title 24 Prototypes for the OfficeLarge, OfficeSmall, RetailLarge, and School Small building types. The U-factors and SHGC values were modified per the table below and all other values were unchanged:

Table 16: Measure Case Energy Use Simulation

Parameter	Parameter Description	Modified Baseline Value/Assumption
U-factor	Thermal Conductance of the Window	0.29 or less
SHGC	Solar Heat Gain Coefficient	CZ01, 3-5, 16: <0.36 all other CZ: <0.23

Calculation of Unit Energy Savings

The annual UES is calculated as the difference between the baseline and measure case annual UEC. Results were normalized per square foot of window area. Window directionality was reviewed, and it was determined to have a minimal effect on savings. The table below provides savings values for retrofit primary windows for large offices as well as the total prototype baseline energy consumption and savings. Modelling results for secondary windows and other building types, vintages, and application types are provided in a supplemental spreadsheet.

Table 17: Calculation of Unit Energy Savings

Building	Title 24 2022	Base Elec	Base Gas	Elec Savings	Gas Savings	Elec Savings /sq.ft of Window	Gas Savings /sq.ft of Window
Prototype	CZ	kWh	Therm	kWh	Therm	kWh	Therm
OfficeLarge	CZ01	3,222,705	46,740	5,727	15,525	0.62	1.68
OfficeLarge	CZ02	3,497,770	43,951	56,486	11,698	6.10	1.26
OfficeLarge	CZ03	3,355,955	35,933	15,266	10,331	1.65	1.12
OfficeLarge	CZ04	3,659,675	40,338	40,250	10,625	4.35	1.15
OfficeLarge	CZ05	3,420,481	38,186	16,908	10,613	1.83	1.15
OfficeLarge	CZ06	3,564,485	16,023	45,566	5,711	4.92	0.62
OfficeLarge	CZ07	3,583,291	15,646	56,528	6,778	6.11	0.73
OfficeLarge	CZ08	3,761,130	18,683	62,854	5,403	6.79	0.58
OfficeLarge	CZ09	3,720,317	19,279	59,275	6,325	6.40	0.68
OfficeLarge	CZ10	3,812,725	20,838	72,292	6,049	7.81	0.65
OfficeLarge	CZ11	3,746,421	39,580	63,498	10,660	6.86	1.15
OfficeLarge	CZ12	3,618,658	37,744	61,058	10,305	6.60	1.11
OfficeLarge	CZ13	3,780,941	29,968	70,177	7,921	7.58	0.86

Building	Title 24 2022	Base Elec	Base Gas	Elec Savings	Gas Savings	Elec Savings /sq.ft of Window	Gas Savings /sq.ft of Window
OfficeLarge	CZ14	3,765,883	39,570	61,386	10,520	6.63	1.14
OfficeLarge	CZ15	4,217,847	13,100	113,712	4,347	12.28	0.47
OfficeLarge	CZ16	3,496,975	56,542	15,126	16,733	1.63	1.81

Peak Electric Demand Reduction (kW)

Peak demand reduction values were derived using the methodology presented in Electric Savings. The peak demand reduction was calculated as the difference between the baseline and measure case average hourly peak demand for the 15 hours of the peak period from 4:00 p.m. to 9:00 p.m. during the three consecutive weekday period within the dates of June 1 through September 30 that was defined within each climate zone by having the highest algebraic sum of the average temperature over the three-day period from 12 noon to 6 p.m.

Peak demand savings will be obtained from future modelling using DEER Commercial Prototypes.

Gas Savings (therm)

Gas unit energy savings (UES) values were derived using the methodology presented in Electric Savings.

Life Cycle

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The methodology to calculate the RUL conforms with Version 6 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.” This approach provides a reasonable RUL estimate without requiring any prior knowledge about the age of the equipment being replaced. Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on equipment measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component.”

Resolution E-5152 allows exceptions to the EUL limit on the life of the add-on equipment measure application type if the life of the add-on measure is not affected by the life of the host equipment. As the secondary window is not installed directly on the primary window, the life of the add-on measure is not affected by the life of the host equipment. Therefore, the full EUL will be used for the lifetime of this measure.

As an EUL ID for commercial windows does not exist, the EUL for residential High-Performance Windows is used as an approximation of the EUL for commercial windows.

Table 18: Effective Useful Life

EUL ID	EUL Description	Sector	EUL YRS	RUL Years (Optional)	Start Date	Expire Date
BS-Win	High Performance Windows	Res	20	6.70	2013-01-01	

Base Case Material Cost

Material costs were pulled from the 2025 NR Envelope CASE Report.

Values are provided in the Economic and Savings Analysis section of this report.

Measure Case Material Cost

See Base Case Material Cost.

Base Case Labor Cost

Labor costs were derived using the 2023 edition of RSMeans Unit Cost data. The data indicated that it would take roughly one hour for a carpenter to install a window up to 16 ft^2 in size. The labor rate used was the 2023 Open Shop labor rate for carpenters.

The base case labor cost for secondary windows is assumed to be zero.

Table 19: Labor Cost

Measure Offering	Baseline Labor Cost ($/$ft^2$)	Measure Labor Cost ($/$ft^2$)
New Construction and Existing Window Replacement	$4.30	$4.30
Secondary Window Insert	$0.00	$4.30

Measure Case Labor Cost

See Base Case Labor Cost (Table 19).

Net-to-Gross

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention.

These NTG values are based upon the average of all NTG ratios for all evaluated commercial sector programs from 2006 to 2008, as documented in the *2011 DEER Update Study* conducted by Itron, Inc. These sector average NTGs ("default NTGs") are applicable to all energy efficiency measures that have been offered through commercial sector programs for more than two years and for which impact evaluation results are not available.

Table 20: Net-to-Gross Ratio

Net to Gross Ratio ID	NTG kWh	NTG Therm	Expire Date
Com-Default>2yrs	0.6000	0.6000	

Gross Savings Installation Adjustment

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method.

This GSIA rate is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

Table 21: Gross Savings Installation Adjustment

GSIA ID	GSIA Value
Def-GSIA	1.000

Non-Energy Impacts

Non-energy impacts for this measure have not been quantified.

DEER Differences Analysis

The table below reflects the expected values when modelling is completed with DEER Prototypes.

Table 22: DEER Differences Analysis

DEER Item	Comment
Modified DEER Methodology	No
Scaled DEER Measure	No

DEER Item	Comment
DEER Base Case	Yes
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	No
DEER Version	N/A
Reason for Deviation from DEER	DEER does not contain this type of measure
DEER Measure IDs Used	N/A

Conclusion

1. **Supply Chain, Customer Journeys, and Market Characterization.** The commercial windows supply chain is convoluted and variable. Similarly, the customer journey for new construction, replacement window, and secondary window projects is subject to any number of delays and complications, in no small part to the complex nature of the commercial windows supply chain. For high-performance commercial windows, there are several barriers like high costs and low awareness that continue to hinder market adoption of the technology.
2. **Market Actors Incentives.** Incentives will drive market adoption of high-performance commercial windows. Incentivizing market actors to increase their promotion and sales efforts of high-performance window models will shift the market.
3. **Recommended Incentive Amounts.** It is recommended incenting 40 to 50 percent of the incremental measure cost (IMC). Covering a majority of the IMC has been proven to influence sales from standard efficiency to high efficiency equipment. It will also encourage market actors to lead campaigns, raise awareness, and upsell high-performance window products. The study explored the costs of windows and secondary windows to determine final incentive amounts.
4. **Provide Education and Training.** To support the market transformation of the commercial windows sector, it is recommended that a training session on the energy and non-energy benefits of high-performance windows be developed. Through a partnership between manufacturers and program implementors, this training will be formulated and delivered to industry architects and commercial building owners. Furthermore, a windows buyer's guide

detailing available high-performance primary and secondary window models is recommended.

5. **HTR/DAC considerations.** For maximum coverage to all potential program participants, special consideration must be given to the HTR/DAC customer segments. These special considerations include additional incentives, partnerships with CBOs for community-specific education, and workforce development with an emphasis on quality window installations.

Next Steps

Distribution Report– Energy Solutions will develop the distribution report and disseminate the Final Report to the distribution list once the Final Report is reviewed and approved.

Measure Package Development – Energy Solutions will submit the draft measure package and measure package plan to Cal TF and coordinate with SCE to move the measure package through the CPUC review process.

DEER Prototypes Modeling Update – Energy Solutions will remodel the energy savings for commercial windows using the DEER Commercial Building Prototypes once they are available to meet CPUC requirement for measure packages with energy modeling as savings methodology.

Areas of Further Study

Secondary Windows – Secondary windows are heavily featured in this report. However, the market for secondary windows is still young and additional field testing and data would help spur the market to increase adoption.

Quality Installation - Energy Solutions recognizes that the ultimate performance of a building envelope cannot be addressed by improved components alone. The quality of the installation is a significant determinant of the energy savings that can be realized with high-performance windows. Poor installation can lead to air leakage around a window unit, negating some of the benefit gained by a high-performance unit. Sparse quantitative data exists on the potential savings that better installation practices can offer.

References

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Appendix A: Product Availability Table

Note: The list presented below does not account for the scope of window product variability. There are several ways in which to customize and configure a window and this list presents a snapshot of finished window products. The thermal efficiency figures below represent one design iteration (of many) for these window products, alterations to these products will impact the window's thermal efficiency.

Table 23: Product Availability

Manufacturer	Product	U-factor	SHGC	Window Type
Manufacturer A	The 1150S Series	0.27- 0.60*	-	Fixed, Awning, Hopper Casement
Manufacturer A	The 1450 Series	0.29 - 0.60*	-	Fixed, Awning, Hopper Casement
Manufacturer A	The 1550 Series	0.29 - 0.61*	-	Fixed, Awning, Hopper Casement
Manufacturer B	Dual-Pane 3L	0.25	0.24	Fixed, Ribbon/Strip Large "Punched" Openings Window Walls
Manufacturer B	All Climate-5	0.19	0.32	Fixed, Ribbon/Strip Large "Punched" Openings Window Walls
Manufacturer B	Solar Control-5	0.19	0.21	Fixed, Ribbon/Strip Large "Punched" Openings Window Walls
Manufacturer C	Series 9000	0.32 - Fixed 0.41 - Operable	0.33 - Fixed 0.28 - Operable	Fixed, Operable
Manufacturer C	Series 9200	0.29 - Fixed 0.37 - Operable	0.32 - Fixed 0.27 - Operable	Fixed, Operable
Manufacturer C	Series 9600	0.30 - Fixed 0.34 - Operable	0.33 - Fixed 0.27 - Operable	Fixed, Operable
Manufacturer D	YWW 45 TU	0.33	-	Window Wall
Manufacturer D	YCW 750 IG/OG	Inside Glaze: 0.49 Outside Glaze: 0.36	-	Curtain Wall
Manufacturer D	YVS 410 TUH	0.46	-	Hung Window

*** Variation due to type and size of the window.**

Source: Online Research of Commercial Window Manufacturers.

Appendix B: Full Market Actor Questionnaire

Market Overview

- What is the U-factor you use to define a high-efficiency window? What about Solar Heat Gain Coefficient?
- Can you walk us through the supply chain from manufacturer to customer?
- Who are the key decision makers of purchasing high-efficiency windows?
- Are sales efforts targeted towards new buildings or retrofits?
- What motivates a customer to replace existing windows?
- Is the commercial building replacement window business dominated by new construction, replacements, or secondary window products? What is the market percentage breakdown?
- What is the typical life of a window? How long until a customer typically replaces high efficiency?

Sales

- What is the typical sales timeline for high-efficiency windows?
- How many windows inquiries do you receive a week? What percentage of those inquiries are about high-efficiency windows?
- Which region of California do you sell the most high-efficiency windows? And in which region do you do the least?
- What percentage of sales are new buildings vs retrofits?
- Are there larger margins for the sale of high-efficiency windows compared to standard windows?
- What percentage of the Commercial window market is whole window vs. glazed in place product?
- What percentage of the Commercial windows sold are certified and labeled in accordance with NFRC 100 or NFRC 200?
- For window assemblies that are not NFRC labeled, are the code-required default values being met?

Barriers

- What barriers will affect the ability to scale the deployment of high-efficiency windows?
- What do you see as a price point for an incentive that will promote sales of high-efficiency models?

Feedback

- On a scale from one to five: How would you rank customer awareness of the benefits of high-efficiency windows?
- Do you have any feedback to help advance the deployment of high-efficiency windows?

Miscellaneous

- What incentives/rebates/tax credits for high-efficiency windows are out there?
- How has the market evolved over the last five to 10 years?

Appendix C: Environmental Justice Resources

- Climate and Energy Resources for State, Local and Tribal Governments - https://www.epa.gov/statelocalenergy#:~:text=EPA's%20State%20and%20Local%20Climate,environmental%2C%20energy%20and%20economic%20objectives.
- Style Guide for Inclusive Language - https:/www.dcfpi.org/wp-content/uploads/2017/12/Style-Guide-for-Inclusive-Language_Dec-2017.pdf
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- Hard-to-reach energy users: An ex-post cross-country assessment of behavioral-oriented interventions - https://www.sciencedirect.com/science/article/pii/S2214629623002657
- Disadvantaged Communities - https://cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/disadvantaged-communities