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## **Commercial Windows Attachment (SGS) Initiative**

SGS Phase 1 Research  
Final Research Summary

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## Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) engaged Navigant Consulting, Inc. (Navigant) to undertake an introductory market assessment of a new product initiative: Window Attachments, which includes products installed in commercial and residential markets. This study focuses on secondary glazing systems (SGS), which are commercial single-pane window retrofits installed on the interior side of a building. SGS products improve the performance of existing windows without replacing existing glass, window frames, or altering the exterior appearance of the building. The study's goal was to conduct initial market research to confirm product performance, barriers, and market information sufficient to inform a preliminary market baseline.<sup>1</sup>

There is roughly 80 billion square feet of existing commercial space in the United States, including approximately 2 billion square feet of single-pane glazing. NEEA estimates roughly 470 million square feet of single-pane glazing in 3,400 existing commercial buildings in the Northwest region, establishing a substantial potential market for these window attachments.

## Objectives and Approach

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The study focuses on the following five research objectives:

1. Assess overall product performance
2. Investigate strategies for sizing the regional market
3. Refine understanding of market barriers
4. Understand product drivers
5. Identify leverage points within the existing supply chain

Navigant first conducted a literature review on the SGS technology, with a focus on product performance and existing potential in the Northwest. This review included an analysis of the Commercial Buildings Stock Assessment (CBSA) and expected growth of secondary glazing products from other secondary research to estimate the size of the national and Northwest markets. Next, the research team conducted interviews with a sample of project participants selected from the manufacturer installation data. Navigant conducted interviews with the three prominent SGS manufacturers, building owners, and installers. The interviews aimed to gather information related to product performance, market drivers and barriers, market sizing and baseline assumptions, and SGS supply chain.

## Key Findings

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### Product Performance

#### *Installation and Product Longevity*

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<sup>1</sup> This study's scope is limited to SGS technological potential. Economic potential was not part of the study due to lack of information.

- Case studies and other literature generally describe positive experiences with the installation of SGS products due to quick installation without significant disruptions to building occupants and increased tenant comfort after the installation.<sup>2 3</sup>
- SGS product installation is a more efficient, non-disruptive window installation in comparison to a full window replacement—typically requiring approximately 20-30 minutes per window, depending on the window size.
- Findings suggest the minor incidences of window condensation and breakage are within industry standards and did not deter the use of SGS products or negatively affect the product’s longevity.
  - Most respondents experienced no issues with condensation or seal breakage; some noted cases of window condensation and breakage related to improper sealing of the original exterior window.
  - Seal failures and breakages are rare. Feedback from building owners and installers suggests that performance issues rarely arise and are within expected range of industry standards.
- Installers recommend using interior retrofits from top manufacturing companies to ensure quality.
- Installers found the process of interacting with tenants to be no more difficult or even easier than when they replaced a window.

**Energy and Non-Energy Benefits**

- Difficulties reaching building-level contacts limited our ability to confirm or disconfirm energy or non-energy benefits associated with SGS installation. However, the three building owners interviewed through this project consistently affirmed discernable energy savings as well as non-energy benefits.
- These non-energy benefits included increased occupant comfort, reduced window glare, and reduced noise due to the installation of SGS products.
- Other non-energy benefits mentioned by installers included potential reduced insurance costs in hurricane-prone regions and security and safety assurance in behavioral health situations.
- The literature described additional potential non-energy benefits including reduced landfill waste, reduced window glare, improved perimeter office area, productivity gains, reduced airborne dust infiltration, and sound reduction.

**Market Drivers and Barriers**

**Market Drivers**

- Many installers are introduced to SGS products by attending industry tradeshow or through pre-determined specifications provided by project architects.
- The main purchase drivers influencing the use of SGS for building representatives included the need to address historic landmarked preservation requirements, the safety of residents in behavioral health facilities, and the desire for energy efficiency improvements.

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<sup>2</sup> For example, one report noted savings of 5% to 29% in electrically heated buildings (SOLARC Engineering and Energy + Architectural Consulting. *Savings and Economic Analysis of Secondary Glazing Systems*. February 2016.). Another report showed savings on a General Services Administration (GSA) building of 7% for the retrofit in electricity savings and 33% in steam savings. (Global Facility Solutions. *Sidney R. Yates Federal Building*. February 2013).

<sup>3</sup> Global Facility Solutions. *Baseline Development Report – Sidney R. Yates Federal Building*. February 2013.

### **Market Barriers**

- Secondary literature<sup>4</sup> highlighted three primary barriers to the SGS technology, including: lack of customer awareness; a focus by manufacturers on other more advanced products (such as advanced films) at the expense of secondary glazing systems; and the potential risk of increased condensation in poorly installed unsealed gaps.
- Interviews confirmed that customer awareness is the main barrier inhibiting the adoption of SGS products.
- Value engineering aimed at achieving whole building designs at the lowest lifecycle cost may conflict with business decisions to install SGS products.
- Although not a primary market barrier, a building engineer interviewed from one of the larger buildings that had received SCG installations, described engineering concerns regarding the weight of SGS products in large buildings with extreme glazing.

### **Competition/Alternatives**

- Standard and low-e window films are a less expensive alternative to SGS products, but do not offer similar thermal performance or NEBs.
- Respondents noted choosing SGS over a full window replacement because secondary glazing was about one-half the price and could be installed in significantly less time than a full replacement.

## **Market Sizing and Baseline**

### **Preliminary Market Baseline**

- A review of data purchased from Persistence Market Research<sup>5</sup> found that: 1) annual sales for all commercial SGS products in the Northwest (Oregon, Washington, Idaho, Montana) is approximately \$1.3 million; 2) the total national market for SGS commercial was \$9.7 million in 2014, and the market is forecast to grow to \$12.2 million by 2024; and 3) the estimated annual growth rate is 2.0%-2.4% for 2016 through 2024.

### **Strategies for Sizing the Regional Market**

- Navigant reviewed Pacific Northwest commercial building stock data to facilitate understanding of market opportunities. The analysis revealed that buildings built before 1990 make up 87% of the total CBSA-estimated single glazed window area, confirming NEEA's expectation that an effort should target buildings built before 1990.
- Buildings greater than 20,000 square feet represent only 7% of the total building count but comprise more than half (56%) of the total single-glazed window area for electric heated buildings built prior to 1990. Therefore, targeting facilities greater than 20,000 square feet in size could help NEEA focus on the largest opportunities for SGS installations. For electrically heated buildings over 20,000 square feet built before 1990, office buildings represent a significant opportunity for NEEA in terms of number of buildings with single glazing and area of single-glazed windows to be improved, followed by schools and residential care facilities.

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<sup>4</sup> Navigant notes that the barriers identified are ones based on the limited availability of SGS technologies. Further research may reveal other barriers beyond the scope of this initial study effort.

<sup>5</sup> Persistence Market Research. *Secondary Glazing Market: U.S. Industry Analysis and Forecast 2016-2024*. November 2016.

- A large percentage of pre-1990 buildings with single glazed windows are primarily heated with natural gas. NEEA should continue to explore the potential energy savings in these buildings, including potential savings from electric terminal reheat. Data is not currently available to confidently size this market.

## Supply Chain

- Market actors who work with SGS usually refer to an *interior window retrofitting product* rather than use the term “attachments.”
- Installers use window mockups to showcase the product’s performance as part of the sales process.
- Frames are mostly custom made.
- Manufacturers provide the window pane warranty, while the installer is responsible for the seal warranty.
- Manufacturers sometimes install the retrofits themselves.

## Suggested NEEA Market Interventions by Interviewees

- Focus on increasing awareness of this product, as this inhibits project identification.
  - Target architectural firms to get the window scoped from the project’s inception.
  - Attend networking events to represent the product.
- Conduct a cost-benefit analysis to show it is the best option for the price point.
- Target buildings where the façade is over 50% glass as the energy savings benefits may be larger.

## Conclusions and Recommendations for Future Research

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Overall, Navigant found SGS has no major performance concerns that should prevent NEEA from continuing to pursue this product. The product appears to suffer primarily from lack of awareness rather than any inherent technological or delivery chain issues. This said, most companies target customers in areas with more extreme climates than the Northwest, so NEEA will need to confirm that the product is cost-effective in the Northwest given the region’s relatively mild year-round climate<sup>6</sup>.

Furthermore, the results are primarily based on interviews with manufacturers and installers, not building representatives, since Navigant was unable to reach a substantial number of end users through this approach. Navigant recommends NEEA continue to look for sources that can support research on tenant or building owner experience, and require building contact information for as many projects going forward as possible.

Navigant found that the installers and building representatives with whom the team spoke were universally favorable toward the window attachments and were satisfied with their performance to date. Based on these conversations, NEEA may want to focus on trade ally alliances as a means of marketing this technology, which is relatively unknown in the Northwest. Beyond this, as noted in the body of the report, architects and other renovation specifiers will need to be informed of the development and expansion of SGS products for commercial sector buildings.

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<sup>6</sup> This study’s scope is limited to SGS technological potential. Additional research will be required to understand economic potential.

SGS may be well positioned to address multiple commercial customer concerns including cost, reliability, visual impacts, and timeframe of installation. In addition, the product can address the needs of several niche markets such as historic buildings, behavioral health and other hospital settings, government buildings, and schools.

Overall, Navigant concludes that the product is sound, potential issues are minimal, and SGS products could achieve increased penetration if marketed to key segments and sub-segments in which the technology is most favorably received.

## Further Research Questions

Navigant identified several areas of potential future research to support the goals of the initiative. The research team lists these potential research areas and research questions below:

- 1. Understand the role of each market actor in specifying secondary glazing products.** For what types of projects is a glazing contractor the primary source of information? For what types of projects is it a design professional, general contractor, or engineer? What is the current level of awareness among these groups and what are their current perceptions of the product? Investigate labeling and naming for supply chain and potential consumers.
- 2. Monitor and confirm product satisfaction with a larger sample of building representatives.** What is the level of satisfaction with SGS products for building representatives (e.g., owners, facility staff, tenants)?
- 3. Confirm SGS Costs and Benefits, Payback, and Potential.** How do expected energy savings vary in specific Northwest states and climate zones where SGS products have the most potential? How do potential reductions in associated HVAC equipment impact payback and cost effectiveness for SGS products? In what scenarios could window attachments enable downsizing or reduced investment in future HVAC sufficient to provide additional benefits?
- 4. Confirm SGS Key Target Markets.** In which markets are secondary glazing products most likely to experience rapid uptake? What are the market characteristics and stakeholder perspectives of high impact, potential energy-saving SGS buildings—namely retail/service buildings, office buildings, warehouses, and assembly buildings constructed before 1990?
- 5. Map the Supply Chain and Identify Channels to Reach Key Target Markets.** Investigate strategies for effectively reaching identified target markets. How can NEEA leverage the position of the trades, manufacturers, and building owners?
- 6. Confirm existing SGS market penetration.** Because there were less than 15 SGS projects in the manufacturer data across NEEA's territory, Navigant estimates that the starting market saturation of SGS is less than 1%. NEEA should continue to validate this assumption as additional market research is completed.



# 1. Introduction

## 1.1 Background

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Secondary glazing systems are a component of NEEA’s Window Attachments initiative, which includes products designed to improve the performance of existing windows in both commercial and residential buildings. Secondary glazing is expected to support NEEA’s ongoing efforts to transform the commercial buildings market in the Northwest to ever higher states of energy efficiency by complementing other existing commercial sector building efforts underway at NEEA.

NEEA defines secondary glazing as high performance insulated glazing units for commercial building that are installed on the interior side of a building without replacing the existing glass, window frames, or altering the exterior appearance of the building. These items cost roughly \$40 per square foot installed and are approximately half the cost of replacing the whole window. NEEA estimates roughly 470 million square feet of single-pane glazing in 3,400 existing buildings in the Northwest region, establishing a substantial potential market for these window attachments.

Other organizations are involved in developing SGS standards and tools that may support the awareness and acceptance of SGS products in the marketplace. Table 1 shows these organizations and their corresponding tools or leverage points.

**Table 1. Organizations and Supporting Efforts**

Organization/Stakeholder	Tool/Effort
Attachments Energy Rating Council (AERC)	Certification standard
Lawrence Berkeley National Lab (LBNL)	SGS Condensation Risk Assessment Tool
Manufacturers	Case studies from select installations
Lawrence Berkeley National Lab (LBNL)	Updating existing energy modeling software to incorporate SGS into energy use forecast

NEEA contracted with Navigant to provide preliminary market research and baseline assessment activities to support the initial startup phase of the initiative. This stage of the research is focused on assessing market opportunities and overall product performance of SGS, and understanding the experience and satisfaction of those with direct experience with the product.

## 1.2 Research Objectives

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Navigant assessed market opportunities and overall product performance by focusing on a set of prioritized research objectives presented in Table 2. A qualitative assessment of the status of each research objective is represented by the circles in the third column, a completely solid ball indicates the research objective was fully addressed by the activities within scope of this project. Circles with more white space will need to be supported by future research to support the initiative.

**Table 2. SGS Phase 1 Research Objectives**

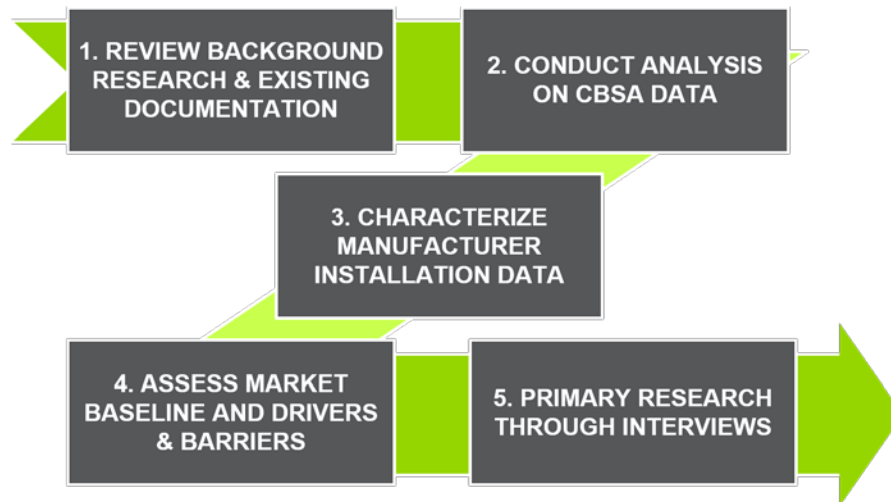
Research Objective	Example Questions	Research Status	Comments
<b>Assess overall product performance</b>	<p>How do representatives of existing installations describe their experience with the product?</p> <p>Do they describe any issues with condensation, breakage, or installation issues?</p>	●	<p>Overall, Navigant found SGS has no major performance concerns that should prevent NEEA from continuing to pursue this product.</p> <p>However, difficulties reaching building level contacts limited our ability to fully vet overall product performance.</p>
<b>Investigate strategies for sizing the regional market</b>	<p>How can NEEA best understand the potential size of the market for SGS products (e.g., square footage of existing windows, number and types of buildings, building representatives, and decision makers)?</p>	●	<p>Navigant estimates that the baseline penetration of SGS products in the Northwest is close to zero but additional research in may be needed to confirm the baseline and potential market size.</p>
<b>Refine understanding of market barriers</b>	<p>What are the primary barriers to market adoption that emerge from preliminary research?</p> <p>How do these align with current initiative assumptions?</p>	●	<p>The product appears to suffer primarily from lack of awareness rather than any inherent technological or performance issues. Additional conversations with building representatives may reveal other product barriers.</p>
<b>Understand product drivers</b>	<p>What are the purchase triggers most associated with opportunities for SGS?</p> <p>To what extent are SGS products seen as a solution to concerns about safety/security, occupant comfort, renovation, regulation, building sale, tenant improvement needs?</p> <p>How do drivers vary by building type or purpose (hospitals, offices, institutional buildings)?</p>	●	<p>Additional research on product drivers by building type, particularly for large office buildings, may be helpful to identify opportunities for secondary glazing products in the Northwest</p>
<b>Identify leverage points within the existing supply chain</b>	<p>How many and what types of market actors are currently providing similar products?</p> <p>What is the relationship between these products and replacement windows?</p> <p>What training is necessary?</p> <p>How are manufacturers currently working within the supply chain?</p> <p>What are the opportunities for effective intervention in the supply chain?</p>	●	<p>The interviews and literature review did not provide an in-depth understanding of the SGS supply chain.</p>

Source for research objectives and example questions: Navigant Scope of Work Request for Bid, December 2016.

## 1.3 Approach

Navigant addressed the research questions through five primary research tasks, shown in Figure 1. The five primary tasks first focused on reviewing secondary research and conducting a gap analysis. Then Navigant conducted interviews with a sample of project participants selected from the manufacturer installation data.

**Figure 1. SGS Phase 1 Research Tasks**



Navigant followed the Sources and Uses table (Appendix B) to align the key research objectives with the research questions and data sources.

### 1.3.1 Secondary Research and Project File Review

In the first stage of the project, Navigant conducted secondary research to complete an initial assessment of SGS baseline market activity and market trends. The analysis draws from information gathered from the most recent Commercial Building Stock Assessment (CBSA), existing NEEA and other market research, and data from manufacturer-provided installations. The Bibliography lists the sources used in the study.

### 1.3.2 Interviews

After the literature review, Navigant conducted primary research using in-depth interviews with market actors associated with existing installations. The market actors fell into three categories: manufacturers, glazing contractors/installers, and building decision makers. The interview guides (provided in Appendix A. Interview Guides) list the questions for each market actor type. Table 3 provides an overview of the interview flow and question list. Navigant tailored the interview questions to each market actor group based on their unique perspectives and role in the market for secondary glazing systems.

**Table 3. Question List Overview for Market Actor Interviews (Manufacturers, Installers, and Building Owners/Decision Makers)**

Topic Area	Objectives
<b>Background</b>	Understand interviewee’s role and responsibilities and how they learned about interior window retrofits.
<b>Product Drivers and Barriers</b>	Understand the key market opportunities, drivers, and barriers to interior window retrofits by geography, building type, and building size. Understand energy and non-energy-related benefits that may exist.
<b>Competition/Alternatives</b>	Identify the alternative products and who makes them.
<b>Installation and Longevity</b>	Explore issues related to installation timeframe and disruptions, and call-back issues after the installation.
<b>Customer Satisfaction</b>	Explore the interviewee’s perspective on customer satisfaction and if any product issues exist that may impact customer and tenant satisfaction.
<b>Supply Chain</b>	Identify supply chain opportunities, issues, challenges, and barriers.
<b>Decision-Making Process</b>	Explore the steps in the decision-making process.
<b>Requests</b>	Identify opportunities for NEEA to support growth of interior window retrofits and request contact information for other market actors who can provide information to support the research.
<b>Closing</b>	Confirm that we have covered everything the interviewee thinks is important.

Source: Navigant

### 1.3.2.1 Interview Targets and Completes

Navigant developed and refined the interview targets based on information on prior installations from the three manufacturers: Wausau, Berkowitz, and Thermolite. Table 4 shows the interview targets and completes by segment (manufacturer, installer/glazing contractor, and building owner). The installer and owner interviews were divided by manufacturer to ensure a reasonable distribution of perspectives across the three products. Navigant completed approximately 60% of targeted interviews, mainly due to difficulty obtaining contact information for building owners. Most of the project data files provided by the manufacturers included information on the glazing contractor but not the building owner or decision maker.

**Table 4. SGS Interview Targets and Completes by Market Actor Type**

Market Actor	Project Contacts	Target	Attempted	Complete
Manufacturers	3	3	3	3
Installers/Glazing Contractors	55	16	34	10
Building Owners/ Decision Makers	4	8	4	3
<b>Total</b>	<b>62</b>	<b>27</b>	<b>41</b>	<b>16</b>

Navigant requested contact information and introductions to building owners from the manufacturers and installation contractors that the team interviewed. In some cases, Navigant received owner contact information, but because of the limited number of contacts provided and relatively low acceptance rate for completing interviews, the team was only able to complete three building owner interviews. Navigant pursued each contact multiple times to complete an interview—usually four touchpoints or attempts were completed before a potential contact was abandoned.

### **Wausau Window Interviews**

Navigant set higher targets for Wausau Window-related interviews than for other manufacturers because of the large number of project records provided by the manufacturer to NEEA. However, the team experienced difficulties in contacting and scheduling the installer and building owner interviews for this manufacturer. For the installer interviews, the initial Wausau project dataset contained over 950 interior window retrofit projects, but only 340 of those projects occurred after 2010. Of those 340 projects, only 31 installation companies had completed more than two projects. Because Navigant did not have any contact names or contact numbers for the projects on file, it was difficult to contact an appropriate representative within the listed companies. Of the 31 installers, Navigant contacted 23 of the companies, including every company on file in the Pacific Northwest. The team spoke with 12 managers. Several of these managers declined the interview request—some did not recognize the product or the project name, while others showed initial interest but did not reply when the team tried to schedule a follow-up interview. The NEEA-provided list did not contain any Wausau-related building owner contact information. The team hoped to obtain owner contacts from the Wausau installers; however, none of the completed interviews provided building owner contacts for follow-up interviews. To expedite recruitment, Navigant offered a \$25 amazon.com gift card for completing the interview, but this did not help in meeting the targets.

### **Thermolite Interviews**

Navigant reached out to Thermolite directly to request their manufacturer project installation list. Thermolite provided the team with a detailed project referral list of 40 completed Thermolite projects that included project manager and building owner contact information. Most of the projects and associated contact information provided to Navigant were part of Thermolite's General Service Administration (GSA) contract. Navigant targeted 22 of the most promising leads on Thermolite's referral list. Receiving Thermolite's project referral list directly helped facilitate an easier introduction to installers and building owners.

An introductory email was sent to Thermolite project managers and building owners explaining Navigant's research objectives, and the team followed up with a phone call 2-3 days later. Similar to Wausau recruits, Navigant offered a \$25 amazon.com gift card to respondents as a token of appreciation for completing a 30-minute interview; in this case, it seemed to facilitate the recruiting and scheduling process. Navigant was successful in completing six Thermolite interviews: five installer interviews and one building owner interview.

### **Berkowitz Interviews**

Following an interview with the Renovate by Berkowitz team, a manager provided introductions to Navigant to several owners and installers for the major projects involving Berkowitz products. Navigant followed up on these introductions and successfully completed interviews with one installer and two building owners. As expected, the introductions helped Navigant conduct its interviews, but there may be a bias for the contacts where the manufacturer provided the introductions.

## 1.4 Product Descriptions

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### 1.4.1 Wausau

Wausau's Sound, Energy, Air, and Light (SEAL) windows, also referred to by company representatives as interior window attachments or interior accessory windows, are hinged on lift-out access panels with optional between-the-glass blinds, fitted into an internal frame. The retrofit glazing options include laminated glass or polycarbonate. The window enhances thermal, structural, and acoustical performance of weather-tight existing windows. These enhancements work best on non-operable windows, representing 75% of Wausau's installations per the manufacturer. The company's products are primarily installed in office buildings, healthcare facilities, and hotels.

### 1.4.2 Berkowitz

Berkowitz's Window Insulating Glass Units (IGUs) are two or more layers of glass separated and sealed to form a single glazed unit with an air space between each layer. These products are used on non-operable single-pane glass in which the façade retrofit system is hermetically sealed to the existing single-pane glass. An LBNL study showed that Berkowitz seals resulted in zero moisture transfer when compared to other interior window retrofit systems<sup>7</sup>. To retrofit a commercial building with Berkowitz's IGU, a structural and thermal analysis must confirm that a building can handle the weight associated with the additional glass. Additionally, a depth of at least 2 1/8" to mount the retrofit at the windowsill is needed. This is usually the case, but if not, Berkowitz installs a custom sill extender to the opening.

### 1.4.3 Thermolite

Thermolite's Secondary Window System transforms existing glass into a high performing new window system in a manner comparable to double or triple glazed windows. The existing glass and frame is retrofitted on the interior of the building with a simple frame system and an interior window. The product can include a range of laminated, suspended film, insulated, and low emissivity coatings.<sup>8</sup>

## 1.5 Project Descriptions

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Table 5 through Table 7 provide summaries of the buildings and project descriptions related to interviews conducted by the research team. Note that for Manufacturer A installer interviews, installers described multiple projects and answered the team's questions for their entire building portfolio.

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<sup>7</sup> Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.

<sup>8</sup> <http://thermolitewindows.com/supplemental-window-systems/interior-windows/>

**Table 5. Manufacturer A Interview Projects**

Manufacturer A	Firm Detail	Project Description
<b>Installer A</b>	<ul style="list-style-type: none"> <li>Focus on healthcare and higher education facilities</li> <li>Distributor for Manufacturer A since the early 2000s</li> </ul>	<ul style="list-style-type: none"> <li>The retrofit is primarily marketed for its price point advantage, use as privacy glass, and ability to lower humidity</li> <li>In psychiatric facilities, it is used for added security</li> </ul>
<b>Installer B</b>	<ul style="list-style-type: none"> <li>Focus on hospitals</li> </ul>	<ul style="list-style-type: none"> <li>Use the product for their interior blinds in privacy settings as well as their acoustic value, with a major focus on in-patient behavioral health settings</li> </ul>
<b>Installer C</b>	<ul style="list-style-type: none"> <li>Located in Florida</li> </ul>	<ul style="list-style-type: none"> <li>Main purchase driver is security and storm protection</li> <li>Unique ventilation requirements due to humidity requirements</li> </ul>

Source: Navigant analysis of manufacturer project data and interviews

**Table 6. Manufacturer B Interview Projects**

Manufacturer B	Project Description	Project Drivers
<b>Installer A</b>	<ul style="list-style-type: none"> <li>Historic building without the ability to replace existing windows</li> <li>Original windows were single-paned, hot-rolled steel windows</li> <li>Project completed in 2013</li> <li>Retrofitted 24 windows</li> </ul>	<ul style="list-style-type: none"> <li>Used SGS products for thermal performance and the need to regulate indoor air temperature</li> </ul>
<b>Installer B</b>	<ul style="list-style-type: none"> <li>12-story federal government office building built in 1939</li> <li>Part of a 6-year modernization project focused on a building envelope upgrade</li> </ul>	<ul style="list-style-type: none"> <li>Used SGS products for thermal performance and blast resistance</li> </ul>
<b>Installer C</b>	<ul style="list-style-type: none"> <li>Constructed in 1855 and designated as a National Historic Landmark</li> <li>One out of five historic buildings included in modernization initiative</li> </ul>	<ul style="list-style-type: none"> <li>Used SGS products for thermal performance and blast resistance</li> </ul>

Manufacturer B	Project Description	Project Drivers
<b>Building Owner</b>	<ul style="list-style-type: none"> <li>42-story, 2.8 million sq. ft. high rise building</li> <li>Original windows were aluminum framed with significant energy loss noted from the window frame</li> <li>Building consists of 29 governmental agency offices, including the Federal Bureau of Investigation</li> <li>Retrofitted 38 office floors with 3-pane glass and some lower floor windows</li> </ul>	<ul style="list-style-type: none"> <li>Retrofit was part of the 2015 federal government's initiative to reduce energy consumption by 30%</li> <li>Building required blast-resistant windows</li> </ul>

Source: Navigant analysis of manufacturer project data and interviews

**Table 7. Manufacturer C Interview Projects**

Manufacturer C	Project Description	Project Drivers
<b>Building Owner</b>	<ul style="list-style-type: none"> <li>1973 office building for a bank, considered Philadelphia's first modern sky scraper</li> <li>20-story building with single-paned, black glass</li> <li>Completed an initial mockup of two offices: a double window 200 sq. ft. office and 150 sq. ft. office with a single window</li> </ul>	<ul style="list-style-type: none"> <li>Improve energy performance</li> </ul>
<b>Building Owner</b>	<ul style="list-style-type: none"> <li>Mixed-use complex, historic landmark</li> <li>The design team specified the Renovate system with two panes of high performance glass, including passive low-e glass to minimize heating costs and solar control low-e glass to minimize cooling costs</li> <li>The retrofit project took 3 months to complete and included replacing broken glass, removing existing window film, cleaning the original glass, and installing the Renovate system to 760 windows</li> </ul>	<ul style="list-style-type: none"> <li>Noise reduction needed for hotel use</li> </ul>

Source: Navigant analysis of manufacturer project data and interviews



## 2. Secondary Research Findings

This section describes the preliminary research findings for the secondary research review.

### 2.1 Product Drivers

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Secondary research on product drivers focused on the following research questions:

- What are the installation/purchase triggers most associated with opportunities for secondary glazing?
- To what extent do these products address concerns other than saving energy?
- Under what scenarios are secondary glazing products most attractive?
- How do product drivers vary by building type or purpose?

The research team identified the following product drivers:

- Reducing noise<sup>9</sup>
- Reducing airborne dust infiltration<sup>10</sup>
- Preserving historic sites<sup>11,12</sup>
- Increasing building thermal performance<sup>13</sup>
- Providing a safety component for patients in behavioral health settings

Navigant considered these findings when developing the market actor interview guides. Despite the positive findings for a range of purchase drivers, the research team wanted to focus on understanding the most common purchase triggers and how energy savings and non-energy benefits (NEBs) might factor into purchasing decisions.

### 2.2 Overall Product Performance

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Navigant conducted secondary research on overall product performance, focusing on the following research questions:

- How do case studies of existing installations describe building representatives' experience with SGS and the installation experience?
- Do the studies describe any issues with condensation, breakage, or installation?
- Do the studies describe any expected or unexpected NEBs?

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<sup>9</sup> Persistence Market Research. *Secondary Glazing Market: U.S. Industry Analysis and Forecast 2016-2024*. November 2016.

<sup>10</sup> Ibid.

<sup>11</sup> Ibid.

<sup>12</sup> Berkowitz RbB Project Summaries, provided to NEEA by Berkowitz.

<sup>13</sup> Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.

A review of existing literature on SGS revealed positive experiences with the installation. Navigant found that installations can be completed quickly without significant disruptions to building occupants and that installations result in increased tenant comfort.<sup>14,15,16</sup> Per building management representatives in US Department of Energy (DOE) case studies, tenants were pleased with the retrofit experience. Through a web-based occupant survey, GSA building occupants did not provide any negative responses or comments regarding the building’s SGS retrofit.<sup>17</sup> Additionally, owners claim that a full window replacement would have taken 2 to 3 times longer to install.<sup>18</sup>

Studies indicate that positive energy savings accrue in projects where SGS technology is used. Table 8 provides a sampling of study findings.

**Table 8. Summary of Energy Savings Findings**

Study	Tool / Effort
SOLARC report 2016 <sup>19</sup>	SGS can reduce total building electrical usage from 5% to 29% for electrically heated buildings depending on operating patterns and heat type; electricity use reductions for gas-heated buildings range from 1.5% to 10%.
LBNL <sup>20</sup>	Occupants reduced portable space heater use after the installed window retrofit.
Global Facility Solution <sup>21</sup>	Case study of large GSA building showed electricity use fell by 7% after the retrofit and steam use fell by 33%.

In addition to energy savings, the secondary literature review revealed several NEBs, which are summarized in Table 9.

<sup>14</sup> Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.

<sup>15</sup> US Department of Energy (DOE) case studies

<sup>16</sup> Integrated Design Lab (IDL), University of Washington. *Rainier Tower: Secondary Glazing System Mockup*. June 2015

<sup>17</sup> Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.

<sup>18</sup> Renovate by Berkowitz. 400 Market Street Case Study.

<sup>19</sup> SOLARC Engineering and Energy + Architectural Consulting. *Savings and Economic Analysis of Secondary Glazing Systems*. February 2016.

<sup>20</sup> Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.

<sup>21</sup> Global Facility Solutions. *Baseline Development Report – Sidney R. Yates Federal Building*. February 2013.

**Table 9. Summary of SGS NEBs**

Topic	Finding	Supporting Statements	Source
<b>Reduced landfill waste</b>	Encouraging/ Difficult to Quantify	SGS retrofits use less new material and reduce waste compared to new window replacement.	LBNL
<b>Reduced window glare</b>	Positive	40% of the GSA occupants stated they experienced interior window glare before the SGS retrofit; no issues of glare discomfort were noted after the retrofit.	LBNL
<b>Improved perimeter office area</b>	Positive	Studies reveal reduced drafts, improved comfort, and increased usable office space near windows.	SOLARC, LBNL, DOE case studies
<b>Reduced airborne dust infiltration</b>	Positive		Persistence Market Research
<b>Sound reduction</b>	Positive	Window upgrades can result in a quieter working environment by blocking outdoor sounds.	DOE case studies

Source: Navigant analysis

## 2.3 Market Barriers

Navigant conducted secondary research on the market barriers to increased adoption of SGS, focusing specifically on the following research questions:

- What are the primary barriers to adoption?
- Are there any barriers that do not match the current NEEA stated barriers?

Navigant confirmed NEEA’s assumption that a primary barrier to adoption is lack of awareness across the supply chain from architects to installers to building owners and representatives. A review of the manufacturer project data suggests that early projects are likely to be government buildings and nonprofits (i.e., healthcare and schools). Persistence Market Research data also suggests that companies who manufacturer SGS may focus on other solutions (such as advanced films) at the expense of secondary glazing systems. Finally, the LBNL SGS Validation study<sup>22</sup> conducted a condensation simulation and found that many SGS products significantly increase the condensation risk in unsealed gaps; thus, risk of condensation may also be a barrier to increased uptake of this product.<sup>23</sup>

Based on these findings, Navigant focused on fully understanding the lack of awareness issue in market actor interviews. The team focused on understanding how current manufacturers are marketing their products and the factors that potential customers consider when deciding between SGS and other options.

<sup>22</sup> Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.

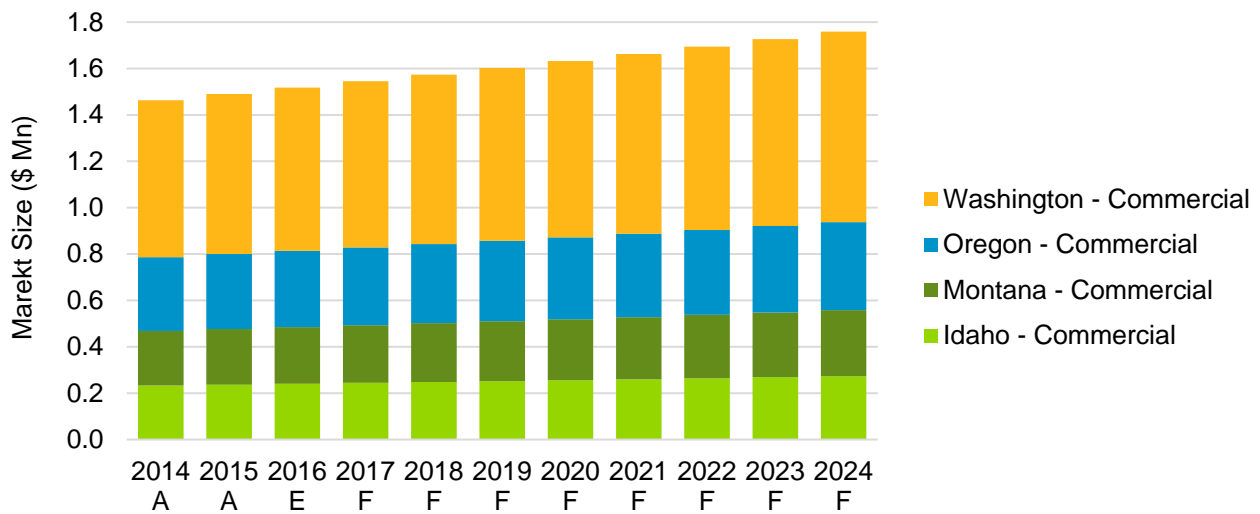
<sup>23</sup> The simulation required simplified and possibly unrealistic assumptions, so the exact risk cannot be quantified and instead should be used for comparison purposes. The results suggest a need for greater understanding of condensation in SGS products.

## 2.4 Preliminary Market Baseline

Navigant reviewed secondary research to examine the preliminary estimates of baseline market activity and expectations for near-term change. Navigant’s analysis of the Persistence Market Research<sup>24</sup> found the following:

- The current market for commercial SGS products in the Northwest (Oregon, Washington, Idaho, Montana) is approximately \$1.3 million. Figure 2 shows the Northwest commercial market size from 2014 through 2024. Figure 2 shows the state-specific market size.
- The total national market for commercial SGS was \$9.7 million in 2014; it is forecast to grow to \$12.2 million by 2024. This means that the Northwest makes up approximately 15% of the national market for commercial SGS.
- The total national market for SGS residential and commercial buildings combined was \$42 million in 2016; it is forecast to grow to \$59 million by 2024.
- The estimated annual growth rate for SGS is 2.0%-2.4% for 2016-2024.

**Figure 2. Total NW Commercial SGS Market Size, Actual (A) and Forecast (F) by State**



Note: A = Actual, F = Forecast

Source: Persistence Market Research

Navigant compared the total market size in sales dollars to the estimated potential market size, assuming a cost of \$40 per square foot, to estimate the current baseline activity. Navigant assumed that the starting market saturation of SGS is essentially zero because there were less than 15 SGS projects in the manufacturer data across NEEA’s territory. To determine the annual installation of SGS products, Navigant multiplied the annual SGS product sales dollar value for sales in the Northwest by the cost of installation (\$40 per square foot according to NEEA) to determine an annual square footage of window installation. The estimated market penetration is cumulative, assuming a measure life of 20 years for SGS products. The total market size is 223 million square feet, which is the square footage of single glazed buildings built prior to 1990 over 20,000 square feet heated by either electricity or gas as estimated in the CBSA. Table 10 shows that the estimated market penetration for SGS in the Northwest is less than one percent and is not forecast to grow significantly over the next 10 years.

<sup>24</sup> Persistence Market Research. *Secondary Glazing Market: U.S. Industry Analysis and Forecast 2016-2024*. November 2016.

**Table 10. Estimated and Forecast SGS Market Penetration in the Northwest 2014-2024**

Current Market Size	2014 A	2015 A	2016 E	2017 F	2018 F	2019 F	2020 F	2021 F	2022 F	2023 F	2024 F
Market Sales (\$M)	1.45	1.5	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.8
Sq. Ft. (assume \$40/sq. ft.)	30,687	31,255	31,832	32,407	32,993	33,606	34,230	34,876	35,525	36,187	36,848
Cumulative Sq. Ft.	30,687	61,942	93,774	126,181	159,174	192,780	227,010	261,886	297,411	333,598	370,446
Potential Market Size (Million sq. ft.)	223	223	223	223	223	223	223	223	223	223	223
<b>Estimated Market Penetration</b>	<b>0.014</b>	<b>0.028</b>	<b>0.042</b>	<b>0.057</b>	<b>0.071</b>	<b>0.086</b>	<b>0.102</b>	<b>0.117</b>	<b>0.113</b>	<b>0.150</b>	<b>0.166</b>
	%	%	%	%	%	%	%	%	%	%	%

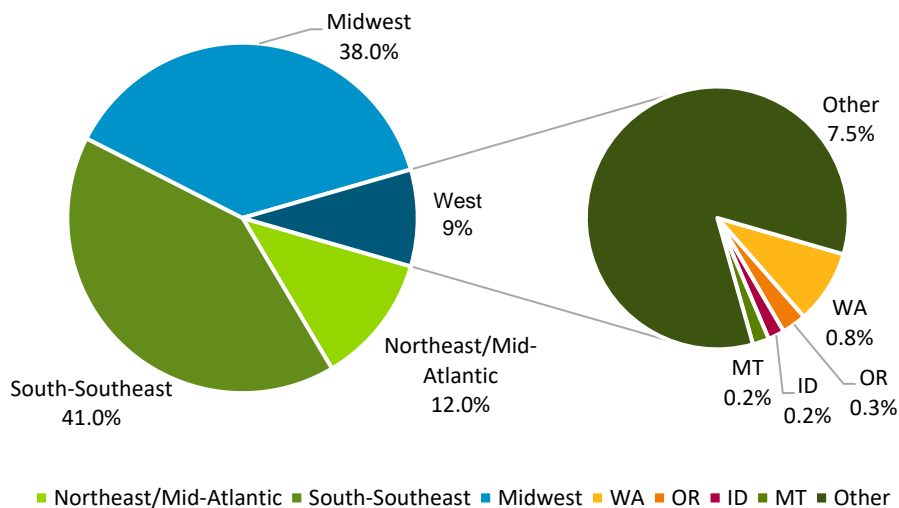
Source: Navigant analysis. Market Sales from Persistence Market Research. Assumed cost per sq. ft. from NEEA. Potential market size comes from the CBSA as single glazed building data for pre-1990 large buildings over 20,000 square feet heated by electricity or gas.

Note: Because there were less than 15 SGS projects in the manufacturer data across NEEA’s territory, Navigant assumed that the starting market saturation of SGS is essentially zero. NEEA could validate this assumption with additional market research.

The analysis in Table 10 is based on data NEEA purchased from Persistence Market Research. In addition, Navigant analyzed project installation data provided by the manufacturers to assess manufacturer installations by region and end-user building type (Figure 3). In terms of installations by region, Navigant found the following:

- Project installations in the West account for 9% of national installations (Figure 3)<sup>25</sup>.
- Of installations in the West, 17% account for installations in the Northwest (Oregon, Washington, Idaho, Montana), which is 1.5% of total national installations.

**Figure 3. Reported Manufacturer Installations by Region<sup>26</sup>**



<sup>25</sup> Projects in the West included Arizona, California, Colorado, Idaho, Utah, Montana, Nevada, Oregon, and Washington.

<sup>26</sup> The 7.5% non-Northwest SGS installations are from the states of California, Colorado, Arizona, Utah. California and Colorado make up 75% of these installations – with equal numbers of SGS -- and the remainder coming from Arizona (16%) and Utah (9%).

Source: Navigant analysis of manufacturer-provided project installation locations, 1997-2016

In terms of building type, the greatest market penetration for SGS nationwide is currently in the healthcare sector, with nearly 600 projects estimated as occurring in hospital, medical center, or healthcare facilities. This represents nearly 60% of overall projects among three manufacturers. Another manufacturer is particularly focused on government buildings. Table 11 summarizes the building type by project.<sup>27</sup>

**Table 11. Summary of Project Building Type**

Project Building Type	Count of Buildings	Percent of Buildings
Medical/Healthcare	589	59%
School/University/Education	65	6%
Government	22	2%
Other/Unknown	326	33%
<b>Total</b>	<b>1002</b>	<b>100%</b>

### 2.4.1 Strategies for Sizing the Regional Market

Navigant reviewed the existing secondary literature to assess potential strategies for sizing the regional market. The information from Persistence Market Research<sup>28</sup> provided a characterization of the current market per annual revenue by state and by sector (residential/commercial). However, there is a lack of information by building type and fuel type. In addition, the Persistence Market Research focused on *multiple* SGS products.<sup>29</sup> Thus, Navigant used CBSA data with a focus on buildings built prior to 1990 to identify potential market opportunities for SGS products.

## 2.5 CBSA Analysis

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### 2.5.1 Introduction

As part of the preliminary assessment of the SGS market potential that also included the analysis of Persistence Market Research in Section 2.4, Navigant reviewed data and assumptions from the 2014 CBSA and conducted analysis to facilitate understanding of opportunities. NEEA provided Navigant with two spreadsheets containing summary tables of the Pacific Northwest single glazed window market, including:

- Spreadsheet 1. Window Area Summary Table:
  - The total window area by building type, glazing type, building vintage, and heating fuel type for buildings that have 100% single glazed windows
  - The total building square feet by building type, state, or rural versus urban
- Spreadsheet 2. SG Heating Type:
  - The building count of single versus non-single glazed windows built before 1990 by building type, single-glazed percentage, and by heating type
  - The building count of single versus non-single glazed windows built before 1990 and over 20,000 sq. ft. by building type, single glaze percentage and heating type

<sup>27</sup> Many of the projects in the “other/unknown” category only provide an address. Many of these are likely office buildings.

<sup>28</sup> Persistence Market Research. *Secondary Glazing Market: U.S. Industry Analysis and Forecast 2016-2024*. November 2016.

<sup>29</sup> Other SGS products may include but are not limited to insulating cellular shades and interior surface films.

With these datasets, Navigant characterized the opportunities for SGS installations. Besides electric and gas primary heating, buildings in the CBSA database also included heated by “Other/NA,” which includes oil, propane, wood, purchased hot water, purchased steam, or no primary heating system<sup>30</sup>. Navigant’s analysis focused on buildings from the CBSA data that were primarily heated by electricity or gas.

### 2.5.2 Objective and Approach

The objective of the CBSA analysis was to identify target building group(s) that make up the largest amount of single-glazed windows in conditioned (gas and/or electric) space areas in the four state NEEA area. At the project initiation meeting NEEA defined its target market as commercial office buildings that are greater than 20,000 sq. ft. The CWA target market definition provided a key focus for the research.

NEEA also noted that buildings built prior to 1990 might provide a good target vintage for the project – should research bear this out -- as prior to this year no high performance, low-e coatings were present in the market.

Navigant categorized the CBSA data at the outset of the research by the building parameters the team reviewed. Table 12 provides the CBSA buildings categorization schema.

**Table 12. CBSA Building Classification Group Parameters**

CBSA Parameter	Description
<b>Building Type</b>	Table 19 in the Appendix describes the building types used in the CBSA.
<b>Percent Single Glaze</b>	The percentage of a building, based on the building’s total window area, that is single-glazed.
<b>Building Vintage</b>	Building construction separated into pre-1990 versus post-1990.
<b>Heating Fuel Type</b>	Primary heating types: electric versus natural gas.
<b>Building Size</b>	Separated into “All Sizes” and “Over 20,000 sq. ft..”

Source: Navigant

#### 2.5.2.1 Window Area and Single-Glazed Window Area

Table 13~~Error! Reference source not found.~~ shows the window area for single-glazing, the total window area, and the percent of window area that is single-glazed by building type for buildings constructed prior to 1990. This is followed by key findings and an analysis of the SGS potential target installation markets from the CBSA data.

<sup>30</sup> Seven percent of the single glaze window area for buildings with over 50% single glazing are primarily heated by “Other/NA” fuel types. Navigant excluded “Other/NA” building types from the CBSA analysis based on comments from NEEA.

**Table 13. Total Window Area and Single-Glazed Window Area for Pre-1990 Buildings by Building Type**

Building Type	Total Window Area (sq. ft.)	Single-Glazed Window Area (sq. ft.)	Percent Single-Glazed
Office	330,573,758	105,627,235	32%
Warehouse	186,444,542	80,610,123	43%
Retail/Service	221,513,893	83,550,937	38%
Assembly	146,595,210	41,590,473	28%
School K-12	98,378,567	42,424,787	43%
Other	81,738,891	18,641,032	23%
Residential Care	37,315,356	17,978,835	48%
Grocery	32,844,863	15,505,703	47%
Restaurant	22,890,200	8,265,553	36%
Lodging	52,594,579	5,221,964	10%
<b>Total</b>	<b>227,383,889</b>	<b>65,613,087</b>	<b>29%</b>

Source: Navigant analysis.

## 2.5.3 Key Findings

### Major Takeaways

- Buildings built prior to 1990 have the highest percentages of single-glazed windows and have been identified as an initial target market for this initiative.
- Buildings built before 1990 make up 87% of the total CBSA-estimated single-glazed window area.
- For electrically heated buildings built prior to 1990, buildings greater than 20,000 square feet represent only 7% of the total building count but comprise more than half (56%) of the total single-glazed window area.
- For gas heated buildings built prior to 1990, buildings greater than 20,000 square feet represent only 9% of the total building count but comprise more than half (52%) of the total single-glazed window area.
- Offices contain the most single-glazed window area for both electric and gas heated buildings out of the CBSA building types.

Based on the above, Navigant finds:

- NEEA's initial target market is consistent with the data that Navigant analyzed.
- Targeting facilities built prior to 1990 will help NEEA focus on the largest opportunities for SGS installations.
- Facilities greater than 20,000 square feet make up more than half of the single-glazed window area.
- For buildings constructed before 1990 and over 20,000 sq. ft., offices provide the greatest SGS potential.
- Within the office category, natural gas heated buildings represent the largest target market for single-glazed SGS applications, as defined by the total square footage of single-glazed window area. Of offices



built prior to 1990 and larger than 20,000 sq. ft., 69% of the single-glazed window area is heated with electric sources and 27% is heated with natural gas.<sup>31</sup>

Below, Navigant provides additional details on these findings.

**Key Findings - NEEA Offices Target Market (Electric and Natural Gas)**

The total square footage of single-glaze window area for natural gas heated buildings is approximately three times greater than the square footage heated by electric sources, which suggests that the potential for SGS applications could be higher for natural gas than electric heated buildings (see Table 14 - Table 15). The following sections describe the potential for buildings heated with electricity and natural gas.

Overall:

- **Offices – Electric, Pre-1990, Greater than 20,000 sq. ft.**

Table 16 shows that there are 241 electrically heated pre-1990 offices greater than 20,000 square feet in the Northwest with single-glazed windows, representing 21.1 million square feet of single-glazed window area. Offices represent 25% of the buildings and 35% of single-glazed window area for electrically-heated pre-1990 large buildings.

Table 15 shows that 27% of pre-1990 office single-glazed window area is heated primarily with electric and Table 13 shows that 32% of all pre-1990 office window area is single-glazed.

- **Offices – Natural Gas, Pre-1990, Greater than 20,000 sq. ft.**

Table 17 shows that there are 437 single-glazed gas-heated pre-1990 office buildings larger than 20,000 square feet in the Northwest, representing 33.5 million square feet of single-glazed window area potential. Office buildings represent 14% of the buildings and 21% of single-glazed window area for gas-heated pre-1990 buildings over 20,000 square feet.

Table 15 shows that 69% of pre-1990 office space is heated primarily with gas and Table 13 shows that 32% of office building window area is single-glazed.

Below, Navigant provides an overview of the pre-1990 CBSA building market by heating fuel type and more details on findings. First, we analyze the pre-1990 CBSA window stock by fuel type for all building types. Then, we analyze the pre-1990, greater than 20,000 sq. ft. electrically heated office market. Finally, we analyze the pre-1990, greater than 20,000 sq. ft. natural gas heated office market. Refer to Appendix D for further information on non-office SGS potentials and below 20,000 sq. ft. SGS markets.

**2.5.3.1 Single-Glazed Window Area Analysis by Primary Heating Type -- Pre-1990**

Table 14 shows the square footage of pre-1990 single-glazed window area by primary building heat type.

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<sup>31</sup> Appendix D.3 provides single glazed window area and building count information for non-office buildings.

**Table 14. Pre-1990 Single-Glazed Window Area (Square Footage) by Primary Building Heating Type**

Building Type	Electric	Gas	Other	Total
Office	29,844,939	75,782,297	4,918,662	110,545,897
Retail/Service	12,323,751	71,227,186	13,453,980	97,004,917
Warehouse	15,361,369	65,248,754	1,451,213	82,061,337
Assembly	10,633,184	30,957,289	9,615,951	51,206,424
School K-12	12,014,864	30,409,923	6,455,050	48,879,837
Other	11,388,564	7,252,468	509,249	19,150,281
Grocery	1,437,465	14,068,238	2,476,141	17,981,844
Restaurant	992,049	7,273,504	923,170	9,188,723
Residential Care	9,566,977	8,411,858	3,005,083	20,983,918
Lodging	3,680,790	1,541,175	-	5,221,964
<b>Total</b>	<b>107,243,952</b>	<b>312,172,691</b>	<b>42,808,498</b>	<b>462,225,141</b>

Source: Navigant analysis of CBSA data.

Table 14 shows that for across all building types and heat sources, offices represent the largest share of single-glazed windows with 110,545,897 sq. ft. total. Table 15 represents the percentage share of single-glazed window area (for pre-1990 buildings) by primary heating types for each building type. For offices, 69% of pre-1990 office buildings are heated with natural gas and 27% are heated with electric.

**Table 15. Pre-1990 Building Single-Glazed Window Area (Percentage) by Primary Building Heating Type**

Building Type	Electric	Gas	Other	Total
Office	27%	69%	4%	100%
Retail/Service	13%	73%	14%	100%
Assembly	19%	80%	2%	100%
School K-12	21%	60%	19%	100%
Warehouse	25%	62%	13%	100%
Other	59%	38%	3%	100%
Residential Care	8%	78%	14%	100%
Grocery	11%	79%	10%	100%
Restaurant	46%	40%	14%	100%
Lodging	70%	30%	0%	100%
<b>Total</b>	<b>23%</b>	<b>68%</b>	<b>9%</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

### 2.5.3.2 Single-Glazed Window Analysis for Electric Heated Buildings -- Pre-1990, Larger than 20,000 sq. ft.

#### Overview:

Buildings greater than 20,000 square feet represent only 7% of the total building count but comprise more than half (56%) of the total single-glazed window area for electric heated buildings built prior to 1990.<sup>32</sup> Therefore, targeting facilities greater than 20,000 square feet in size could help NEEA focus on the largest opportunities for SGS installations

**Discussion:**

Table 16 shows the number and square footage of single-glazed pre-1990 buildings with electric heat (>20,000 sq. ft.).

**Table 16. Single-Glazed Pre-1990 Buildings with Electric Heat (>20,000 Sq. Ft.)**

Building Type	Single-Glazed Building Count	Percent of all Building Types	Single-Glazed Window Area Sq. Ft.	Percent of all Building Types
Office	241	25%	21,156,265	35%
Retail/service	23	2%	3,045,142	5%
Assembly	16	2%	3,341,701	6%
School K-12	84	9%	10,578,910	18%
Warehouse	-	-	-	-
Other	148	15%	9,144,155	15%
Residential Care	330	34%	9,566,977	16%
Grocery	-	-	-	-
Restaurant	-	-	-	-
Lodging	123	13%	3,392,221	6%
<b>Total</b>	<b>962</b>	<b>100%</b>	<b>60,225,370</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

Note: Buildings are considered single-glazed if >50% of the window area is single-glazed. The single-glazed window square footage shows the actual estimated window area for single-glazing, not the entire building window area for buildings considered single-glazed.

Among pre-1990 buildings over 20,000 square feet, **office buildings** represent a significant opportunity for NEEA in terms of number of buildings with single glazing (241) and percent of total area of single-glazed windows (35%) to be improved. Secondary targets -- should NEEA choose to expand its target market definition -- could include K-12 Schools (84 buildings count/18% of target sq. ft., Appendix D.2) and residential care facilities (330 count/16% window area, Appendix D.2).

**Office**

The CBSA shows that there are 241 offices greater than 20,000 square feet in the Northwest with single-glazed windows, representing 21.1 million square feet of single glaze window area.

Offices represent 25% of the buildings and 35% of single-glazed window area for electrically-heated pre-1990 large buildings. Table 15 shows that 27% of pre-1990 office space is heated primarily with electric and Table 13 shows that 32% of office window area is single-glazed.

<sup>32</sup> From Appendix D.2, for electrically primary heated buildings:

- Pre-1990, >20,000 sq.ft., (1) building count = 962 and (2) single glazed window area = 60,225,370 sq.ft.
- Pre-1990, all sizes, (1) building count = 13,671 and (2) single glazed window area = 107,243,954 sq.ft.

### 2.5.3.3 Single-Glazed Window Analysis for Gas Heated Buildings -- Pre-1990, larger than 20,000 sq. ft.

**Overview:**

Buildings greater than 20,000 square feet represent only 9% of the total building count but comprise more than half (52%) of the total single-glazed window area for gas heated buildings built prior to 1990.<sup>33</sup> Therefore, like electric heated buildings, targeting facilities greater than 20,000 square feet in size should help NEEA focus on the largest opportunities for SGS installations.

**Discussion:**

Table 17 shows the number and square footage of single-glazed pre-1990 buildings with gas heat (>20,000 sq. ft.).

**Table 17. Single-Glazed Pre-1990 Buildings with Gas Heat (>20,000 Sq. Ft.)**

Building Type	Single-Glazed Building Count	Percent of all Building Types	Single-Glazed Window Area Sq. Ft	Percent of all Building Types
Office	437	14%	33,472,734	21%
Retail/service	478	15%	24,590,991	15%
Assembly	348	11%	17,400,886	11%
School K-12	547	18%	29,302,138	18%
Warehouse	1,015	33%	47,199,694	29%
Other	108	3%	4,389,922	3%
Residential Care	87	3%	2,710,733	2%
Grocery	90	3%	2,658,330	2%
Restaurant	-	-	-	-
Lodging	6	0%	1,541,175	1%
<b>Total</b>	<b>3,116</b>	<b>100%</b>	<b>163,266,601</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

Note: Buildings are considered single-glazed if >50% of the window area is single-glazed. The single-glazed window square footage shows the actual estimated window area for single-glazing, not the entire building window area for buildings considered single-glazed.

For buildings larger than 20,000 square feet in size, offices, along with warehouses and schools, represent the most significant opportunities for improving window performance (see Appendix D.3 for further discussion of the SGS potential in warehouses and schools).

**Office**

There are 437 single-glazed office buildings larger than 20,000 square feet in the Northwest, representing 33.5 million square feet of single glaze window area potential.

Office buildings represent 14% of the buildings and 21% of single-glazed window area for gas-heated pre-1990 buildings over 20,000 square feet. Table 15 shows that 69% of pre-1990 office space is heated primarily with gas and Table 13 shows that 32% of office building window area is single-glazed.

<sup>33</sup> From Appendix D.2, for gas primary heated buildings:

- Pre-1990, >20,000 sq.ft., (1) building count = 3,116 and (2) single glazed window area = 163,266,601 sq.ft.
- Pre-1990, all sizes, (1) building count = 33,104 and (2) single glazed window area = 312,172,690 sq.ft.

### 3. Interview Findings

This section describes key findings from in-depth interviews with SGS product manufacturers, installers, and building owners and decision makers. The research team aggregated the findings across the market actor groups, noting differences across groups when needed. The findings are presented by interview topic, as described in Table 3.

#### 3.1 Purchase Drivers

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**Key takeaways:**

- Initial introduction to the product for installers stemmed from attendance at industry tradeshows and pre-determined specifications provided by project architects.
- Main purchase drivers influencing the use of SGS for building representatives included the need to address historic landmarked preservation requirements, the safety of residents in behavioral health facilities, and energy efficiency improvements.
- Market actors commonly refer to SGS products as an interior window retrofitting product rather than use the term attachments.

The Navigant team sought to understand how interviewees became aware of the product and understand the purchase drivers. Contacts stated their initial introduction to the product was through industry tradeshows and pre-determined specifications provided by project architects. Attendance at industry tradeshows and the preliminary mockups influenced one building owner's decision to move forward with SGS retrofit installations. Several contacts described SGS retrofit projects that were solidified by mockup demonstrations that demonstrated the viability and performance of the SGS application. Several respondents stated that project requirements, typically dictated by the project's architect, strongly influenced the use of SGS products. Specific project requirements, such as blast resistance or thermal performance, may also contribute to an architect's decision to use SGS. The research team noted that many common applications of SGS products were found in governmental buildings, such as the General Service Administration and Federal Bureau of Investigation offices, requiring high security, blast-resistant specifications.

The main purchase drivers influencing respondents' use of SGS products included historic preservation requirements and the need for energy efficiency improvements. Installers and building owners cited SGS products as the only feasible window upgrade option for historic buildings, which often cannot have exterior windows replaced to protect a building's original exterior architecture. Many historic buildings benefit from substantial energy efficiency improvements when aging, low performance windows are upgraded with secondary glazing products. One installer described a retrofit project that protected the rare book room in a historic building. This room required a specific solution to regulate air temperature through enhanced window thermal performance to ensure the long-term preservation of the rare book collection.

Respondents also stated that a primary application for secondary glazing is in behavioral health settings, where blinds can be installed between two strong poly-glass windows to ensure patient safety and security, as well as sound reduction.

Respondents use a variety of labeling or nomenclature for SGS products in the marketplace. The term "window attachments" is not commonly used to identify or market the retrofit product. For example, an installer reported labeling products in terms of the customer's need or purpose, such as "interior thermal window, blast window, or interior window screens." Other respondents identified the products as interior window retrofits, interior sashes, interior access panels, or interior secondary windows, suggesting that no one naming convention of these

products currently exists in the marketplace. Nomenclature commonalities revolve around descriptions of an interior window retrofitting product versus the term attachments.

## 3.2 Energy and Non-Energy Benefits

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### Key takeaways:

- Building representatives reported substantial energy and non-energy benefits attributable to the installation of secondary glazing products.
- Non-energy benefits included increased occupant comfort and reduced window glare and noise.
- For certain types of buildings, other benefits can include reduced insurance costs in hurricane-prone regions and security and safety assurance in behavioral health facilities.

Two of the three building owners interviewed reported substantial energy and non-energy benefits directly related to the installation of SGS products.<sup>34</sup> One respondent stated the decision to retrofit his Philadelphia building with secondary glazing products was a “game changer” that reduced the building’s yearly energy needs by 50%. Prior to the building’s SGS retrofit, this building had high window glass temperatures of 117-120 °F and office room temperatures at 85 degrees, even when the thermostat temperature was set at 65 degrees. Post-retrofit, the interior office temperatures remain at ambient room temperatures even on cool mornings and there are fewer temperature-related complaints from occupants. The respondent also reported reduced window glare and noise from treated windows.

Installing SGS at a federally owned building in New York City also yielded a substantial reduction in energy usage. The respondent explained that prior to the SGS installation, the building’s HVAC system could not meet energy demands on extreme heating and cooling days and noted that the building consumed one-quarter of the energy of the federal government’s portfolio of 64 GSA buildings nationwide. After the retrofit, the respondent reported that the SGS retrofit reduced the building’s yearly energy usage by 13% in which 3% of the building’s energy reduction was attributed to energy loss of the pre-existing window frame itself. The respondent also noted that tenants reported reduced window drafts.

In addition to noticeable reductions in energy usage, building representatives described other non-energy benefits associated with secondary glazing products:

- Increased occupant comfort and reduced drafts from perimeter windows
- Reduced window glare
- Reduced noise due to the installation

Interviews with installers identified additional non-energy benefits including increased safety for storm protection and behavioral health<sup>35</sup>-related reasons.

## 3.3 Barriers

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### Key takeaways:

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<sup>34</sup> The third building owner could not comment on energy reduction because the individual did not own the building prior to the retrofit.

<sup>35</sup> Navigant was unable to speak with behavioral health staff at targeted facilities. Thus, the information provided came from installers as their major understanding of the NEB.

- Product awareness—across the supply chain—is the main barrier inhibiting the adoption of SGS products.
- Value engineering aimed at achieving whole building designs at the lowest lifecycle cost may conflict with business decisions to install SGS products.
- Concerns about engineering issues related to SGS weight in large buildings with extreme glazing needs.

Installers reported that awareness is the main barrier inhibiting the adoption of SGS products and that market actors across the supply chain need information about the availability and benefits of SGS products. Respondents expressed the value of the energy and cost savings associated with SGS products and described explaining to their customers that SGS products are a cost-effective, competitive option to re-doing a building's entire exterior façade.

One owner's representative, a building engineer, noted that even though his company was extremely pleased with the results of the retrofits done on one floor of his large high rise, he was reluctant to install the SGS in all 20 stories because of concerns about the weight of the additional glass. He also said that despite several engineering studies completed showing that the weight was not an issue, concerns remained.

### 3.4 Competition/Alternatives

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#### Key takeaways:

- Standard and low-e window films are a less expensive alternative to SGS products, but these products do not offer a similar thermal performance or sound reduction.
- SGS is attractive compared to a full window replacement because the costs are about one-half the price and installation time is significantly shorter.

Several interview respondents identified standard window films as an alternative window application to SGS products. Window films are applied directly to a window's glass surface to help reduce solar heat transmittal. A common issue experienced with standard and reflective film options is a noticeable lack of visual clarity that can affect outdoor views during inclement weather. Respondents also added that emissivity values can be incorporated into the window film as an alternative to SGS products. Low-e window films offer thermal performance by helping to prevent heat loss in the winter and solar heating in the summer months. Window films are a less expensive option, though one installer stated these products do not offer a similar thermal performance compared to SGS products.

### 3.5 Installation and Product Longevity

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#### Key takeaways:

- Installing SGS products is more efficient and less disruptive than a full window replacement. The installation typically takes 20-30 minutes per window depending on window size.
- Most respondents did not experience issues with condensation or seal breakage. Some noted cases of window condensation and breakage related to improper sealing of the original exterior window.
- Installers who reported minor incidences of window condensation and breakage believe that these incidents are within industry standards; they have not deterred the use of SGS products or negatively affected the product's longevity.

Through installer and building owner interviews, the research team explored possible issues and disruptions related to the installation of SGS products. Respondents were asked about product longevity and customer call-back issues related to window condensation or breakage. Installers generally reported that the installation process was quick and easy, taking approximately 20-30 minutes per window depending on the window size. Blast-resistant secondary glazing installations require a more advanced process and additional install time. One installer expressed professional and customer service satisfaction of “getting in and out” with little-to-no disruption to office occupants. Respondents explained that the installation of SGS products is more efficient and less disruptive compared to a full window replacement, which typically involves several days of disruptive tear-out work from a building’s exterior structure. One installer described the convenience of completing an SGS install during an occupant’s lunch hour; the only noted inconvenience was the need to physically move desks and office furniture prior to starting the installation. To minimize disruption to day-to-day business operations, another respondent preferred to complete the work during non-operational hours.

An important objective of this research included understanding the incidence of window condensation and breakage associated with SGS products. Most respondents did not experience issues with condensation or seal breakage. One building facilities manager explained their approach to preventing condensation, which involved removing moisture with desiccants using a device to extract all the air, and a final seal bead protector on the outside of the windows to ensure the seal’s integrity. Another installer described minor condensation issues related to improper sealing of the original exterior window. Another respondent reported four or five breakage issues in approximately 500 SGS retrofits installed over the past seven years but stated these observed breakage issues were well within the norm or acceptable range of industry standards. The respondents also noted incidents of minor window breakage related to the thickness of the original glass and how tightly the existing exterior window was sealed.

### 3.6 Customer Satisfaction

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#### Key takeaways:

- Seal failures and breakage are rare. Product failure is usually the result of improper sealing by the installer.
- Condensation issues are not a concern.
- Installer experience indicates that there are few concerns about time and disruption among tenants affected by SGS installation.

Interview respondents expressed almost no complaints with SGS product performance or the installation process. Representatives from one manufacturer reported no known seal failures on its internal glazing unit, while another reported no warranty claims in over 5 years. According to interviewees, breakages associated with the retrofit windows typically occurred during the installation process and were quickly replaced. Most installers interviewed reported no callbacks for their SGS projects and noted that owners often prefer this installation as it minimizes tenant disruption. The three owners interviewed reported that they were pleased with the thermal performance. One owner commented that he was “pleasantly surprised with the performance. I would have not expected the difference in the two windows’ temperature to be so great. One glass was cool while the other is red hot.”

### 3.7 Supply Chain

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#### Key takeaways:

- Frames are typically custom made.
- Manufacturers provide the window pane warranty, while the installer is responsible for the seal warranty.



- Manufacturers sometimes install the retrofits themselves.

Installers reported having generally good relationships with secondary glazing product manufacturers. Table 18 summarizes the findings for interviews that explicitly commented on supply chain.

**Table 18. Supply Chain Summaries from Interviews**

Topic	Supply Chain Summary
<b>Warranty</b>	<ul style="list-style-type: none"> <li>• Manufacturers provide the warranty (up to 10 years) for the window pane.</li> <li>• The installer is usually responsible for providing the warranty on the window seal and the labor (generally 1-2 years).</li> </ul>
<b>Installation, Training and QC</b>	<ul style="list-style-type: none"> <li>• Manufacturers sometimes install the product themselves but usually the installation is performed by a glazing contractor.</li> <li>• One manufacturer requires all new installers to complete certification and training. Another manufacturer offers training but doesn't require it.</li> <li>• Manufacturers often perform spot checks on installations to ensure quality.</li> </ul>
<b>Sales Process and Partnerships</b>	<ul style="list-style-type: none"> <li>• One manufacturer prefers customers order from them directly rather than through a general contractor as contractors can be unaware of the product or may want to install something more complex and expensive. This was echoed by an installer who explained that building representatives often buy direct from manufacturers who provide technical support.</li> <li>• Some installers only work with one SGS manufacturer, others will hire different manufacturers on a job-specific basis. Similarly, manufacturers work with a variety of installers.</li> </ul>
<b>Project Timeline</b>	<ul style="list-style-type: none"> <li>• The entire project from initiation to completion can take sometimes take 2-3 years.</li> <li>• Installation takes 4-16 weeks (8 weeks on average) depending on the project size, window type and wall condition.</li> </ul>

Source: Navigant analysis of market actor interviews

### 3.8 Suggestions for NEEA Intervention<sup>36</sup>

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**Key takeaways:**

- Because awareness of this product is considered the primary barrier to adoption, NEEA could intervene in the market by:
  - Targeted outreach to architectural firms to ensure they have accurate information about of SGS products and to ensure they are scoped into a project at project inception
  - Attend architectural networking events, trade shows, and conferences to build awareness about the product
- Provide cost-benefit analyses that captures the value of SGS solutions relative to other options

The research team asked interviewees for suggestions to improve the adoption of SGS products in commercial buildings. Most interviewees stated that product awareness is the most significant barrier to increased adoption. To increase product awareness, several installers suggested targeting architectural firms to ensure the windows are included on the specification sheet during the project scoping stage. One contracting firm reported only having one or two projects where the interior window retrofit was specified from the start. Instead, the secondary glazing solution is typically introduced as an alternative, often for its price point. Other installers suggested that NEEA attend architectural networking events, such as building manager or building code tradeshow, to represent the product. Case studies and referrals can also help showcase the interior window retrofit’s energy performance competitiveness and cost savings compared to traditional window replacements. One installer commented the retrofit’s payback period is much better when a building’s façade is over 50% glass.

### 3.9 Other/Additional Feedback

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**Key takeaways:**

- Promote interior retrofits from reputable manufacturers to ensure quality.
- Consider window mockups to showcase the product’s performance.

Interviews provided insight into several other topics. Overall, the installers and building owners were pleased with the interior retrofits’ thermal performance, product longevity, lack of seal failures, and the NEBs associated with products from the manufacturers engaged with NEEA. One installer commented that he would be “hesitant to use spinoffs in a commercial application. I recommend using the top four manufacturing companies. If everything isn’t sealed correctly, you will run into those leakage, dust, and condensation problems.” Several installers also commented that if a customer does an initial mockup, they will then usually use the retrofit for the rest of the building. One installation company recommends customers do the initial mockup first and then re-evaluate six months later.

### 3.10 Outstanding Questions/Research Needs

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**Key takeaways:**

- What are the structural implications for installing an interior window retrofit, especially in older buildings?
- How do installation requirements vary across different climate regions?

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<sup>36</sup> As might be expected, beyond the suggestions listed in the section, manufacturers expressed interest in partnering with NEEA for referrals.

As part of the interview process, the research team asked the interviewees if they had any outstanding comments for the interior window retrofit that had not been covered in the interview. While most interviewees did not have any additional comments, manufacturers, installers, and building owners commented on the need to analyze the structural effects of the added weight from the window installations. One manufacturer requires a structural and thermal stress analysis be completed before installing their products to ensure a building is fit for the installation.

Another potential research topic emerged during an installer interview. For many regions, ensuring that the interior window retrofit is sealed is critical to obtaining many of the thermal and NEB retrofit benefits; however, one glazing contractor vents the interior window retrofit to minimize condensation. This firm operates in Florida where the outside air is more humid than the interior air; providing interior airflow helps minimize the condensation on the window. A better understanding of the climate-specific installation requirements might lead to region-specific installation guidelines.

## 4. Limitations and Challenges

Overall, Navigant found that the project lists provided by NEEA were adequate to understand the current market for three manufacturers: Thermolite, Berkowitz, and Wausau. However, the data did not always have sufficient detail about site conditions and end-use customers. The project team was not able to speak directly with enough decision makers to fully verify their objectives (comfort, savings, security, safety, noise, etc.) and develop a deep understanding of the product's value proposition in the marketplace.

Because NEEA works to move a product from market innovators and early adopters to mass market adoption, Navigant believes that a broader market study is warranted—one in which specific efforts are made to include potential owners and property managers in the Northwest sufficient to allow NEEA a better understanding of the long-term market and the drivers that will encourage designers, specifiers, and glazing contractors to recommend secondary glazing products to their customers in the Northwest.

While SGS products are available in the Northwest, Navigant was unable to identify and speak with any building owners or representatives in the Northwest who have experience with SGS products. Therefore, the research team was unable to identify specific issues that SGS products might face in the Northwest.

Finally, it is important to understand that this study was conducted in a limited timeframe with a limited scope—i.e., to verify the product usability and identify key barriers and concerns that the NEEA team may not have known about or identified. Additional research will be required to understand the status of the supply chain in the Northwest and confirm the regional technical and market potential available.

## 5. Conclusions and Recommendations

Navigant lists general conclusions and recommendations below.

- Overall, Navigant found that secondary glazing systems perform within expected parameters.
- The product appears to suffer primarily from lack of awareness for installers/architects and building owners rather than any inherent technological or supply chain issues.
- The cost-effectiveness of secondary glazing installations is uncertain for the relatively mild climate that exists in most Northwest cities.
- Installers and the owners/owner representatives with whom the research team spoke were universally favorable toward the windows and their performance.
- Based on these conversations, NEEA may consider focusing on marketing this relatively new technology to design and specification professionals. Architects and other renovation specifiers will need to be informed and engaged in the development and expansion of SGS products for commercial sector buildings.
- SGS products may be well positioned as a solution for multiple commercial customer concerns—cost, reliability, visual impacts, timeframe of installation—and for specific niche markets such as historic buildings, behavioral health and other hospital settings, government buildings, and schools.
- Overall, Navigant concludes that that the product is sound, performance concerns are minimal, and that SGS products could provide energy savings if marketed to the key market segments and sub-segments for which the solution is likely to be most favorably received.

### 5.1 Further Research Questions

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Navigant identified several areas of potential future research:

1. **Understand the role of each market actor in specifying secondary glazing products.** For what types of projects is a glazing contractor the primary source of information? For what types of projects is it a design professional, general contractor, or engineer? What is the current level of awareness among these groups and what are their current perceptions of the product? Investigate labeling and naming for supply chain and potential consumers.
2. **Monitor and confirm product satisfaction with a larger sample of building representatives.** What is the level of satisfaction with SGS products for building representatives (e.g., owners, facility staff, tenants)?
3. **Confirm SGS Costs and Benefits, Payback, and Potential.** How do expected energy savings vary in specific Northwest states and climate zones where SGS products have the most potential? How do potential reductions in associated HVAC equipment impact payback and cost effectiveness for SGS products? In what scenarios could window attachments enable downsizing or reduced investment in future HVAC sufficient to provide additional benefits?
4. **Confirm SGS Key Target Markets.** In which markets are secondary glazing products most likely to experience rapid uptake? What are the market characteristics and stakeholder perspectives of high impact, potential energy-saving SGS buildings—namely retail/service buildings, office buildings, warehouses, and assembly buildings constructed before 1990?
5. **Map the Supply Chain and Identify Channels to Reach Key Target Markets.** Investigate strategies for effectively reaching identified target markets. How can NEEA leverage the position of the trades, manufacturers, and building owners?

- 6. Confirm existing SGS market penetration.** Because there were less than 15 SGS projects in the manufacturer data across NEEA's territory, Navigant estimates that the starting market saturation of SGS is less than 1%. NEEA should continue to validate this assumption as additional market research is completed.

## Appendix A. Appendix A. Interview Guides

### A.1 Interview Guide – Manufacturer

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Thank you for speaking with us today. The objective of this meeting is to document your perspective on key market issues and drivers and seek your help in next steps for us to support NEEA’s program development process. We’d like to keep this informal so feel free to add any important topics we may have missed. I’d like to talk to you about:

- Product drivers and opportunities for commercial window attachments
- How SGS products compare to other window glazing options/alternatives
- Customer satisfaction
- Description of the supply chain
- Approaches to identifying installers and building owners of your product with whom we could speak about the product
- Any other issues that may help us better understand your product and its potential in the Northwest

#### A. Background

A1. To start, can you please give some background on your day-to-day role in relation to commercial window attachments at [COMPANY]?

NEEA is working to develop effective market intervention strategies for secondary glazing products installed in commercial buildings.

How many types of window attachment products do you produce or sell?

[If more than SGS, have them describe each product.]

What do you call secondary glazing products when you talk to customers? How are they labeled?

#### B. Product Drivers and Barriers

B2. In your opinion, what types of buildings or projects are typically good candidates for your company’s commercial window attachment products?

B3. What are the primary reasons that people choose to buy commercial window attachment products?

B4. Do the product drivers vary by building type?

B5. Do the product drivers vary by size of the building?

B6. Do the product drivers vary by ownership?

B7. What portion of sales would you attribute to the [primary product driver]? The secondary product driver? etc. (e.g., 10% buy for comfort, 50% for blast protection and security, 10% for noise reduction, etc.)

B8. Are there other markets that you believe might also be open to the product in the future?

B9. What are the primary reasons that people choose not to purchase commercial window attachment products?

B10. For those that decide not to install commercial window attachments, what do they do instead?

B11. What regions of the country make up of your sales? What drives the differences between regions?

#### C. Competition/Alternatives

C12. What alternatives do potential customers have—are these products primarily competing with new windows, or are there other alternatives for improved window performance? Do you manufacture these products?

C13. Who else manufacturers similar products?

C14. Who are your primary competitors?

C15. Why do you think building owners and decision makers choose secondary glazing over other options?

C16. What portion of your sales are window attachment products? (*i.e., do you see bigger opportunities for alternative products?*)

## D. Customer Satisfaction

D17. What type of information do you have about long-term satisfaction with window attachment products among commercial building owners? Does the overall satisfaction vary by region or type of building? How?

D18. Do you regularly gather feedback on these products or measure customer satisfaction? How?

## E. Supply Chain

E19. Please describe your supply chain, how do products typically flow from your company to the end user?

E20. Who carries the warranty on the product?

E21. Do you require your installers to be certified? Why or why not?

E22. What is preventing you from selling more of your product in the Northwest? [*Probe on topics, including:*

- *Supply chain proximity?*
- *Internal company market focus*
- *Unfamiliarity/lack of knowledge about the Northwest market*
- *other*

## F. Requests

F23. What can NEEA do to help you to increase your sales of window attachment products in the Northwest? Specifically, please order priority one through five the following:

- Consumer education
- Trade alley training and/or education
- Linkages to utility programs
- Financial incentives (as possible through utilities)
- Coordinated market strategies

F24. We will be speaking with glazing contractors, installers, and building owners to better understand the market for commercial window attachments.

- For the installers and contractors, we'd like your help with the contact information. We have an idea of who we would like to speak to (those who have not yet been involved with case studies) and will send you those names after this call.
- For building owners, we'd like your thoughts on how best to speak to them.

## G. Closing

G25. Thank you very much for your time. Is there anything else that you'd like to share that we have not covered in our questions before we close the conversation?

## A.2 Interview Guide – Installer

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Thank you for speaking with us today. Your perspective and experience with these products is very important for us to understand as we seek to support energy efficiency improvements in commercial buildings through interior window retrofits or secondary glazing.

We are conducting this research on behalf of the Northwest Energy Efficiency Alliance, or NEEA. The alliance is funded by the Bonneville Power Administration and works together with utilities and organizations in Oregon,



Washing, Montana, and Idaho, to encourage energy efficiency market transformation. NEEA's unique role is to look to the future to find emerging technologies and create a path forward to make these a reality for the region, through efforts such as increased awareness, utility incentives, and partnerships with trade allies.

Before we start, do you have any questions for me?

## A. Background

- A1. To start, please describe your company and the types of services you provide?
  - A1a. Please describe your day-to-day role in relation to interior window retrofits?
  - A1b. What portion of your work is new windows? What portion is retrofits? What else do you do?
  - A1c. What states do you work in?
- A2. How did you first learn about interior window retrofit products?
- A3. How many types of window retrofit products do you install?  
(if not covered: which brands?) [If more than SGS, have them describe each product.]
- A4. What do you call secondary glazing products when you talk to customers? How are they labeled?

## B. Purchase Drivers and Barriers

- B5. In your opinion, what types of buildings or projects are typically good candidates for interior window retrofit products?
- B6. What are the primary reasons that people choose to buy interior window retrofit products? (Probe to explain the "why" for each reason provided.)
- B7. Do these reasons vary by building type?
- B8. By size of the building?
- B9. What about by building ownership?
- B10. What portion of your installations would you attribute to the [primary product driver]? The secondary product driver? etc. (e.g., 10% buy for comfort, 50% for blast protection and security, 10% for noise reduction, etc.)
- B11. What other markets might be open to the product in the future?
- B12. What are the primary reasons that people choose not to purchase interior window retrofit products?
- B13. For those that decide not to install interior window retrofits, what do they do instead?
- B14. What regions of the state or country make up your company's interior window retrofit installation work?  
What drives the differences between regions?

## C. Competition/Alternatives

- C15. What alternatives do customers have—are these products primarily competing with new windows, or are there other alternatives for improved window performance?
- C16. Are you aware of different products besides [Renovate by Berkowitz]?
- C17. Why do you think building owners and decision makers choose interior window retrofits over other options?

## D. Installation and Product Longevity

- D18. How does installing interior window retrofits compare to other projects? Are there different concerns or challenges associated with these products?
- D19. How does the installation time compare to new window installation or other glazing repairs? Are there similar products that we should be comparing?
- D20. Have you experienced any breakage problems either with the interior window retrofit or the original window as part of the installation process?
- D21. Are you aware of any breakage issues AFTER installation?

D22. How long do these products typically stay installed? In your experience, once installed, do they typically remain in place for the warranted period or longer?

### E. Customer Satisfaction

E23. In general, how satisfied are your customers with commercial interior window retrofits?

E24. Have you had any complaints or issues from your customers?

E25. Have you experienced any seal failure or leakage issues? If so, how frequent are your callbacks specifically related to these issues?

E26. How about any issues with window condensation? If so, how frequent are your callbacks specifically related to window condensation?

E27. Have you experienced any unexpected issues during installation? If so, would you please explain?

### F. Supply Chain

F28. Who do you purchase the retrofit products from- are there distributors or do the manufacturers sell direct to them?

F28a. What support do the manufacturers provide to you (if any)?

F28b. How many products are available?

F28c. Are they stocked somewhere, or all custom made-to-order?

F28d. How long does it take to get the products once a building is committed??

F29. Who carries the warranty on the product?

F30. Do you install the products directly? If not: who does??

### G. Decision-Making Process

G31. In your experience, who is the person ultimately responsible for deciding to purchase interior window retrofits for your projects?

G32. Do you know the steps your customer must take in choosing this product and moving forward with installing interior window retrofits?

G33. What are the main reasons why your customers decide to install interior window retrofits?

### H. Requests

NEEA is working to develop effective market intervention strategies for interior window retrofit installed in commercial buildings.

H34. In your opinion, what prevents these products from being installed in more buildings?

H34a. What would increase the market for these products in your market?

### I. Closing

I35. Thank you very much for your time. Is there anything else that you'd like to share that we have not covered in our questions before we close the conversation?

## A.3 Interview Guide – Owner

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Thank you for speaking with us today. Our goal is to understand your experience with the interior window retrofits you installed in (address, date). We are not selling anything. I work for a research firm under contract to document the potential benefits and drawbacks of interior window retrofit products. Your perspective and experience with these products is very important for us to understand as we seek to support energy efficiency improvements in commercial buildings through interior window retrofits or secondary glazing.

Before we start, do you have any questions for me?

### A. Background

- A1. To start, can you describe your current position and day-to-day responsibilities at [BUILDING NAME]?
- A2. How did you first learn about interior window retrofits?
- A3. And, what did you learn about interior window retrofits?

### B. Purchase Drivers and Barriers

- B17. What were the main reasons you decided to install interior window retrofits? (Probe to explain the “why” for each reason provided.)
- B18. Did you consider other options? What other options did you consider?

### C. Customer Satisfaction

- C25. Please describe your experience with the installation process.
- C26. Were there any issues during the installation process?  
(If needed: what happened? And how was it resolved?)
- C27. Are you satisfied with the interior window retrofits product (name company) you installed? (Why, why not?)
- C28. Have you received any feedback that you have received from your tenants/employees, if any?
- C29. Have you experienced any complaints about the interior window retrofits?  
(If so: how frequent? What was their concern?)
- C30. Have you experienced any issues with seals failing or breaking? Or any experiences with other breakage issues?  
(If so: how did you find out about it? How many windows?)
- C31. Have you had any issues with window condensation?  
(If so: how frequently? Were the issues resolved, if so, how?)

### D. Energy and Non-Energy Benefits

- D13. Have you observed any reduction in energy consumption since retrofitting your building with interior window retrofits?
- D14. Since installing your window attachments have you noticed:
  - Reduced glare from treated windows?
  - Less noise?
  - Reduced drafts from treated windows?
  - More even heat or cool distribution?
  - Fewer complaints from occupants?

### E. Decision-Making Process

- E15. Who is the person ultimately responsible for deciding to purchase interior window retrofits for your project?
- E16. Could you describe the steps required to choose this product and move forward with installing interior window retrofits in your building? (*e.g., internal steps to come to the decision to move ahead and/or external steps like submitting building specs, seeking external approvals of any sort, etc.*)
- E17. What were the main factors in selecting interior window retrofits for your project?
- E18. How likely would you be to install interior window retrofits on another building that you own or manage?

### F. Installation Issues

F19. Where there any particular issues in the installation process that you thought were very simple and easy, or others that may have disrupted your process more than you originally thought?

## **G. Closing**

G20. How would you characterize your overall experience with the process of selection, installation, and results from installing (name company) interior window retrofits?

G21. Thank you very much for your time. Is there anything else that you'd like to share about your experience before we close the conversation?

## Appendix B. Sources and Uses Table

Research Objectives	Research Questions	Existing Research	CBSA	Manufacturer Installation Data	Purchased Market Research	Interviews
		Task 1	Task 2	Task 3	Task 4	Task 5
<b>Assess overall product performance</b>	How do representatives of existing installations describe their experience w/ SGS, and the installation experience?					X
	Do they describe any issues with condensation, breakage, installation?					X
	Do they describe any expected or unexpected non-energy benefits?					X
<b>Investigate strategies for sizing the regional market</b>	How does the other market research size the market for SGS? What option might be best for NEEA?	X	X	X	X	
<b>Refine understanding of market barriers</b>	What are the primary barriers to adoption?				X	X
	Are there any barriers that do not match the current NEEA stated barriers?	X			X	X
<b>Understand product drivers</b>	What are the installation/purchase triggers most associated with opportunities for secondary glazing?	X			X	X
	To what extent do SGS products address concerns about other needs besides saving energy?	X				X
	Under what scenarios are secondary glazing products most attractive?	X			X	X
	How do product drivers vary by building type or purpose?	X			X	X
<b>Identify leverage points within the existing supply chain</b>	Number and types of market actors who currently provide similar products?	X			X	
	What training is necessary to install?	X				X
	How are manufacturers currently working within the supply chain?					X
<b>Characterize the SGS market</b>	What are the opportunities for intervention in the supply chain?	X			X	X
	Where are, installations occurring geographically and by business type?			X	X	
	What other insights can we gain by analyzing the existing installations?			X	X	
	How does this data compare to NEEA assumptions about baseline installations and market barriers/drivers?	X		X		

Research Objectives	Research Questions	Existing Research	CBSA	Manufacturer Installation Data	Purchased Market Research	Interviews
		Task 1	Task 2	Task 3	Task 4	Task 5
<b>Estimate the preliminary baseline</b>	What are the preliminary estimates of baseline market activity?	X	X	X	X	
	What are the expectations for near-term change in the baseline market activity?	X	X	X	X	X

## Appendix C. Bibliography

- Persistence Market Research. *Secondary Glazing Market: U.S. Industry Analysis and Forecast 2016-2024*. November 2016.
- Lawrence Berkeley National Laboratory (LBNL). *Secondary Glazing System (SGS) Thermal, Moisture, and Solar Performance Analysis and Validation*. August 2015.
- US Department of Energy (DOE) case studies
- Integrated Design Lab (IDL), University of Washington. *Ranier Tower: Secondary Glazing System Mockup*. June 2015
- SOLARC Engineering and Energy + Architectural Consulting. *Savings and Economic Analysis of Secondary Glazing Systems*. February 2016.
- Global Facility Solutions. *Baseline Development Report – Sidney R. Yates Federal Building*. February 2013.

## Appendix D. CBSA Analysis

### D.1 CBSA Building Types

**Table 19. CBSA Building Types**

Building Classification	Description
<b>Assembly</b>	Arena, Auditorium, Boat Slips, Marina, Yacht Club, Bowling Alley, Casino, Club, Lodges, Community Center, Convention Center, Gym, Exercise, Health Spa, Ice Skating, Library, Museum, Movie Theater, Performing Arts Theater, Pool, Recreation Center, Religious Assembly, Roller Skating, Senior Center, Other Assembly
<b>Grocery Store</b>	Convenience Store (<=5,000 sqft), Grocery (> 5000 sqft), Gas Station with a Convenience Store, Other Grocery
<b>Retail</b>	Auto Parts, Auto/Boat Dealer/ Show room, Beauty / Barber, Beer, Wine, or Liquor Store, Car Wash, Clothing, Department Store, Dept. Store W/ Grocery, Dry Cleaner, Electronics/Appliances, Florist, Nursery, Hardware, Home Improvement, Laundromat (Self-Service), Pharmacy, Post Office, Rental Center, Repair Shop, Studio/Gallery, Vehicle Repair, Warehouse Club, Other Specialty Merchandise
<b>Hospital</b>	Hospital
<b>Lodging</b>	Hotel, Motel, Bed & Breakfast, Boarding/Rooming House, Apt Hotel, Convent or Monastery, Dormitory, Fraternity, Or Sorority, Halfway House, Hotel - Resort, Shelter, Orphanage, Or Children's' Home, Other Lodging
<b>Residential Care</b>	Assisted Living, In-Patient Rehab, Nursing Home, Retirement Home, Other Residential Care
<b>Office</b>	Office- Admin, Professional, Government, Financial, Call Center, City Hall, Dental Office, Medical Clinic / Outpatient Medical, Medical Office, Medical Urgent Care Clinic, Outpatient Rehab, Retail Banking, Sales Office, Veterinarian Office/Clinic, Other Office
<b>Restaurant</b>	Coffee, Doughnut, Or Bagel Shop, Fast Food Restaurant, Ice Cream or Frozen Yogurt Shop, Sit Down Restaurant, Take-Out Restaurant, Truck Stop, Other Restaurant
<b>School</b>	Elementary School, Middle School, High School, Pre-School, Other K-12 School
<b>University</b>	University/College
<b>Warehouse</b>	Ministorage, Warehouse, Distribution, Warehouse, Storage, Cold Storage, Non-Ammonia Base Refrigeration, Other Warehouse
<b>Other</b>	Adult/Career Education, Airplane Hanger, Asylum, Courthouse, Crematorium, Data Center or Server Farm, Fire Station, Jail, Police Station, Police & Fire, Prison, Telephone Switching, Vocational Training, Other
<b>Unsampled</b>	Agriculture, Industrial, Cold Storage, Ammonia Base Refrigeration, Manufacturing, Residential

Source: CBSA



## D.2 Single Glaze Building Count and Window Area Summary Tables

**Table 20. Pre-1990 CBSA Building Summary, All Sizes**

	Electric Primary Heating				Gas Primary Heating				Electric or Gas Primary Heating			
	Building Count (SG > 50%)		Single Glaze Window Area		Building Count (SG > 50%)		Single Glaze Window Area		Building Count (SG > 50%)		Single Glaze Window Area	
	Count	Percent	Sq. Ft	Percent	Count	Percent	Sq. Ft	Percent	Count	Percent	Sq. Ft	Percent
Office	2,287	17%	29,844,939	28%	11,954	36%	75,782,297	24%	14,241	30%	105,627,235	25%
Retail/service	6,697	49%	12,323,751	11%	9,649	29%	71,227,186	23%	16,346	35%	83,550,937	20%
Assembly	964	7%	10,633,184	10%	2,062	6%	30,957,289	10%	3,026	6%	41,590,473	10%
School K-12	215	2%	12,014,864	11%	700	2%	30,409,923	10%	915	2%	42,424,787	10%
Warehouse	1,635	12%	15,361,369	14%	3,710	11%	65,248,754	21%	5,345	11%	80,610,123	19%
Other	656	5%	11,388,564	11%	427	1%	7,252,468	2%	1,083	2%	18,641,032	4%
Residential Care	330	2%	9,566,977	9%	448	1%	8,411,858	3%	778	2%	17,978,835	4%
Grocery	286	2%	1,437,465	1%	1,361	4%	14,068,238	5%	1,647	4%	15,505,703	4%
Restaurant	437	3%	992,049	1%	2,788	8%	7,273,504	2%	3,225	7%	8,265,553	2%
Lodging	165	1%	3,680,790	3%	6	0%	1,541,175	0%	171	0%	5,221,964	1%
<b>All</b>	<b>13,671</b>	<b>100%</b>	<b>107,243,954</b>	<b>100%</b>	<b>33,104</b>	<b>100%</b>	<b>312,172,690</b>	<b>100%</b>	<b>46,775</b>	<b>100%</b>	<b>419,416,644</b>	<b>100%</b>

**Table 21. Pre-1990 CBSA Building Summary, Larger than 20,000 sq. ft.**

	Electric Primary Heating				Gas Primary Heating				Electric or Gas Primary Heating			
	Building Count (SG > 50%)		Single Glaze Window Area		Building Count (SG > 50%)		Single Glaze Window Area		Building Count (SG > 50%)		Single Glaze Window Area	
	Count	Percent	Sq. Ft	Percent	Count	Percent	Sq. Ft	Percent	Count	Percent	Sq. Ft	Percent
Office	241	25%	21,156,265	35%	437	14%	33,472,734	21%	678	17%	54,628,999	24%
Retail/service	23	2%	3,045,142	5%	478	15%	24,590,991	15%	501	12%	27,636,133	12%
Assembly	16	2%	3,341,701	6%	348	11%	17,400,886	11%	364	9%	20,742,587	9%
School K-12	84	9%	10,578,910	18%	547	18%	29,302,138	18%	631	15%	39,881,048	18%
Warehouse	0	0%	0	0%	1,015	33%	47,199,694	29%	1,015	25%	47,199,694	21%
Other	148	15%	9,144,155	15%	108	3%	4,389,922	3%	256	6%	13,534,076	6%
Residential Care	330	34%	9,566,977	16%	87	3%	2,710,733	2%	417	10%	12,277,710	5%
Grocery	0	0%	0	0%	90	3%	2,658,330	2%	90	2%	2,658,330	1%
Restaurant	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Lodging	123	13%	3,392,221	6%	6	0%	1,541,175	1%	129	3%	4,933,395	2%
<b>All</b>	<b>962</b>	<b>100%</b>	<b>60,225,370</b>	<b>100%</b>	<b>3,116</b>	<b>100%</b>	<b>163,266,601</b>	<b>100%</b>	<b>4,078</b>	<b>100%</b>	<b>223,491,971</b>	<b>100%</b>

**Table 22. Pre-1990 CBSA Building Summary, Smaller than 20,000 sq. ft.**

	Electric Primary Heating				Gas Primary Heating				Electric or Gas Primary Heating			
	Building Count (SG > 50%)		Single Glaze Window Area		Building Count (SG > 50%)		Single Glaze Window Area		Building Count (SG > 50%)		Single Glaze Window Area	
	Count	Percent	Sq. Ft	Percent	Count	Percent	Sq. Ft	Percent	Count	Percent	Sq. Ft	Percent
Office	2,046	16%	8,688,674	18%	11,517	38%	42,309,562	28%	13,563	32%	50,998,236	26%
Retail/service	6,674	53%	9,278,609	20%	9,171	31%	46,636,195	31%	15,845	37%	55,914,804	29%
Assembly	948	7%	7,291,483	16%	1,714	6%	13,556,403	9%	2,662	6%	20,847,886	11%
School K-12	131	1%	1,435,954	3%	153	1%	1,107,785	1%	284	1%	2,543,739	1%
Warehouse	1,635	13%	15,361,369	33%	2,695	9%	18,049,061	12%	4,330	10%	33,410,430	17%
Other	508	4%	2,244,409	5%	319	1%	2,862,546	2%	827	2%	5,106,955	3%
Residential Care	0	0%	0	0%	361	1%	5,701,125	4%	361	1%	5,701,125	3%
Grocery	286	2%	1,437,465	3%	1,271	4%	11,409,908	8%	1,557	4%	12,847,373	7%
Restaurant	437	3%	992,049	2%	2,788	9%	7,273,504	5%	3,225	8%	8,265,553	4%
Lodging	42	0%	288,569	1%	0	0%	0	0%	42	0%	288,569	0%
<b>Total</b>	<b>12,707</b>	<b>100%</b>	<b>47,018,582</b>	<b>100%</b>	<b>29,989</b>	<b>100%</b>	<b>148,906,090</b>	<b>100%</b>	<b>42,696</b>	<b>100%</b>	<b>195,924,671</b>	<b>100%</b>

### D.3 Secondary Target Market Findings

#### Single-Glazed Window Analysis for Electric Heated Buildings – Pre-1990, larger than 20,000 sq. ft.

Table 23 shows the number and square footage of single-glazed pre-1990 buildings with electric heat (>20,000 sq. ft.).

**Table 23. Single-Glazed Pre-1990 Buildings with Electric Heat (>20,000 Sq. Ft.)**

Building Type	Single Glaze Building Count	Percent	Single Glaze Window Area Sq. Ft	Percent
Office	241	25%	21,156,265	35%
Retail/service	23	2%	3,045,142	5%
Assembly	16	2%	3,341,701	6%
School K-12	84	9%	10,578,910	18%
Warehouse	-	-	-	-
Other	148	15%	9,144,155	15%
Residential Care	330	34%	9,566,977	16%
Grocery	-	-	-	-
Restaurant	-	-	-	-
Lodging	123	13%	3,392,221	6%
<b>Total</b>	<b>962</b>	<b>100%</b>	<b>60,225,370</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

Note: Buildings are considered single-glazed if >50% of the window area is single-glazed. The single-glazed window square footage shows the actual estimated window area for single-glazing, not the entire building window area for buildings considered single-glazed.

Secondary targets, could include -- should NEEA choose to expand its target market definition -- K-12 Schools (84 buildings count/18% of target sq. ft.) and residential care facilities (330 count/16% sq.).

#### **Schools K-12**

The CBSA indicates that there are 84 schools in the Northwest built prior to 1990 heated primarily by electric, representing 10.6 million square feet of single-glazed window area.

Schools represent 9% of the buildings and 18% of the single-glazed window area for electrically heated pre-1990 large buildings. Table 23 shows that 25% of pre-1990 residential care facility space is heated primarily with electric and Table 13 shows that 43% of residential care facility window area is single-glazed.

#### **Residential Care Facilities**

There are 330 residential care facilities greater than 20,000 square feet in size built before 1990 heated primarily by electric, representing 9.6 million square feet of single-glazed window area.

Residential care buildings represent 34% of the large buildings and 16% of the single-glazed window area, suggesting that these facilities are smaller on average than the large offices and schools, so it may take more projects to yield the same amount of window area coverage. Table 23 shows that 46% of pre-1990 residential care facility space is heated primarily with electric and Table 13 shows that 48% of residential care facility window area is single-glazed.

**Single-Glazed Window Analysis for Electric Heated Buildings – Pre-1990, smaller than 20,000 sq. ft.**

Table 24 **Error! Reference source not found.** shows the number and square footage of single-glazed pre-1990 buildings with electric heat (<20,000 sq. ft.). While buildings less than 20,000 square feet represent 93% of the total building count, they only comprise less than half (44%) of the total single-glazed window area for electric heated buildings built prior to 1990.

**Table 24. Single-Glazed Pre-1990 Buildings with Electric Heat (<20,000 Sq. Ft.)**

Building Type	Single Glaze Building Count	Percent	Single Glaze Window Area Sq. Ft	Percent
Office	2,046	16%	8,688,674	18%
Retail/service	6,674	53%	9,278,609	20%
Assembly	948	7%	7,291,483	16%
School K-12	131	1%	1,435,954	3%
Warehouse	1,635	13%	15,361,369	33%
Other	508	4%	2,244,409	5%
Residential Care	-	-	-	-
Grocery	286	2%	1,437,465	3%
Restaurant	437	3%	992,049	2%
Lodging	42	0%	288,569	1%
<b>Total</b>	<b>12,707</b>	<b>100%</b>	<b>47,018,582</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

Note: Buildings are considered single-glazed if >50% of the window area is single-glazed. The single-glazed window square footage shows the actual estimated window area for single-glazing, not the entire building window area for buildings considered single-glazed.

For all large pre-1990 buildings under 20,000 square feet, **office buildings** do not represent a significant opportunity for NEEA in terms of number of buildings with single glazing (2,046) and percent of total area of single-glazed windows (18%) to be improved. Secondary targets, could include -- should NEEA choose to expand its target market definition -- warehouses and retail as they represent most significant opportunity for SGS in terms of single-glazed window area and number of buildings with single-glazing.

**Warehouse**

The CBSA shows that there are 1,635 single-glazed warehouse buildings smaller than 20,000 square feet in the Northwest, representing 15.4 million square feet of single glaze window area potential.

Warehouses represent 13% of the buildings and 33% of single-glazed window area for electrically-heated pre-1990 buildings less than 20,000 square feet. Table 24 shows that 19% of pre-1990 warehouse space is heated primarily with electric and Table 13 shows that 43% of warehouse window area is single-glazed.

**Retail**

There are 6,674 single-glazed warehouse buildings less than 20,000 square feet in the Northwest, representing 9.3 million square feet of single glaze window area potential.

Retail buildings represent 53% of the buildings and 20% of single-glazed window area for electrically-heated pre-1990 buildings less than 20,000 square feet. Table 24 shows that 13% of pre-1990 retail

space is heated primarily with electric and Table 13 shows that 38% of retail building window area is single-glazed.

**Single-Glazed Window Analysis for Gas Heated Buildings – Pre-1990, larger than 20,000 sq. ft.**

Table 25 shows the number and square footage of single-glazed pre-1990 buildings with gas heat (>20,000 sq. ft.). For buildings larger than 20,000 square feet in size, warehouses, followed by offices and schools, represent the most significant opportunities for improving window performance.

**Table 25. Single-Glazed Pre-1990 Buildings with Gas Heat (>20,000 Sq. Ft.)**

Building Type	Single Glaze Building Count	Percent	Single Glaze Window Area Sq. Ft	Percent
Office	437	14%	33,472,734	21%
Retail/service	478	15%	24,590,991	15%
Assembly	348	11%	17,400,886	11%
School K-12	547	18%	29,302,138	18%
Warehouse	1,015	33%	47,199,694	29%
Other	108	3%	4,389,922	3%
Residential Care	87	3%	2,710,733	2%
Grocery	90	3%	2,658,330	2%
Restaurant	-	-	-	-
Lodging	6	0%	1,541,175	1%
<b>Total</b>	<b>3,116</b>	<b>100%</b>	<b>163,266,601</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

Note: Buildings are considered single-glazed if >50% of the window area is single-glazed. The single-glazed window square footage shows the actual estimated window area for single-glazing, not the entire building window area for buildings considered single-glazed.

**Warehouse**

There are 1,015 single-glazed warehouse buildings larger than 20,000 square feet in the Northwest, representing 47.2 million square feet of single glaze window area potential.

Warehouse buildings represent 33% of the buildings and 20% of single-glazed window area for gas-heated pre-1990 buildings over 20,000 square feet. Table 25 shows that 80% of pre-1990 warehouse space is heated primarily with gas and Table 13 shows that 43% of warehouse building window area is single-glazed.

**School K-12**

There are 547 single-glazed K-12 school buildings larger than 20,000 square feet in the Northwest with gas heat, representing 29.3 million square feet of single glaze window area potential.

School buildings represent 18% of the buildings and 18% of single-glazed window area for gas-heated pre-1990 school buildings over 20,000 square feet. Table 25 shows that 62% of pre-1990 school building space is heated primarily with gas and Table 13 shows that 43% of school building window area is single-glazed.

**Single-Glazed Window Analysis for Gas Heated Buildings – Pre-1990, smaller than 20,000 sq. ft.**

Table 26 shows the number and square footage of single-glazed pre-1990 buildings with gas heat (<20,000 sq. ft.).

**Table 26. Single-Glazed Pre-1990 Buildings with Gas Heat (<20,000 Sq. Ft.)**

Building Type	Single Glaze Building Count	Percent	Single Glaze Window Area Sq. Ft	Percent
Office	11,517	38%	42,309,562	28%
Retail/service	9,171	31%	46,636,195	31%
Assembly	1,714	6%	13,556,403	9%
School K-12	153	1%	1,107,785	1%
Warehouse	2,695	9%	18,049,061	12%
Other	319	1%	2,862,546	2%
Residential Care	361	1%	5,701,125	4%
Grocery	1,271	4%	11,409,908	8%
Restaurant	2,788	9%	7,273,504	5%
Lodging	-	-	-	-
<b>Total</b>	<b>29,989</b>	<b>100%</b>	<b>148,906,090</b>	<b>100%</b>

Source: Navigant analysis of CBSA data.

Note: Buildings are considered single-glazed if >50% of the window area is single-glazed. The single-glazed window square footage shows the actual estimated window area for single-glazing, not the entire building window area for buildings considered single-glazed.

Of buildings built before 1990 that are *less than* 20,000 square feet in size, offices and retail represents most significant opportunity for SGS in terms of single-glazed window area and number of buildings with single-glazing, followed by warehouses.

**Office**

There are 11,517 single-glazed office buildings smaller than 20,000 square feet in the Northwest, representing 42.3 million square feet of single glaze window area potential.

Office buildings represent 38% of the buildings and 28% of single-glazed window area for gas-heated pre-1990 office buildings less than 20,000 square feet. Table 26 shows that 69% of pre-1990 office space is heated primarily with gas and Table 13 shows that 32% of office building window area is single-glazed.

**Retail**

There are 9,171 single-glazed retail buildings less than 20,000 square feet in the Northwest, representing 46.6 million square feet of single glaze window area potential.

Retail buildings represent 31% of the buildings and 31% of single-glazed window area for gas-heated pre-1990 buildings less than 20,000 square feet. Table 26 shows that 73% of pre-1990 retail space is heated primarily with gas and Table 13 shows that 38% of retail building window area is single-glazed.