PNNL-32076

Residential Façade Upgrades: Market Assessment and Recommendations

March 2022

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

Older homes with aging façades, built before residential building energy codes were established, represent more than half of the U.S. residential building stock. Windows and walls slowly deteriorate over time and, unlike appliances or heating, ventilation, and air-conditioning (HVAC) equipment, the end of life for these façade components is not always obvious. Even when thermal, moisture, and infiltration issues with a home's façade are recognized, the path toward resolving them is often fraught with technological, financial, and social challenges. Additionally, the problems and solutions will vary by region, climate zone, and type of construction.

In support of the U.S. Department of Energy's move toward transformational whole-building upgrades and enclosure solutions, national laboratories are partnering and collaborating with leading building science researchers and home-performance entities to identify and characterize technical and economic barriers to façade retrofits in an effort to identify market-viable façade solutions and opportunities for an actionable plan to transform the market. This report includes a market analysis of façade retrofits to help characterize the technical and market barriers to energy-efficient façade upgrades, and it identifies opportunities for providing technical assistance and developing programs to help address these challenges.

The barriers to residential façade retrofits are classified into technical, financial, and market/educational barriers.

- *Technical:* Key technical barriers include (a) lack of consistent and standardized solutions (every house is different and warrants some customization); (b) lack of skilled workers; and (c) risks and shortcomings associated with technical solutions coupled with complications and long disruptions to homeowners.
- *Financial:* Key financial barriers include (a) high up-front costs and owner reluctance to borrow funds for energy renovation purposes; (b) uncertainty about total costs of the project; (c) long payback periods of façade upgrade measures; (d) lack of homeowner confidence in the overall return on investment; and (e) insufficient funding sources and investors, particularly for low- and medium-income homeowners and rental homes.
- *Market/Educational:* Key barriers include (a) lack of homeowner/end-user and contractor building science knowledge and trust in effective energy renovation savings and associated benefits (b) lack of understanding by home occupants that often hinders timely upgrades; (c) decision-making and contracting processes that are long and complex; and (d) disruption to home occupants or their reluctance or inability to relocate, if necessary, during renovation.

A number of efforts are recommended to address these barriers and challenges including carrying out a series of window-wall Façade Upgrade Case Studies in coordination with re-siding contractors to evaluate the level of effort and business model potential for integrating added air-sealing and insulating measures to both the wall and windows during re-siding jobs. Additional recommendations for technical assistance include updating and refining retrofit guidance and developing retrofit decision trees to assist homeowners and contractors with their planning and retrofit decisions. This report also recommends continued support for workforce development programs focused on façade retrofits and a comprehensive economic study of both the impact and cost-effectiveness of façade upgrades across the United States.

Acknowledgments

The project team gratefully acknowledges the U.S. Department of Energy (DOE) Building Technologies Office for funding this project, and Mark LaFrance, manager of the DOE Residential Façade Upgrade Project, for his technical guidance.

Additionally, the authors thank the participants of the DOE National Laboratory team from Oak Ridge National Laboratory (ORNL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), the Building Science Corporation (BSC) and New Jersey Institute of Technology (NJIT) who participated in coordination calls and provided feedback and technical guidance throughout this project:

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Acronyms and Abbreviations

ABC	Advanced Building Construction (DOE Energy Efficiency and Renewable Energy initiative)
ACEEE	American Council for an Energy-Efficient Economy
BASC	Building America Solution Center
DIY	do it yourself
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
HVAC	heating, ventilation, and air-conditioning
JCHS	(Harvard) Joint Center for Housing Studies
LBNL	Lawrence Berkeley National Laboratory
NREL	National Renewable Energy Laboratory
PNNL	Pacific Northwest National Laboratory
PNW	Pacific Northwest
RECS	Residential Energy Consumption Survey (DOE/EIA)
USCB	U.S. Census Bureau
WAP	Weatherization Assistance Program

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1.0 Introduction

Older homes, built before 1992 when the U.S. Department of Energy's (DOE's) Residential Building Energy Codes program was established, represent approximately 70% of the residential building stock in the country and often have significant air leakage, inadequate insulation, and inefficient windows. Windows and walls slowly deteriorate over time and, unlike appliances or heating, ventilation, and air-conditioning (HVAC) equipment, the end of life for these components is not always obvious. Even when thermal, moisture, and infiltration issues with a home's façade are recognized, the path toward resolving these issues is often fraught with technological, financial, and market challenges. Additionally, the problems and solutions will typically vary by region, climate zone, and type of construction.

In support of DOE's move toward transformational whole-building upgrades and enclosure solutions, the Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL) are partnering and collaborating with leading building science researchers and home-performance entities to identify and characterize technical and economic barriers to façade retrofits in an effort to identify market-viable façade solutions and opportunities for an actionable plan to transform the market. The project includes partnerships with the Building Science Corporation and a combination of strategic implementation partners with home-performance and retrofit expertise and industry contacts. The project will include expert advisory and review consultation by Lawrence Berkeley National Laboratory's Residential Windows & Attachments team and Oak Ridge National Laboratory's Building Envelope team.

The project consists of three parts:

1. a market analysis that captures the current state of the façade retrofit market and includes housing characteristics and retrofit costs, façade retrofit approaches and materials, and contractor business models and workforce requirements to support advanced façade approaches;
2. an economic analysis focused on the viability of advanced façade retrofit approaches and materials; and
3. a field demonstration of façade retrofits that include enhanced insulation/air-sealing and window technologies in multiple climate zones.

This report represents the market analysis, as outlined in item 1 above. The goal of this analysis is to provide a market-focused study that supports comprehensive retrofits of residential enclosures that include traditional approaches and integrated wall assemblies and windows that result in durable, energy-efficient, and marketable strategies. This study provides a better knowledge base regarding the viable market for façade retrofit strategies, identifies the barriers to uptake, analyzes economic opportunities, and develops documentation specifically aimed to overcome technical and market barriers associated with installation.

This project provides market background and context for DOE's Advanced Building Construction (ABC) initiative and projects selected for residential enclosure research.

1.1 Background and Scope

In 2020, the residential sector consumed 21 quadrillion British thermal units (Btu) of energy, and more than 40% of this energy was consumed to heat and cool homes (EIA 2021). A significant portion of the residential heating and cooling loads is attributable to thermal losses and gains through the windows and walls of a home, many of which need performance upgrades. The energy savings potential of upgrading façades with added insulation, air sealing, and higher performing windows is significant. This report draws from recent DOE-sponsored market and technology assessments (Antonopoulos et al. 2019; Cort and Gilbride 2019; Gilbride et al. 2019; Cort 2013) and previous DOE and regional utility-sponsored technology and market assessments and case studies related to emerging wall and windows technologies, a selection of which are summarized in Table 1.1.

The façade upgrade market assessment is focused on identifying areas in which there is a potential to increase the market uptake of energy-efficient façade upgrades in a sustainable manner. To increase retrofits of higher performing façades in the near term, this assessment identifies strategies based on the following key principles:

- Work within the existing residential façade market structure to develop partnerships between government, private sector, energy utilities, and other stakeholders that influence the residential buildings market.
- Respond directly to identified market barriers.
- Focus efforts on consumer benefits that are inherently sustained and strengthen building contractor business models for energy-efficient retrofits, where consumer demand and competitive market forces drive energy-efficiency gains.

The following sections characterize the market with these key principles as a guide. To assess the market barriers and better understand the market for high-performance façade retrofits, PNNL and NREL conducted a home-performance Contractor Workshop that included a survey and follow-up discussions focused on identifying and characterizing the market motivations, challenges, and potential solutions for façade upgrades. The findings of the survey and workshop are presented in Appendix A of this report.

Table 1.1. Summary of energy savings from window and wall case studies.

Technology	Study	Baseline Description	Findings
High-R Window Replacement Energy-Saving Potential	LBNL study of energy simulated savings potential of thin triple glazing (Hart et al. 2019)	Typical windows based on NFRC-certified products	• 16% annual savings in heating-dominated climates • 12% annual savings in mixed climates • 7% annual savings in cooling-dominated climates
High-R Thin Glass Triple-Pane Window Replacement	PNNL Lab Homes side-by-side triple-pane study (Widder et al. 2012)	Double-pane, clear-glass, aluminum-framed windows	• 12% annual savings in Richland, Washington • 11.6% heating savings/18.4% cooling savings
Highly insulating Triple-Pane Window Replacement	PNNL Lab Homes side-by-side triple-pane study (Hunt et al. 2021)	Double-pane, clear-glass, aluminum-framed windows	• 18% annual savings in Richland, Washington • 12% heating savings/28% cooling savings
Exterior and Interior Low-e Storm Panels	PNNL Lab Homes: Exterior and Interior Low-e Storm Panels (Knox and Widder 2014; Petersen et al. 2015)	Double-pane, clear-glass, aluminum-framed windows	• Annual average savings percentage of • 10.1±1.4 • Annual average savings percentage of 7.8±1.5 (covering 74% window area)
Exterior Low-e Storm Windows	Chicago case study (Drumheller et al. 2007)	Six low-income homes; single-pane wood-framed windows	Low-e storm windows showed: • 21% reduction in overall home heating load • 7% reduction in overall home air infiltration • Simple payback of 4 to 5 years
Exterior Shades	PNNL Lab Homes side-by-side triple-pane study (Hunt and Cort 2020)	Double-pane, clear-glass, aluminum-framed windows and compared to interior vinyl blinds	• 10% cooling savings when compared to interior vinyl blinds • 20% cooling savings when compared to home with no shading on same windows
Wall Upgrades	Deep-Energy Retrofit Review (Antonopoulos et al. 2019)	Various	• Review of current insulating wall materials with R-values ranging from R-2.2 to R-26 (expanded polystyrene – EPS)
High-Performance Walls	Market-Ready High-Performance Walls (Heslam et al. 2020)	Conventional walls in Oregon, Idaho, and Washington	Energy Savings by percentage of Heating and Cooling Load • TBS: 5–7% • Exterior Rigid Foam: 5–9% • Double Wall 8”: 6–9% • Double Wall 10”: 10–12%
Wall Upgrades	Evaluation of Exterior Insulation and Over-Clad Retrofit (Neuhauser 2013)	Exterior insulation and over-clad for masonry walls	Energy Savings by percentage of Heating Load (Chicago, IL study area) • 47% reduction in duplex • 44% reduction in multifamily

CEC = California Energy Commission; IGU = insulated glazing unit; LBNL = Lawrence Berkeley National Laboratory; NFRC = National Fenestration Rating Council; NTNU = Norwegian University of Science and Technology; TBS = thermal break shear wall.

1.2 What Is a Façade Upgrade?

In this study, upgrading building façades involves improving the front or face of a building, i.e., its exterior walls and windows. When replacing siding in an existing home, a modern, high-performance wall assembly (as illustrated in Figure 1.1) should be employed that ensures the air, water, vapor, and thermal control layers are properly installed and integrated. In Figure 1.1, the interior surface includes gypsum board (i.e., dry wall) with a vapor semi-permeable wall finish like latex paint, which is providing the Class 3 vapor control layer.[1]

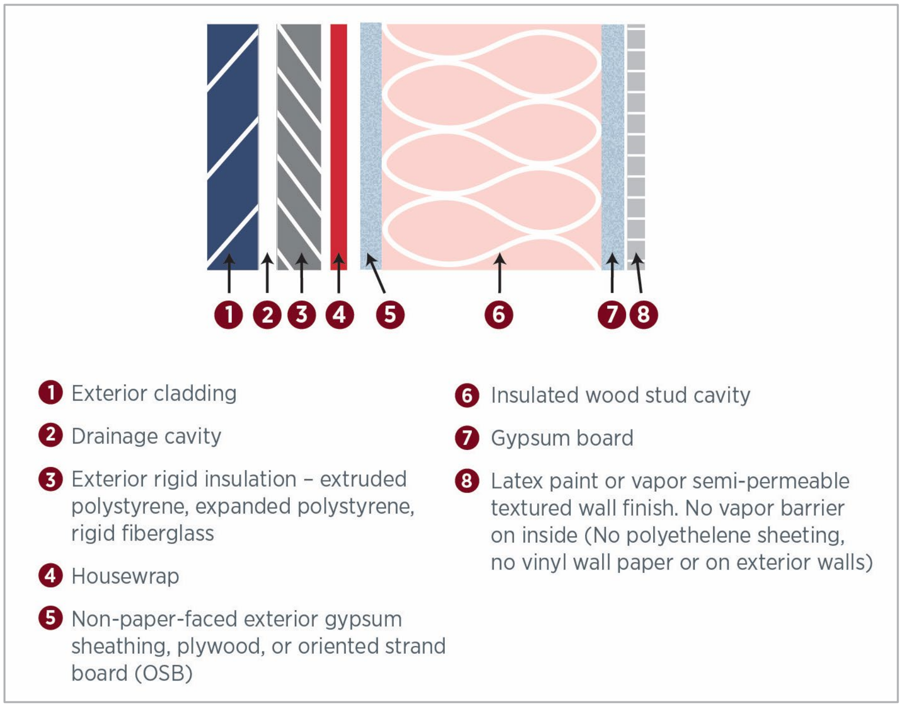

Figure 1.1. Examples of the basic components of a residential wall assembly retrofitted with exterior rigid insulation and correct control layers.

The wall cavity typically includes wood stud framing and insulation (batts, blown cellulose or fiberglass, or spray foam). The exterior of the wall cavity is covered with a sheathing of plywood, oriented strand board, or exterior-rated gypsum board, then covered with a weather-resistant barrier, such as house wrap or a paint-on product which provides the water control layer, when taped at the seams and integrated with flashing around the doors and windows. The oriented strand board (or other sheathing) on the exterior side of the wall cavity is intended to provide shear strength for the building structure. Exterior continuous rigid insulation can be installed over, or under the sheathing. Together with the cavity insulation, this continuous exterior insulation provides the wall's thermal control layer. If installed over the sheathing, some foam products have an integral weather-resistant skin or film that allows the foam to take the place of the house wrap if all seams are sealed with a compatible tape. Common cladding materials for existing residential buildings include fiber-cement, wood, vinyl, or metal lap siding; stucco; or masonry.

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[1] Note that, except in very cold climates, one should avoid Class 1 vapor-impermeable layers on the interior of the wall like polyethylene sheeting under the drywall or vinyl wallpaper as a wall finish.

Many older homes are missing control layers. In many cases, insulation is missing and air barriers are inconsistent. Additionally, moisture control, such as correctly installed flashing or drainage is absent. It is common in older homes to find damaged materials, such as dry rot in framing, or unsafe conditions, such as lead paint and asbestos. These conditions must be addressed prior to installing new siding by assessing the as-is conditions and making necessary repairs of the wall structure inside and out. Detailed assessment procedures are documented by Pettit et al. (2013).

In addition to addressing the needs of the wall assembly, façade upgrades can also include increasing the efficiency of the windows, either by adding window attachments such as insulating window panels (e.g., storm window) or by replacing the windows. There are many approaches to retrofitting windows—from full frame replacement to lower-cost inserts. The choice to rehabilitate a window versus replacing it depends on many factors, and the amount of work required to rehabilitate the windows will depend on the starting condition of the windows. One critical factor is preparing the rough opening for integrating the control layers and flashing details of the wall-window intersection, as shown in Figure 1.2; this would be possible if a full window and frame replacement is planned.

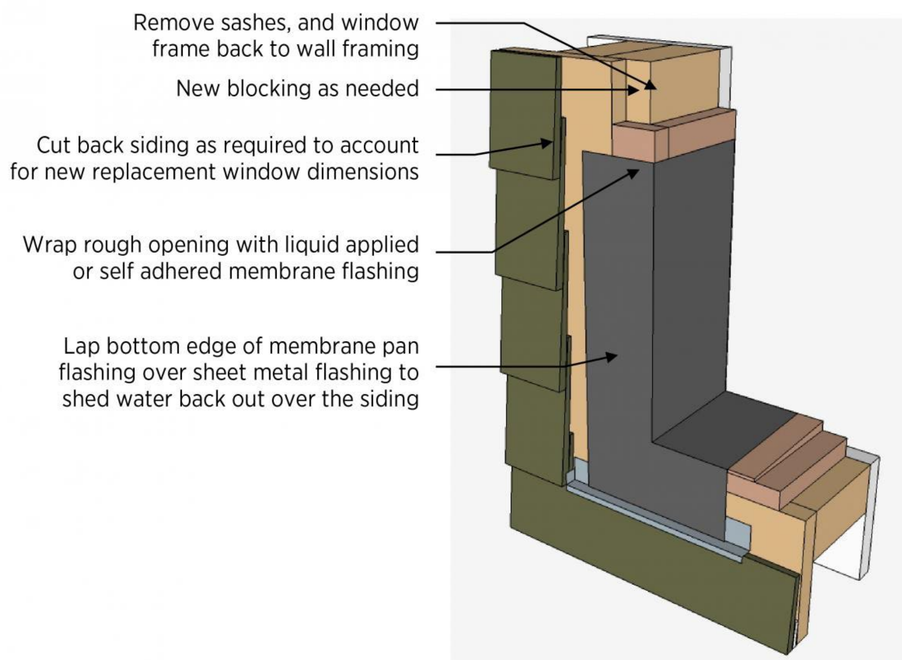

Figure 1.2. Replacement window rough opening preparation for a complete window and frame replacement (Baker 2012).

1.3 Scope of this Report

The remainder of this document provides a market assessment associated with residential building façades with the goal of identifying and documenting current practices in industry and identifying opportunities for retrofitting U.S. homes. The following topics are discussed:

- analysis of the existing home characteristics, energy costs, and upgrade needs
- upgrade expenditures, remodeling choices, occupant attitudes, and energy-efficiency incentives

- contractor business models and the market structure
- market and technology barriers to façade upgrades
- opportunities and challenges for façade upgrades.

2.0 Current State of Residential Façades

The residential façade upgrade market is composed of existing homes that would benefit from improvements in window and wall air-sealing and insulating performance. The key challenge to developing a business case for energy-efficient façade retrofits and remodels is related to the overall cost of the project and the return on investment, both of which are influenced by housing characteristics, energy use and sources, and regional energy and labor rates. The following sections describe these influencing factors by region where the regions are either described in terms of the four primary U.S. Census regions used by the DOE's Energy Information Administration (EIA) to characterize building stock or the climate zone regions used by DOE's Building America program (displayed in Figure 2.1).

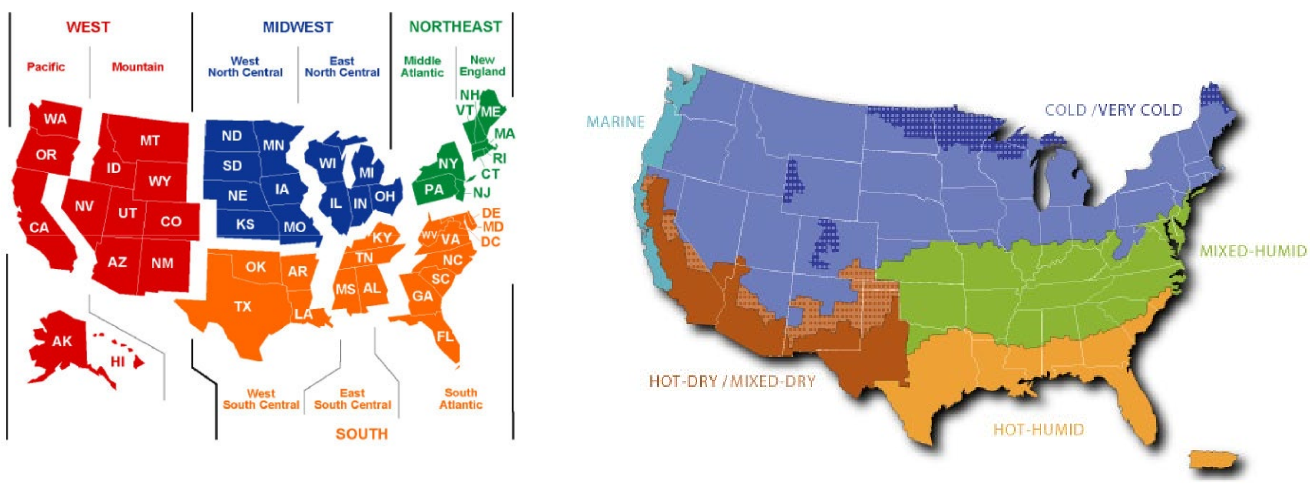

Figure 2.1. U.S. Census regions and divisions used by EIA (left) and climate zone regions used by DOE's Building America program (right).

2.1 Existing Façade Characteristics

Building façades are traditionally defined as the front, or face, of a building. Unlike the building enclosure or building shell, which includes the roof and foundation, the term façade is used in this study to specifically identify wall and window assemblies. Roofs, foundations, and other building openings (doors, skylights, etc.) are not in the scope of the current analysis.

2.1.1 Exterior Walls

Exterior cladding materials differ by region. In the Northeast, Midwest, and South, cladding is dominated by aluminum, vinyl, or steel siding and brick (EIA 2019). In the West, stucco and wood are dominant (see Figure 2.2).

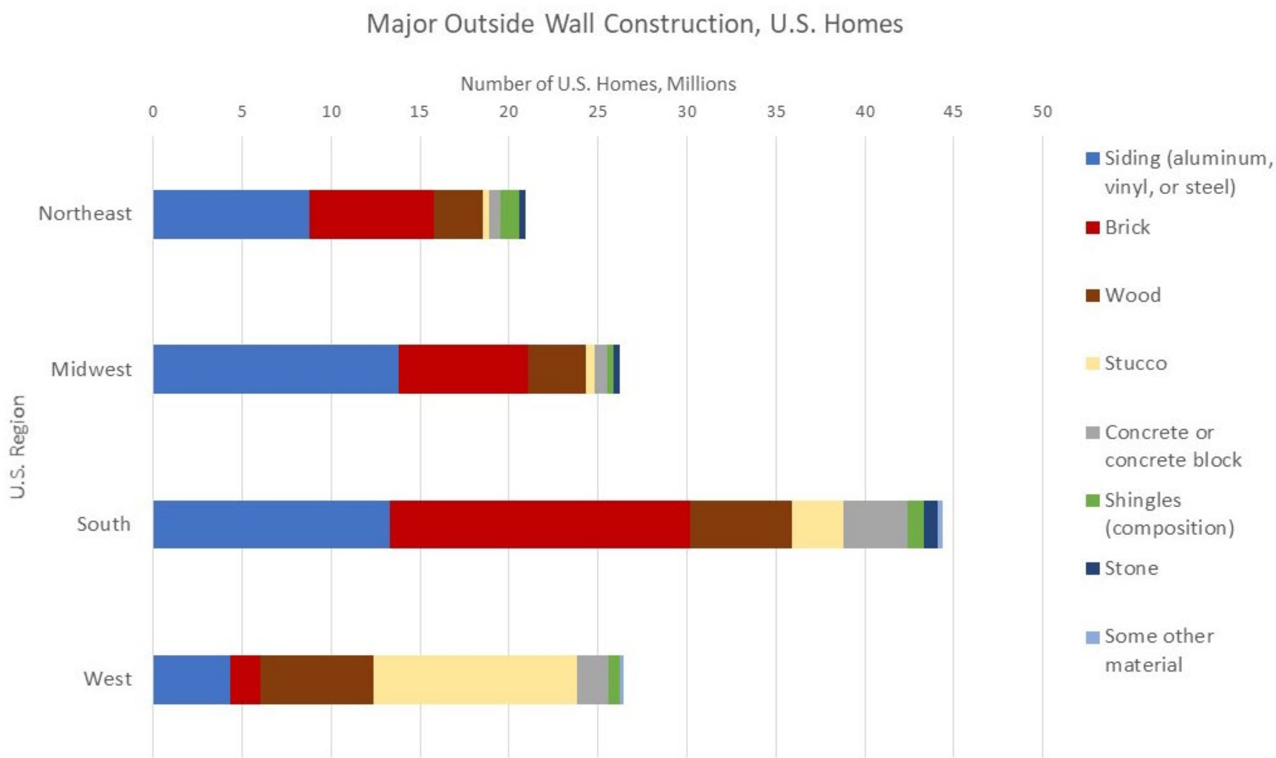

Figure 2.2. Residential exterior wall siding choices in the U.S. by region (Source: EIA 2019).

Surveys of approximately 80% of homes completed by EIA's Residential Energy Consumption Survey (RECS) in 2015 indicated they were adequately or well insulated. However, this qualitative assessment of insulation levels stands in contrast to the assessment of air sealing, for which 12% of RECS respondents indicated their homes are drafty most or all of the time, and 41% indicated their homes are drafty sometimes. A 2017 NREL energy-efficiency potential study (Wilson et al. 2017), which estimated insulation levels for existing stock using probability distributions based on National Association of Home Builders surveys, energy code adoption rates, and remodeling/stock turnover assumptions, determined that most existing homes would benefit from wall insulation and air-sealing upgrades. In fact, wall cavity insulation retrofits were collectively ranked as one of the highest value efficiency upgrades for a home in terms of the net present value of energy savings (Wilson et al. 2017) when compared to HVAC, lighting, and window upgrades.

Based on sales data, the revenues of siding companies have steadily increased in recent years, exceeding $7.5 billion in 2019 and more than half of those sales were attributable to siding repairs, retrofits, and renovations. Most siding renovation sales are associated with single-family homes (Anything Research 2021).

2.1.2 Residential Windows

Before installation of double-pane windows became common practice in northern climate zones in the 1970s and 1980s, single-pane windows were the standard. Today about 40% of all households still have single-pane windows, while about 58% have double-pane windows and a small fraction (less than 3%) have triple-pane windows installed. Based on window sales and replacement rates, it is likely that about half the double-pane windows include a low-emissivity (low-e) coating to enhance the insulating properties. Even though sales of low-e double-pane windows now dominate the market (see Figure 2.3), more than half of the windows in existing homes are non-thermally improved single-pane or double-pane clear-glass (i.e., not low-e) windows (EIA 2019). Although no current data are available related to the number of storm window installations nationwide, some fraction of the single-pane windows use storm windows to provide thermal insulating and air-infiltration benefits. A 2013 PNNL market assessment of storm windows suggests that the percentage of sales and storm window installations varies by region, where more than 40% of storm window sales are to homes in the Midwest, while 25% of sales are distributed to the Northeast. Less than 10% of storm window sales are to the 13 states in the West and the remaining sales are in the South (Cort 2013). A 2011 residential baseline characterization survey in Michigan found that approximately 20% of surveyed single-family homes had storm windows installed at least on a seasonal basis (Cadmus 2011), while a 2019 study in the Northwest estimated that only 5% of the single-family homes in the states of Idaho, Montana, Oregon, and Washington had storm windows installed (NEEA 2019).

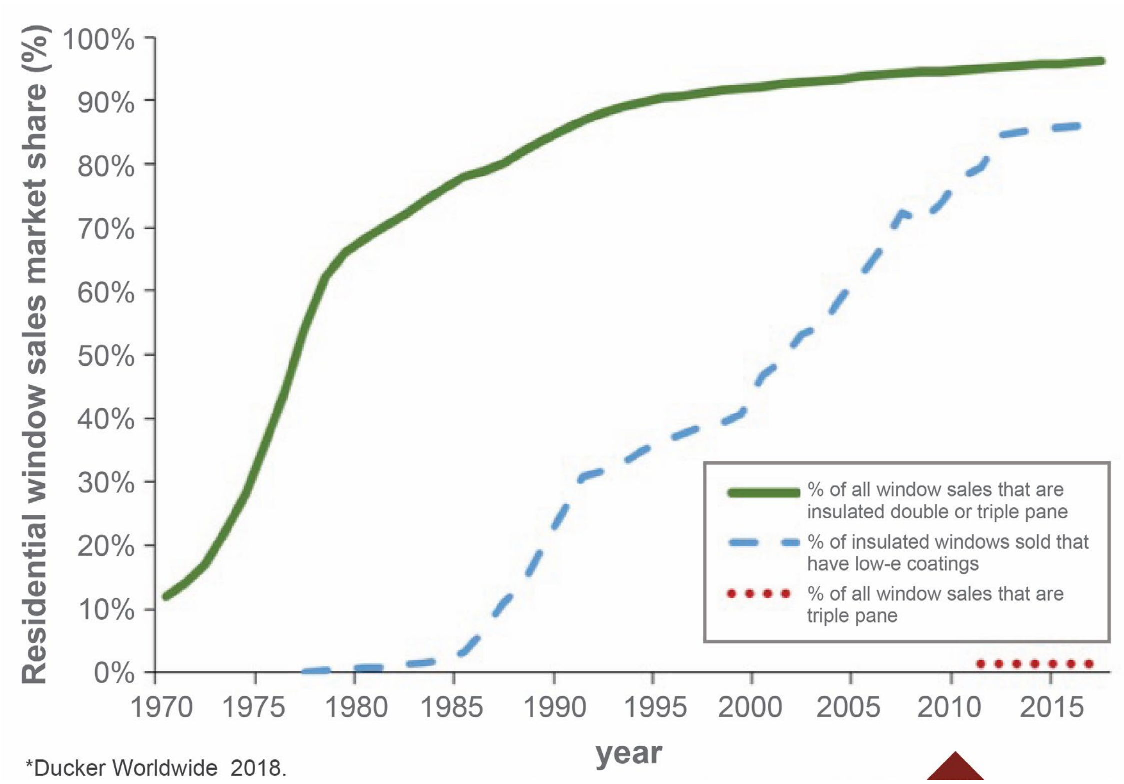

Figure 2.3. U.S. residential window sales since 1970 show double-pane windows with low-emissivity coatings now dominate the U.S. market (Source: Ducker Worldwide 2018 as reported by Selkowitz et al. 2018).

Metal and wood are the most common window frame materials in the United States in existing homes; however, the portion of sales of vinyl-framed windows has been growing in recent years (Figure 2.4). Although very strong, light, and almost maintenance free, metal (especially aluminum) conduct heat readily, which makes metal a very poor insulating material. Some metal frames come with thermal breaks to reduce heat flow and lower the U-factor; however, it is likely that a significant portion of existing windows have metal-framed windows without the thermal break and without thermally improved glass, providing a large opportunity for energy-efficient window retrofits.

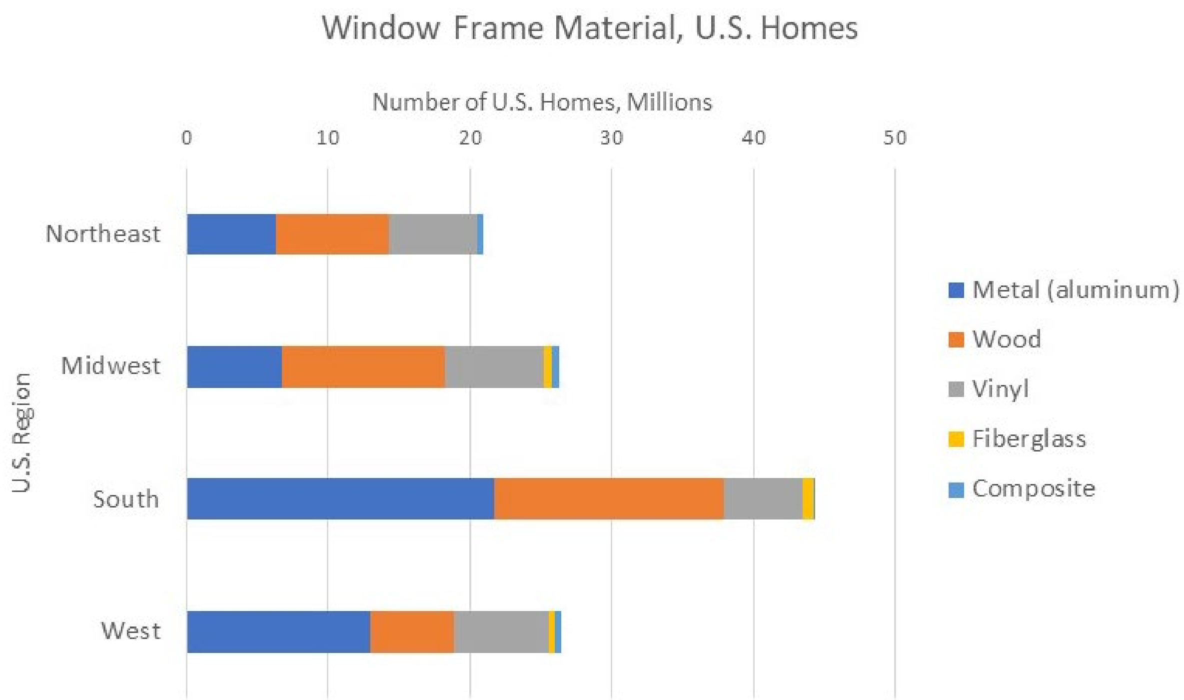

Figure 2.4. Window frame materials for all windows in the United States by region (Source: EIA 2019).

Based on market sales data, annual U.S. sales of all windows have exceeded 50 million units in recent years, reaching 56 million units in 2019, and more than 50% of these windows are designated as replacement windows (Principia 2019). Vinyl-framed windows are now the biggest sellers, accounting for 60% of window unit sales nationally and growth has also been seen in wood composite frames in recent years. In recent years, nearly 4 million homes have replaced some or all of their windows on an annual basis, at a cost to the consumer averaging approximately $3,800 per job (JCHS 2021).

2.2 Housing Vintage, Energy Intensity, and Energy Costs

According to the most recent RECS, the U.S. housing stock includes approximately 118 million occupied houses that serve as primary residences (EIA 2019). Of those homes, 69% were built before 1990, which is before the 1992 Energy Policy Act, which mandated more stringent building energy-efficiency codes. This would suggest that the energy-efficient façade upgrade market could include as many as 80 million homes. Homes by vintage and region are presented in Figure 2.5.

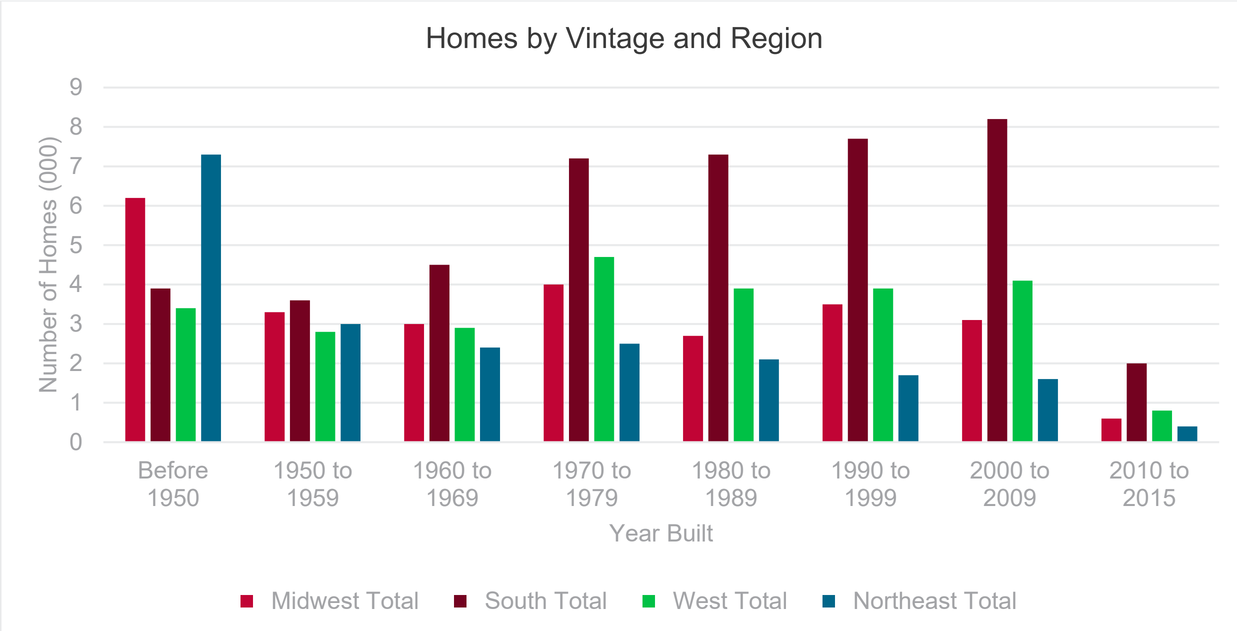

Figure 2.5. Vintage of U.S. homes by region (Source: EIA 2019).

In general, older homes tend to have leakier, less insulated façades, which results in a higher energy-use intensity on a per-square-foot basis (i.e., BTU/ ft^2) making these homes candidates for energy-efficient façade improvements. Indeed, long-term studies of efficiency indicators have demonstrated that energy-efficiency improvements in residential building shell construction and HVAC have resulted in reduced energy-use intensity on a square footage basis in the residential sector from 1970 through 2017 (Belzer et al. 2020). RECS tracks energy-use intensity in the residential sector on a per-household basis (see Figure 2.6 bar chart), and the energy-use intensity of homes steadily declined for homes built between 1950 and 1980, but then increased for homes built after 1985. Note, however, that the increase in per-household energy-use intensity is also associated with a 25% increase in average housing unit size (indicated by horizontal pink lines in bar graph in Figure 2.6) for homes built after 1990. Thus, despite the noted reductions in energy-use intensity stemming from thermal shell improvements (Belzer et al. 2020), homes built between 2000 and 2015 consume the same amount of energy on a per-household basis (on average) as homes built in 1960 (indicated by dark blue bars in Figure 2.6). On a per-square-foot basis, however, the homes built before the 1970s have the highest energy-use intensity and would be some of the best candidates for façade upgrades in terms of potential benefits gained from addressing window and wall air-leakage issues, improving insulation, and replacing degraded siding.

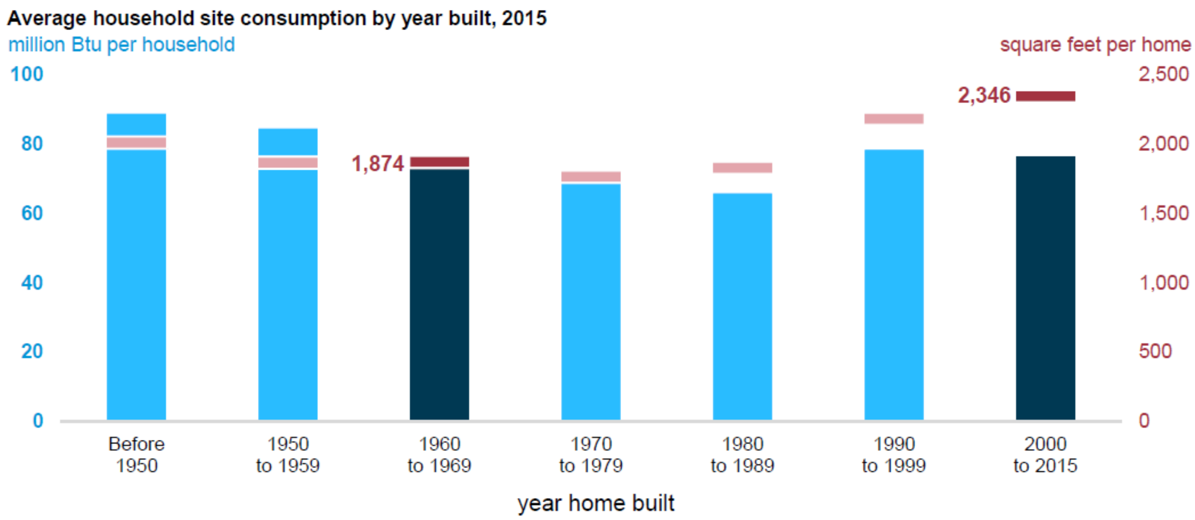

Figure 2.6. Average household site energy consumption by year built (EIA 2019).

Energy expenses per household are driven by energy intensity per household (shown as average consumption in Figure 2.7) as well as the regional residential energy rates (represented by the $ signs in Figure 2.7). The colder, heating-dominated climate zones of the Northeast and Midwest also include a relatively higher proportion of pre-1960s existing homes, and as a result, these two climate zones have the highest energy-use intensity per household, represented by the blue bars in Figure 2.7. These regions will benefit the most from façade upgrades, from both energy- and cost-savings perspectives. Despite the higher-than-average household energy consumption in the Midwest, their energy costs per household are lower than the average, as are energy costs in the West, due in part to lower energy rates. Average energy costs per household are highest in the Northeast followed by the South.

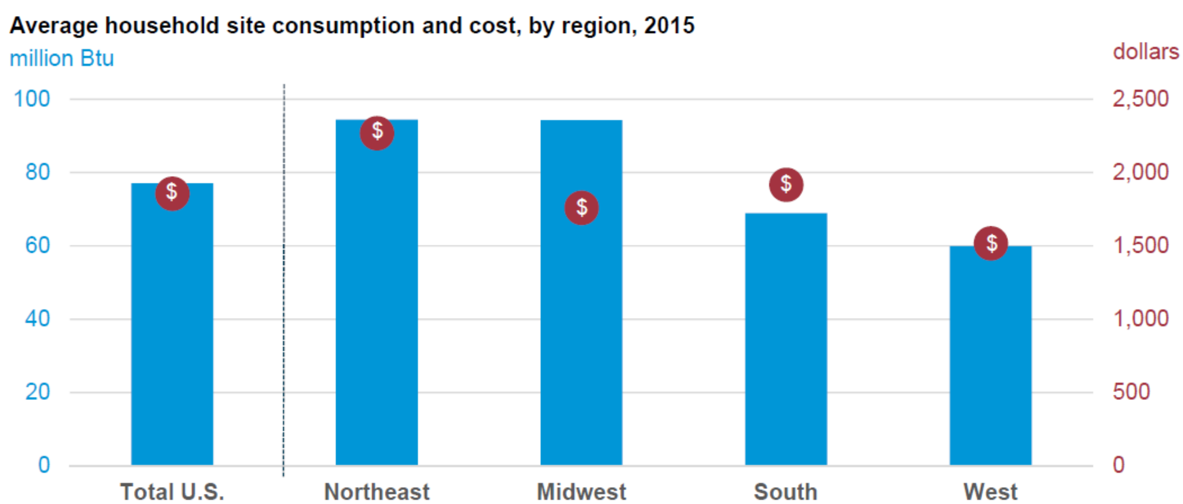

Figure 2.7. Average household site energy consumption and energy costs (Source: EIA 2019).

Energy use by sector is presented in Figure 2.8. In residential buildings, energy use is dominated by heating and cooling, which makes up 7.8 quadrillion Btu or 38% of total residential energy use per year. Water heating (2.8 quadrillion Btu, 13%) and lighting (1.3 quadrillion Btu, 6.3%) are also significant contributors, and together with heating and cooling, represent more than half of total residential energy use (EIA 2019).

HVAC accounts for more than half the total residential end-use energy consumption, but the share varies by climate region. In the cold climates of the Northeast and Midwest, for example, the heating consumption alone is well over 50% of total energy use, but in the hot-humid climate zones of the Southeast, non-HVAC end uses make up more than 60% of the total consumption and heating consumption is less than 10%.

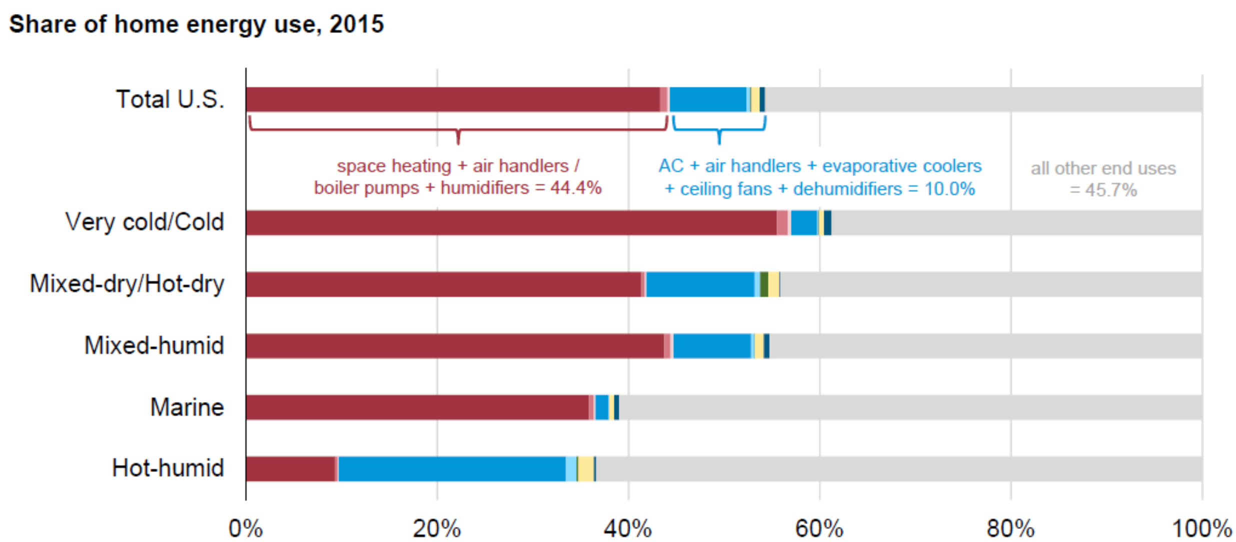

Figure 2.8. Total residential site energy consumption by end source and region (Source: EIA 2019).

According to the RECS survey, total residential energy expenditures in the United States are approximately $218 billion annually, an average of $1,900 per household (EIA 2019). The average residential monthly expenses for electricity in 2019 were $115, while natural gas expenses averaged approximately $50 per month (EIA 2019). The cost of running a drafty, poorly insulated home is especially pronounced for lower income households, where energy burdens are higher. Although energy burdens tend to be problematic in areas that have a heavy heating load, such as the Midwest and Northeast, based on recent studies estimating household energy burden, the percentage of households that have high and severe energy burdens (i.e., energy bills in excess of 6% and 10%, respectively, of total monthly income) is highest in the southeastern states of Mississippi, Alabama, Tennessee, and Kentucky (see Figure 2.9). This is, in part, because of a combination of relatively high poverty rates, high cooling loads, and high electric rates. These high cooling loads are likely exacerbated by aging and degrading residential façades, highlighting the need for energy-efficiency upgrades.

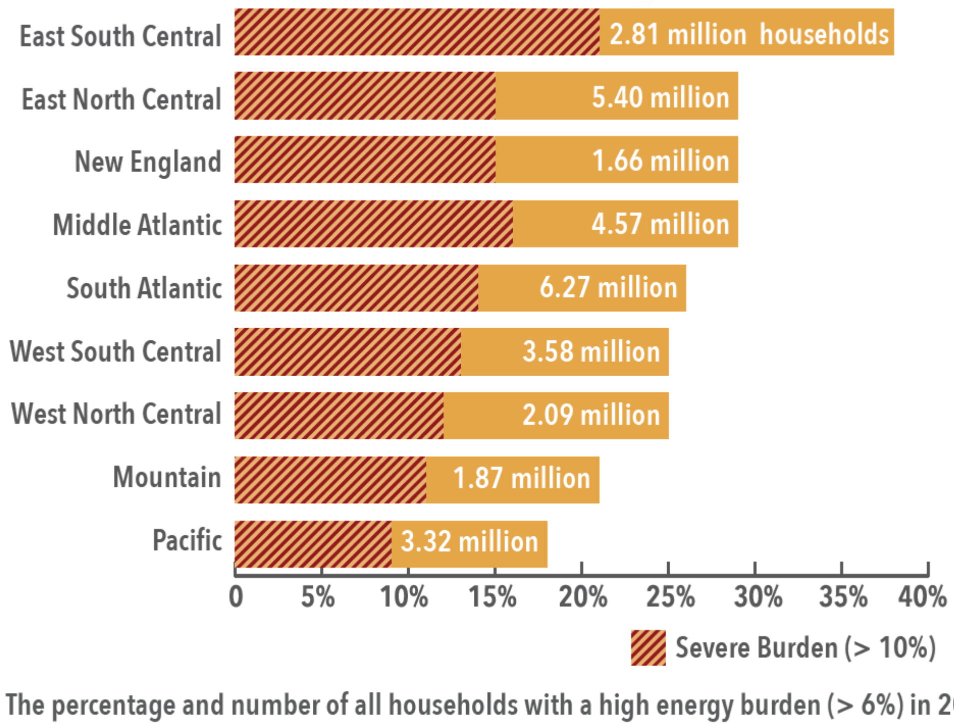

Figure 2.9. The percentage and number of all households that have a high energy burden (>6% household income) by Census/RECS region (Source: ACEEE 2020).

2.3 Façade Upgrade Needs and Opportunities

Table 2.1 provides a cursory assessment of the façade upgrade needs and opportunities by region based on findings related to the current façade characteristics, vintage, climate conditions, and market conditions throughout the United States.

For this high-level assessment, the façade upgrade needs are characterized by the age of building stock, energy-use intensity, and associated expenses. It also includes the energy burden, as defined in Section 2.2 of this report. Overall regional needs and opportunities are characterized on a relative basis in comparison to other regions. The façade upgrade opportunities are primarily characterized by the level of remodeling and retrofit activities in the market, but also include exterior wall construction type (where certain exterior cladding types are easier to retrofit than others) and the number of active utility programs and incentives in a given area (see Section 3.3 of this report). Overall, the Northeast region has both the greatest needs and the greatest opportunities relative to the other regions. The West has a relatively low level of retrofit upgrade needs; however, the opportunities in terms of remodeling and retrofit activities are abundant. This would suggest that the remodeling activity is driven primarily by the tight seller's market for real estate rather than "needs" in terms of degrading façades. On the other hand, the West also has a great number of programs and utility incentives for insulation and window upgrades, which could influence this market as well. The Midwest is also characterized as having a great amount of façade upgrade needs; however, the level of remodeling and re-siding activities and lack of programs and incentives suggested more limited opportunities relative to the Northeast. Note, however, that there are relatively more insulation jobs taking place in the Midwest than in other regions, which would suggest that this activity is truly driven by thermal comfort needs rather than the housing market activities. The South region has a some of the greatest proportions of homes with disproportionately high energy burdens and the most common façade upgrades are window replacements.

Table 2.1. Façade upgrade needs and opportunities.

Greatest Need/ Opportunity; Moderate Need/ Opportunity; Average Need/ Limited Opportunity	Vintage (condition of façade)	Energy Use Intensity	Energy Rates	Energy Burden (energy equity)	Exterior Siding Type (existing)	Remodeling Activity	Residing jobs	Insulation jobs	Window/Door Replacements	Program/Utility Incentives
	NEEDS				OPPORTUNITIES					
Northeast	Greatest	Greatest	Greatest	Moderate	Greatest	Greatest	Greatest	Greatest	Moderate	Greatest
Midwest	Greatest	Greatest	Average	Greatest	Greatest	Average	Moderate	Greatest	Average	Average
South	Moderate	Average	Moderate	Greatest	Moderate	Moderate	Average	Average	Greatest	Average
West	Average	Average	Average	Average	Average	Greatest	Greatest	Moderate	Moderate	Greatest

3.0 Residential Façade Upgrades: Retrofit and Renovation Market

The U.S. Census Bureau's (USCB's) American Housing Survey estimates total revenues stemming from home renovations in the United States to be $522 billion, and approximately 115 million renovations are completed annually (USCB 2020). In terms of market size, these renovations translate to around $96.6 billion in revenue across 455,608 companies in the sector, which employs 692,673 people nationwide. Growth in the residential retrofit market is expected to continue over the next few years (IBIS World 2020). While two companies, Belfor Holdings, Inc. and Power Home Remodeling Group LLC, represent the two largest market actors, neither holds more than 5% of the total market share, which is indicative of the local nature of home remodeling work (IBIS World 2020). Furthermore, a significant portion of renovation projects are conducted by the homeowner as "do it yourself" (DIY) projects. While DIY projects represent less than 20% of the total renovation expenditures nationally (see Table 3.1), they are a significant portion of the number of ongoing projects. Table 3.1 summarizes nationwide trends in projects, broken down by professional versus DIY.

Table 3.1. Nationwide home renovations by type (Source: USCB 2020).

	Total	Professional	DIY
Number of projects	115 million	72 million (62%)	43 million (38%)
Median expenditures per household	$1,500	$2,600	$600
Mean expenditures per household	$4,749	$6,262	$2,216
Total expenditures (1,000)	**$522 billion**	**$431 billion (83%)**	**$91 billion (17%)**

Siding and re-siding contractors constitute a small fraction of the 456,000 renovation companies currently in operation. In 2020, 8,236 siding companies were in operation, a market size of $7.85 billion, or less than 2% of the total renovation market, although the market for re-siding contractors is forecasted to reach $11.5 billion annually by 2026 (Anything Research 2021). Over the past decade, the re-siding jobs completed have averaged over a million annually, with the homeowner cost per job averaging $5,900, while window/door replacement jobs have averaged about 4 million per year, with the homeowner cost per job averaging $3,800 (JCHS 2021).

3.1 Renovation Expenditures

Figure 3.1 breaks down the total number of home renovation/replacement projects occurring in U.S. homes into the following categories: siding, windows/doors, insulation, HVAC, and roofing. Each of these project types was chosen because it has either a key perceived significant impact on home energy efficiency as defined by homeowners in a nationwide survey or it directly relates to upgrades of the home façade/exterior. The percentages reflect each of these categories relative to the total number of energy-efficiency-related upgrades for the region based on the schema outlined above.

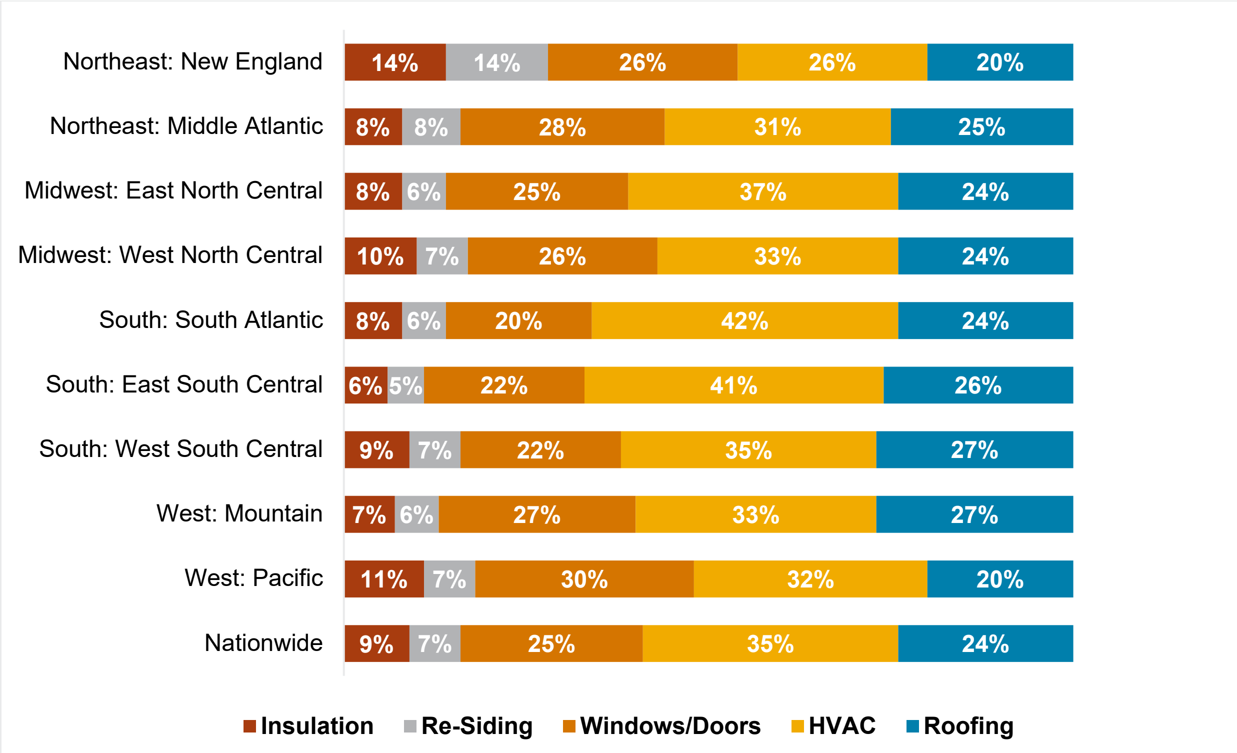

Figure 3.1. Re-siding as a percentage of common home renovation projects, shown by U.S. Census region (Source: USCB 2020).

Immediately noticeable is the larger than average percentage of projects in New England that involve re-siding a home—twice as many in fact as any other region in the United States. With costs ranging in the mid-$7,000s, on the upper band of costs per project, the region deserves further attention to discern where and to what extent façade projects are viable. To a lesser extent, this phenomenon also applies to insulation projects where the division has a higher-than-average percentage of projects dealing with insulation. Conversely, East South Central and South Atlantic homeowners are focusing less on siding and insulation, and significantly more on HVAC.

The ratio of DIY-to-professional projects remains the same throughout the United States when broken down by Census division, the exceptions being in the southeastern United States where the proportion of professional projects exceeds DIY projects. Figure 3.2 provides the average remodeling expenditures across the United States in 2019 as estimated by USCB's American Housing Survey. Average expenditures on home renovations vary significantly between Census divisions, with homeowners spending 50% more, on average, in the Pacific West (i.e., Washington, Oregon, and California) than they do in the southern states of Mississippi, Alabama, Tennessee, and Kentucky (see blue line in Figure 3.2). These expenses are positively correlated with the average home values of a region, where California and Washington States have some the highest average home values in the United States, ranking 2 and 4 just below Hawaii and Massachusetts, respectively, while Mississippi and Alabama rank among the lowest in state average home values (46 and 49)[2].

[2] Based on August 4, 2020, *Motley Fool* report, "Average House Price by State in 2020." https://www.fool.com/the-ascent/research/average-house-price-state/.

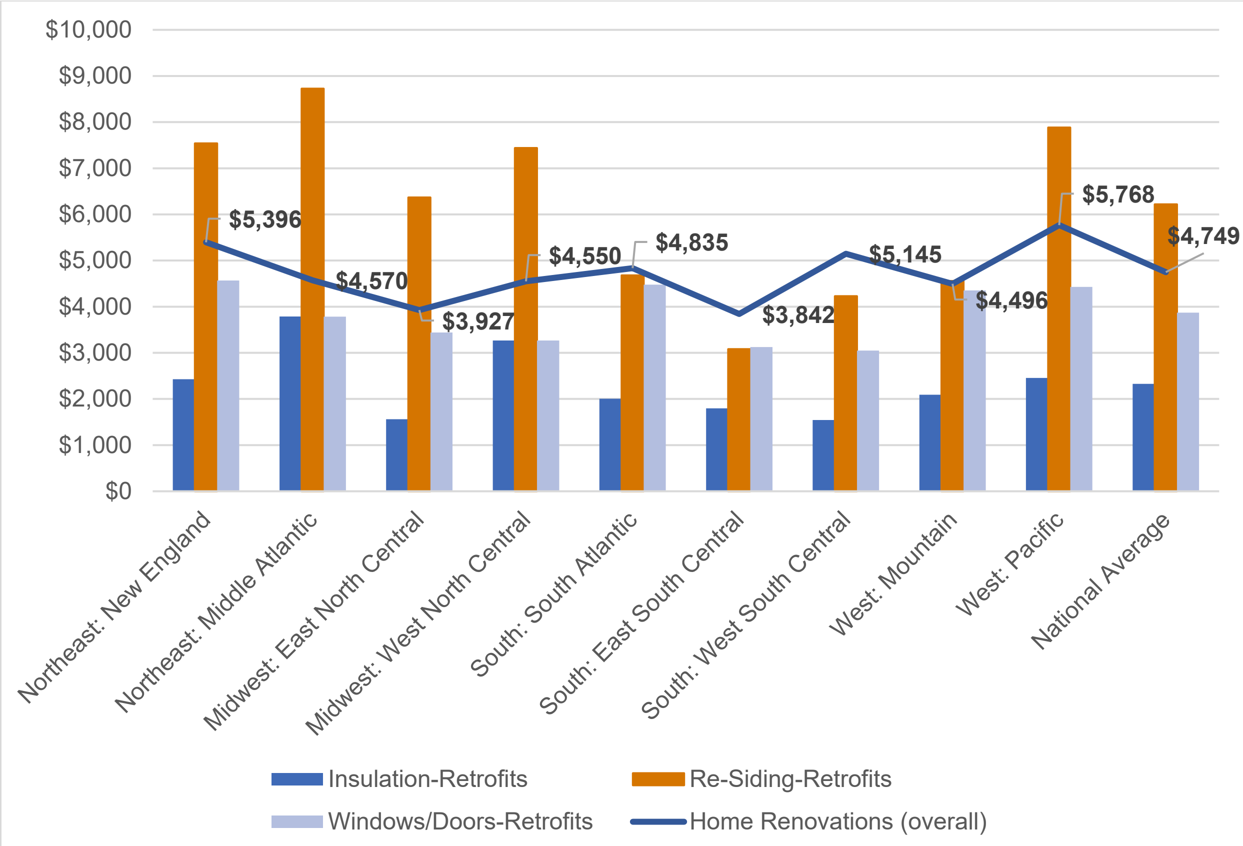

Figure 3.2. Average home renovation expenditures for common retrofits in 2019 by Census division (Source: USCB 2020; overall renovation averages in bold).

Average renovation expenditures are driven largely by the same factors that drive up housing prices—a combination of factors affecting the demand and supply of housing in a given region, including population growth, limitations on housing inventory, the availability of skilled labor, and building supply constraints, to name a few. As shown in Figure 3.2, the regions where average renovation expenditures exceeded the national average included the Pacific West (Washington, Oregon, and California) and the New England states in the Northeast. These are all regions that have had "hot" housing markets with a combination of high demand and supply constraints.

While nationally, the West Pacific region has the highest mean costs for renovation projects, states in the Northeast (Middle Atlantic division) and the Midwest (West North Central) have the highest mean expenditures on insulation-focused renovation projects (see Figure 3.2). These same regions (West: Pacific, Northeast: Middle Atlantic, and Midwest: West North Central) have the highest average spending on re-siding projects. This trend would suggest some correlation between insulation and re-siding expenditures and trends in major renovations, in general, paired with the aging housing stock and inclement weather experienced in these regions. However, it is notable that the Midwest states of Minnesota and Iowa, and the Northeast Atlantic states of New York, New Jersey, and Pennsylvania all have lower than average renovation expenditures but higher-than-average expenditures on insulation and siding, which would suggest that the façade renovations in these regions may be influenced relatively more by "need" (i.e., degradation and climate) rather than the leading drivers of the housing and renovation market.

By contrast, window and door expenditures are highest in the markets where average renovation expenditures are the highest: New England, Pacific West, and South Atlantic. This would suggest that the factors affecting the overall housing market and prices are also drivers in the window replacement market. The exceptions to this trend include the Mountain West states, where average window expenses exceed the national average (while renovation expenses are slightly lower than the national average). Conversely, the Southern division including Texas, where average renovation expenditures exceed the national average, has lower than average window retrofit expenses. In general, there is less variation in average window expenses across regional divisions. In addition to the overall housing market trends, the average spending on window replacement may be driven more by the code and rating requirements for windows in each region, where more stringent codes and “green” building requirements in the mixed and cold-climate zones of the north would necessitate higher performance and thus higher priced windows (Cort and Gilbride 2019).

Based on the USCB’s American Housing Survey, most homeowners use existing funds to complete renovations, either saved for the renovation itself or out of existing savings. Most respondents (58%) do not believe that access to financing would change their willingness to make an investment in energy-efficiency upgrades. Few respondents (less than 10%) have spent more than \$20,000 on energy-related renovations since owning their home, and most respondents spent less than \$10,000 on energy-efficiency upgrades. More than half of respondents want to see returns on these investments in less than 4 years (62%), and only 6.6% indicate they would be willing to wait 10 or more years. These regional variations indicate that a successful façade renovation program will need to address how different regions value and carry out home improvement investments and adjust program designs to align with these preferences. More detailed data related to region-by-region variations in perceptions and trends related to energy-efficient remodels are captured in Appendix B.

One notable trend in renovation expenses reported by Harvard’s Joint Center for Housing Studies (JCHS) is that there has been a significant and steady increase in “disaster repairs” over the past decade, which would likely affect the level of re-siding and window-related repairs (2021). The increased number of major disasters hit a new high in 2020, in response to which \$26 billion was spent by homeowners on fire, flood, and severe storm damage repair in that year alone. These increases have lifted the share of homeowner remodeling expenditures devoted to disaster repairs from 4% to 10% over the last two decades (JCHS 2021).

3.2 Renovation Choices, Perceptions, and Trends

In a recent nationwide survey (Tidwell 2021) focusing on homeowner perceptions of energy-efficiency retrofits, approximately 30% had added caulking or weather stripping around windows and exterior doors and approximately 20% had installed energy-efficient windows. Figure 3.3 lists the envelope measures that survey respondents indicated they had completed in the past 5 years. Approximately 1% of the respondents reported that they had replaced siding, but none reported adding wall insulation or installing window attachments, such as low-e storm windows or shading measures (Tidwell 2021).

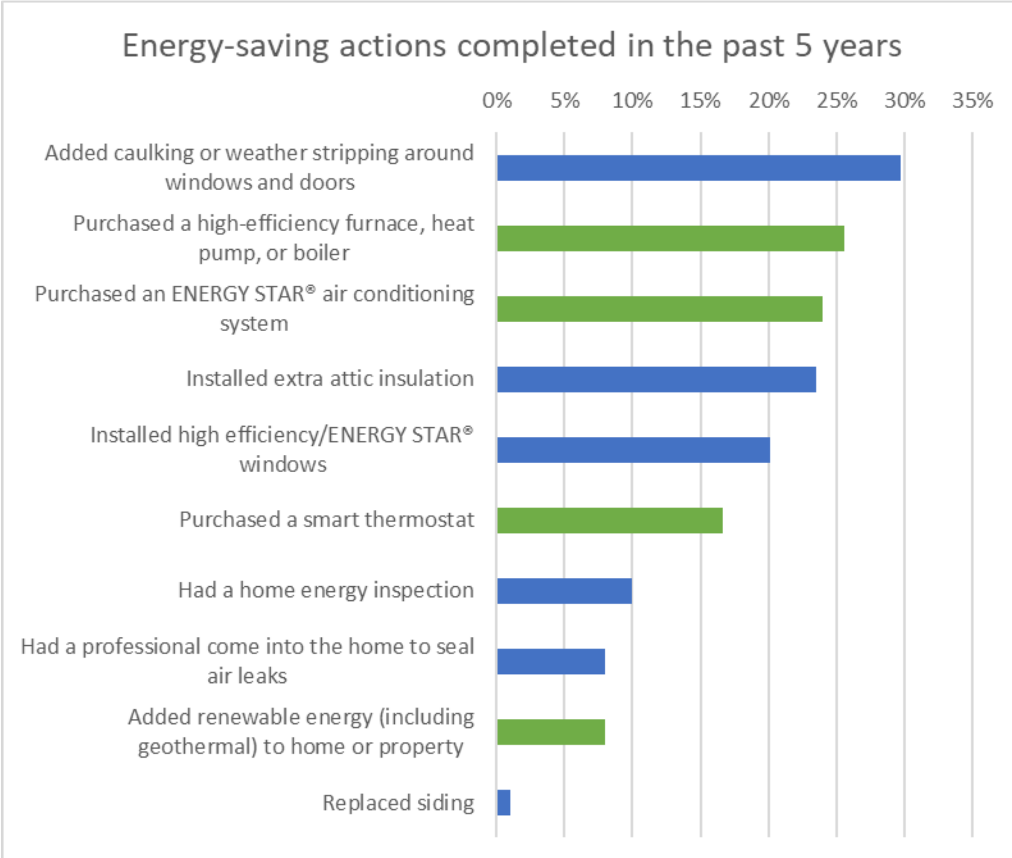

Figure 3.3. Energy-saving activities completed (only subset of HVAC [green bars] and envelope measures [blue bars] listed) (n = 2,015) (Source: Tidwell 2021).

When asked *which* renovations would have the most impact on the energy efficiency of their homes, 26% of the respondents considered replacing older, inefficient HVAC equipment as the most impactful, which was followed by window replacement (21%) and replacing attic insulation (11%). Only 3% of all respondents (62) chose replacing exterior siding or cladding as their top choice.

When asked to discuss their perceptions of energy efficiency, respondents indicated a belief that energy conservation is both necessary (i.e., important to them in term of costs and their own choices) and something the government should devote more effort to addressing. The exception to this pattern was the perceptions respondents held about paying for renovations versus paying for extra energy consumption. Table 3.2 shows one-third of respondents felt it is easier to pay more for energy than to make the effort to save energy. Nearly 70% of the respondents were of the opinion that the government should do more to increase energy efficiency in homes.

Table 3.2. Perceptions of why individuals may not adopt more energy-efficient ways of living (n = 2,015) (Source: Tidwell 2021).

Statement	Agree	Disagree	Neither Agree nor Disagree
No need to conserve energy	15.7%	71.8%	12.5%

Statement	Agree	Disagree	Neither Agree nor Disagree
It's easier to pay more for energy than make the effort to save energy.	31.6%	44.2%	17.2%
My energy bills are too low for me to care about energy efficiency.	20.6%	62.1%	17.3%
Individual efforts won't make much of a difference.	22.9%	60.4%	17.7%
The government should do more to increase energy efficiency.	67.5%	11.0%	21.5%

Overall, survey respondents indicated they would be more motivated to engage in energy-efficiency-related renovation to their home if there were rebates from their utilities (Table 3.3). These trends did not change for the respondent sub-groups that had either completed façade-related renovations or thought such renovations would have the largest impact on their home's energy efficiency.

Table 3.3. Top ways to encourage a specific energy-efficient renovation (n = 2,015) (Source: Tidwell 2021).

Top Reasons	Agree
1. Rebates from my utility	48%
2. All updates completed in one day	19%
3. Zero interruptions to my routine	12%
4. Quality components assembled offsite	8%
5. Contractor recommended by my utility	7%
6. Other reason	6%

3.3 Utility and Weatherization Program Activities

Most of the heating-dominated northern states have at least some form of utility programs that provide incentives for window and wall insulation upgrades. Most window programs are targeted toward window replacements for existing homes and offer relatively modest rebates ranging from \$1 to \$3.00/ft^2 of window area.[3] However, a few utilities in Washington, Oregon, Michigan, and New York offer more generous rebates for window replacement. Some southern cooling-dominated states offer modest window replacement incentives as well as window films and exterior shade incentives to reduce solar heat gain through the windows. Only a few utilities have programs that target storm window or secondary glazing systems. About half the states have utility rebates in place that directly target insulation upgrades. Insulation programs are primarily geared toward adding attic insulation, and rebates range from a few cents per square foot to whole home rebates in excess of \$2,000. Weatherization programs found in every state provide at least some incentives to upgrade façades; however, the bulk of these efforts are focused on air-sealing and weather-stripping activities and do not include deeper energy retrofits that would include upgrading wall insulation or windows.

[3] Program data gathered from the Database of State Incentives for Renewables & Efficiency (dsireusa.org).

4.0 Business Models Used to Carryout Façade Upgrades

Although some homeowners will take on some forms of façade repairs and upgrades as DIY projects, the vast majority of façade upgrades are carried out by professional builders and/or home-performance contractors. Most of these professional contractors will have certain siding and insulation materials, window brands, and vendors or distribution centers that they tend to favor or partner with directly. While some contractors may be formally tied to a particular building material or window supplier (Gilbride et al. 2019), many of these contractor-supplier relationships are flexible and informal. In either case, these “arrangements” drive the technology choice and delivery of most façade upgrade projects, with some variations in influences based on homeowner preferences.

4.1.1 Homeowner Involvement

The homeowner will have the final say on all remodeling projects; however, there are different components for which the homeowner will often rely on the expertise and advice of the consulting designer or contractor. In general, matters where aesthetics play a leading role will be largely driven by the homeowner. These would include choices of siding material and colors, and window types and styles. The choice of components that hide behind the scenes, such as wall insulation, air barriers, drainage, and flashing details, will often be left in the hands of the contractor. As a result, contractors will often default to minimum code requirements to drive choices and therefore if insulation/air barrier upgrades are not required by code as part of a remodel, this energy-efficiency upgrade may not occur unless explicitly requested by the homeowner. When insulation and/or air barriers are part of the project, contractors will tend to favor materials that can be easily acquired at a good price and they will employ familiar approaches that can be accomplished with available labor. Based on remodeling studies, both the homeowner and contractors will be sensitive to first costs, because homeowners need to keep within a budget and contractors need to keep the cost of labor and materials down in order to make a profit on any given job.

Home valuation studies show that homeowners tend to be more interested in projects that add resale value to the home, which would favor siding and window replacement projects, while added wall insulation would be expected to add less of a boost to home values. As reported by *Builder Magazine*, in a Zonda Media survey of remodeling projects that assessed the return on investment for various remodeling projects (Table 4.1), siding enhancement or replacement projects made up 3 of the top 10 projects, where manufactured stone veneer and fiber-cement have trended more favorably in resale value in recent years. Wood- and vinyl-framed window replacements also ranked high in terms of their return on investment (Salmonsen 2021). Thus, these consumer-backed façade components have some market momentum behind them, while insulation and window attachments, such as storm windows, face some added consumer-acceptance and recognition hurdles. The National Association of the Remodeling Industry (NARI) and the National Association of REALTORS® Research Group (REALTORS) also published a cost versus valuation study that found results similar to those of the Zonda Media survey, where fiber-cement and vinyl siding recovered 76% and 63% or their respective project costs. Vinyl replacement windows were estimated to recoup 71% of the project cost, while wood-framed window replacements recovered 57% of the project costs (NARI and REALTORS

2019). A recent survey by Homelight[4] estimated that window replacement increases resale value enough to recoup more than 80% of the original project cost.

Table 4.1. Cost versus value of remodeling projects (2021 Averages) (Source: Salmonsen 2021).

Projects	Job Cost	Resale Value	Cost Recouped
Garage Door Replacement	$3,907	$3,663	93.8%
Manufactured Stone Veneer (siding)	$10,838	$9,571	92.1%
Minor Kitchen Remodel	$26,214	$18,927	72.2%
Siding Replacement Fiber-Cement	$19,626	$13,297	69.4%
Window Replacement (vinyl)	$19,385	$13,297	68.6%
Siding Replacement Vinyl	$16,576	$11,315	68.3%
Window Replacement (wood)	$23,219	$15,644	67.4%

For replacement windows of all types, homeowner preference appears to focus on energy efficiency, low maintenance, durability, style, and curb appeal. Thus, in addition to recouping on an investment, homeowner choices are often driven by the low-maintenance and durability aspects of a given product. For example, commonly cited selling points for vinyl and compositive frame windows include lower cost, scratch resistance, reduced warping, and low maintenance (i.e., no need to repaint).

4.1.2 Manufacturing Distribution

Most siding and insulating materials that are used to support a façade upgrade would be purchased by the contractors at a lumber yard-style regional building supplier or a big box home improvement store such as Lowe's or Home Depot. Some brands of windows and window attachments are also purchased at these supply stores, but windows are often distributed through local window dealers that have trained window installers for their product offerings. Window attachments, such as storm windows are distributed through lumber yards, big box retailers, and online custom sales from the manufacturers. Some product lines of interior and exterior window attachments, such as awnings, shutters, screens, blinds, and shades, can also be purchased through big box retailers, but most are sold through exclusive dealers and some paint and flooring stores.

These distributors play a key role in facilitating contractor discounts and supply networks, disseminating information about newly developed materials and practices, and even hosting training and education events. In past builder workshops and surveys (Gilbride et al. 2019), contractors have emphasized the importance of developing relationships with their suppliers and dealer networks to help facilitate timely assistance, repairs, and replacement when needed. When a homeowner has a problem with a product, they are not going to call the manufacturer, rather they will call the contractor. Thus, the contractor needs to be able to navigate warranties and product replacement when necessary.

[4] Homelight is an online real estate platform that provides services to realtors. Data on window valuation is from a February 27, 2020, blog post by Emma Diehl, "Adding Value to Your House with New Windows: Energy Efficiency Matters." https://www.homelight.com/blog/do-new-windows-increase-property-value/.

Issues with warranties were identified as potential barriers to energy-efficient façade upgrades in the NREL-PNNL-sponsored March 2021 Contractor Workshop (see Appendix A) when concern was voiced regarding mixing and integrating different brands of building supplies, such as exterior foam insulation with new siding. Contractors at the workshop noted that the possibility of getting sued when working with the building shell is significant enough that contractors are often extremely risk averse. For example, they will buy everything from one vendor (house wrap, tape, etc.) and forego adding insulation from another manufacturer to avoid the risk of voiding the warranty. Other contractors who routinely add exterior insulation with their siding jobs indicated that as long as you follow the manufacturer's installation instructions, which will often indicate the best way to integrate insulation with a particular siding assembly, the risk of voiding a warranty is minimal.

4.1.3 Contractor Networks

In addition to upstream supplier networks, the contractor business model relies on building networks with other contractors and homeowner clients. Traditionally, these networks have been facilitated by the combination of lumber yard bulletin boards, print material, and word of mouth, but in recent years they have been much more influenced by online home service advisors and web-based platforms for locating and reviewing contractors. These services offer the vetting of professionals, which can be a service for both homeowners and other contractors. The services often enable the ability to obtain multiple quotes for a given project for comparison. These services also provide valuable market channels for contractors to connect with potential clients who need services. HomeAdvisor and ANGI Homeservices (formerly Angie's List) are two of the most well-established digital home service marketplaces. Contractors may have to pay a monthly fee to be listed on these search sites. As with the manufacturing distribution channels and networks, these home advisor networks are also becoming platforms for the dissemination of information and building science education materials for both building contractors and homeowners.

4.1.4 High-Performance Retrofit Business Models

Although comprehensive remodelers are commonplace in residential buildings, integrated façade delivery or "deep-energy retrofit" business models are not nearly as well developed for remodeling and retrofits as they are for new home builders. Nevertheless, there are home-performance contractors and designers who specialize and have made successful businesses of deep-energy retrofits (Baechler et. al. 2012). One such builder who participated in the Contractor Workshop (see Appendix A) emphasized the importance of making sound building science the foundation of your business but selling the customer on the benefits that matter to them—comfort, quiet, resilience, and lower energy costs.

> We have a huge mix of clientele. We have a lot of the very left-leaning side of the spectrum but also out in the rural areas we have a lot of the right-leaning more libertarian side of the political spectrum. So we don't sell [energy efficiency] because it is the right thing to do from an environmental standpoint because for some of our clientele it wouldn't resonate with them. But what does resonate with everyone is comfort, resiliency, and more durability to their buildings.
>
> –Pacific Northwest Residential Designer

5.0 Barriers to Façade Upgrades

The barriers to residential deep-energy retrofits have been well documented. They can be classified into technical, financial, and market and educational barriers.

- *Technical:* Key technical barriers include (a) lack of consistent and standardized solutions (every house is different and warrants some customization); (b) lack of skilled workers; and (c) risks and shortcomings associated with technical solutions coupled with complications and long disruptions to homeowners.
- *Financial:* Key financial barriers include (a) high up-front costs and owner reluctance to borrow funds for energy renovation purposes; (b) uncertainty about total costs of project; (c) long payback periods of façade upgrade measures; (d) lack of homeowner confidence in the overall return on investment; and (e) insufficient funding sources and investors, particularly for low- and medium-income homeowners and rental homes.
- *Market/Educational:* Key barriers include (a) lack of homeowner/end-user and contractor building science knowledge and trust in effective energy renovation savings and associated benefits; (b) lack of understanding by home occupants that often hinders timely upgrades; (c) decision-making and contracting processes that are long and complex; and (d) disruption to home occupants or their reluctance or inability to relocate if necessary, during renovation.

5.1 Technical Challenges

The successful implementation of energy-efficient façade retrofits faces an interrelated set of technical, financial, and market challenges. DOE has established a research agenda and programs targeting market-relevant strategies to achieve deep-energy retrofits, including a series of technical retrofit guides, checklists, case studies, and code briefs available through DOE's Building America Solution Center (BASC).[5] This assessment focuses on near-term integrated technical solutions that could build off DOE's existing platforms, research, and resources.

5.1.1 Building Science Solutions

Every home's façade presents a unique set of remodeling challenges based on the original construction practices and materials used and its current condition. Every home also comes with different occupants with varied objectives, which makes it very difficult to standardize solutions for façade upgrades. These challenges are compounded by the homeowner's lack of building science knowledge. Contractors will also tend to specialize in envelope components (i.e., roofing, siding, insulation, windows) and many lack the knowledge of integrated façade solutions and how all the different systems in the building work together. Both contractors and homeowners have identified the complexity of deep retrofit work as a key barrier, so any resources and tools that simplify decision-making or planning processes could be useful in addressing this barrier.

5.1.2 Workforce Shortage

The construction industry has identified the labor shortage as a growing concern over the past decade, with the percent of builders identifying it as a top challenge rising from 13% in 2011 to

[5] BASC provides access to expert information about high-performance construction and retrofit topics https://basc.pnnl.gov/.

87% in 2019, according to the National Association of Home Builders (Chaluvadi 2021). The lack of skilled labor is especially pronounced in the market for façade upgrades, such that the relatively higher risk and minimal reward (i.e., tight margins) of these projects leaves them at the bottom of the list for many contractors. Industry efforts to address the problem have had limited success to date. As an information companion to this report, Gilbride and Hefty's 2021 report on the topic explores residential construction workforce labor shortage trends, causes, and potential solutions. The report also looks at related DOE and U.S. Department of Labor initiatives and resources, with the goal of helping to overcome the labor shortage barrier associated with façade retrofits.

Some key reasons noted for this shortage include the home building industry's size and growth, the aging workforce, difficulty attracting employees, and barriers to training. From the depths of the recession of 2009, when the industry hit a 60-year low of 554,000 new home starts, the industry has roared back, climbing to 1,400,000 housing starts in 2020 (USCB 2021), while unfilled construction jobs have hovered around 300,000 nationwide for the past 3 years. As of March 2021, 3.3 million of those employed in the construction industry were under the age of 35 while more than twice that number (7.5 million) were 35 or older (BLS 2021). In a 2020 builder survey taken by the Building Performance Association, respondents identified the lack of experience and technical skills as a key challenge to hiring new staff and the top three challenges to expanding the building performance industry were identified as (1) accessibility of training and jobs, (2) awareness of career opportunities, and (3) affordability of training and certifications (Gilbride and Hefty 2021).

5.1.3 Risk-Reward

During the Contractor Workshop (see Appendix A), participants noted that the risk-reward ratio associated with façade upgrade projects along with the overall risk aversion that is inherent in many contractor business models creates a substantial barrier to scaling up the number of energy-efficient façade upgrades completed each year. Contractors noted that re-siding comes with significant risks because it is challenging to make retrofit assemblies weathertight and any time existing siding is removed, there is always the possibility that serious problems and damage will be revealed, including the presence of hazardous materials like asbestos, which increases the risk even more. If asbestos is present, there is often an expensive removal and remediation cost that increases the overall project cost. For contractors to take on this risk, there needs to be a high level of demand and motivation from the homeowner, and contractors will often select risk-minimizing strategies. For example, some contractors might choose to lay new siding over the existing siding just to avoid uncovering any rot or revealing any areas of water intrusion so that there is less chance of being liable for any issues that are uncovered. Siding contractors may also avoid recommending going beyond a standard siding replacement to include installation of rigid foam because of the warranty-voiding concerns mentioned earlier. These practices eliminate the opportunity to upgrade the façade properly with added insulation and air barriers. Contractors participating in the workshop indicated that the biggest lost opportunity for improving home window and wall performance is failure to insulate and insulate properly during a re-siding job.

5.2 Financial Challenges

Financial aspects are among the highest barriers for homeowners when it comes to façade renovations. The time taken for the initial outlay to be recouped is one of the major barriers, and homeowners are often not likely to consider investments that do not pay for themselves in less than 10 years, even for long-lasting façade renovations. The profitability of façade upgrades in terms of building life cycle, comfort, and acoustic improvements, avoided maintenance costs, and home valuation (and higher rent) needs to be highlighted to justify additional investments.

Nearly half of the older (i.e., built before 1970) existing single-family homes are occupied by low-income residents and one-quarter of the 55 million single-family homes built before 1990 are considered rentals (EIA 2019). In the case of low-income residents, whether homeowners or renters, the financial burden to take on larger comprehensive façade upgrades is likely not affordable and/or feasible. While some of these low-income residents could qualify for assistance from programs such as the federal Weatherization Assistance Program, these programs seldom offer comprehensive façade upgrades. For rental housing stock, one predominant factor driving investment decisions in home improvements includes the “split-incentive” issue, where the property owner has little incentive to make energy-efficiency improvements while the renter is paying the utility bills. This is particularly pronounced for energy-efficiency measures that are hidden, such as wall insulation.

To address these challenges, some financial institutions have started to issue various forms of “green mortgages,” where the bank offers lower interest rates and/or increased loan amounts for energy-efficient buildings and upgrades. These loans can provide homeowners an affordable way to make upgrades that may be costly up front, but save money over the long run, such as window replacement or added wall insulation. Although the market for multifamily green mortgages has grown substantially in recent years, the single-family market is only beginning to emerge as a destination for green capital and could benefit from additional pilots and testing of qualification criteria for the “green” securities in order to scale up this market (Ballesteros et al. 2021).

5.3 Market/Education Challenges

Lack of education related to building envelope systems and lack of confidence in building contractors is a leading market challenge with energy-efficient façade upgrades. Homeowners and occupants often do not realize that their exterior walls lack insulation, or they may not properly identify low-performance exterior walls and windows as the source of their discomfort and high energy bills. Even when home occupants identify thermal integrity or moisture issues related to their façade, the lack of knowledge about available solutions is an obstacle. There is also some mistrust of building contractors, and homeowners are often not sure where to find reliable experts and professionals to ask for advice and assistance. Consumers are also often reluctant to try new innovative solutions. The disruption factor with big renovations is also frequently a barrier to major façade renovations.

6.0 Façade Retrofit Challenges, Opportunities and Recommendations

The road to wide-scale energy-efficient upgrades of today's existing home façades includes a litany of challenges and barriers, many of which are shared with efforts to increase residential deep-energy retrofits in general. But as various DOE research and development efforts focus on addressing some of the technical challenges, there are some near-term opportunities to work within the current market structure, working with market drivers that could improve market uptake of existing and proven façade retrofit solutions. The following list characterizes the barriers and challenges that DOE market transformation activities could and should address to effectively meet the goals of DOE's ABC initiative.

- *Lack of Consistent and Standardized Solutions for Façade Upgrades* – Unlike new builds, where building approaches can be guided by standardized designs, building codes and practices, the baseline conditions, codes, and guidance will likely vary from one situation and jurisdiction to the next. DOE technical assistance and guidance that focus on integrated window-wall solutions with an aim toward reducing the time and complexity of the retrofit measures are needed.
- *Building Science Knowledge Gap (Homeowner-Contractor)* – There is a lack of building science knowledge on both sides of the homeowner-contractor equation that greatly deters energy-efficient envelope upgrades. Home occupants will often blame their heating and cooling systems for comfort issues that in reality are due to poorly insulated walls, poor-performance windows, and air infiltration through windows and walls. Likewise, considering that the desire to enhance a home's curb appeal and aesthetics is the primary reason for re-siding remodels, a re-siding contractor may miss the opportunity to include needed thermal improvements even when this could be an easy add-on to a remodeling job. DOE could design its outreach and education programs to specifically target both homeowners and contractors.
- *Workforce Shortage* –To implement façade upgrades, a skilled workforce trained to recognize and address the required improvements is needed. DOE and other governmental workforce programs should specifically consider the building science and construction skills needed to both recognize and implement energy-efficient façade upgrades.
- *Risk-Reward Dilemma* – A perceived and real level of risk exists for homeowners and contractors who take on extensive exterior wall and window retrofits. The very act of pulling off siding and potentially revealing the existing structural and moisture control issues of a home make façade upgrades one of the highest risk remodeling activities for a homeowner or contractor. Because remodeling horror stories sometimes circulate unchecked, there is also a heightened perceived risk perception associated with façade upgrades that may or may not be warranted. On the flip side, the rewards of addressing these façade needs is often under-valued and under-sold. Whether these risks are real or perceived, DOE needs to gather more "boots-on-the-ground" knowledge to assess the level of risk and focus technical and economic solutions toward addressing these risks as well as enhancing and publicizing the associated rewards of these upgrades.
- *Financial/Structural Barriers (split incentives, financing constraints)* – Because of the vast number of income-constrained and rental stocks with inherent split-incentive barriers, significant financial and structural barriers exist for large-scale market adoption of façade upgrade remodeling and retrofits. This is compounded by the decreasing availability of affordable housing in areas with thriving job markets. This presents a large, complex, and

persistent barrier to the implementation of deep-energy retrofits in general; however, considering that this affects more than half of the single-family building stock that is likely in the greatest need of energy-efficient retrofits, it needs to be addressed in order to truly transform the market. Some financial instruments, such as green mortgages and the associated frameworks to determine qualifying property upgrades for single-family homes, could help incentivize energy-efficient façade upgrades.

Based on the market characterization, distribution channels, business models, and consumer benefits described in Sections 3 and 4, and the barriers to market adoption identified above, Table 6.1 summarizes challenges to façade upgrades and identifies pathways to reach consumers as well as the near-term research and technical assistance that is needed to achieve these upgrades. Recommendations for future research and technical assistance are discussed in Sections 6.1 through 6.5.

Table 6.1. Barriers, strategies, and pathways to market transformation for façade upgrades.

Barriers/Challenges	Strategies/Opportunities	Pathways to End Users
Lack of **Consistent and Standardized Solutions for Façade Upgrades**	Carry out **Façade Upgrade Case Studies** that could help gather data and support the development of **Retrofit Decision Trees** for both windows and walls. Refine and **update Building Retrofit Guides** with latest technical solutions.	Building America Solution Center (BASC), Bonneville Power Administration, Weatherization Assistance Program (WAP), codes and rating organizations, and utilities
Risk-Reward Dilemma	Carry out **Façade Upgrade Case Studies** that could help gather data and help refine **Business Models** for façade upgrades. Conduct **Building/Economics Modeling** to assess market potential and opportunities for façade upgrades.	BASC and Training, Utilities, Consortium for Energy Efficiency (CEE), WAP, and DOE/FEMP/DoD pilots and programs
Building Science Knowledge Gap (Contractor-Homeowner)	Carry out **Façade Upgrade Case Studies** that could help gather data to support outreach and education efforts. Continue to support **Energy Ratings and Codes** working groups for high-performance windows and window attachments. Work with **Home Performance with ENERGY STAR®** and **Home Energy Score** teams to ensure that façade upgrade measures are fully recognized and valued in these programs.	Codes and Rating Organizations (AERC, NFRC, IECC energy codes), Home Energy Score (DOE), Home Performance with ENERGY STAR, BASC, Manufacturing Associations
Workforce Shortage	Carry out **Façade Upgrade Case Studies** that could help gather data in support of **Workforce Initiatives** in an effort to emphasize the need for integrated solutions for façade upgrades.	BASC, Better Buildings Workforce Accelerator
Financial/ Structural Barriers (split incentives, financing constraints)	Consider dedicated residential retrofit initiatives and pilot programs that work with community organizations, local governments, and financial institutions to help incentivize and implement façade upgrades. Drive the demand for integrated façade upgrade solutions and skilled workforce availability to carry out solutions at scale.	Home Energy Score; Better Buildings, WAP; Local governments and community action organizations with knowledge of problem areas and solutions

AERC = Attachments Energy Rating Council; DoD = U.S. Department of Defense; DOE = U.S. Department of Energy; FEMP = Federal Energy Management Program; IECC = International Energy Conservation Code; NFRC = National Fenestration Rating Council.

6.1 Façade Upgrade Case Studies

To address the technical and market barriers to façade upgrades listed above, part of this project includes facilitating a series of Façade Upgrade Case Studies working with residential siding contractors in multiple climate zones to help identify the needs and opportunities related to façade retrofits. By working with home-performance contractors who regularly do complete re-siding jobs, DOE could “field-test” the existing resources and messaging related to energy-efficient façade upgrades and evaluate the “on-the-ground” realities of material distribution, decision-making, costs, and implementation. DOE could develop retrofit resources to assist with the planning and implementation of façade upgrades where a conventional re-siding retrofits will be enhanced with additional wall and window insulation measures to optimize the thermal performance of the façade. Each case study, for example, could involve providing retrofit guidance to upgrade conventional single-family home re-siding jobs to include additional (R-5) rigid exterior insulation, house wrap, flashing, sheathing if needed, and insulating window panels (i.e., storm windows) for homes with single- or double-pane clear-glass windows. Feedback would then be solicited from the home-performance contractors regarding the effectiveness of the retrofit guidance and the additional effort required (in terms of time, planning, logistics, construction, etc.) to integrate the energy-efficient retrofits into a conventional re-siding job.

6.2 Refine Retrofit Guidance

DOE has invested in developing solution sets and building guides to help address energy-efficient retrofit challenges and barriers, all available on the BASC website. Although these resources are used by many, with regard to energy-efficient façade retrofits, information from the market analysis and façade retrofit case studies can help inform refinements and ensure that this information is getting to the right people in the right format.

6.3 Retrofit Decision Trees

To reduce the complexity and risks associated with façade retrofits and help address the “risk-reward” barrier described above, a series of targeted and well-designed decision trees could be developed to examine the possible consequences and outcomes of both window and wall retrofit decisions throughout the remodeling process. There is an opportunity to both field-test and gather feedback related to the decision-making process with the Façade Upgrade Case Studies. A window retrofit and wall retrofit decision tree could be designed to help evaluate current conditions and help determine feasible and optimized retrofit solutions for a given situation. Preliminary draft decision trees for window and wall retrofits, based on initial feedback from Case Study participants and input from LBNL and ORNL researchers are presented in Appendix C.

6.4 Modeling and Economic Analysis

An economic analysis based on building energy modeling could help address market barriers to façade upgrades by identifying market needs and opportunities for façade upgrades. Using NREL’s ResStock analysis tool and data set, an economic analysis could be performed for various façade upgrade combinations and strategies for different climate zones. This analysis would consider the combined life cycle cost of re-siding and window upgrades, including both home value impacts and recurring bill savings estimates from a ResStock analysis, for varying years of home ownership. These could also be presented as modified versions of the cost vs.

value tables published annually by *Remodeling Magazine*. Currently, the NREL team is conducting a valuation study aimed at calculating a country-wide energy and costs savings potential for façade upgrades. The results of that analysis will be reported a separate document subsequently.[6]

In the following examples, we present two cases using available cost data that can show a potential payback for integrating insulation, air-infiltration reduction, and better windows into typical remodeling projects.

6.4.1 Example 1: Siding Enhancement

U.S. Environmental Protection Agency studies show that air leakage accounts for 25%–40% of the heating and cooling loads in a typical home. In 2013, the New Jersey Institute of Technology (NJIT) conducted a field study looking at the energy and indoor air quality benefits of reducing air leakage during common re-siding jobs by installing an air barrier as part of the re-siding process. The NJIT study found an average decrease in air-leakage rate of 19%, which translates to an average energy savings of $105 per year (NJIT 2013). Considering that fiber-cement and vinyl siding projects already have the potential to recoup costs by as much as 69% without adding energy-efficiency upgrades (see Table 4.1), it is reasonable to suggest that adding insulation and air barriers during the re-siding process can be cost effective.

6.4.2 Example 2: Siding Enhancement and Window Upgrades

Similar to re-siding projects, window upgrades in the form of vinyl- or wood-framed replacement windows are estimated to recoup as much as 80% of their costs in terms of increasing the value of a home (see Section 4.1.1). Thus, in terms of appraisal value, both the contractor and homeowner could justify improvements to windows during a re-siding job when the up-front capital investment is available to the homeowner. When windows are in need of an upgrade, but capital or financing is constrained, the homeowner and contractor could consider the addition of storm windows, which achieve savings similar to those of double-pane replacement windows at a fraction of the cost. Although the resale valuation improvement from storm windows would be less than full window replacement, the addition of low-e storm windows would be similar to adding an air barrier or additional insulation during re-siding projects, where these measures could be added to a re-siding project that is under way for a relatively low cost while significantly improving the energy efficiency of the home. Previous PNNL analyses have concluded that the additional costs of adding low-e storm windows can be less than $100 per window with minimal additional labor required, while achieving annual HVAC savings of 10%–30% when applied over single-pane or double-pane clear-glass windows, resulting in a savings-to-investment ratio over 1 for all mixed and cold U.S. climate zones (Knox and Widder 2014; Culp and Cort 2014). This would yield an annual cost savings range similar to the wall air-sealing and insulating retrofits (~$100–$500) depending on the type of HVAC, energy rates, existing condition of the home, and climate zone.

6.5 Addressing the Workforce Shortage

A mass scale-up of façade upgrades will require additional workforce with appropriate skills. The Gilbride and Hefty (2021) report highlights a DOE initiative to address the residential construction workforce: the Better Buildings Workforce Accelerator. This DOE program

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[6] NREL white paper, “Residential Façade Retrofits Modeling NREL Documentation,” by Elaina Present, Eric Wilson, and Rachel Romero forthcoming in 2022.

facilitates industry and stakeholder partnerships to set and meet goals to improve building science training and educational programs. More specifically, this 3-year program leverages partner organizations to increase awareness, fill knowledge gaps, and streamline pathways for high-performance building careers.[7] Other government initiatives summarized are the U.S. Department of Labor user-facing websites that can be accessed by government, industry, builders, educators, and those seeking jobs to find the latest data related to construction workforce trends and employment and training opportunities. More details about these resources are found in the report by Gilbride and Hefty (2021).

The Gilbride and Hefty report (2021) also gives several examples of how specific individual industries and high-performance builders in residential construction are approaching their labor shortages and training issues and, based on the analysis of current conditions and programs, it provides a series of recommendations to address the labor shortage, including the following:

- Support builder and contractor in-house training efforts with good building science-based best practices resources like the Building America-sponsored research sourced through the BASC. Promote this resource through the National Association of Home Builders, state and local home builder associations, ENERGY STAR, conferences, and builder/contractor round tables.
- Support manufacturer and vendor training efforts with good building science-based best practices resources like the Building America-sponsored research sourced through the BASC. Promote this resource through the DOE’s Home Improvement Expert partnerships and leading manufacturer and vendor round tables sponsored by DOE.
- Expand the support for and the reach of YouthBuild, Vets Build, and Employment Re-entry for formerly incarcerated, unemployed, and displaced workers.
- Develop and promote a green construction track within the Job Corps program to provide mentoring, education, and training for youth who are placed in cohorts with large builders doing market-based affordable home construction that is based on high-performance home criteria such as DOE Zero Energy Ready Home or Home Performance with ENERGY STAR programs.
- Promote development of high-performance home construction and renovation construction and design skills as a track in science, technology, engineering, and mathematics high school programs.
- Promote an actual and/or virtual parade of new homes for DOE Zero Energy Ready Home certified homes and deep-energy retrofit make-over homes to promote awareness of high-performance home construction and remodeling, with prize money or gate receipts going to fund training scholarships. Seek promotion through national outlets such as Home and Garden television (i.e., HGTV) stations, builder, and other trade magazines. Seek local support and promotion through banks, lenders, mortgage companies, and realtor associations.

[7] DOE and NREL (U.S. Department of Energy and the National Renewable Energy Laboratory). 2020. “Workforce Accelerator Technical Assistance Providers Kick-off Meeting.” Presented October 9, 2020, via Zoom.

7.0 Conclusion

This report outlines the current state of the market for window and wall retrofits, along with opportunities and barriers related to enhancing energy efficiency through façade upgrades. Appropriately characterizing the market demand for better walls and windows, identifying better wall and window technologies, and addressing barriers to façade upgrades are critical steps to improving wall assemblies in existing homes. Table 7.1 provides a cursory assessment of the façade upgrade needs and opportunities by region based on findings related to the current façade characteristics, vintage, climate conditions, and market conditions throughout the United States.

Table 7.1. Residential façade upgrade needs and opportunities.

Legend: ● Greatest Need/ Opportunity; ◍ Moderate Need/ Opportunity; ○ Average Need/ Limited Opportunity

	NEEDS				OPPORTUNITIES					
	Vintage (condition of façade)	Energy Use Intensity	Energy Rates	Energy Burden (energy equity)	Exterior Siding Type (existing)	Remodeling Activity	Residing jobs	Insulation jobs	Window/Door Replacements	Program/Utility Incentives
Northeast	Greatest	Greatest	Greatest	Moderate	Greatest	Greatest	Greatest	Greatest	Moderate	Greatest
Midwest	Greatest	Greatest	Average	Greatest	Greatest	Average	Moderate	Greatest	Average	Average
South	Moderate	Average	Moderate	Greatest	Moderate	Moderate	Average	Average	Greatest	Average
West	Average	Average	Average	Average	Average	Greatest	Greatest	Moderate	Moderate	Greatest

For this high-level assessment, the façade upgrade needs are characterized by the age of the building stock, energy-use intensity, and associated expenses. It also includes the energy burden, as defined in Section 2.2 of this report. Overall regional needs are characterized relative to other regions. The façade upgrade opportunities are primarily characterized by the level of remodeling and retrofit activities in the market, but also include exterior wall construction types (where certain exterior cladding types are easier to retrofit than others) and the number of active utility programs and incentives in each area (see Section 3.3 of this report). Overall, the Northeast region has both the greatest needs and the greatest opportunities relative to the other regions. The West has a relatively low number of retrofit upgrade needs, but remodeling and retrofit activities are abundant in the West. This suggests that the remodeling activity is driven primarily by the tight seller's market for real estate rather than "needs" in terms of degrading façades. On the other hand, the West also has a great number of programs and utility incentives for insulation and window upgrades, which could influence this market as well. The Midwest is also characterized as having a high number of façade upgrade needs, but the level of remodeling and re-siding activities and lack of programs and incentives suggest more limited opportunities relative to the Northeast. Note, however, that there are relatively more insulation jobs taking place in the Midwest than in other regions, which suggests that this activity is driven relatively more by thermal comfort needs rather than housing market transactions. The South has the largest proportion of homes with disproportionately high energy burdens; there, the most common façade upgrades are window replacements.

Based on the market characterization, distribution channels, business models, and consumer benefits described in Sections 3 and 4, and the barriers to market adoption identified in Sections 5 and 6, Table 6.1 summarizes the target barriers, pathways to consumers, near-term research, technical assistance, and outreach strategies to transform the market for energy-efficient façade upgrades.

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Appendix A – Contractor Workshop and Survey Results

2021 U.S. Department of Energy
Siding and Windows Workshop and Survey Summary
March 2021

A.1 Introduction

On March 10, 2021, the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy, in coordination with Pacific Northwest National Laboratory (PNNL), sponsored an expert workshop focused on siding and windows. The intent of the workshop was to discuss concerns related to material costs and skilled labor availability, specifically for siding and windows. The goal was to gather input from contractors across the United States who have hands-on experience installing said products but also perform many other home remodel/repair services. The workshop was preceded by a survey to help collect more detailed information about contractor practices, perceptions, challenges, and opportunities identified in the market for energy-efficient façade retrofits and remodels. This summary includes results from both the survey and the follow-up discussions covered during the March 10 virtual workshop.

A.2 Workshop Participants

Chris Peters (New York)
Terry Emelander (Michigan)
Tom Tishler (Michigan)
Don Hynek (Wisconsin)
J West (Illinois)
Dan Welch (Washington)
Rick Wertheim (New York)
Cleo Nichols (Mississippi)
Jonathan Waterworth (Arizona)
Terrence Mosley, (DOE)
*Robert Schwartz (American AWS Corp)
*Beverly Deel (People Inc.)
*Jay Best (Green Team)
*Ramon Rucci (Sun Tracker Construction LLC)
*Did not attend the virtual workshop, but provided feedback on the survey.

Workshop Agenda

I. Introductions
II. Contractor concerns
III. Siding jobs and added insulation
IV. Window replacement
V. Window attachments
VI. Motivations, concerns, and opportunities

A.3 Summary of Discussion and Survey Questions

Information gathered from all of the contractors is summarized below based on their responses to a survey and follow-up discussions conducted during the workshop. The workshop included participants from all regions of the United States (Northwest, Midwest, Northeast, Southeast, and Southwest), with multiple contractors representing the northern Midwest cold-climate zone. In their respective regions, participants work in urban, suburban, and rural neighborhoods. For these contractors, most of their work involves weatherization retrofits, renovations, remodels, or additions, but rarely new construction. About 90% of the homes they work on are single-family homes of an average size of between 1,000–2,000 ft^2. Contractor participants indicated that most of their jobs were associated in some manner with government or energy-efficiency programs, but they also get a number of jobs from referrals and through their company websites. Participants indicated that most of their home-performance contracting work is funded by the homeowners, but about half the time at least a portion of the project is federally funded by the DOE Weatherization Assistance Program (WAP). There are also instances when other local, federal government, and/or utility programs will fund the renovation work that they do. Most of the training they receive would be described as on-the-job training, but contractors are also using internet and conference/tradeshow resources for training. Conferences and online resources provide contractors with certifications form the Building Performance Institute, Leadership in Energy and Environmental Design, Certified Green Building Professional and Passive House Institute, Certified Passive House Consultant. All this allows them to provide a wide variety of services such as siding, window, and insulation installation, air-sealing, heating, ventilation, and air-conditioning (HVAC), and even solar installations. However, about 90% of their jobs would be categorized as weatherization retrofits in single-family detached homes.

When asked about their biggest concerns about re-siding contracting work, more than 80% of the participants responded that materials costs and skilled labor availability were their biggest concerns (Figure A.1). But another concern that ran the distance between “not a concern” to “a major concern” was related to product warranties; some participants indicated that energy-efficient modifications in the form of adding insulation could have the potential of voiding the warranty for certain siding materials if they mixed and matched brand names. This topic was discussed further during the workshop and some participants indicated that if there were any product issues, the homeowner would come after the contractor (and not the siding company), so contractors are understandably hesitant to try anything that is not explicitly identified in product installation information for fear of voiding the warranty. They went on to say the possibility of getting sued when working with the building shell is significant enough that it is difficult to avoid altogether, so contractors are often extremely risk averse. For example, they will just make it easier on themselves and buy everything from one vendor, so that there is no chance of voiding the warranty if not using their proprietary tape, for example. Other contractors who routinely add exterior insulation with their siding jobs indicated that there really was not much risk in doing this and that siding instructions often indicate the best way to integrate insulation with any particular siding assembly.

About half the respondents indicated “other” concerns in their survey response. There is hope that insurance companies will be more apt to give better rates for a house with these kinds of upgrades/retrofits, but there is not much incentive from the insurance sector yet regarding energy-efficient remodeling. One builder mentioned that insurance companies may come around if they can enhance the fire-retardant aspect of energy-efficient materials such as densely packed insulation. Sooner or later, a case will be made for the fire resistance of the building. People will be more apt to sell that particular aspect if the materials are fire-retardant. Another participant mentioned that they have shifted away from foam on the exterior in part because of the risk of fires—especially in the West where there has been such a prevalence of wildfires. Fire-sense building is becoming more and more important, so they have started to move toward materials that are more fireproof. Foam is also a concern from the carbon footprint standpoint, so they are moving toward mineral wool, wood fiber, and cork insulation.

Ranking of Concerns related to Residing

Please rank the following categories based on how much of a concern each is for your company (1 = not a concern at all; 5 = a major concern)

	1	2	3	4	5	Not applicable
Materials cost						
Material availability						
Skilled labor availability						
Keeping up with new technologies						
Siding retrofit warranties						
Customers willing to take on high-performance retrofits						
Other (please specify)						

- Material Costs and Skilled Labor Availability were major concerns for over 80% of the respondents.
- Concerns ranged from “not a concern” to “major concern” for Siding Retrofit Warranties.
  - ➢ What might be some of the factors that would make warranties more or less of a concern for a given project? Would this be vendor specific? Would the addition of insulation to a siding job increase this concern? Is there any specific training or guidance that could be provided to minimize this concern?
- About half the respondents had major concerns with “Other.”
  - ➢ What are some of the “Other” Major concerns that you have?

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Figure A.1. Ranking of contractor concerns.

Siding jobs and Added Insulation

Some Findings from the Survey

- **Most respondents install vinyl siding and blown or spray-in cellulose wall (i.e., cavity insulation)**
- **Rarely do siding clients ask about adding insulation, but most of the contractor respondents “Often” ask their siding clients about adding insulation.**
- **This mix of interest results in most of the respondents “sometimes” adding insulation to siding jobs.**
  - ➢ Does “selling up” a siding client on added insulation make good business sense from your perspective? Why or Why Not?
  - ➢ Drill and fill or exterior siding? Any concerns/benefits with either?

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Figure A.2. Re-siding and wall insulation jobs sample survey responses.

A.3.1 Upselling insulation

When asked about upselling insulation when already installing siding, many of the contractors said they already do this as a common practice, but the region they are in greatly affects whether the customer wants to do it or not. In general, the contractors from the northern cold-climate zones routinely include quality insulation in wall retrofits, while this practice was less common in the southern warmer and mixed climate zones (See Figure A.3.).

A.3.2 Pacific Northwest

A participant from the Pacific Northwest (PNW) indicated that added insulation is standard practice for him, because he focuses his business on high-performance remodels and passive house design, so they push the building science and energy-efficiency angle pretty hard (and with success). He mentioned that if you rely on very simplistic return on investment estimates based on homeowner energy bill savings, then energy-efficient retrofits are a hard sell in a mild climate. So instead, they focus on comfort, moisture control, and durability issues as well, which resonates with the homeowners. You sell what makes sense for your climate zone, so in addition to exterior insulation, sell rain screens in the PNW, because exterior insulation and rain screens go hand-in-hand.

> We have a huge mix of clientele. We have a lot of the very left-leaning side of the spectrum but also out in the rural areas we have a lot of the right-leaning more libertarian side of the political spectrum. So we don't sell [energy efficiency] because it is the right thing to do from an environmental standpoint because for some of our clientele it wouldn't resonate with them. But what does resonate with everyone is comfort, resiliency and more durability to their buildings.
>
> –PNW Residential Designer

A.3.3 Southwest and Midwest

A contractor from the Southwest mentioned that they also push the comfort and building science angle, including the impact that these energy-efficient renovations have on air quality in a home. Façade upgrades will also reduce the burden on HVAC equipment, which can extend the life of the equipment. Adding insulation also improves the acoustics in a home (i.e., reduces outdoor noise), which is another feature that sells. A participant from the Midwest mentioned the need to educate clients about some of these issues and show them the insulation is going to help the assembly as a whole. This is not always easy, because very often clients just want a bid and they want the lowest bidder. He notes that although it is sometimes a tough sell, the clients who listen and learn tend to be more satisfied with the process and outcomes of installing 1 inch of added exterior insulation.

One other builder from the Midwest agreed that building science matters but cautioned that contractors have to get it right. He mentioned that they often deal with houses that do not have pre-existing interior vapor barriers.

> So, if you are adding exterior insulation and it doesn't at least match the cavity insulation value, then moisture will start pulling into the sheathing and things start to look pretty ugly in January when you are seeing temperatures in the negatives. Even with a product like Thermax at least 2 inches of insulation needs to be added. Once you add 2 inches of insulation, you will also need window extensions and then things get really tricky. Trying to preserve existing windows and put an assembly together that provides good building science in our climate zone is a real challenge. A simple R-5 retrofit is often not an option.

A.3.4 Southeast

A contractor participant from the Southeast mentioned that they do not have much luck pushing R-5 wall retrofits in the warmer southern climates. His customers are more concerned about countertops and windows. He noted that residents notice the heat from the windows, so they focus on windows, but this contractor often advises them that if they just do window replacements and do not also insulate the walls, they will not be getting the comfort improvements they are expecting. With the WAP that he works with in the Southeast, participants will only qualify for weatherization grants every 2–3 years and they are not big enough grants to do deeper energy retrofits, so people have to choose between windows and roof insulation, for example. As a result, contractors working with this program tend to prioritize and focus on attics first (~R-30) and then try to get them to an R-13 wall. But he notes,

> If their home is left with single-pane windows, then it's an incomplete retrofit. We have a good weatherization program, but you have to wait 2–3 years before you can apply for another grant and then if you put windows in 2–3 years later, the integrity of your wall insulation could be compromised with the window replacement disturbance. It's not an ideal process from the building science perspective.

The concept of selling up on "resilience" features of the home was discussed in the context of other southern climate zones. One participant brought up the example of the 2021 Texas ice storm that left most of Texas without power—a lot of those buildings were under-insulated and did not take the proper precautions for those environmental conditions. With additional insulation and more attention paid to the building thermal envelope, those buildings tend to cycle with the climate in both good and bad situations. This puts less stress on the grid (so it should be a local government code enforcement issue), and it also keeps people more comfortable during extreme events. It also keeps your pipes from freezing.

Several participants indicated that customers rarely know what is available in terms of incentives or grants and that it is important for home-performance contractors to have a full grasp of what is available and how the homeowner can take advantage of these programs. One participant mentioned that in his area multiple entities (utilities and weatherization programs) provided incentives as high as $5,000 for deep-energy retrofits. These types of incentives can move the needle on some of these insulation upgrade decisions. One builder made a point to push all their renovations through a Home Energy Rating System Rater to ensure that they receive the maximum incentives and benefits from their high-performance upgrades.

A.3.5 Drill-and-Fill Insulation

Some contractors mentioned that one of the problems with drill-and-fill insulation jobs was that most of the homes that require this kind of retrofit are outdated and maybe the band around the house is gone, so you get air gaps. One participant mentioned he always recommends re-siding with drill-and-fill insulation for this reason because it allows you to see the structure of the home then address these kinds of issues, which will help provide longevity to your retrofit. He mentioned that he has had cases where the bottom half of the wall structure was no good and "if we drilled and filled it would never last—it would take in moisture from the ground." Once it absorbs the moisture, the wall structure is losing the R-value immediately.

A builder who works in the Northeast mentioned that they will typically pull the siding and install cellulose or injection foam, so it goes in fully expanded. They avoid going through the siding.

Another cold-climate builder agreed that it is important to avoid drilling through the siding and that their “go-to” practice was to unzip the siding or to lift siding and then do the drill-and-fill insulation. A contractor from the Southwest, where most of the housing stock is stucco and most have insulated wall cavities, provided the “desert perspective.” When they do need to add insulation to these homes, they have cored and densely packed from the inside through the drywall because it’s much easier to patch and repair. When they have worked with T1-11 siding, they try to pull the vat insulation out of the wall cavity because it gives them the opportunity to look for termite and moisture damage in the bottom sill plate. Then they spray foam, sheath it, install a vapor barrier, and replace the T1-11 siding. For the slump block homes of the Southwest, the contractor did not see that it was worth trying to fill the blocks with insulation, but he would be interested in applying exterior insulation to some of these homes.

When asked whether there were any moisture concerns with drill-and-fill, one participant mentioned that when they do drill-and-fill insulation, there is typically no vapor barrier on the interior but there is also no vapor barrier on the outside of the house. As a result, they have had no issues getting that wall to dry out in the winter. If some condensation does get into the wall in the spring or fall, it dries out.

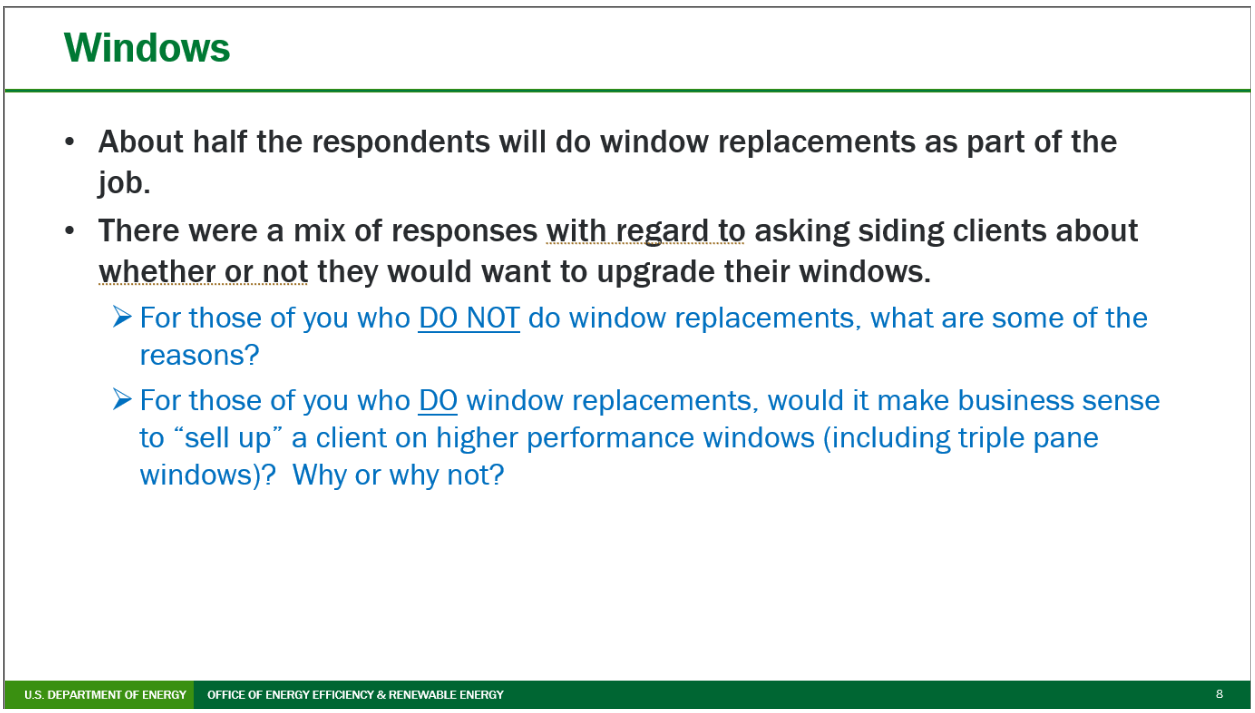

Figure A.4. Window replacement and retrofits sample survey responses.

Of the contractors who install windows, most install double-pane ENERGY STAR windows, although some had experience installing triple panes as well (see Figure A.5).

One participant mentioned that, with all their recommendations and decisions, they try to look at the whole home and the whole project and what the homeowner has proposed and try to balance that assembly. They always try to improve windows when they can because it is the least insulated portion of the building. It was previously mentioned that when you upgrade insulation and leave a home with single-pane windows, it does not make a whole lot of sense. But if they have a simple 2 x 4 wall where they are just being asked to pack insulation, then it probably does not make sense to try to sell homeowners really nice triple-pane windows (but some mediocre triple-pane or some regionally tuned windows could make sense). It was also mentioned if the client has already made the decision to replace windows, then it makes it easier to encourage use of high-R windows.

A couple of the participants had experience with thin triple-pane windows made with suspended film center panes. They were excited about the possibility of using thin glass for the center pane, because they had received some call backs about the stretched film versions getting warped.

Several contractors mentioned that they tend to work with lower- and middle-income folks, so many of the high-performance windows are priced too high to make this an affordable retrofit for most of them. Very few participants had experience with window attachments, such as low-e storm windows. One home-performance contractor said he had personal experience with Larson Storm Windows and thought they performed very well. He wishes that his weatherization program included them.

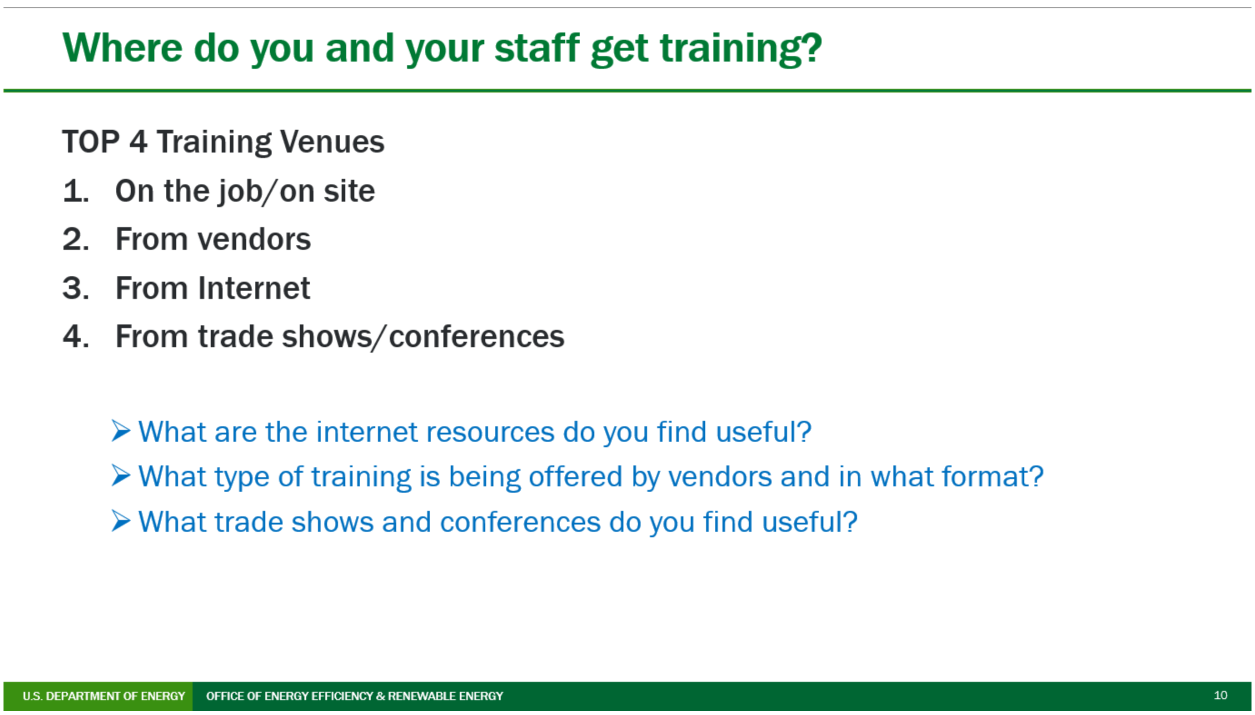

Figure A.6. Workforce and training sample survey responses.

One participant indicated that his company mostly did their own training onsite and mentioned that “we will work with any contractor we can get our hands on because the market is so crazy.” Figure A.7 lists the top four training venues used by contractors. They use quite a bit of information from Building Science Corporation and some information from RDH Building Science, especially related to exterior insulation and siding attachment. They have some really good lab tests for what you can hang on fasteners; for example, some people get very concerned about the weight of hardy plank once you get a lot of exterior insulation outside of it. DOE has a really great document called “thick layers,” but it goes through the detailing of exterior insulation for all different scenarios.

One participant worked as a trainer and indicated that one of the first places they go to for training are the vendors and manufacturer resources because they live and die based on being able to get people trained to use their products. Another builder mentioned that regionally, the Better Buildings conferences in their respective regions have always been successful at bringing in some really good national talent and occasionally some international talent.

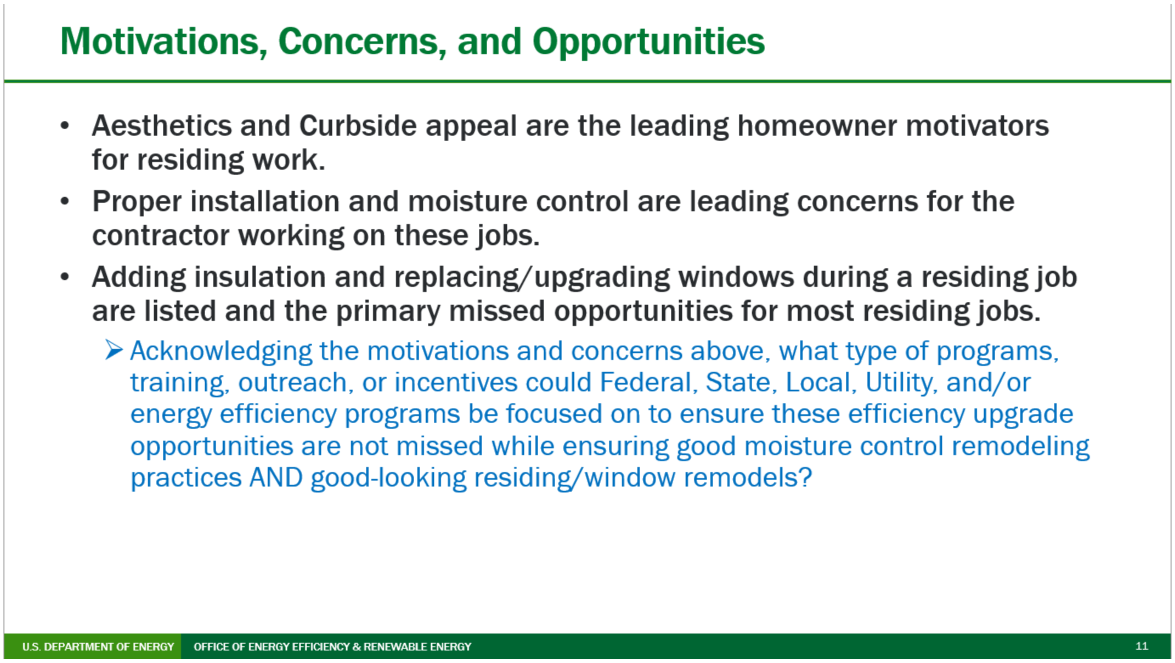

Figure A.8. Sample survey responses related to homeowner motivations, concerns, and insulation upgrade opportunities.

Typically, when siding is installed, it is for curb appeal or aesthetics, so energy-efficient upgrades are not necessarily on customers' minds and the added cost deters them. However, there are exceptions and even times when the customer requests insulation upgrades. Almost half the time when installing new siding, new insulation is installed as well. The motivation for most homeowners was cost or energy savings. Being able to save money and therefore energy was appealing to them. However, cost was also a deterrent to some because it involved a higher price than they were comfortable with paying at that time. Figure A.9 provides sample survey respones related to homeowner motivations, concerns, and insulation upgrade opportunities. If there were cases of installing insulation, the preferrable type was blown or spray-in cellulose rather than ridged foam board because improper installation of the latter can lead to either air leakage or trapped moisture in the walls.

Just under half of these contractors provided siding installation as one of the services they offer customers. When talking about siding, they noted the motivation behind homeowners replacing their siding was anything from curb appeal/aesthetics, air leaks in the envelope, to damage. Contractors noted that re-siding comes with risks, because it is challenging to make a weathertight retrofit assembly and any time existing siding is removed, there is always the possibility that serious problems and damage will be revealed, which are challenging to deal with. When asked if they do remove existing siding or rather just lay over that siding, those that do siding installation do remove the existing siding first because it is considered the right thing to do. When they are taking on these jobs, they note that the biggest lost opportunity for improving the home's performance is failure to insulate and insulate properly.

As part of siding/window installation, there is an opportunity for window attachment installation. Though most contractors do not install window attachments, nor do they typically suggest them to customers, customers occasionally ask for them. However, contractors try to steer away from window attachments because of possible condensation and mold buildup on the windowsills. Even though exterior low-e storm windows are available in places, contractors are not yet very well educated about them, but they do see a possibility for them in the future as retrofits.

Appendix B – Regional Trends and Perceptions Related to Energy-Efficient Remodels

This appendix provides details about regional trends and perceptions related to energy-efficient remodels in the United States based on U.S. Census Bureau's (USCB) American Housing Survey data.

B.1 Regional Analysis – New England Census Division

New England looks to have a high potential for façade-related upgrade interest, but respondents showed little interest in these types of renovations compared to the national average (Table B.1). Moreover, New England respondents indicated they had spent considerably less on home renovations to improve energy efficiency in the last 5 years than the national average. This tendency to spend less presents a complex challenge: according to the AHS, New England is at least motivated to make façade-related upgrades, but who is driving this interest is unclear, as is the elasticity of the market to embrace upgrades that are more expensive up front but will drive improved energy savings in the long term.

Table B.1. Which of these energy-saving actions and home improvements have you completed in the past 5 years? (New England Census Division [n = 100]).

Upgrade/Service/Change	Yes, I have done this	No, I have not
Installed extra attic insulation	35.0%	65.0%
Added caulking or weather-stripping around windows and doors	34.0%	66.0%
Installed high-efficiency/ENERGY STAR certified windows	29.0%	71.0%
Had a home energy inspection	21.0%	79.0%
Had a professional come into the home to seal air leaks	15.0%	85.0%

New England respondents indicated a higher than national average tendency to engage in façade-related renovations. More than a third of the respondents added extra attic insulation or caulking/weather-stripping to windows and doors. Moreover, only 1 of the 100 sampled respondents in New England indicated they had made no types of energy-efficiency-related renovations to their current home—less than a sixth of the national average.

Despite the higher preference for engaging in these types of renovations, New England respondents were less likely to rank replacing existing windows as a top mechanism for reducing energy consumption (17% versus 21% for the national average), ranked attic insulation upgrades as highly as the greater sample (14% versus 15% nationally), and preferred siding replacement only slightly more than the overall sample (5% versus 3%) (Table B.2). New England respondents also did not demonstrate any difference in preference for incentives (Figure B.1)—utility incentives still ranked highest (52%), followed by completing renovations (20%) in a single day and zero interruptions to the homeowner's daily routine (12%).

Table B.2. Respondent beliefs about the most impactful upgrade on home energy efficiency (New England Census Division [n = 100]).

Most Impactful Home Improvement	Percentage of Total Respondents
Replacing an older, inefficient HVAC with a more efficient model	23.0%
Replacing older, inefficient windows with more efficient ones	17.0%
Adding or replacing attic insulation	14.0 %
Replacing older appliances (refrigerator, dishwasher, washer/dryer) with new, more efficient ones	13.0%
Replacing an older, inefficient water heater with a more efficient model	11.0%
Replacing all bulbs with LEDs	8.0%
Replacing an old thermostat with a "smart" thermostat	7.0%
Replacing the siding or exterior cladding	5.0%
Adding an automated lighting control system	2.0%

HVAC = heating, ventilation, and air-conditioning; LED = light-emitting diode.

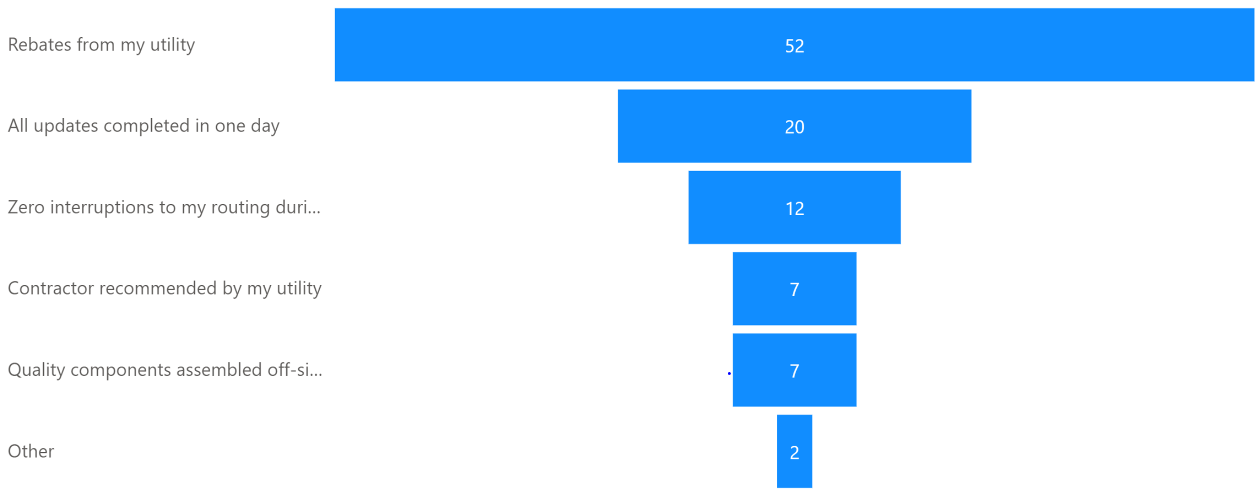

Figure B.1. Top incentive to motivate energy-efficient renovation (New England Census Division [n = 100]).

In contrast to the wider sample, however, New England respondents have spent less on home renovations in the past 5 years; most respondents have spent less than $5,000 per renovation (Figure B.2). This tendency to spend less is problematic: New England renovations related to building façades run, on average, higher than national trends by $500–$1,000. New England respondents were, however, more willing than the nationwide sample to think longer-term about returns on energy-efficiency investments (Figure B.3). Most (58%) were willing to wait between 3 and 8 years to see a return on investment, compared to the 62% nationally who want to see the same in 4 years or less.

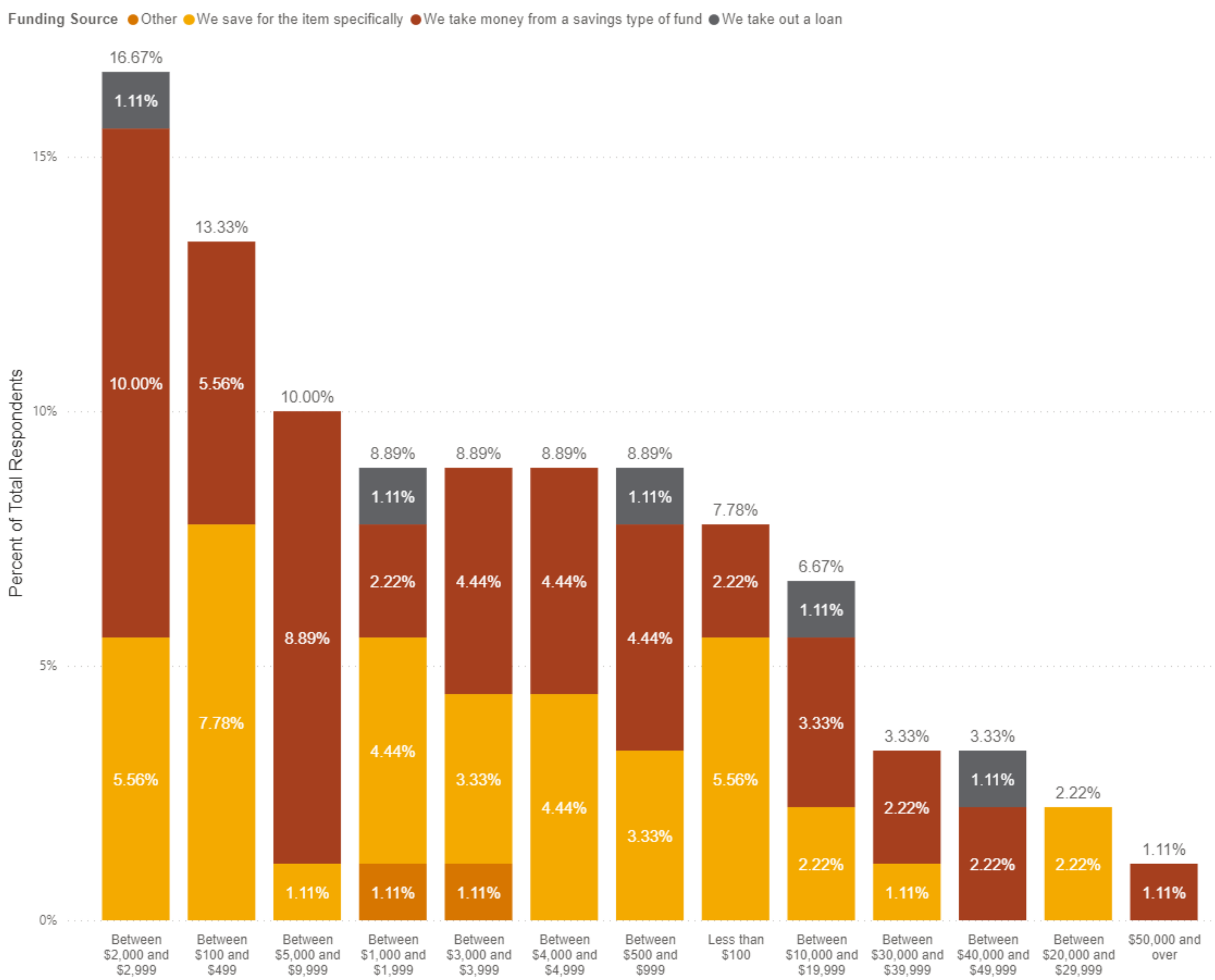

Figure B.2. Investments made in energy-efficient renovations in the last 5 years (New England Census Division [n = 100]).

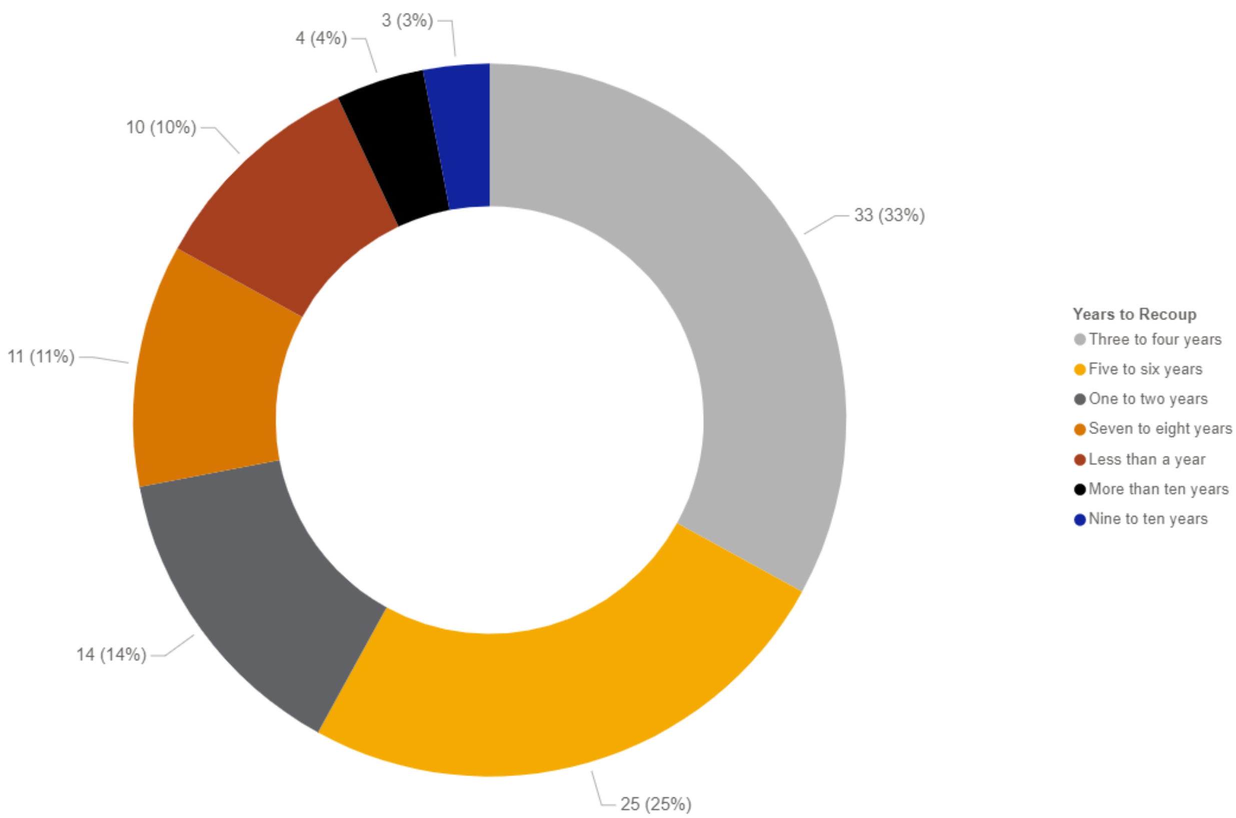

Figure B.3. Preferred time to return on energy-efficient investments (New England Census Division [n = 100]).

New England respondents overwhelmingly indicated they see the crucial importance of energy efficiency and energy conservation (Table B.3), as well as their role in saving energy. Respondents also saw the role of government as being important and needing further expansion to improve energy efficiency. Despite these positive signs, and greater emphasis on energy conservation than the national sample, New England respondents were more likely to say they thought it was easier to spend money on higher energy bills than make changes to save energy (34% versus 31% of the nationwide sample). This feedback indicates a key challenge for façade (and other expensive) renovations: inertia. Respondents value saving energy and conserving energy but are almost as likely to not make changes to achieve this goal as they are to make an effort. Because effort here may also include making behavioral changes, it is unclear to what extent this tendency toward inertia shifts (favorably or otherwise) toward house infrastructure upgrades.

Table B.3. Perceptions of why individuals may not adopt more energy-efficient ways of living (New England Census Division [n = 100]).

Statement	Agree	Disagree	Neither Agree nor Disagree
No need to conserve energy.	17.0%	73.0%	10%
It's easier to pay more for energy than make the effort to save energy.	34.0%	41.0%	25.0%

Statement	Agree	Disagree	Neither Agree nor Disagree
My energy bills are too low for me to care about energy efficiency.	60.0%	20.0%	20.0%
Individual efforts won't make much of a difference.	60.0%	20.0%	20.0%
The government should do more to increase energy efficiency.	71.0%	22.0%	7.0%

B.2 Regional Analysis – South Atlantic Division

Respondents from the South Atlantic Census division expressed lower tendencies toward making façade-related upgrades to their homes than New England respondents, but they were not significantly different than the national averages for the study (Table B.4). Over 30% of respondents from the South Atlantic perceived heating, ventilation, and air-conditioning (HVAC) upgrades as having the most important impact on their energy use, followed by window upgrades and attic insulation. Less than 3% of respondents listed siding upgrades as a top energy-saving renovation pathway (Table B.5). Only adding automated lighting control systems ranked below this option (2.13%).

Table B.4. Which of these energy-saving actions and home improvements have you completed in the past 5 years? (South Atlantic Census Division [n = 470]).

Upgrade/Service/Change	Yes, I have done this	No, I have not
Added caulking or weather-stripping around windows and doors	24.3%	75.7%
Installed extra attic insulation	20.2%	79.8%
Installed high-efficiency/ENERGY STAR® certified windows	16.8%	83.2%
Had a professional come into the home to seal air leaks	9.6%	90.4%
Had a home energy inspection	8.1%	91.9%

Table B.5. Respondents' beliefs about the most impactful upgrade on home energy efficiency (South Atlantic Census Division [n = 470]).

Most Impactful Home Improvement	Percentage of Total Respondents
Replacing an older, inefficient HVAC with a more efficient model	31.3%
Replacing older, inefficient windows with more efficient ones	18.3%
Adding or replacing attic insulation	13.8%
Replacing all bulbs with LEDs	10.9%
Replacing older appliances (refrigerator, dishwasher, washer/dryer) with new, more efficient ones	7.9%
Replacing an old thermostat with a "smart" thermostat	6.6%
Replacing an older, inefficient water heater with a more efficient model	6.2%
Replacing the siding or exterior cladding	3.0%
Adding an automated lighting control system	2.1%

HVAC = heating, ventilation, and air-conditioning; LED = light-emitting diode.

Like New England respondents, those in the South Atlantic also rated utility rebates (45.3%) as the factor that would make it easier on them to complete an energy-efficient home renovation (Figure B.4). Completing a renovation in a single day was the second most frequently chosen option (19%), followed by no interruptions to the respondent's daily routine (10.6%).

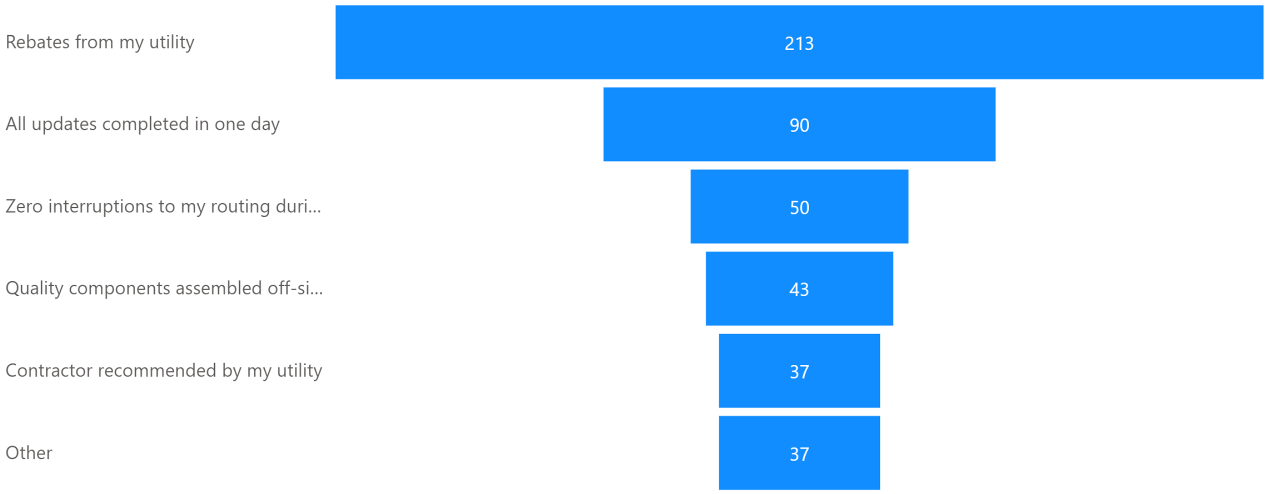

Figure B.4. Top incentives to motivate energy-efficient renovation (South Atlantic Census Division).

On average, respondents from the South Atlantic have spent more money in the last 5 years on energy-efficiency-related upgrades than New England respondents and the nationwide sample as a whole (Figure B.6). Of the regional subsample, 16.3% indicated they have paid between $5,000 and $9,999 in the last 5 years on energy-efficiency upgrades, and 27% have spent between $5,000 and $19,999 in the same window of time. Along with the increased expenses over the past 5 years, South Atlantic respondents also show a shorter window of time during which on average they expect to see the benefits of energy-efficiency renovations (Figure B.7).

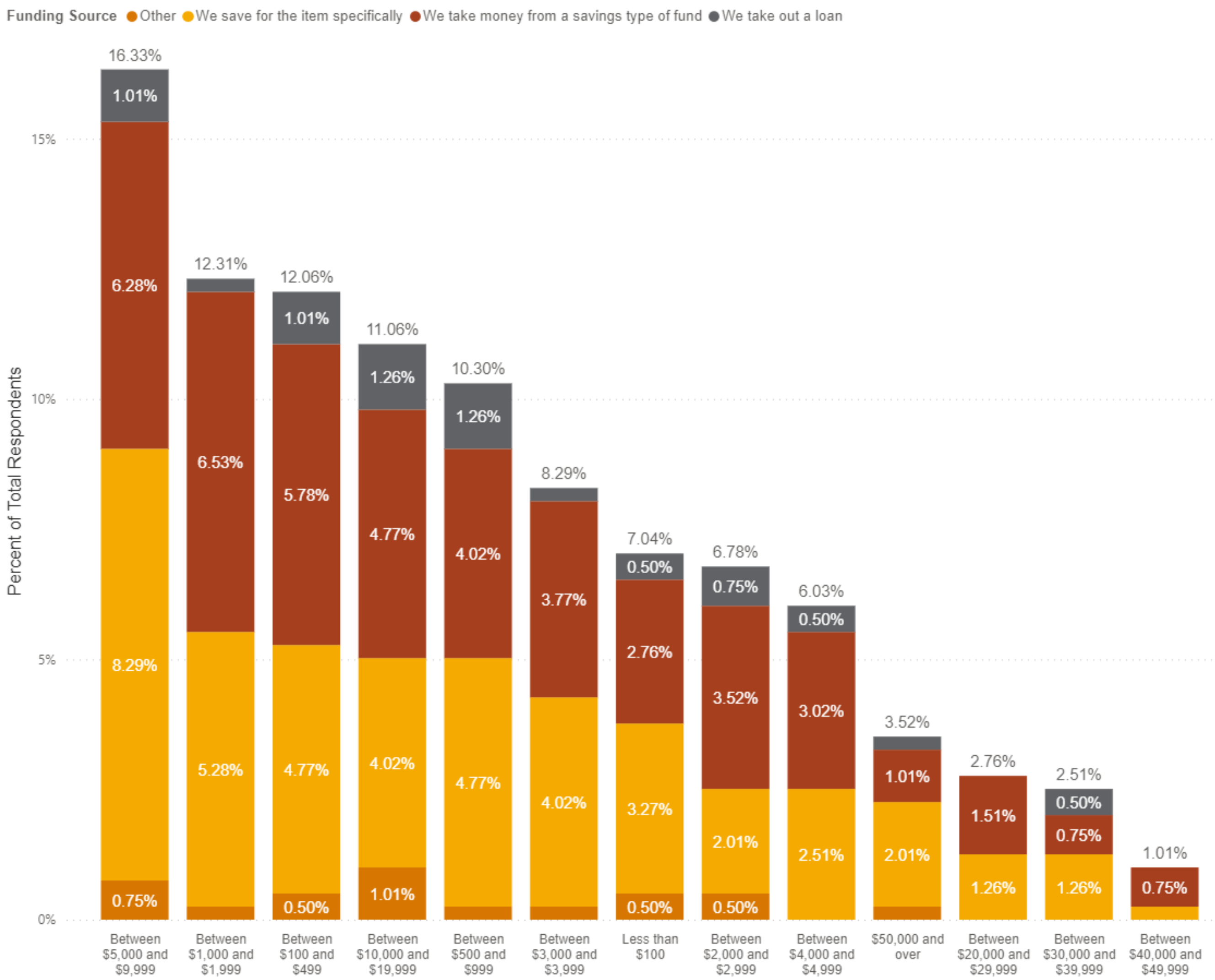

Figure B.5. Investments made in energy-efficient renovations in the last 5 years (South Atlantic Census Division [n = 470]).

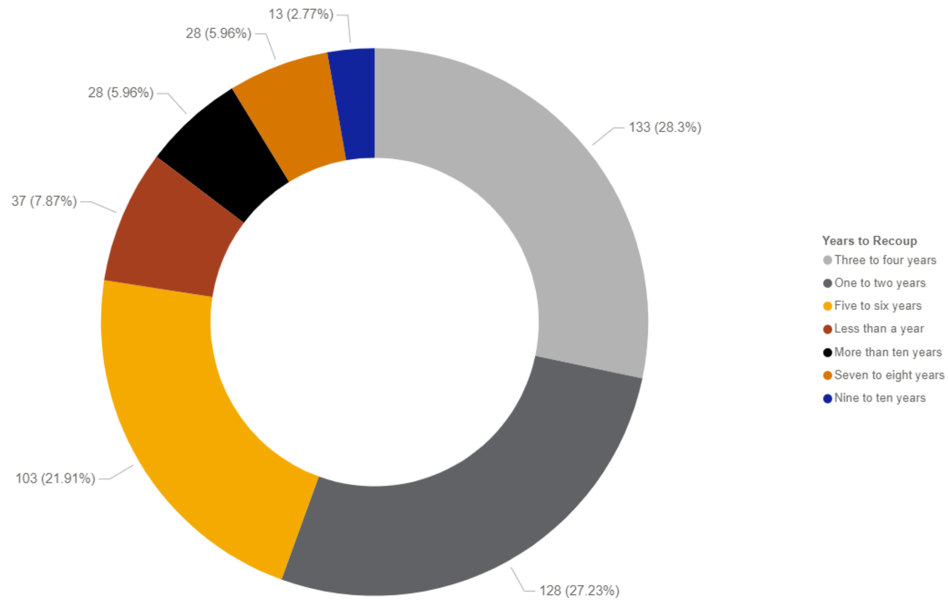

Figure B.6. Preferred time for return on energy-efficient investments (South Atlantic Census Division [n = 470])

While 28% of respondents indicated they were willing to wait 3 to 4 years to recoup an energy-efficiency upgrade investment—a number similar to that in New England—another 27% would only be willing to wait 1 to 2 years. At nearly double the frequency of the New England group, this is a significant difference in the planning and financing of windows that shape South Atlantic perspectives on energy-efficiency upgrades. South Atlantic respondents value energy-efficiency upgrades and social importance relatively the same as their New England counterparts (see Table B.6), but they expect to notice a return on investment quicker.

Table B.6. Perceptions of why individuals may not adopt more energy-efficient ways of living (South Atlantic Census Division [n = 470]).

Statement	Agree	Disagree	Neither Agree nor Disagree
No need to conserve energy	15.3%	71.3%	13.4%
It’s easier to pay more for energy than make the effort to save energy.	34.0%	42.3%	23.6%
My energy bills are too low for me to care about energy efficiency.	22.8%	59.8%	17.4%
Individual efforts won’t make much of a difference.	23.0%	60.2%	16.8%
The government should do more to increase energy efficiency.	68.5%	21.5%	10.0%

The reasoning behind these preferences was beyond the scope of the survey data, but it is plausible that the key factor that is driving this difference in perceptions is income: the largest group of South Atlantic respondents made $25,000 or less, and among these respondents, there was a 2:1 ratio of those who would prefer to see returns on energy-efficient investments in 1 to 2 years versus 3 to 4 years (Figure B.7). These same low-income respondents have also spent very little (less than $1,000) on upgrades in the last 5 years, and with that being a significant portion of their gross income it is reasonable to expect they need to recoup those investments within a short time frame (Figure B.8).

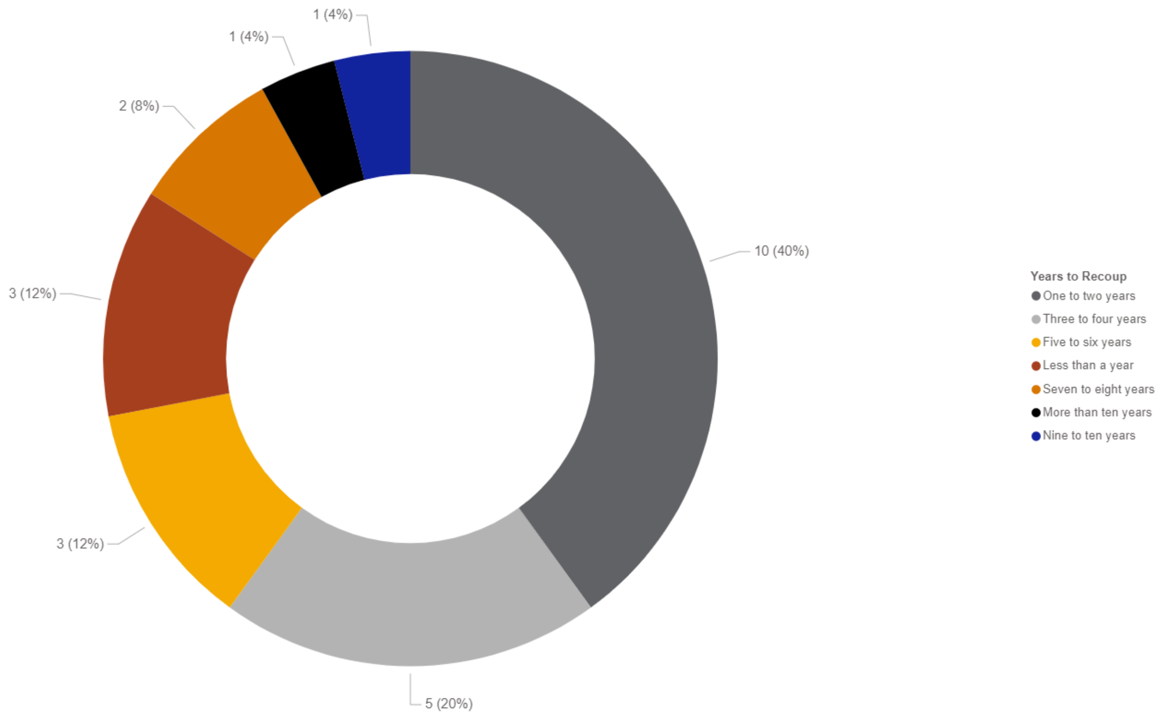

Figure B.7. South Atlantic low-income ($25K or less a year) desired return time frame on energy-efficient investments (n = 25).

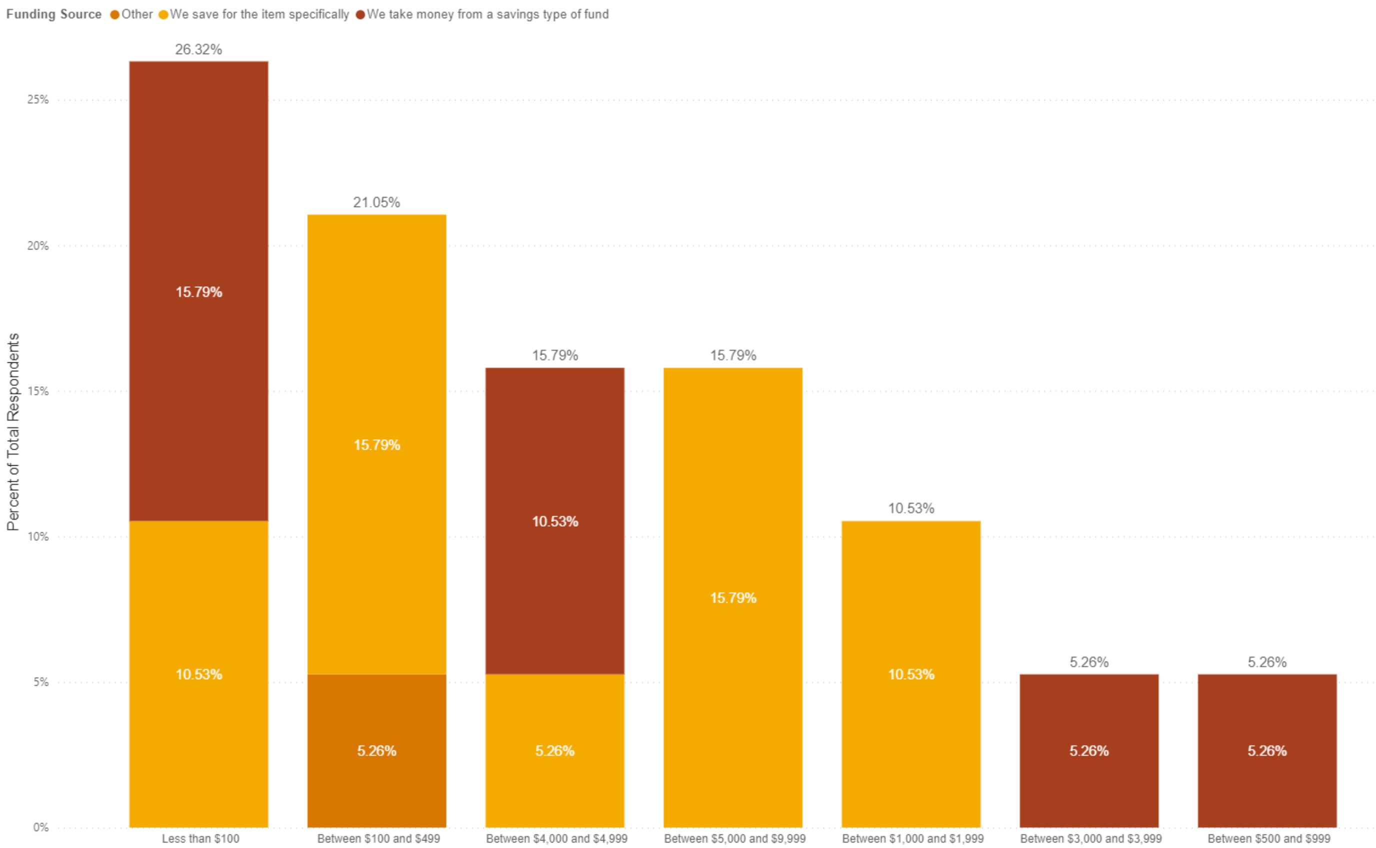

Figure B.8. South Atlantic low-income ($25K or less a year) responses funds spent on energy-efficient upgrades in the last 5 years.

These trends did not hold among the very small portion of New England residents at this income level, but given the size of this subsample (n = 3) the insight should be considered with caution.

B.3 Role of Aesthetics in Shaping Preferences

As part of the workshop hosted by the research team during the development of this report, a common issue shared by contractors pertaining to façade upgrades was the importance of aesthetics to consumers. Three-quarters (75%) of all respondents to an initial survey preceding the workshop indicated that homeowners are primarily motivated to replace their siding to improve aesthetics (either to improve existing aesthetics or deal with aging siding materials). The emphasis on aesthetics aligns with responses from the nationwide survey discussed in the previous section, where an equal number of respondents (75%) rated having a beautiful home as either important or very important. Those who rate aesthetics as important tend to have higher incomes than the larger population of homeowners surveyed, live in houses built between 10 and 29 years ago (1990–2009), and are willing to spend more than all homeowners on renovations. The respondents (n = 107) with lower incomes (54.6% have incomes between $0 and $50,000) per year, spend significantly less on renovations, and few (less than 2%) rate replacing siding or exterior cladding as having the biggest impact on building energy efficiency.

Appendix C – Window and Wall Retrofit Decision Trees

This Appendix provides some preliminary draft decision trees for window and wall retrofits, based on initial feedback from Case Study participants and input from research team members at Lawrence Berkeley National Laboratory (LBNL) and Oak Ridge National Laboratory (ORNL). Figure C.1 is a condensed version of all of the decision trees developed that shows in summary form the steps the builder and homeowner would go through when determining what wall and window retrofits to make while re-siding a home. Figure C.2 is a detailed version of the combined wall and window retrofit decision tree incorporating input from ORNL's Building Envelope Materials Research team within the Building Technologies Research and Integration Center and LBNL, along with input from the case study builders and contractors. Figures C.3 and C.4 are decision trees detailing decision making regarding windows and window shading that were developed by the fenestration researchers at LBNL.

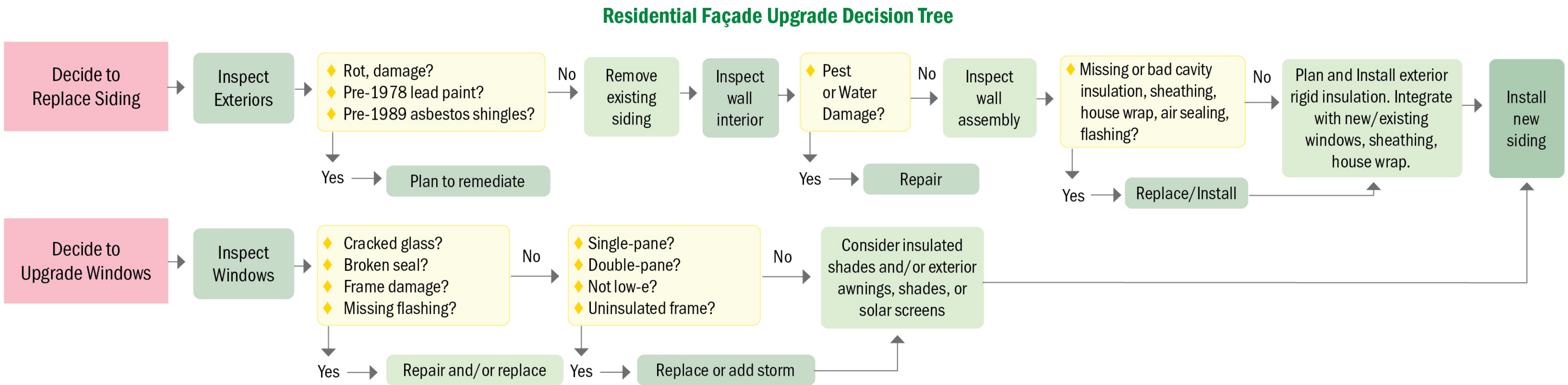

Figure C.1. Simplified Decision Tree for Wall Re-Siding with Window Upgrades

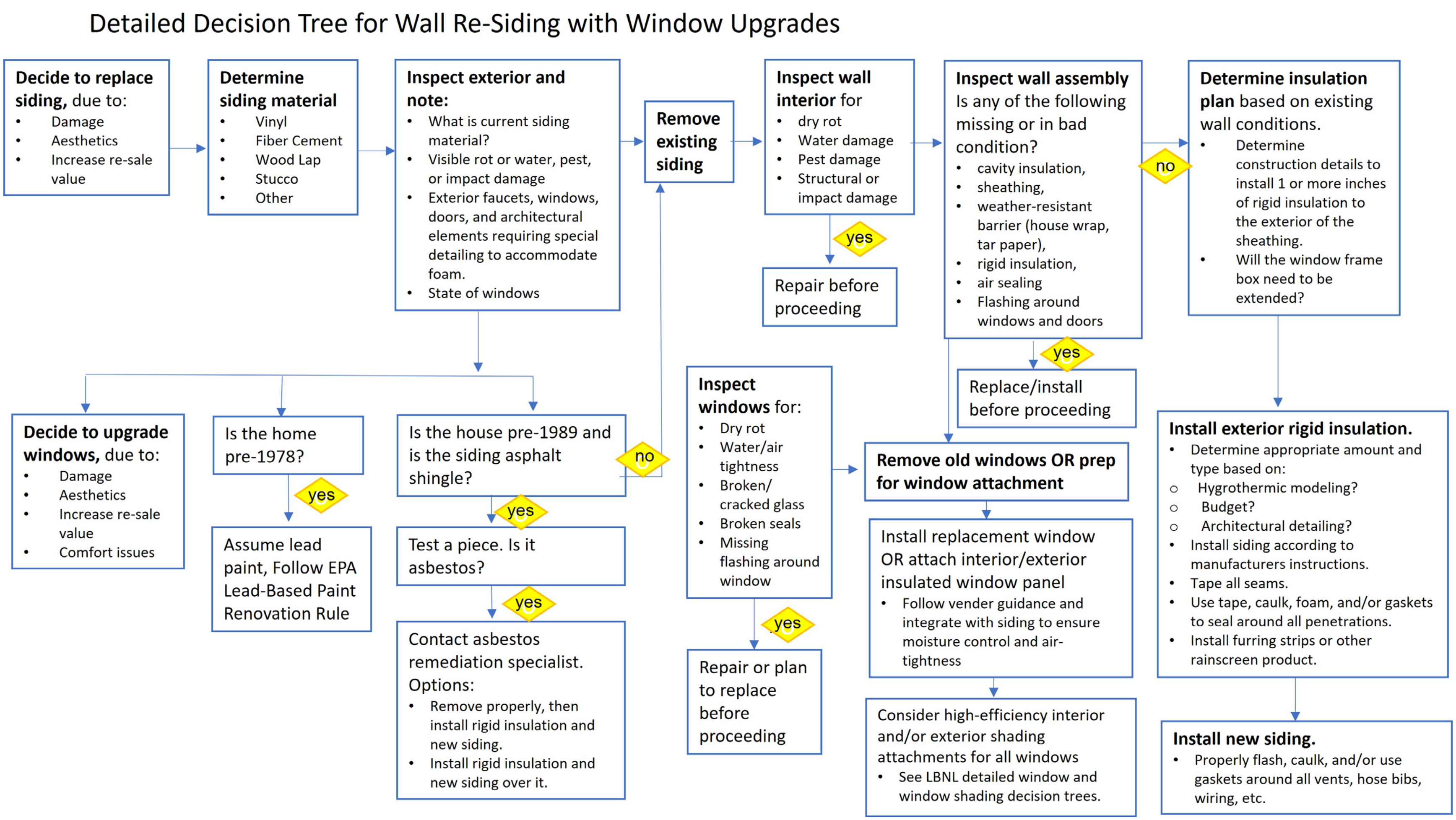

Figure C.2. Detailed Decision Tree for Wall and Window Upgrades while Re-Siding

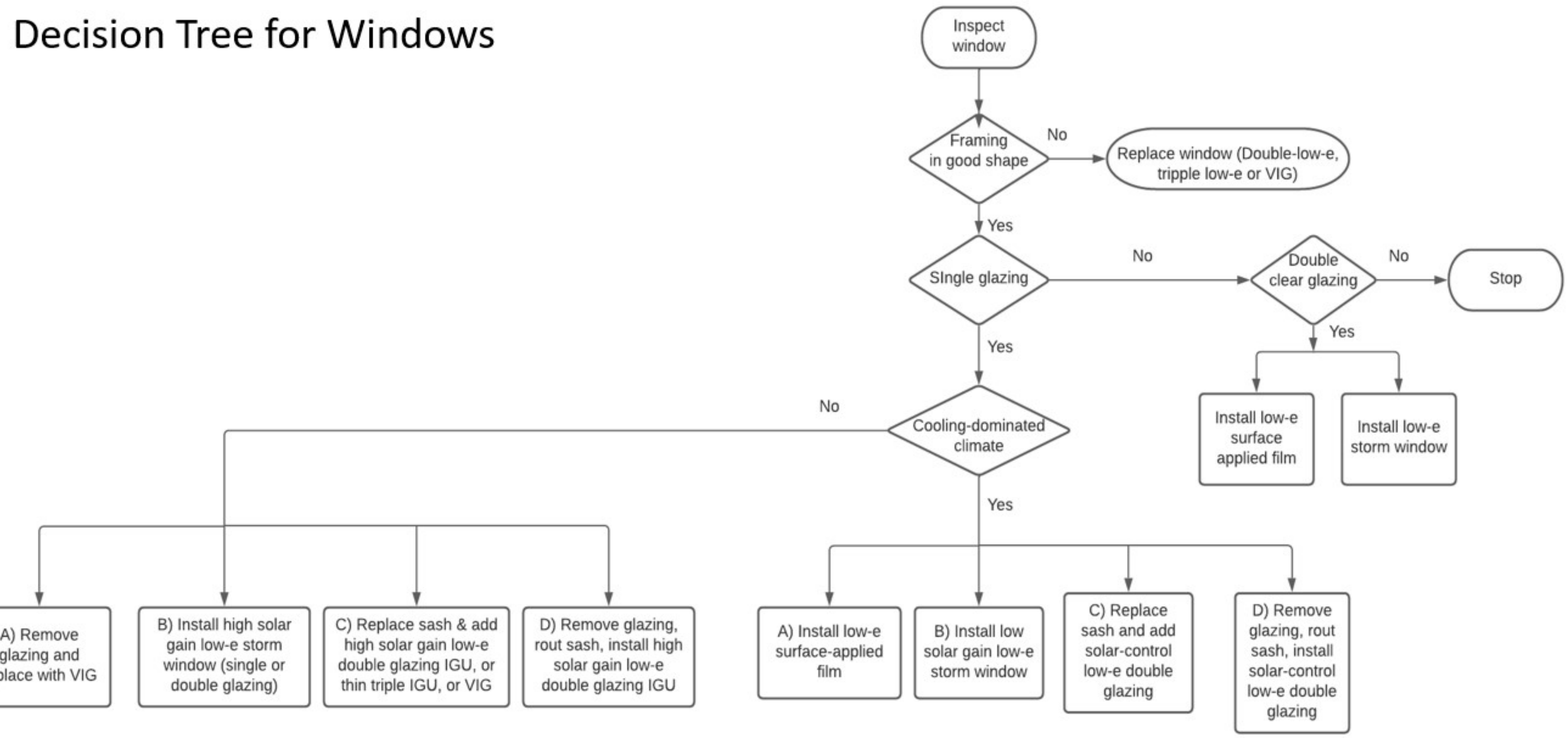

Figure C.3. Detailed Decision Tree for Window Upgrades while Re-Siding

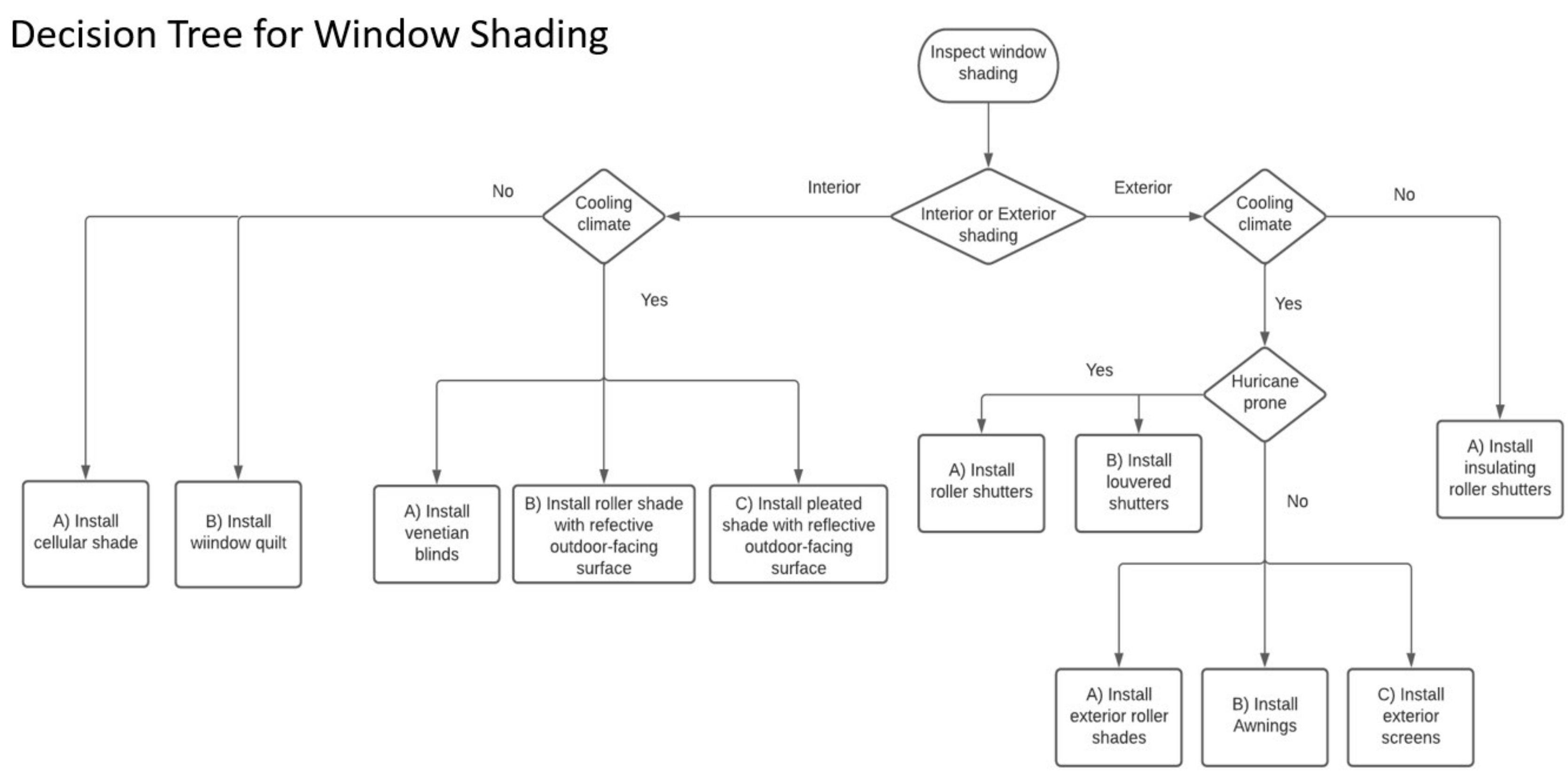

Figure C.4. Detailed Decision Tree for Window Shading Upgrades while Re-Siding

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