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Workforce Instruction for Standards and Efficiency (WISE)

Gavin Newsom, Governor

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Workforce Instruction for Standards and Efficiency (WISE) is the final report for the WISE project (Contract Number EPC 15-009) conducted by the California Homebuilding Foundation. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at ERDD@energy.ca.gov.

ABSTRACT

The Workforce Instruction for Standards and Efficiency program was established to educate the building industry about the higher standards for wall and attics introduced in California's residential building energy efficiency standards for the 2016 code cycle, and to assist with the transition from building with traditional wall and attic constructions to using high performance walls and attics. The project team provided training to builders, architects, energy consultants, insulation installers, manufacturers, home performance contractors, and trade organizations. The trainings included code changes, compliance options and costs, and the building science behind the different wall and attic options. Over the course of the project, the team provided more than 4,140 trainings statewide. The team also assisted with energy modeling by reviewing models for builders and energy consultants to ensure that new features were captured correctly, and worked with building product manufacturers to verify that compliance software would correctly model new attic and wall solutions. The team also worked to expand training available to high school students to help meet the need for a skilled workforce to satisfy the demand for housing production. Over the course of the project, the share of new construction single family homes in California using high performance attics increased from under 3 percent to 45 percent.

Keywords: Title 24, Building Energy Efficiency Standards, 2016, high performance walls, high performance attics, training, education, energy efficiency

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Introduction

California developed the nation's first energy conservation standards for buildings and appliances in the 1970s. Continued implementation of cost-effective appliance and building energy efficiency standards has saved California consumers more than $100 billion in utility bills and improved air quality by reducing the need for new fossil-fired electricity generation. The state's focus on achieving greenhouse gas reductions through energy efficiency continued with the Clean Energy and Pollution Reduction Act (Senate Bill 350, De León, Chapter 547, Statutes of 2015), which requires the state to double statewide energy efficiency savings by 2030.

A combination of approaches must be used in concert for California to meet its ambitious targets for reducing energy use and lowering carbon emissions. For new construction, these approaches include improving mechanical equipment and appliance efficiency levels to provide the same benefit while using less energy, incorporating demand responsiveness to take advantage of times of plentiful power and reduce loads at times of high demand, and improving building envelope efficiency to reduce energy needed for heating and cooling.

California's Building Energy Efficiency Standards prescribe efficiency levels for every energy-impacting component of new buildings and become more stringent with every triennial update. Therefore, building methods and technology must evolve to keep up. Buildings are not required to meet the prescriptive standard, but to be granted a permit, the building overall must be as efficient as if it were built using the prescribed standards. Ultimately, the changes required will save money because the energy cost savings will exceed the cost of the changes since California requires all energy measures to be cost effective when amortized over the life of the building. The energy measures will be beneficial in the long term, but the upfront costs will need to be either absorbed by the builder or passed on to the buyer, which will have a negative effect on the market. Therefore, it is in the best interest of all concerned to minimize costs.

The 2016 update to the Building Energy Efficiency Standards introduced new prescriptive standards for walls and attics in low-rise residential buildings that were considerably more efficient than the previous version. The intent of the California Energy Commission was to move the construction industry towards buildings with better envelopes (the structural barrier between the interior and exterior of a building) and lower energy use.

The transition to new higher performance walls and attics requires new building practices, and the building industry is slow to change. Manufacturers will need to develop new products to help meet the new standards, and energy consultants, Home Energy Rating System raters, and other stakeholders will need to understand the impact and implications of the new standards. Therefore, the Workforce Instruction for Standards and Efficiency program was established to assist the industry in transitioning to these higher standards for attics and walls.

Project Purpose

The Workforce Instruction for Standards and Efficiency program was intended to provide training and education to the building industry to help meet the higher standards required for walls and attics under the 2016 Building Energy Efficiency Standards. To meet the overall efficiency standards, designers and builders have multiple options such as using higher efficiency heating, ventilation, and air conditioning equipment or better windows to reduce energy use instead of designing a more efficient building envelope. The life of a building is typically longer than that of the mechanical equipment, so meeting efficiency standards through a better envelope will provide a more lasting benefit than using more efficient equipment. The goal of this project was to tip the balance in favor of meeting code through better envelopes by helping stakeholders to simplify the issues involved in building with high performance attics and high performance walls.

The production building industry tends to rely on tried and tested construction methods that allow streamlined production, accurate cost prediction, and adherence to schedules. Using new methods typically increases complexity and is more likely to lead to cost or time overruns. The goal of the Workforce Instruction for Standards and Efficiency program was to help move the construction techniques and products needed in high performance walls and attics from the unfamiliar to the familiar as smoothly as possible. Once this knowledge enters the industry and building high performance walls and attics becomes commonplace, the benefits to California in the form of a more energy efficient housing stock will be significant and long lasting.

Project Approach

The project team began by assessing the homebuilding and residential construction labor markets to target training to appropriate areas and to set baselines for measuring progress. In parallel with this effort, the team promoted a dialogue between industry stakeholders, including builders, manufacturers, energy consultants, building science consultants, and others, to foster an understanding of the diverse issues involved with introducing high performance walls and attics in production homebuilding. The researchers organized a series of forums at which all participants could get an understanding of the challenges involved: builders could discuss their concerns, manufacturers could present products and assemblies designed for high performance walls and attics, and energy consultants could discuss modeling questions and issues. To market directly to the building industry, the Workforce Instruction for Standards and Efficiency team used the California Building Industry Association, the trade association for California homebuilders who build more than 85 percent of the new homes in California, and their local chapters.

Based on discussions at the forums, the primary issues involved were:

- Builders were not fully aware of the details of the code changes and the resulting effects on compliance and construction.
- Builders were not aware of the range of products available that were either designed for high performance walls and attics or could be used in the implementation of them.
- Builders were not aware of how the new standards affect building techniques and long-term building durability and moisture management (for example, placing insulation

directly below roof decks). These issues should be addressed before construction begins.

- Modeling new features in compliance software is not straightforward.

The project team approached these issues using two main avenues. The first was to create presentations covering all the relevant topics to provide training upon request to any interested companies or organizations. The team organized presentations by topic to allow trainings to be targeted to audience needs. The second was to set up a website to act as a clearinghouse of resources for the project. The team provided informational materials developed during the project as well as other useful content such as manufacturers literature for relevant products and links to third party sites.

One of the initial goals of the project was to provide training for insulation installers and investigate the need for installer certification. However, based on discussions with industry stakeholders, the team found that there was neither desire nor need for an independent certification for installers.

Project Results and Market Adoption

The Workforce Instruction for Standards and Efficiency team held 141 training events during the course of the project. The project results are best judged by the degree to which they succeed in promoting market adoption of walls and attics. While it is not possible to definitively attribute any increase in market adoption of high performance attics and walls to a specific action by the project team, training provided to builders and other market actors in the building practices required to successfully incorporate these measures into new buildings is clearly likely to be a major driver of any increase in market share. Using high performance walls typically requires a change in the way walls are built, whether that is by using thicker studs to allow for more cavity insulation or using exterior foam board insulation. As such, high performance walls are more disruptive to standard building practices than many of the methods and materials used in high performance attics. Therefore, the researchers expect high performance attics to be adopted more readily than high performance walls, an expectation borne out by the results of this project.

The use of high performance walls, defined as those meeting the prescriptive standard for the 2016 Building Energy Efficiency Standards, increased from effectively zero at the start of 2016 to 10 percent of the market at the end of 2019. In the same period, the market share of high-performance attics rose from almost zero to nearly half of new single-family construction. Additionally, the use of 2x6 studs, one of the most effective ways to build high performance walls, has increased from less than a tenth of the market to close to two thirds. This increase suggests that the market penetration of high performance walls could increase even further.

Benefits to California

Builders have many options to meet compliance requirements. The use of better building shells to meet compliance will provide a longer lasting benefit than the use of more efficient equipment that has a shorter useful life than the building itself. It is therefore of more benefit to California for the building industry to adopt the use of high performance attics and walls than it would be to meet compliance through equipment efficiency. Focusing on the building envelope ahead of equipment efficiency reduces the energy use and therefore the required size of the heating, ventilation, and air conditioning equipment; produces benefits likely to last for the life of the structure; and can enhance comfort and indoor air quality.

The benefits to California from this project are in the increased knowledge within the building industry of how to properly install high-performance walls and attics, knowledge which can be transferred to other building components. Additionally, increased energy efficiency and lower carbon emissions of the buildings built using the techniques, methods, and products that have been popularized and promoted through this project, can be realized.

CHAPTER 1: Introduction

Building Codes

The energy efficiency of buildings in California is regulated by the California Energy Commission (CEC) through Title 24, Parts 6 and 11 of the California Code of Regulations, the Building Energy Efficiency Standards (BEES). These regulations are updated every three years, with the most recent updates being introduced in 2016 and 2019. The 2016 BEES went into effect on January 1, 2017 and the 2019 BEES became effective on January 1, 2020. The regulations cover the building shell and mechanical systems such as heating, cooling, ventilation, and water-heating systems. There are separate regulations for low-rise residential buildings (which includes single family homes and multifamily homes up to three stories) and high-rise residential and commercial buildings.

Compliance Options

For a permit to be issued for new construction, builders must show that the proposed building complies with the energy efficiency levels required by the BEES. This can be done in two different ways: the prescriptive path or the performance path.

Prescriptive Path

For each building type, and for each of California's 16 climate zones,[1] the BEES prescribe an energy efficiency level for each element of the building shell and for each of the mechanical systems. A permit will be granted for a building that meets all the prescribed requirements with no further analysis or calculation required. The prescriptive path does not allow compromises on any aspect of the building so it restricts design and architectural options, such as having a larger window area than the prescribed value. This limitation can be overcome by using the performance path to compliance.

Performance Path

The performance path to compliance allows trade-offs between the energy efficiency of different elements of the building while requiring the same overall level of efficiency. For example, using a larger window area will lead to higher heating or cooling loads (or both), depending on the climate, reducing the overall energy efficiency of the building. However, this could be compensated for by using more highly insulated walls or a higher efficiency air conditioner. The flexibility offered by the performance compliance path has resulted in the vast majority of builders taking this route.

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[1] Climate zones are defined differently by different authorities. Throughout this report, the term "climate zone" refers to one or more of the California Climate Zones defined by California Energy Commission, details of which can be found at: https://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf (accessed April 27th, 2020).

Compliance Modeling

To obtain a permit using the performance path, the builder must show that the proposed building will use no more energy than it would if it had been built to the prescriptive standards. This demonstration is done using the CEC-approved building energy modeling software to simulate the annual energy use of the proposed building and a "standard" building of the same size that uses all the prescriptive features.

Energy end-uses in the modeled buildings are divided into two types, regulated and unregulated. Regulated loads are those used for heating, cooling, water heating, and ventilation and only the regulated loads are compared for compliance.[2] The energy used by a proposed versus a standard building is not compared by simply taking the total annual number of kilowatt-hours (kWh) and therms for each, but by using a time dependent value (TDV) for the energy used. The TDV accounts for the fact that energy is more expensive to produce when demand is high, so comparing annual TDV energy use will favor building methods that save energy at times of high demand over savings at times of low demand. The metric used to determine whether the proposed building complies is thus the total TDV energy used annually.

Measurement of Insulation: R-value and U-factor

How well a material (for example, fiberglass insulation batts) or an assembly (such as a wall) performs as an insulator is measured by how well it resists the transfer of heat. This is given using either the R-value or the U-factor. The R-value shows resistance to the transfer of heat (a material with a higher R-value is a better insulator) and the U-factor shows conductance of heat (a material with a lower U-factor is a better insulator). Mathematically, they are the inverse or reciprocal of each other (R-value = 1/U-factor), but typically the R-value is used when looking at a single material, and the U-factor is used for materials rated or tested as an assembly. As an example, the fiberglass insulation in the wall of a "typical" house built using 2x4 wood studs would have an R-value of 13, nominally corresponding to a U-factor of 0.077. However, because a 2x4 wood stud has an R-value only slightly better than R-4, the studs transfer significantly greater amounts of energy than the insulated stud cavity. The studs bridge the gap between the interior drywall and the exterior sheathing, hence the term "thermal bridging": they act as heat leaks, reducing the thermal resistance of the wall below that of the insulation. Once this effect is considered, the combined U-factor of the studs and insulation is 0.111, equivalent to an R-value of 9.

2016 Building Energy Efficiency Standards Updates

In the 2016 update of the residential building code, the most significant change in the prescriptive standards was to the insulation levels of exterior walls and in attics.

Walls

The 2013 BEES had a prescribed wall U-factor of 0.065. This requirement can be met by a wall built using 2x4 studs, with an R-15 fiberglass batt insulation between the studs and continuous R-4 insulation on the outside, finished with standard stucco.

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[2] This is not to say that other energy uses, such as lighting, are not regulated for efficiency, but they are not included in compliance.

For the 2016 BEES, the prescriptive requirement for walls was raised to a U-factor of 0.051 (except in the 2 mildest climate zones, 6 and 7, where it stayed at 0.065). There are many ways in which this level of insulation could be met. Table 1 gives some examples, using wood framing.

Table 1: Examples of High-Performance Wall Options

U-factor	Framing	Stud Spacing	Cavity Insulation	Exterior Insulation	Cavity Insulation Type
0.050	2x6	24” OC	R-19	R-5 (1")	Low density fiberglass batt
0.051	2x6	16” OC	R-21	R-4 (1")	High density batt
0.049	2x6	16” OC	R-19	R-6 (1.25")	Low density fiberglass batt
0.051	2x6	16” OC	R-19	R-5 (1”)	Low density fiberglass batt
0.050	2x4	16” OC	R-15	R-8 (2")	High density batt

Source: Author analysis

Wall construction practices in production building have not changed significantly in recent decades. The “standard” wall is built using 2x4 studs, spaced 16 inches apart, with fiberglass insulation between the studs. In recent years, the energy efficiency of these walls has been improved by the addition of exterior insulation, usually not more than 1 inch thick. As suggested by Table 1, meeting the performance level of high performance walls (HPW) will typically require either 2x6 studs or a layer of continuous insulation more than 1.5 inches thick. The drawbacks of each of these are detailed below.

Construction Issues for High Performance Walls

Builders expressed numerous concerns about building HPW. Those concerns included the cost and availability of 2x6 studs, the lack of framing contractors who have experience building with 2x6 studs, the impact on lot lines and side yard clearances, and the impact on interior conditioned space. Over time most of these issues have been resolved.

The HPW requirement began when the residential construction market was still depressed. No shortage of 2x6 material materialized and the 2x6 framing market has grown substantially since 2016. 2x6 framing remains as 16 inches on center (IOC), thus lumber costs are 50 percent greater than 2x4 16 IOC framing. As the market for 2x6 has grown, the framing contractors have responded to the demand. No examples of lot line adjustments were observed during the Workforce Instruction for Standards and Efficiency (WISE) program trainings, possibly because builders with existing lots continued to build with 2x4 framing by using the solar trade-off or additional energy features. As more builders use 2x6 framing, the issue of loss of interior space was avoided by marketing their product using exterior wall dimensions.

Attics

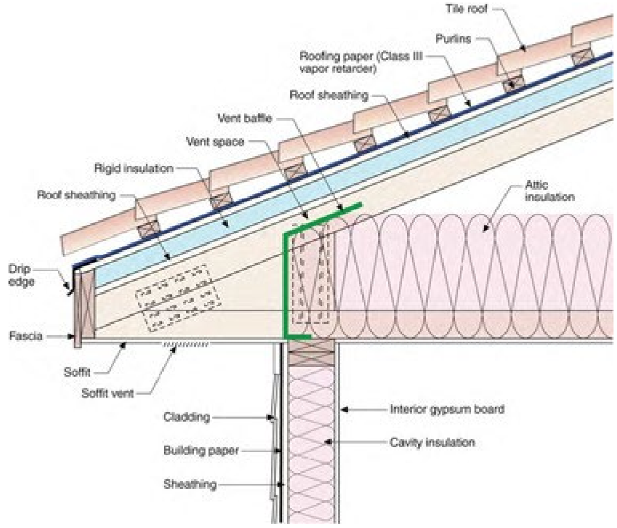
Traditional construction for single family homes in California uses ventilated attics with any insulation being on the attic floor. In the 2013 BEES, the prescriptive requirement for insulation was either R-30 or R-38 depending on which climate zone the building was in. On a hot day, the temperature in this type of attic can reach temperatures up to 135°F, and the insulation will prevent the house below from overheating.

The disadvantage of this design is that many houses have air conditioning ductwork in the attic that, under the 2013 code, is only required to be insulated to R-6 or R-8. When the air conditioner is running, the cold air (typically 55-60 degrees Fahrenheit) in the ducts is heated due to the high temperature in the attic, reducing the efficiency of the air conditioning system and increasing energy use and utility bills.

This disadvantage was addressed in the 2016 BEES, which included three prescriptive attic options in the code. For all but the mildest climate zones, the options were:

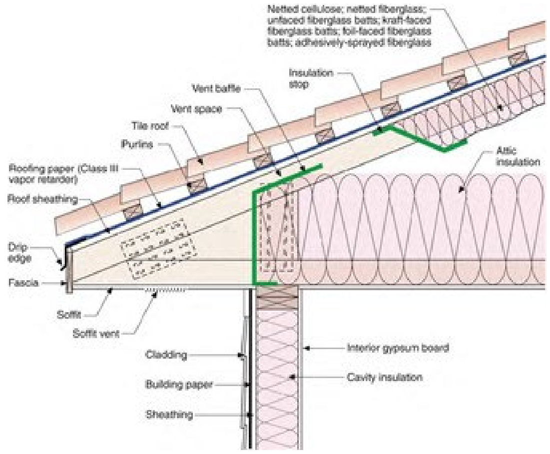
A. Adding insulation above the roof deck (underneath the tiles or shingles) while keeping the insulation on the floor, as shown in Figure 1.
B. Adding insulation below the roof deck (between the roof joists) while keeping the insulation on the floor, as shown in Figure 2.
C. Keeping the attic the same as under the 2013 BEES but moving the air conditioning ducts out of the attic and into the building's conditioned space by creating a dropped soffit to contain the ducts, as shown in Figure 3.

Figure 1: Schematic of Attic with Above Deck Insulation



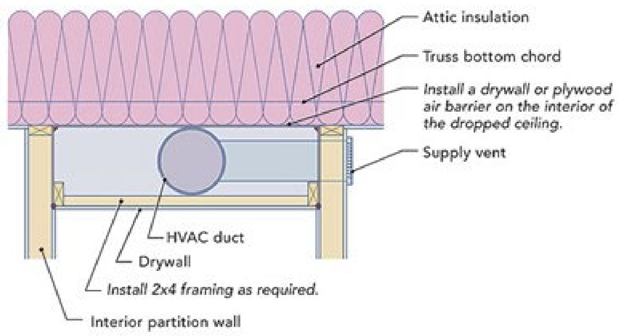
Source: Building Science Corporation

Figure 2: Schematic of Attic with Below Deck Insulation



Source: Building Science Corporation

Figure 3: Dropped Soffit with Duct in Conditioned Space



Source: Building Science Corporation

For options A and B, adding insulation at the level of the roof moderates the attic temperature and reduces losses from the ducts as well as heat transfer between the attic and the living area below. In summer and winter, lowering the temperature difference between the attic and the house results in lower cooling or heating loads, which provides further savings. This strategy has a greater influence on the compliance of homes in cooling-dominated climate zones because the outdoor air temperatures are higher and the heating, ventilation, and air conditioning (HVAC) system tends to be used more. Option A, adding insulation between the roof deck and the roofing material (tiles or shingles) was not a popular choice and has been dropped as a prescriptive option from the 2019 code. With option C, moving the ducts into conditioned space means that any heat exchange between the ducts and the surroundings will happen within the conditioned space and will not add to building heating or cooling load. Because the attic construction is not changed from the standard method, this compliance option is not considered a high performance attic (HPA).

The prescriptive options A and B are not the only possible designs for HPA. Another design is an unvented attic created by moving the thermal envelope of the home to the roof by air-sealing and insulating at the roof deck rather than the attic floor. This further reduces the attic temperatures, providing a better environment for the HVAC system and ducting. Unvented attics often use spray foam insulation rather than batts or loose fill insulation because the spray foam can provide an air barrier (which seals the attic) and insulation in one product.

Construction Issues for High Performance Attics

Builders initially expressed numerous concerns about building using HPA. The concerns included moisture, cost, lack of insulation subcontractors familiar with HPA installation, effect on subcontractor sequencing, and impact on Home Energy Rating System (HERS) and building code inspections.

HPA were cost effective compliance trade-offs for the 2016 BEES; however, in 2016 there were few HPA solutions offered by insulation subcontractors. The primary builder HPA concern was moisture that could be trapped between the insulation and the roof deck and condense, causing premature failure of the roof sheathing. Some builders, with the assistance of manufacturers, installed moisture monitoring equipment to determine if moisture was an issue in HPAs and in general, few moisture issues were found. The market responded by building vented HPAs or unvented HPAs with vapor retarders per manufacturer specification. The moisture concerns remain unresolved as some major production builders ban the use of HPAs.

The unvented, box netting and spray foam HPAs affected construction sequencing and increased construction time and cost. Builders and subcontractors adapted but, due to increased construction costs and effects on time, neither of these HPA methods have gained significant market share. As the HPA market matured and more products were offered, the market moved toward the vented under deck roof solutions. Currently, most major insulation subcontractors offer HPA solutions. Building departments still have some concerns about HPA insulation labeling and stapling requirements; however, manufacturers are responsive with improved labeling and training for their installers.

Definitions of High-Performance Walls and Attics

The change in prescriptive requirements for walls and attics between the 2013 and 2016 standards does not result in a black and white choice for builders. Using the performance compliance path, credit is given for incremental improvements in efficiency. A wall with a U-factor of, for example, 0.06 is more efficient than the 2013 prescriptive wall (U-factor of 0.065), but less efficient than the 2016 prescriptive wall (U-factor of 0.051). Given that the purpose of the change in prescriptive standards in 2016 was to encourage improvements in the efficiency of the building shell, it is, in the researchers' opinion, reasonable to count any wall that exceeds the 2013 prescriptive standard as an HPW. Similarly, any attic that exceeds the 2013 prescriptive standard will be counted as an HPA.

Market Assessment

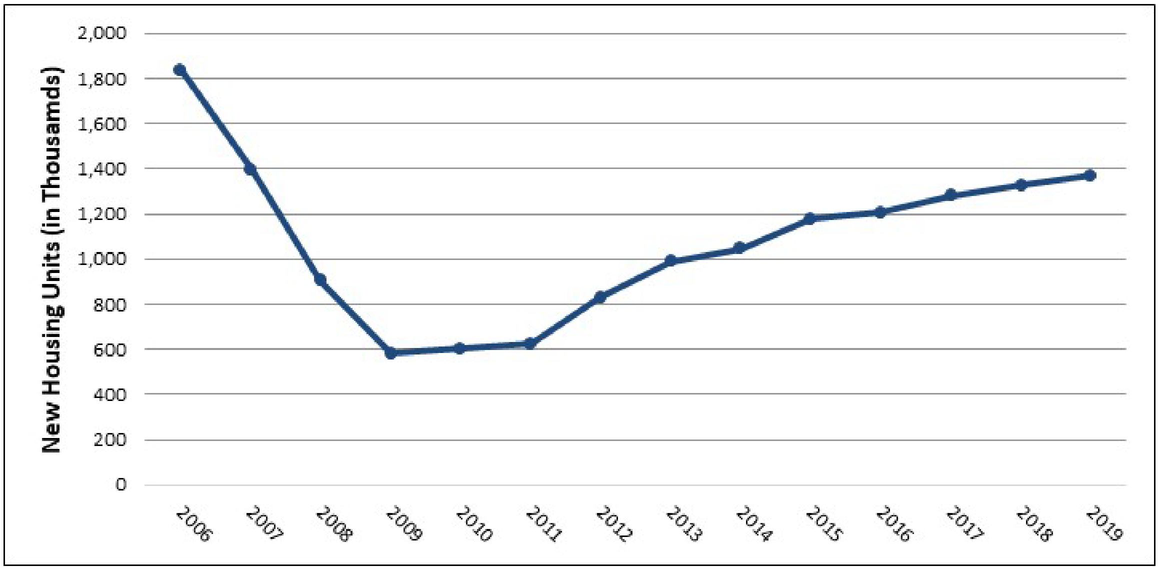
To provide context for the work carried out in this project, at the start of the project the team analyzed the state of the construction industry in California including trends in construction activity and employment from 2006 onwards.

Construction Activity

Using data from the U.S. Census Bureau for national statistics and the California Department of Finance for statewide statistics, the research team analyzed trends in the new housing construction market from 2006 onwards. Single-family homes are detached, semi-detached, row houses, and townhouse units with one to two dwelling units. Multi-family homes are duplexes and other residential buildings with three or more dwelling units and fewer than four habitable floors.

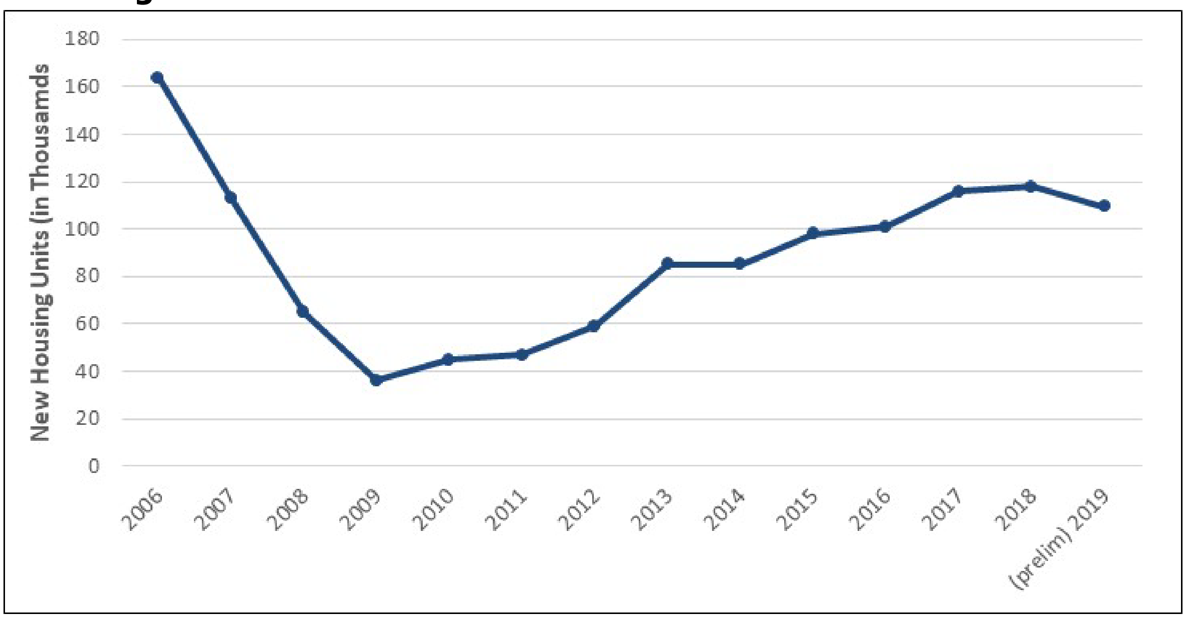
The national and statewide construction industries were severely hit by the recession. Nationally, construction in 2009 was down to 32 percent of the level in 2006 (Figure 4) while in California the drop was even larger, with construction down to 22 percent of the 2006 level in 2009 (Figure 5).

Figure 4: Nationwide Residential Unit Construction 2006-2019



Source: US Census Bureau Data

Figure 5: California Residential Unit Construction 2006-2019



Source: California Department of Finance data

The authors reviewed the same data for the five largest metropolitan statistical areas (MSAs) in California:

- Los Angeles, Long Beach, Anaheim
- Riverside, San Bernardino, Ontario

- Sacramento, Arden-Arcade, Roseville
- San Diego, Carlsbad
- San Francisco Bay Area[3]

The results show that while both single- and multifamily construction was similarly affected across the entire state by the recession, the recovery has been very uneven. In the Los Angeles area, total construction in 2018 is at 80 percent of the 2006 level. Riverside, in contrast, has seen a much weaker recovery with total construction in 2019 at about 30 percent of the 2006 level.

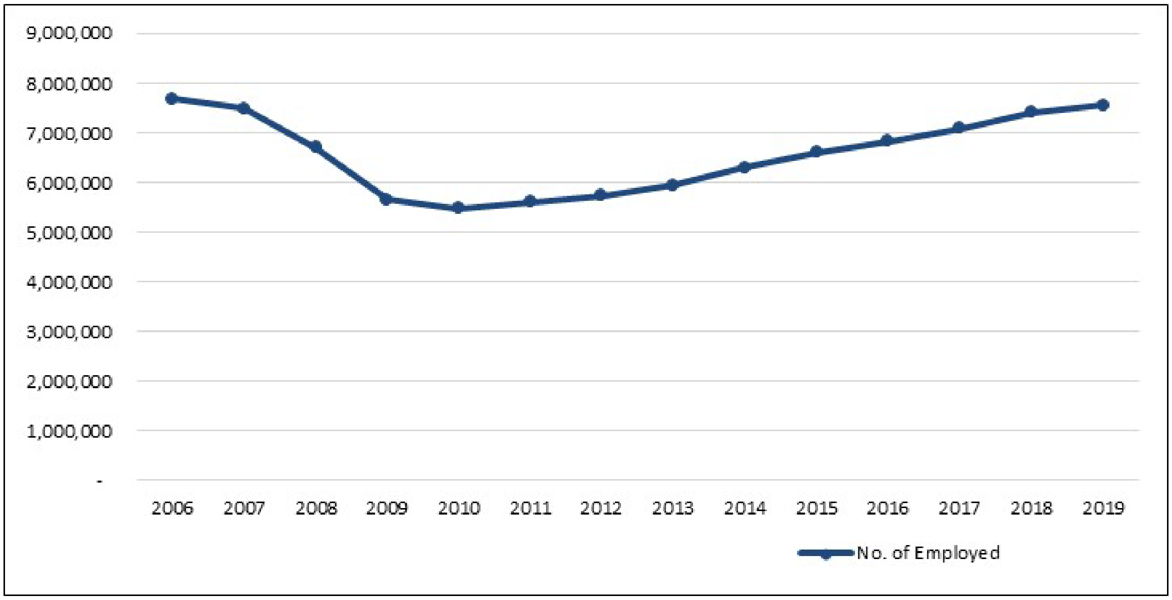
The authors also studied the differences in recovery across the 16 different California climate zones and between single- and multi-family construction. Although there have been increases in the rate of single-family construction for some climate zones between 2012 to 2019, none have recovered to the levels seen in 2006. However, climate zones along the coast, mainly within the San Francisco Bay Area and the Los Angeles area, have seen increased construction rates in multi-family housing construction that surpass prerecession levels.

Employment

The analysis used employment statistics to identify annual labor trends for the homebuilding industry nationwide, statewide, and in California's five largest MSAs. Findings indicate that the homebuilding workforce has increased in recent years on the regional, statewide, and national levels; however, these improvements are still below the employment volume of prerecession years. In California alone, findings revealed that the construction labor market experienced a deeper recession and is recovering at a slower pace than the national market as a whole. Nationwide, employment bottomed out in 2010 at 71 percent of the prerecession 2006 number, and by 2019 had recovered to 95 percent of the 2006 level (Figure 6). In California, the 2010 employment level was 60 percent of the 2006 level and had recovered to 95 percent by 2019 (Figure 7).

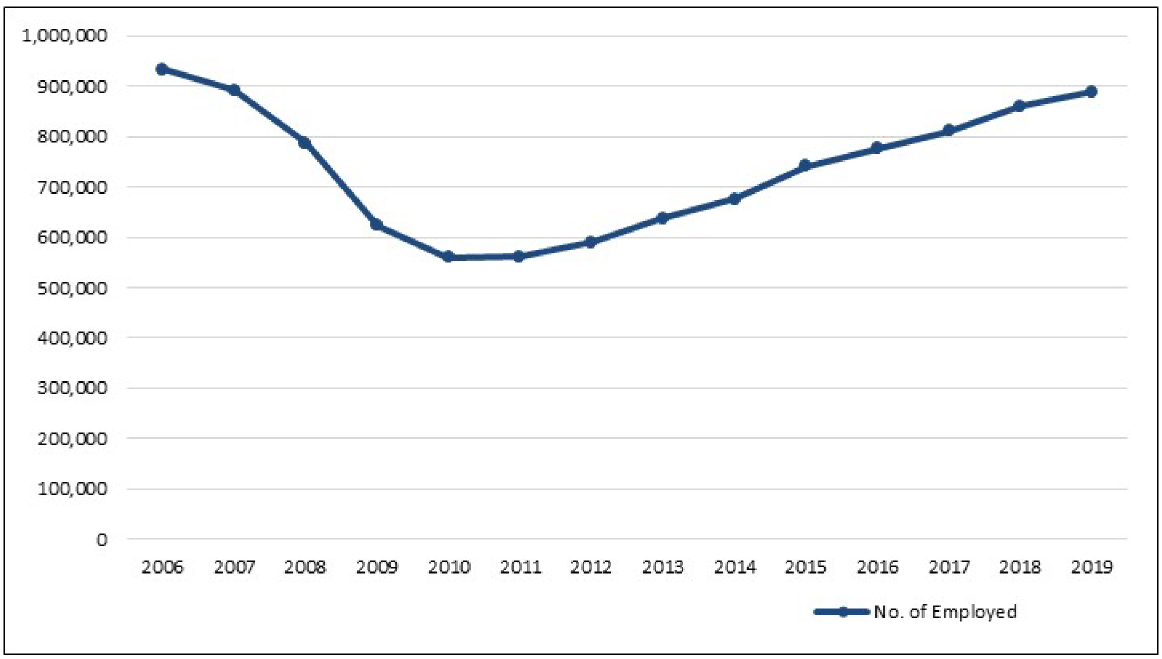
[3] The San Francisco Bay Area is two adjacent MSAs - San Francisco, Oakland, Hayward and San Jose, Santa Clara. Due to their closely linked employment and housing markets, it is logical to consider them as a single market.

Figure 6: Construction Employees in the United States 2006-2019



Source: Bureau of Labor Statistics Data

Figure 7: Construction Employees in California 2006-2019



Source: California Employment Development Department Labor Market Information Division data

When reviewing the data for the same MSAs, the researchers found that the statewide pattern of employment dropping through 2010 and recovering thereafter held for all the areas studied.

The project team found that there have been no metropolitan areas in California that have fully reached the previous 2006 peak employment levels within the construction labor market. However, the San Francisco Bay Area has seen the most growth in the market since the recession, while the Los Angeles, Long Beach, and Anaheim area was almost as buoyant. Two MSAs have seen limited recovery since the recession: Sacramento and Riverside. Riverside has experienced the worst labor market recovery since the recession, with construction employment in 2019 down 18 percent from the 2006 peak, while Sacramento follows closely behind. It is important to note that many of the trade works left the construction industry in the recession and took other jobs but did not return to the industry when it recovered, creating a shortage of skilled subcontractors.

Wall and Attic Construction

To determine the initial prevalence of HPA and HPW, ConSol surveyed 10 subdivisions in each of the top 5 MSAs listed above. The subdivisions were selected to include one each from the top 10 builders by volume in the relevant MSAs to ensure that the data captured the typical practices of the industry.

Wall Insulation and Framing

The results showed that walls are almost universally insulated using fiberglass batts – 47 of the 50 subdivisions surveyed used this, with two using blown-in cellulose and one using spray polyurethane foam insulation. It is common for houses built primarily using 2x4 stud walls to have a small section of wall built using 2x6 studs to provide more space for in-wall plumbing pipes. This would not usually be a large enough section to have a significant impact on the overall thermal performance of the walls. For this study, the researchers classified the building as using 2x4 construction or 2x6 construction according to the framing of the wall section with the largest area. Only one of the fifty subdivisions surveyed used 2x6 framing.

Attic Construction

The distinguishing features of different attic designs are whether the attic is ventilated and the location of the insulation. A ventilated attic is designed to separate the attic from the air in the conditioned space by air sealing the attic floor, and to allow a natural flow of outdoor air into and out of the attic. A ventilated attic will typically have 1 square foot of vents for every 300 square feet of floor area. In hot weather, the attic temperature will often be significantly higher than the air temperature, so the ventilation will help keep the attic cool and thus reduce heat transfer into the conditioned space below. In cold weather, the ventilation will help prevent moisture issues from warm moist air entering the attic from the conditioned space below and condensing on the colder roof and attic walls. Because of the large temperature differences between the attic and the conditioned space, vented attics have insulation on the attic floor. Vented attics can also be designed with additional insulation at the roof deck to help reduce heat flow into the attic.

An unvented attic is designed to prevent or minimize any exchange of air with the outside and to keep the attic temperature closer to the temperature of the space below. The roof and attic walls are sealed to prevent air exchange with the outdoors, and the insulation is moved from the attic floor to the roof.

Unvented attics are designed to have smaller temperature differences between the attic and the conditioned space than vented attics. This should both reduce heat transfer between the attic and the conditioned space and reduce energy losses from any heating or air-conditioning ductwork in the attic.

In this project, a high performance attic is defined as any attic construction other than a traditional vented attic with insulation on the attic floor only. Of the 50 subdivisions studied, 48 used standard vented attics and only 2 used unvented attics. All 50 projects used either R-30 or R-38 insulation as specified by the code for that climate zone.

CHAPTER 2:
Project Approach

Construction techniques for building with HPW and HPA differ from the standard practices of the building industry. To meet the higher energy efficiency levels required due to the inclusion of HPW and HPA in the 2016 BEES,[4] stakeholders in the building industry needed to understand the changes and learn how to build with HPW and HPA. The WISE program was established to help educate the building industry about all aspects of the code changes. The primary goals were to develop and implement education on HPWs and HPAs at two primary levels in the industry: (1) building science and Title 24 education at the builder management level as well as architects, design community, energy consultants, and (2) on-the-job training for field superintendents and trade workers for constructing high performance attics and walls for new homes. The education content was consistent with the 2016 BEES to provide technical, market, risk-mitigation, and cost data to builders to help persuade them to transition to portfolio-wide HPA and HPW construction practices, and to establish a comprehensive online catalog of technical and performance information on HPA and HPW for use by the building industry.

Outreach and Publicity

The first phase of the project involved outreach to inform the industry about the project and forums to gauge the level of knowledge of the stakeholders and the availability of products.

Forums

The goals of the forums were to inform the building industry about the code changes and their likely impact on new construction. The WISE team invited participation from builders, manufacturers, utilities, energy consultants, and the CEC. The forums were advertised through multiple channels, which included leveraging the team's pre-existing connections to the industry and using existing mailing lists to broaden the outreach. The extensive mailing list of the California Building Industry Association (CBIA) and the support of the local building industry associations were particularly beneficial and resulted in the largest number of eventual participants.

The WISE project team made presentations on the scope of the project; the CEC presented on the scope of the changes to the code; and multiple manufacturers made presentations to provide insight and information into products and solutions available for HPA and HPW.

In addition to the presentations, participants discussed concerns about potential barriers that would limit or slow the adoption of HPA and HPW and possible resources that would be helpful. The information that resulted from these discussions provided a framework for the analysis of barriers and solutions that the project team carried out and was instrumental in establishing the product catalog that the project team assembled.

[4] The inclusion of HPW and HPA was not the only change to the standards in 2016 but was the most significant for residential new construction and is the focus of this project.

Training and Support

The core purpose of the project was to train and educate the building industry. The primary audience for the trainings was builders, on whom the code changes would have the most direct impact. For builders to comply with the 2016 code updates, they needed to understand and be aware of both the code changes themselves and the impact of the changes on their building practices. To this end, the training provided covered:

- Changes to the prescriptive requirements in the 2016 code.
- Building science of HPA & HPW to make builders comfortable with the best practices to reduce callbacks and enhance building durability.
- Design features of the new prescriptive wall and attic options.
- Alternative compliance options.
- Overview of products and materials available to meet the new HPA and HPW requirements.
- Energy efficiency and cost impacts of the different options.
- Best practices for incorporating the new options into buildings.

The training can largely be divided into three types: office-based, onsite, and support.

Office-Based Training

Office based training covered the code changes relating to walls and attics and familiarized participants with the details of the new prescriptive requirements. The project team created training materials covering the full breadth of topics included in the list above. For each training, materials used were finalized after discussion with the recipients to ensure that the session covered areas specific to their needs. Prior to training, many builders provided plan sets for the training team to review and provided feedback for HPA and HPW options.

Onsite Training

Onsite training followed office-based training to answer questions or issues raised during installation and ensure that the workforce was aware of best practices. Onsite training was also provided independently of any office training, for example for insulation subcontractors whose needs were for more practical advice and training.

Support Training

Compliance Modeling

In addition to the training provided to builders and installers, the WISE team offered support to energy consultants and architects to assist with modeling. This support included reviewing plans and models and analyzing different compliance options to help optimize the design for energy efficiency and cost effectiveness. To ensure that new products that would benefit the industry were properly credited in the compliance software, the WISE team also worked with manufacturers to see how best to model new product or assemblies.

Online Portal

To provide the widest possible access to the materials created for and during the project, the WISE team created an online portal (wisewarehouse.org) as an information clearinghouse. The site hosts copies of training materials (videos and presentations) created by the team; demonstration videos of installations of wall and roofing products filmed in collaboration with manufacturers; brochures and datasheets for useful wall and roofing products; and links to relevant third-party materials including building codes, articles in trade publications, and blog posts. The WISE team published periodic newsletters to inform the industry of updates to the site and to give notice of upcoming trainings.

CHAPTER 3: Project Results

Forums

Forums were held in both 2016 and 2017 to familiarize the industry with the project and to shape the direction and curriculum of the proposed trainings. The forums were well attended in 2016, with attendees representing a wide cross section of the building industry. Forums in 2017 had lower attendance because of the success of the project team in publicizing the HPAs and walls.

The following large production builders sent staff to one or more of the forums:

- KB Home
- Meritage Homes
- Taylor Morrison
- K Hovanian
- Lennar
- CalAtlantic Group
- Toll Brothers
- Beazer Homes
- TriPoint Group
- Shea Homes
- Wm. Lyon Homes
- Habitat for Humanity
- Woodside Homes
- The New Home Co.
- Elliott Homes
- Brookfield Residential
- Pulte
- DR Horton
- Richmond American
- The Irvine Company

These companies represent 87 percent of the top 10 builders in the 6 largest housing markets in California. The top 10 builder market share ranges from 60 percent to 85 percent per market. These markets include Los Angeles, Riverside, San Francisco, San Jose, and San

Diego. These builders construct 42 percent of the new single-family homes in California each year.[5] The forums were also attended by a broad group of local and regional builders.

Manufacturers who presented at these forums for HPWs included:

- APA (plywood sheathing)
- BASF (HPW systems)
- Insulfoam (insulating foam sheathing)
- JELD-WEN (window sealing and flashing installation)
- Johns Manville (insulation)
- Knauf (insulation)
- Merlex (one coat stucco)
- Owens Corning (insulation)
- Polyisocyanurate Insulation Manufacturers Association (high density foam sheathing)
- Rmax (insulating foam sheathing)
- Structural Insulated Panel Association (preformed insulated wall panels)
- SWD Urethane (low density spray foam for walls and attics)
- ThermalBuck (insulating window buck)
- Window & Door Manufacturers Association (window mounting and flashing)

Manufacturers who presented at these forums for HPAs included:

- Bayer Material Science (spray foam in unvented attics)
- Covestro (spray foam in unvented attics)
- Green Hybrid Roofing (insulated roof tiles)
- Icynene (spray foam in unvented attics)
- Johns Manville (composite nail board for unvented attics)
- Knauf (under roof deck insulation and fastening system)
- Owens Corning (box netting under roof deck insulation)
- Rmax (under roof deck insulation)
- Spray Polyurethane Foam Alliance (closed cell spray foam)
- Wedge-It (above roof deck rigid insulation)

Additional technical presentations presented at forums included:

- California Energy Commission (2016 Standards)
- Various solar manufacturers (impact of 2016 solar trade-off)
- California Lighting Technology Center (2016 Code Lighting Options)
- PG&E, SCE, SDG&E, SoCalGas, and SMUD (utility incentive programs)
- ConSol (HPW and attics options, 2016 T-24 compliance options)

[5] www.builderonline/land/local-leaders-list/2015/.

Attendance ranged from 30 to 80 participants per forum. The presentations were moderated with active audience interaction. Questions were limited only when time was short. The original scope of the WISE project proposed encouraging builders who attended the forums to enroll in field training and support during the construction of high-performance attics and walls on-site.

Unfortunately, neither the WISE team nor the CEC predicted the impact of the solar trade-off. To encourage the adoption of solar in new homes, the CEC established a compliance trade-off for installing solar. If a builder installed a minimal amount of solar — less than would be installed for a typical residential system — the builder could avoid (trade-off) HPAs and walls. The 2016 Building Energy Efficiency Standards became effective on January 1, 2017. By the middle of 2017, was apparent that the solar trade-off substantially decreased the energy code requirement for HPW and HPA. As shown in Figure 20 later in the chapter, the solar trade-off dominated the 2016 compliance market. Builder interest decreased for training because there was no immediate need to build with HPAs and walls.

ConSol, with the approval of the CEC contract manager, moved from forum and onsite training to individual and local builder training sessions in 2018 and 2019. Those WISE training sessions were performed at the builder's office or the local BIA with a WISE technical trainer and a building scientist over a two- to four-hour session. At some sessions, onsite field walks were available to observe and train on HPAs and walls.

Training

The WISE team held 141 trainings during the project. The majority were office-based trainings, either given to individual companies or organized through trade organizations; classes held at trade shows; and trainings provided in collaboration with utility learning centers. A smaller number of trainings were given to energy consultants, insulation sub-contractors, architects, and building officials. The trainings given to the more specialized audiences, such as insulation subcontractors or energy consultants, were restricted to specific topics, while the remainder covered codes, compliance options, and building science. Examples of the training presentations can be found on the project website.[6]

Table 2: Training Sessions by Audience Breakdown

Audience/location	Number
Builders/Architects	53
Trade shows and trade bodies	40
Sub-contractor/specialized trades	11
Utility training center	26
Energy consultants	3
Building officials	2
Onsite trainings	6
Total	141

Source: Authors attendance records

[6] https://www.wisewarehouse.org/training-certification/training-resources/

WiseWarehouse.org

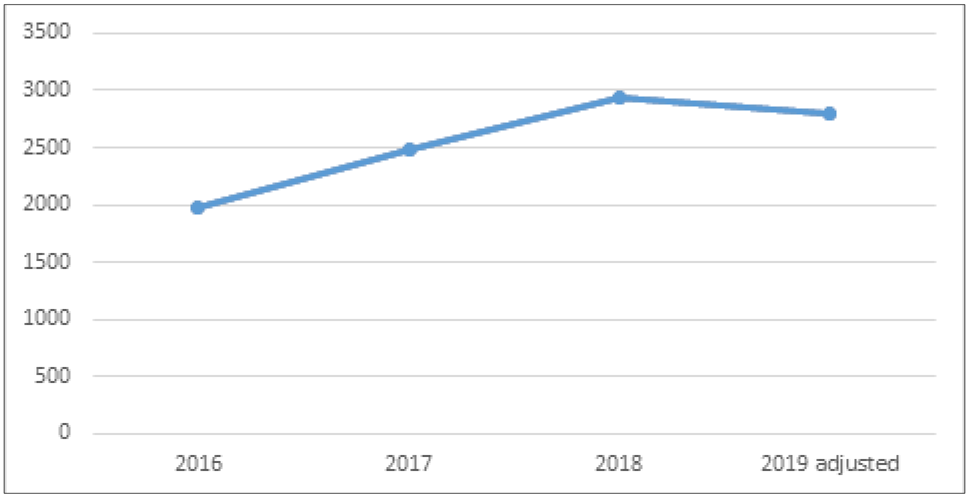
The WISE program's website was launched in June 2016. The original build was intended to be an information clearinghouse and the site was built for the express purpose of providing access to informative links and PDFs from WISE and partners. The clearinghouse reflected this goal, including minimal site pages each with a series of headings and links, as well as an event calendar. Documents provided from partners were posted to the site with little user feedback. User visits were varied in quality but trended both to the media library and the events pages, indicating that users may be open to more events/interactive content.

In 2017, the site became more of an informative website rather than a document clearinghouse in conjunction with how users interacted with the site. To help engage repeat visitors, a subscription field was added to collect email addresses for outreach. To entice visitors to engage more actively with WISE trainings, increased training opportunities were posted to the events and home pages. As these activities were implemented, 2017 saw an increase in users and quality of visits overall.

In 2018, there was a larger investment in site updates, driving a larger volume of quality referral traffic from years previous. Peaks in traffic can be attributed to this additional outreach, including publishing of videos and newsletters throughout the year. Newsletters directed recipients to the site's news, trainings, and video sections, occasionally promoting specific training opportunities. These activities resulted in the highest annual traffic the site has seen to date. New and repeat users spent the most time on the media library, indicating that the repository was still a valid resource for visitors, and the training resources and code requirements pages.

User behaviors were maintained in 2019. Media library, code requirements, and training opportunities had the highest page views and repeat visitors. Users engaged the longest with materials on resources pages (for example, wall case studies, training resources). Overall traffic for the year was down from 2018, which is to be expected as fewer newsletters were sent, likely resulting in the dip in visits. The traffic onsite was primarily quality (not a high number of users bouncing from key pages), indicating that users generally knew how they wanted to interact with the site and used it as intended. Traffic in 2020 was largely direct traffic (users typing in the URL directly as opposed to searching.)

Figure 8: WiseWarehouse.org Site Visits



Source: Wallrich

Market Share of High Performance Attics and High Performance Walls

At the start of this project, the market share of HPW and HPA was negligible in the production housing market. This section reviews how market share changed over the course of this project.

Data Source

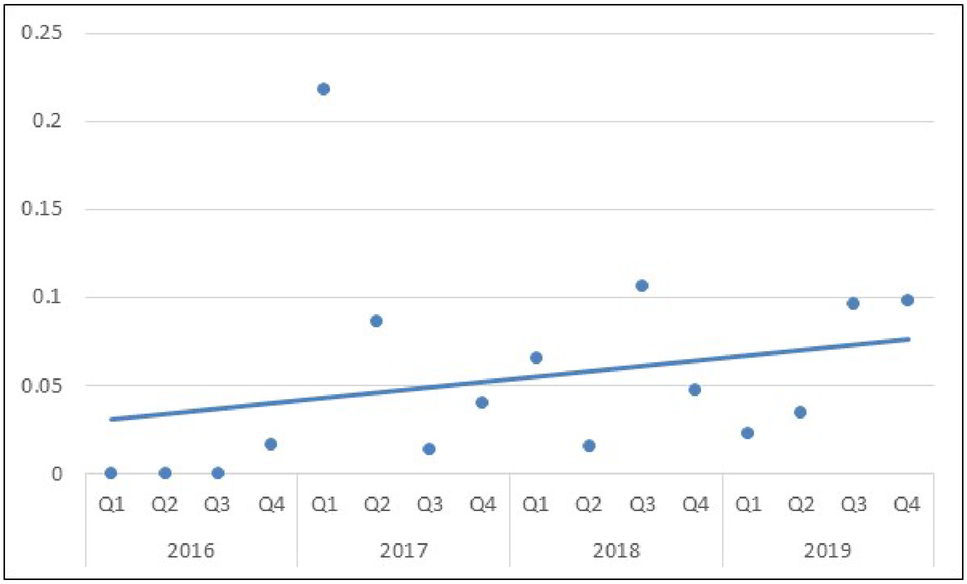
The analysis was carried out using the full set of records in the ConSol Home Energy Efficiency Rating Services (CHEERS) data registry[7] for 2016–2019. The statewide HERS data registries, including CHEERS, contain records of all residential buildings for which permits have been issued. Although the CHEERS data does not cover all buildings registered in that period, the number of data points was enough to provide a robust sample, accounting for 15 percent of single-family construction in 2018–2019. The registries contain details of the building features used to create energy models from which the project team was able to extract the information provided in the following sections. To ensure that data did not contain information on buildings that were modeled but not built, only records that included a CF-3R inspection report (indicating that the building had been inspected, and therefore existed) were included in the analysis.

Walls

In determining the change in wall construction techniques over time, the most significant parameters are the stud size (2x4 or 2x6), the use of continuous exterior sheathing, and the total wall U-factor. An HPW will typically use 2x6 studs, but it does not follow that the use of 2x6 studs implies an HPW. Figure 9 shows that the market penetration of HPW (defined here as meeting the 2016 prescriptive requirement) has risen from effectively zero to close to 10 percent between 2016 and 2019.

[7] The CHEERS registry is now CalEnergy.

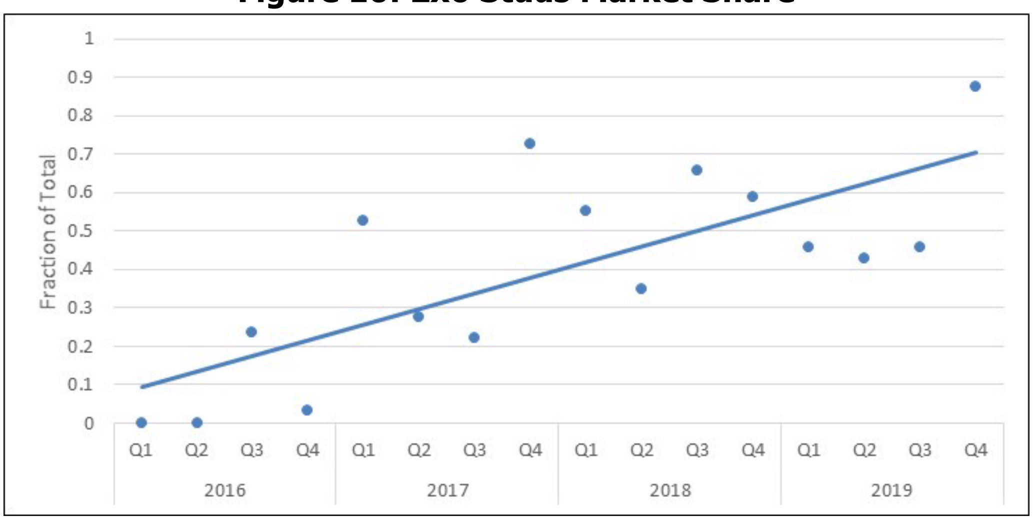
Figure 9: High Performance Wall Market Share



Source: CHEERS registry data

Given the large number of houses that, while being built primarily with 2x4 studs, contain a section of wall built with 2x6 studs to allow for plumbing, the buildings in this dataset were filtered using the stud size of the largest exterior wall area in the building. The fraction of houses built using 2x6 studs has risen from less than 10 percent of the market to close to 70 percent between 2016 and 2019 as shown in Figure 10.

Figure 10: 2x6 Studs Market Share

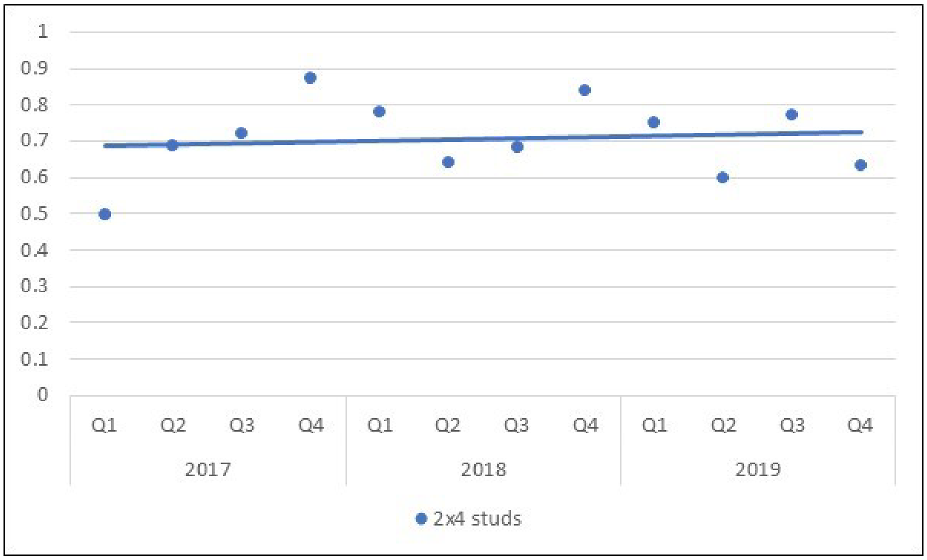


Source: CHEERS registry data

Exterior Sheathing

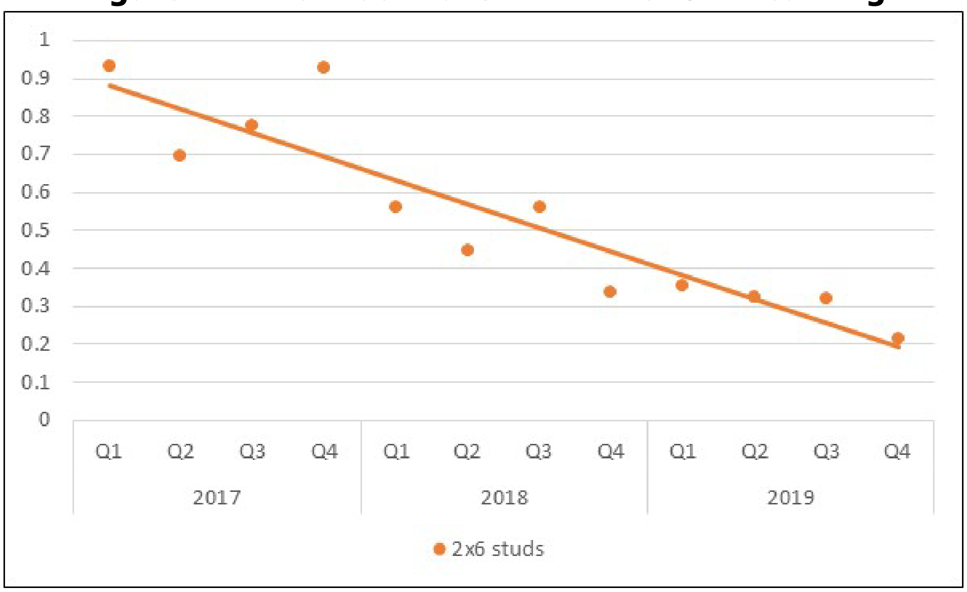
The use of continuous exterior sheathing to improve the overall U-factor of the wall is a well-established building practice. For example, the 2013 BEES had a prescriptive wall U-factor of 0.065 that would need continuous exterior insulation to achieve in a wall using 2x4 studs and fiberglass cavity insulation. Figure 11 and Figure 12 show the market penetration of exterior insulation for single family homes built using either 2x4 or 2x6 studs. While the use of exterior insulation does not change appreciably over the course of the project for walls built using 2x4 studs, the drop in the fraction of 2x6 stud walls using exterior insulation contrasts with the increase in the fraction of buildings using 2x6 studs. The authors attribute this to a change in the use of 2x6 studs from high performance buildings at the beginning of the project, where 2x6 studs and exterior insulation were used to create an above envelope, to lower performing code compliant buildings at the end of the project, where the use of 2x6 studs and cavity insulation alone is sufficient to allow the building to meet code.

Figure 11: 2x4 Stud Walls with Exterior Sheathing



Source: CHEERS registry data

Figure 12: 2x6 Stud Walls with Exterior Sheathing



Source: CHEERS registry data

Compliance Modeling Irregularities

While analyzing the CHEERS registry data on the use of exterior sheathing insulation, the team found multiple data entries that showed higher than expected R-values for the sheathing. Based on conversations with builders and the team's own experience, it was thought unlikely that many if any buildings would have sheathing with an R-value higher than 10. To investigate the issue, the team filtered the records to select those where the CF-1R reported a sheathing R-value of greater than 10, using the criteria that the record must include a CF-3R and be for single-family new construction.

There were 7,039 filtered records with 633 meeting the criteria of a reported R-value greater than 10 for the sheathing. To eliminate the possibility that the results were due to an error in downloaded the data from the registry, 100 irregular records were reviewed manually. The CF-1R forms all showed the insulation values expected. Figure 13 shows the opaque surface construction details for one of the irregular records taken from the CF-1R uploaded to CHEERS. The exterior wall construction shows both interior and exterior sheathing with R-values of 13, which is unlikely for standard building practices. Figure 14 shows the exterior wall section of the corresponding CF2R-ENV-03-E, which records the installed insulation on the project. The CF-2R shows that in this case there is no continuous sheathing listed as being installed.

Figure 13: CF-1R Detail

OPAQUE SURFACE CONSTRUCTIONS						
01	02	03	04	05	06	07
Construction Name	Surface Type	Construction Type	Framing	Total Cavity R-value	Winter Design U-factor	Assembly Layers
Attic RoofLiving Area	Attic Roofs	Wood Framed Ceiling	2x4 Top Chord of Roof Truss @ 24 in. O.C.	none	0.644	• *Cavity / Frame: no insul. / 2x4 Top Chrd* • *Roof Deck: Wood Siding/sheathing/decking* • *Roofing: Light Roof (Asphalt Shingle)*
R-13 Wall w/1 XPS	Exterior Walls	Wood Framed Wall	2x4 @ 16 in. O.C.	R 13	0.027	• *Inside Finish: Gypsum Board* • *Sheathing / Insulation: R13 Sheathing* • *Cavity / Frame: R-13 / 2x4* • *Sheathing / Insulation: R13 Sheathing* • *Exterior Finish: 3 Coat Stucco*
R-30 Roof Attic	Ceilings (below attic)	Wood Framed Ceiling	2x10 @ 16 in. O.C.	R 38	0.026	• *Inside Finish: Gypsum Board* • *Cavity / Frame: R-24.1 / 2x10* • *Over Ceiling Joists: R-13.9 insul.*

Source: CHEERS registry

Figure 14: CF-2R Detail

B. Wall Insulation									
01	02	03	04	05	06	07	08	09	10
I.D.	Manufacturer and Brand	Assembly/Framing Material	Assembly Thickness (inches)	Framing Size and Spacing	Insulation Type	ESR Number	Core/Cavity Insulation R-value	Insulation Depth (inches)	Continuous Insulation R-value
Front Wall	CORNING	Wood Framed Wall	6.88	2x4 @ 16 in. O.C.	Cellulose	This field or section is not applicable	13	3.5	This field or section is not applicable
Right Wall	CORNING	Wood Framed Wall	6.88	2x4 @ 16 in. O.C.	Cellulose	This field or section is not applicable	13	3.5	This field or section is not applicable
Back Wall	CORNING	Wood Framed Wall	6.88	2x4 @ 16 in. O.C.	Cellulose	This field or section is not applicable	13	3.5	This field or section is not applicable
Left Wall	CORNING	Wood Framed Wall	6.88	2x4 @ 16 in. O.C.	Cellulose	This field or section is not applicable	13	3.5	This field or section is not applicable

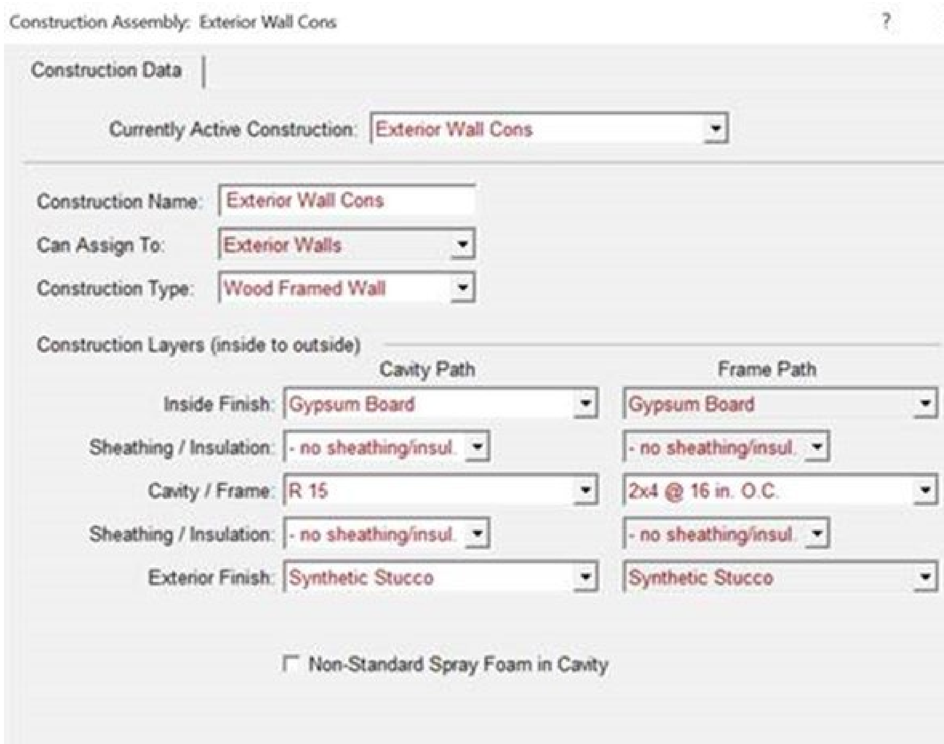
Source: CHEERS registry

The project team analyzed the pattern of data records with irregular insulation values and found that the distribution of the irregular results was uneven. Energy consultants have two options for modeling software: CBECC-Res,[8] a free software package developed and maintained by the CEC, and EnergyPro,[9] a commercial software package. Of the 633 irregular results, only 4 were modeled using CBECC-Res compliance software, with the remainder using EnergyPro. None of the irregular records were associated with large production builders or the energy consultants who typically work for large builders.

Software Differences

In the opinion of the team, the most likely reason why most of the irregular results were modeled in EnergyPro is due to differences in how wall assemblies are entered in CBECC-Res and EnergyPro. In CBECC-Res, if the wall assembly tab is opened the layers that make up the wall are visible, as seen in Figure 15

Figure 15: CBECC-Res Wall Assembly Tab



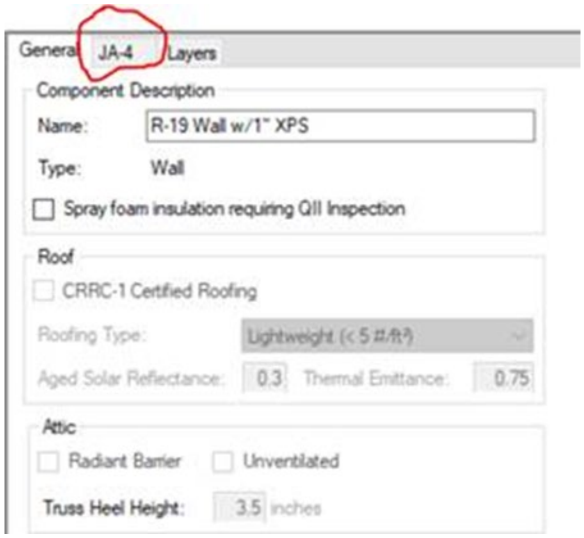
Source: CBECC-Res screenshot

However, in EnergyPro, opening the general wall construction tab, shown in Figure 16, does not show the individual layers of the wall. The wall in Figure 16 is named R-19 wall with 1" XPS, but the name can be chosen independently of the construction. To view the construction details of the wall, another tab (which is labeled JA4) must be opened. This tab, shown in Figure 17, lists details of the wall construction layers, which are shown with R-13 continuous sheathing insulation.

[8] http://www.bwilcox.com/BEES/cbecc2019.html.

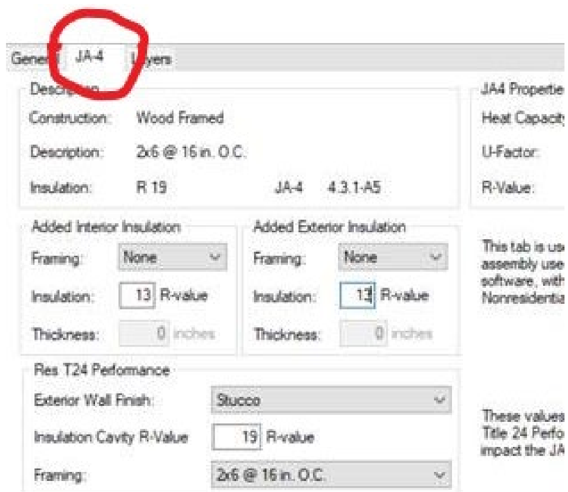
[9] http://www.energysoft.com/.

Figure 16: Energy Pro Wall Construction Tab



Source: EnergyPro

Figure 17: EnergyPro Wall Layers Tab



Source: EnergyPro

How wall construction is input and displayed in EnergyPro, as seen in Figure 16 and Figure 17, shows that it is possible to create a model using a wall construction with continuous insulation that is not immediately apparent when reviewing the model. When the model is saved, the wall construction is saved. If a subsequent model is needed for a different building, it is common practice to start with an existing model and modify the design as needed. If this is done starting with the model used as the example in Figure 16, it would be a simple error to use the wall construction shown here without reviewing details of the sheathing, and thus end up with a model that has more sheathing than the designer intended. In the opinion of the authors, this is the most likely cause of the irregular insulation values seen in the CHEERS data.

Compliance Impact

The buildings modeled with excess insulation were issued building permits on the basis that they complied with Title 24, based on the results of the models. Some of these had compliance margins large enough to expect that they would have met complied with Title 24 if modeled with the correct insulation levels, but some of them had margins of less than 0.5 EDR points and would almost certainly not have complied if modeled correctly. It is not possible to determine this for each model without recreating the original models used in the permit application, which is beyond the scope of this project.

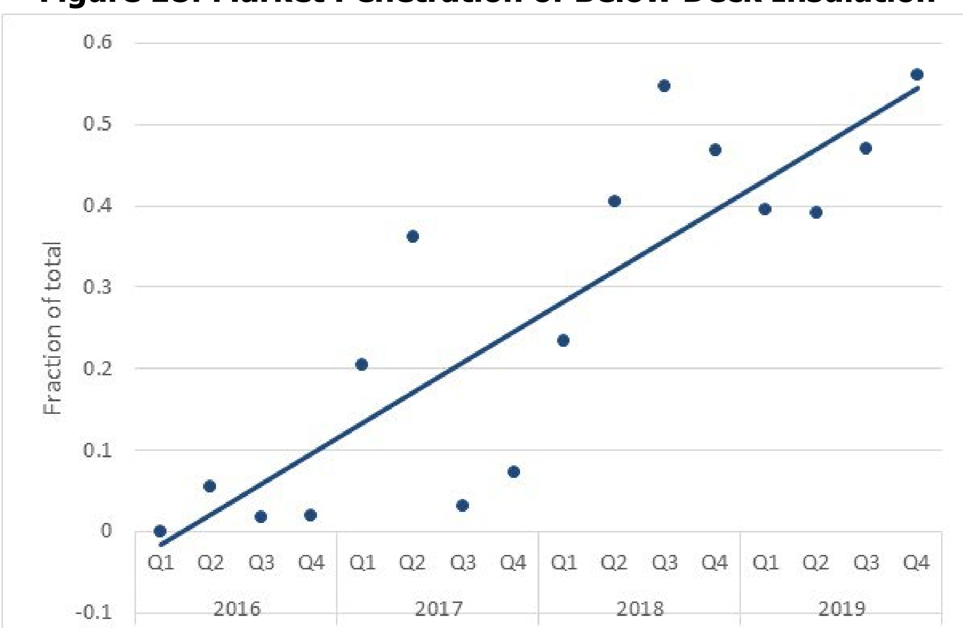
Attics

To determine the increase in market share of HPA over the course of the project, the WISE team analyzed the fraction of attics that were unvented, used spray foam insulation, or had below deck insulation.

The proportion of unvented attics remains a small fraction of the total, never rising above 5 percent over the course of this project. Similarly, the market share of spray foam insulation is small, picking up slightly in 2019, but remaining below 2 percent.

In contrast, the use of below deck insulation shows a clear increase over time from close to zero at the beginning of 2016 to approximately 50 percent at the end of 2019 (Figure 18). The below deck insulation is typically one of two types: either fitting between the roof joists or extending below them. If the insulation fits between the joists, it is likely to be an R-13 batt, which is easily attached to the joists by stapling or nailing. Once the insulation thickness is greater than the depth of the joists, the attachment method will be different, and the insulation level can be substantially increased. At the time of writing, the market is evenly split between R-13 and R-30.

Figure 18: Market Penetration of Below Deck Insulation



Source: CHEERS registry data

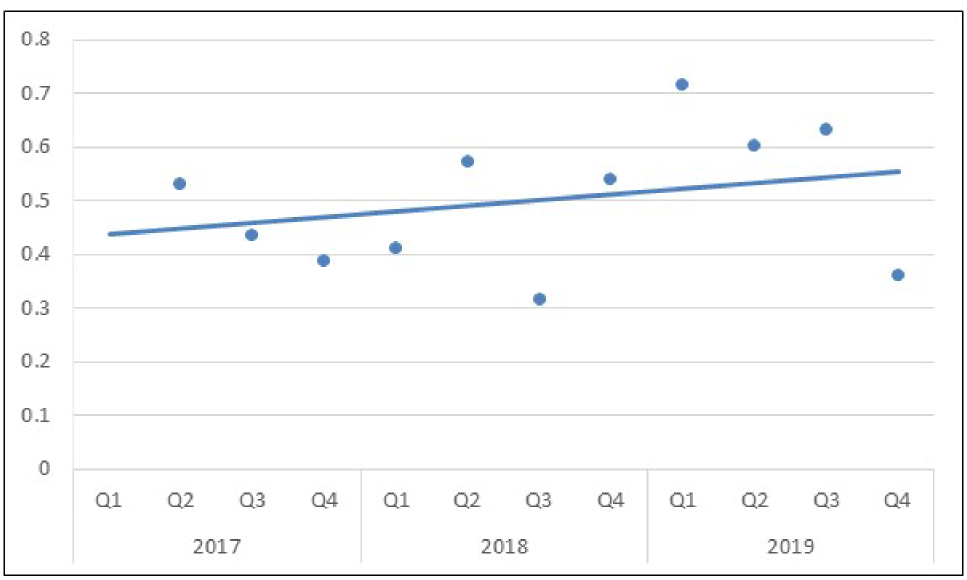
Based on the Construction Industry Research Board (CIRB) data for 2019 which show 57,000 single family permits issued, this data would indicate that some 25,000 single family homes were built using below deck insulation, compared to fewer than 1,500 in 2016

Impact of Solar Credit

The introduction of HPA and HPW as prescriptive measures in the 2016 BEES raised the energy efficiency levels required for compliance significantly and increased the price of compliance for builders. To provide additional compliance options, the 2016 BEES also included a solar credit, whereby installing a solar photovoltaic (PV) system provides a compliance credit that can be traded off against building energy efficiency. The size of the allowable trade-off varies by climate zone with Climate Zone 8 having the largest credit of 27.5 percent, meaning that a building with a PV system that meets the requirements for the trade-off could use 27.5 percent more TDV energy than one without a PV system, which would eliminate the need to use HPA and HPW to meet compliance standards. The size of the tradeoff is based on the difference in energy use between a building modeled with the 2016 prescriptive features and the same building but replacing the 2016 HPA and HPW features with the 2013 versions. From the way the solar credit is calculated, it is clear that although it can be used to trade-off any efficiency measures, the credit was explicitly intended to allow trade-offs for HPA and HPW. This credit gives builders the option to avoid changing building practices while still requiring reduced building energy use.

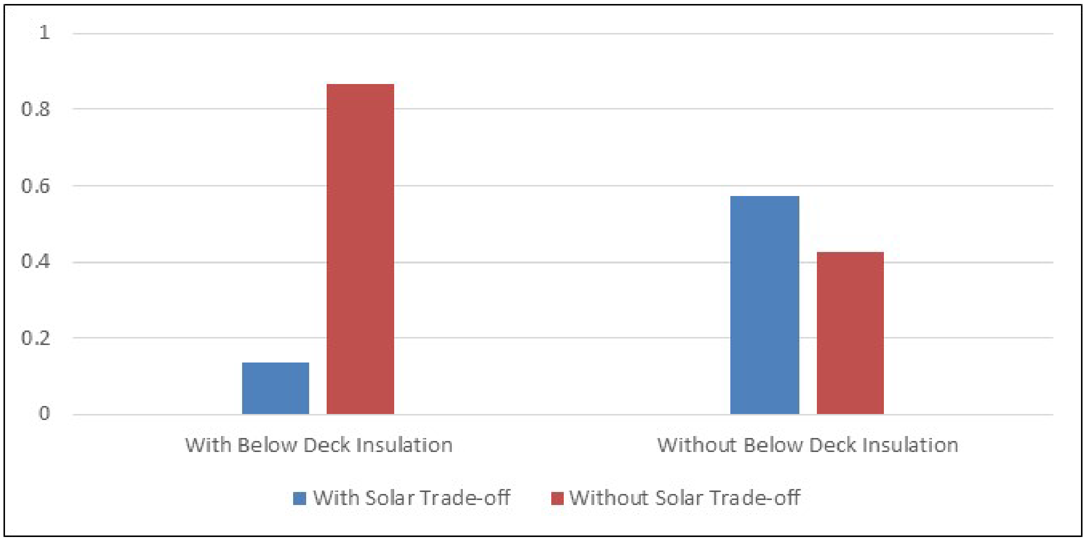
The effect of the solar credit is shown in Figure 19 and Figure 20. Figure 19 shows that the use of the solar credit during the three years from 2017 to 2019 was around 50 percent, rising slightly over time. Figure 20 compares the use of the solar trade-off in buildings with and without below deck insulation, this being the most significant method used for HPA. Buildings with below deck insulation use the solar trade-off in fewer than 20 percent of cases, whereas those without it use the trade-off in about 50 percent of cases.

Figure 19: Use of Solar Tradeoff



Source: CHEERS registry data

Figure 20: Market Share of Solar Tradeoff



Source: CHEERS registry data

Thin Triple Windows

In early 2019, CEC staff approached the WISE team to assist the HPW Collaborative in developing a market for a more-usable triple-pane window. Lawrence Berkeley National Laboratory (LBNL) had developed a window concept for a triple pane window with the center pane using thin glass (1.0 mm) developed for cell phones and TVs. This concept was called the thin triple-pane window. Figure 21 shows, from left to right, sections of traditional triple-pane, thin triple-pane, and dual-pane windows. Due to the thinness of the middle pane of glass, the thin triple-pane window is closer to the dual-pane in overall thickness, allowing it to be used in a standard depth window frame, and the thinness of the center pane reduces the weight of the insulated glass unit, meaning no additional support is needed compared to a dual pane window. The conundrum was that although it was technically feasible, builders were not asking for it and thus manufacturers did not build it. The WISE team was recruited to demonstrate how thin triples could be used in the 2016 Standards and to generate builder interest. A forum was organized by the WISE team in conjunction with CEC and LBNL staff and held at Sacramento Municipal Utility District's (SMUD) training facility in Sacramento on July 9, 2019. There were approximately 85 attendees including builders, manufacturers, window product suppliers, energy consultants, HERS raters, CEC staff, LBNL staff, utility staff, and interested parties.

Figure 21: Comparison of Triple and Dual Pane Windows

Source: California Energy Commission presentation

To determine the value of thin triple windows to builders, the WISE team modeled a single-family home and a multi-family home in both cooling dominated climate zones and milder coastal climate zones. The team first modeled a building with standard windows, then replaced the modeled windows with thin triple windows. The improved performance of the thin triple windows allowed other items to be modeled with lower cost alternatives, and the building still complied with the BEES. The lower cost alternatives allowed the savings shown in Table 3. From this, the team determined the savings per square foot of window area.

The WISE team determined that thin triple windows allowed 2019 compliance trade-offs worth $5.50 per square foot of window area in cooling climate zones and slightly more in moderate climates. Using this analysis and their internal team's review, PG&E currently offers a rebate of $5.00–$6.00 per square foot for the installation of thin triple windows. At the SMUD Forum, several window manufacturers and builders expressed interest in this window concept. PlyGem, one of the larger residential window manufacturers, started to build thin triple windows in their West Sacramento plant at the end of 2019. PlyGem has expressed interest in growing their thin triple market in new and existing construction.

Table 3: Cost Impact of Thin Triple Windows

	Savings per House	Savings per sqft Glazing
Single family		
Cooling Climate Zones	$2,967	$5.50
Coastal Climate Zones	$3,567	$6.61
Multi-family	Savings per Unit	
Cooling Climate Zones	$416	$3.19
Coastal Climate Zones	$412	$3.16

Source: Author analysis

Insulated glass units were made and windows were installed and tested in new construction single family homes. No issues were found with the window construction or installation, and PlyGem is moving to install windows permanently in several other buildings. PlyGemis offers windows with U-factors as low as 0.17, compared to the prescriptive 0.30 U-factor in the 2019 BEES. The effect of replacing the prescriptive windows with thin triple-pane windows on a representative single-family home is roughly as large as moving from a 2013 prescriptive wall to an HPW, or from a standard attic to an HPA.

Barriers and Solutions

During and after the initial forums, the WISE team discussed the issues that might limit the uptake of these measures with builders, manufacturers, installers, and other stakeholders to identify barriers and solutions. The principal barriers and potential solutions identified are discussed below.

Communication

When a builder decides to use either HPWs or attics, the implications of that decision are not necessarily communicated to all relevant parties, including purchasing departments, field supervisors, or installation subcontractors. The proposed solution is to add the use of HPW and HPA into the builder's value engineering meetings to ensure that all parties are aware of the decision and can plan accordingly among the various subcontractors. The outcome is that builders using HPWs and attics reported that communication of the issues became integrated into normal project communication practices

Sequencing

Traditionally, attic insulation is blown in as one of the final steps of a building project after mechanical systems and venting have been installed in the attic. For HPA with insulation at the roof level, insulation contractors prefer to install the insulation early in the process when the comparatively empty attic simplifies installation. This makes the subsequent installation of vents and venting more difficult without damaging the insulation. If the insulation is installed after the mechanical systems, it is considerably more difficult to ensure proper installation.

The solution to this issue involved all relevant subcontractors participating in the value engineering meeting to discuss potential installation issues and create a mutually satisfactory schedule. As with communication, when familiarity with the new practices increased this became less problematic than initially anticipated.

Incremental Costs

HPW and HPA require the use of new products and installation techniques, leading to higher material and labor costs. The solution includes reducing labor costs by educating and training installers to familiarize them with the new methods, thereby:

- Reducing installation times and lowering the possibility of poor installations.
- Reducing material costs by facilitating collaboration between manufacturer and builders to accelerate uptake of the new methods, which increases volume and reduces unit costs.

- Increasing homebuyer awareness and understanding of the impact of the new efficiency measures, thus increasing demand for efficient homes and allowing builders to recoup more of the cost.

Lot Lines

Builders typically build to the same plans on different projects and lots are laid out to ensure that minimum setbacks at the sides are met. Using HPW will often require switching from 2x4 studs to 2x6 studs, increasing the wall thickness. This will require either reducing the interior area of a given plan or increasing the width of the lot. For existing projects where the lot dimensions are fixed, a solution is to use higher density batts in wall cavities, which can improve the insulation value of the wall enough to allow 2x4 studs to be used. For future projects, increasing the lot width allowing for thicker walls would be the preferred solution. This remains an issue for current projects and has contributed to the slow rate of penetration of HPW into the market when compared to HPA.

Unfamiliarity with Requirements

Building departments have heavy workloads and little spare time to familiarize themselves with new methods. Some builders report being asked to provide engineering sign-off for walls due to the inspectors' unfamiliarity with the techniques. The solution is to provide training materials and options for onsite training to building departments. Onsite training should be ideally held at building departments offices to minimize the impact on the officials' inspection schedules.

Competing with Solar Offset

The 2016 standards allow some tradeoff between building efficiency and solar PV, which leads to many builders installing solar PV as a simpler way of complying than using HPWs or attics, a tradeoff which is made easier by the wide variety of financing options developed by the solar industry. The solution to this is to emphasize to the building trade that this tradeoff will not be possible under the 2019 standards, and that experience with HPW and HPA will provide builders with a competitive advantage under the next code cycle. The solar offset continues to be reported as the primary reason why HPA and HPW are not being used.

Insulation Installation Training

HPA and HPW involve increased levels of insulation compared to more standard attics and walls. The quality of installation of insulation is vital to its performance. A poorly designed and/or constructed thermal envelope is the leading cause of excessive energy use by space conditioning systems, resulting in high utility bills for the homeowner. One of the goals of this project was to investigate whether there was a need for a statewide training and certification program for insulation installers.

The project team conducted research with insulation manufacturers and installers and industry stakeholders, including the North American Insulation Manufacturer Association (NAIMA), Owens Corning, Knauf Insulation, and our own internal market segment experts.

Existing Certification Programs

High Performance Insulation Professionals Certification

High-Performance Insulation Professionals (HPIP) is a nonprofit organization that aims to establish a unified certification for current and prospective contractors. HPIP promotes a unified insulation certification training offering through online learning, live, in-person events and training, and accreditation of partner events and trainings. Beginning in 1989 as the Blow-in Blanket (BIB) Contractors Association, the organization first trained and supported BIBs dealers in the United States and Canada. In 2013, the organization expanded to support contractors offering a variety of high-performance systems and changed its name to HPIP. In 2017, HPIP became a 501(c)(3) and independent certifying body for the insulation industry. In 2018 alone, HPIP trained more than 2,000 individuals in partnership with the U.S. Department of Labor to meet labor needs of certified contractors across the country. HPIP partners with Owens Corning, Knauf Insulation, IDI Distributors, and Cameron Ashley Building Products, all of whom either manufacture or supply high-performance building materials.

The HPIP training program relies on these industry partnerships to deliver training specific to individual state and market needs and leverages local experts to address applicable state and national energy efficiency building code changes and requirements. Through training workshops, HPIP and its industry partners educate contractors on air leakage and sealing, energy code requirements, building science principles, blower door testing, installation practices, and various products and systems. The training includes one day of classroom instruction and a half-day of hands-on demonstration and instruction. Following the certification training, participating contractors pursue continuing education credits and must demonstrate their ongoing training through scheduled workshops, the HPIP online training system, or another accredited education course.

HPIP has partnered with ConSol to offer discounted training and certification to California insulation contractors as part of the WISE program. For these contractors, HPIP continues to provide live, in-person training workshops.

Other Market Knowledge and Resources

According to NAIMA, Owens Corning, and Knauf, there are few, if any, installation certification opportunities outside of what HPIP offers. Most manufacturers rely on their installation partners to provide local, onsite training for their staff. Manufacturers will partner with HPIP to join trainings and demonstrate proper product installation and use. While some manufacturers develop literature to accompany installation instructions, the authors were unable to confirm that any offer any additional training that would resemble the depth of material that HPIP covers through its certification offering.

CalCERTS has developed the *QII Handbook for Installers and HERS Raters* as a quality insulation installation (QII) verification resource for California's 2016 energy code. However, the document explicitly articulates that it is not a certification or training program and defers to the CEC for proper QII compliance.

The Spray Polyurethane Foam Alliance offers an insulation installation certification program due to the nature of the product and the need to essentially manufacture and properly install the product on site. Primarily, manufacturers train the contractors and contractors train their teams on site.

Training and Certification Programs as a Tool for Ensuring Insulation Quality in California

The viability of HPIP's certification training or any similar program as a tool for ensuring quality installation in California hinges on the role of QII in part 6 of the Title 24 building code. First, it is important to understand that, unlike the 2016 code, the upcoming 2019 code will include QII as prescriptive requirement that requires field verification or diagnostic testing. This change expands the need for training or certification programs beyond just installation installers or contractors to HERS raters. While installers must continue to understand and implement an installation approach that achieves QII requirements, all HERS raters must have the knowledge necessary to assess compliance with such requirements.

Under the California Statewide Utility Codes and Standards Program,[10] the 2013 and 2016 codes award compliance credits for installations that perform QII. The Standard Design assumes that builders are not performing QII, and automatically de-rates the insulation values to 70 percent of the R-value of the installed insulation. If a builder opts for QII, the modeling software will assign credit for actual insulation values (100 percent), and this triggers the requirement for HERS verification.

Because of the shift in the 2019 code to QII as a prescriptive requirement, the researchers in this project believe that the real opportunity in positioning training or certification programs as a tool for ensuring insulation quality lies with HERS raters. There are likely several HERS raters with little or no experience verifying QII. This is because previous codes positioned QII as optional, that is, buildings could meet code compliance by achieving enough performance credit to make up the difference lost from not pursuing QII. Because the 2019 code will compare all new low-rise homes to buildings that have QII in their standard T-24 budget, and because QII is the only prescriptive measure that can yield a double-digit compliance percentage, QII will be a key measure to achieving code compliance. The 2019 Alternative Compliance Manual (ACM) Reference Manual, Section 2.2.5, of the code outlines the procedure for verifying the quality of insulation installation and air leakage control used in low-rise residential buildings. The insulation installer must follow this procedure and HERS raters must verify compliance to meet the associated requirements (Sections 150.1(c) and 110.7) of the Standards. These procedures could be the basis for a rater-focused training or certification program.

At this point in California's energy efficiency timeline, training and certification programs that support HERS raters in developing the knowledge and skills necessary to verify QII will likely prove more effective at ensuring insulation quality than training or certification focused solely on high performance insulation installation and supporting contractors**.** A training program for HERS raters, offered through the same channels as other HERS training services, would complement existing insulation installation trainings, such as the program that HPIP offers, to help bridge the knowledge and experience gap that will surely exist as building practices transition to align with the more-advanced 2019 code.

[10] https://title24stakeholders.com/measures/cycle-2019/residential-quality-insulation-installation/.

Insulation installer companies typically face a great deal of employee turnover and employers hesitate to invest in training because of the low return on investment. Therefore, establishing a training curriculum that focuses on supporting HERS raters appears to be a more-effective option for ensuring the development and application of knowledge necessary to verify quality insulation installation.

Workforce Education

Expand the Training Curriculum and Program Infrastructure

Recognizing the need for a well-trained employment pool to meet the demand of home production and replace an aging labor force, the Building Industry Association responded with the Building Industry Technology Academy (BITA), a comprehensive four-year high school curriculum aimed at producing skilled professionals who will be qualified and confident to enter the homebuilding workforce.

BITA was founded in 2002 by the Building Industry Association of Southern California (BIASC), its member companies, and educational leaders. The program was acquired by the California Homebuilding Foundation (CHF) from the BIASC in 2012.

Since then, BITA has grown to a statewide initiative, providing career technical education (CTE) curricula to high schools. BITA is a joint venture between CHF and individual high schools in California. Courses are taught by high school instructors, with support and oversight provided by CHF. The BITA curriculum is supplied at no cost to participating California high schools.

From the beginning, it was the intention of the founders to see BITA expand beyond Southern California. It is the goal of CHF to carry out the original mission of the BITA program and make it a successful venture for students, schools, and industry alike by fostering a relationship between the community and the local BITA programs.

Due to the efforts and goals of the EPIC WISE initiative, the BITA program has shown strong growth over the last four years, increasing from 8 schools in 2017 to 35 schools in 2020. The bulk of the expansion was in San Bernardino County, Riverside, Orange County, San Diego, Stockton, and the Sacramento region.

High-Performance Walls and High-Performance Attics Curriculum

Part of guaranteeing program and student success is ensuring the curriculum is relevant to current industry standards and practices to prepare students with the knowledge and skills necessary to enter the workforce. The new measures for high-performance attics and high-performance walls, as a part of the CEC's goal to achieve zero net energy by 2020, is a considered a new industry standard and has been fully implemented into the existing BITA curriculum. The curriculum offers a well-rounded approach to construction training and exposure to various industry niches, but not until recently have HPA and HPW been incorporated into the lesson plans as part of this initiative.

During the 2019 spring instructor conferences held in Northern and Southern California, Brian Selby from Energy Code Ace trained BITA instructors on concepts of the new curriculum for building science, energy efficiency design, measurement verification, and HPA and HPW. The training went in-depth to educate on Title 24 Energy Standards, home envelope systems and how to deliver new concepts of building science and building practices to the BITA students. Instructors now have access to educational and industry resources as a part of their classroom and course materials. The curriculum is available in print and online.

Learning objectives for understanding building energy efficiency, codes and standards, and HPW and HPA are now embedded within the current BITA curriculum starting in year one and building on student knowledge and skills in years two and three. Each unit includes a lesson plan, teacher guides, presentation or videos, vocabulary, suggested projects or activities, and an assessment. The course curriculum is aligned with the California Construction Pathway Standards[11] and the standards of the industry, and is outlined below:

Year One

- Understand key building energy efficiency terms and measurement units.
- Describe methods of heat transfer (heat gain and loss) and ways to maintain comfortable conditions within living spaces.
- Identify basic climate zones and explain how HPA and HPW affect building energy efficiency.

Year Two

- Understand the history, intent, and benefits of California's Title 24 Part 6 Energy Standards.
- Understand how California's Title 24 Part 6 Energy Standards have evolved to meet the energy goals for residential new construction.
- Identify key strategies for meeting HPW requirements of the Title 24 Energy Standards.
- Identify key strategies for meeting the HPA requirements of the Title 24 Energy Standards.

Year Three

- Identify key insulating materials and strategies for reducing heat transfer through attics and walls.
- Describe methods for reducing building energy consumption through attic roofs and walls.

Industry Partnership Plan

The CHF provides this critical building industry support through coordination and oversight activities at BITA sites statewide to ensure program relevance, quality, and consistency. Organizations support BITA by providing work-based learning experiences and supplying students with the materials necessary to complete projects in the classroom. Through the WISE program, industry has engaged with the BITA students and instructors on the jobsite and in the classroom.

[11] https://www.cde.ca.gov/ci/ct/sf/documents/buildingconstruct.pdf (accessed 3/2/2020)

Onsite Project Visits

BITA students and instructors were invited to tour Southern California Edison's (SCE) Energy Education Centers in Irwindale to provide cutting-edge solutions to help our customers make energy-related decisions that save energy and money while helping create a smarter, safer, and reliable energy future. During the tour, HPW and HPA systems were presented as a part of the EPIC WISE expansion and training program.

Southern California Design Build Competition

In 2018, the Southern California Design Build competition committee voted to upgrade the competition plans to incorporate HPW and HPA. With support from Dahlin Group, an architecture firm, the EPIC WISE team, CHF, Reliable Lumber, and SCE, the plans were updated to demonstrate HPW framing and systems, as well as space for HPA insulation installation.

During the competition, WISE trainers were onsite to answer questions and offer technique tips to the students as they built the structure. CHF and ConSol worked with product partners, sponsors, and the Design Build team instructors to ensure a fruitful and successful event for all participants. The teams and instructors were enthusiastic and very engaged in the competition, and the event was a valuable learning experience for all involved.

Due to the overwhelming support for these upgrades and industry trainings, the Northern California Design Build competition has added a high-performance subcategory to its competition that will be introduced in 2020.

With the addition of HPW and HPA to Northern and Southern California in 2020, a total of 76 teams (or 1,140 students) over three years will have received information or training on the HPA and HPW prescriptive requirement and Title 24 BEES.

Instructor Training

BITA instructors meet biannually to share best practices, discuss updates to the curriculum, and hear from the industry on new standard practices and updated building codes. Industry can participate in these meetings to share knowledge and experience as well as network with instructors. This gives the building industry a direct link to the up-and-coming workforce. EPIC WISE trainers attended several of instructor conferences during the four-year period sharing resources and information around Title-24, HPW, and HPA, and how to incorporate the new building codes into their classroom instruction.

High Performance Walls and Attics Higher Education and Job Placement Plan

A goal of the EPIC WISE initiative was to build upon the BITA program and its curriculum to enhance job placement and higher education opportunities by connecting BITA graduates to community-colleges or four-year universities, as well as immediate job opportunities with trades responsible for building envelope construction.

Higher Education

To have a quality CTE program recognized by the California Department of Education (CDE), programs like BITA must be articulated with a community college or apprenticeship program. Nearly 60 percent of the current BITA programs have articulation agreements with their local community colleges to further their construction pathway training. Arrangements are made between instructors at the two institutions, cross walking curriculum to confirm the learning objectives are similar at each program site. Through these conversations, community colleges are becoming aware of HPA and HPW and adding the new curriculum into their course outlines, reaching students outside of the high school level.

Job Placement

CHF works with the local BIA members, manufacturers, and supplies to connect BITA graduates to employers in the industry. This is done through job fairs, word of mouth, internship programs, and working with instructors to match qualified students with specific employers based on their needs. As a result of the EPIC WISE program, CHF has identified several employers within the building envelope construction trades and will continue to work on an industry directory and webpage center that serves as a single point of contact for job-ready candidates seeking careers in these fields and the construction industry.

High-Performance Insulation Professional Certification Training

HPIP[12] offered WISE participants specialized access to training and an opportunity to become nationally certified. Insulation contractors can gain access to in-depth, online training in high-performance building techniques and installation practices, and take online exams to earn national certification. Once certified, contractors have the option to renew certification annually through continuing education as an HPIP member. Members gain full access to HPIP's extensive training library year-round, making continued education easy and affordable.

EPIC WISE and HPIP partnered on two live job site training events in California, one in October of 2018 and one in February 2019 at the first new-construction passive house in California.[13] HPIP certification was made available as an option for participants in both trainings.

Tracking

CHF has contracted with UpMetrics[14] to analyze, interpret, and learn from data to make informed decisions and build capacity. Prior to 2020, BITA student success stories and accomplishments were not systematically documented. An implementation of a student success tracking system will allow measurable data to be captured and reported.

The new database will record dates of course completion, career or college goals, demographic information, and contact information if the participant opts to be contacted with job opportunities, which will help us connect students to employers and post-secondary training programs.

Student data documentation will also measure the impact of our training and analyze post student working and instructive statistics, assisting BITA instructors in determining which training strategies are effective.

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[12] https://www.insulationtraining.org/.

[13] http://passivehousecal.org/what-passive-house.

[14] https://www.upmetrics.com/home.

Measurement and Verification

Frontier Energy was tasked with conducting an independent, third-party, unbiased measurement and verification (M&V) review of the effectiveness of workforce development training related to HPAs and advanced wall systems. The primary goal of this review is to ensure that the execution and quality of work are consistent with the training objectives.

The M&V process was originally intended to be quite extensive: conducted over a multi-year period as homes are constructed, observed, and monitored, and including measurement of temperature and humidity in attic spaces and simulation to evaluate the performance of building assemblies and whole building energy savings. However, over the course of the project the objectives were revised somewhat and transitioned to:

- Evaluate at a high level the trainings provided throughout the program.
- Assess the quality insulation processes used in a small number of building projects to identify some of the areas where builder training is particularly effective.
- Analyze data collected by the HERS registries to describe the number of jobs that are claiming QII credit and the air leakage measurements taken in homes.
- Focus on the work done by the WISE Team to advocate for Thin Triple Pane Windows and document in a case study the unique process that has resulted in rapid deployment of this emerging technology.

This section summarizes the work that was done to assess the WISE training program, the objectives of the tasks, and some of the key findings. More detail is available in the full assessment report which can be found on the project website.[15]

Training Evaluation

The objective of this task was to assess, from a high level, the training offerings, in terms of learning objectives, how well the learning objectives were achieved, and the mplications of the trainings for the building industry.

Frontier Energy staff attended four trainings, including one trade show event — a builder forum, two builder meetings, and one onsite walkthrough. In conjunction with observing these trainings, Frontier Energy staff reviewed training materials and interviewed several participants in the trainings.

Builder training is a crowded field in California but the trainings offered by the WISE program were unique in several ways:

- Outreach methodology that focused on understanding the players at key builders and working to engage with them.
- Focus with high-level decision-makers on the business case, analyzing their own plans and potential strategies, without competitors present.
- Training Title 24 consultants along with construction company executives.

[15] https://www.wisewarehouse.org/.

- Providing follow-through from builder forum to builder meeting to onsite walkthrough is a unique and effective way to maximize impact and promote deeper change.

Field Assessment of Quality of Insulation Installation

The objectives of this task were to witness attention to detail and identify areas where insulation installation quality was lacking for homes taking QII, HPA, and HPW credit.

Frontier Energy contracted with Amaro Construction to conduct site audits. The tasks included:

- Developing a checklist of components of insulation installation quality, based upon compliance inspection forms for QII in 2019 (although most of the homes were not taking credit for QII, and the 2019 version of the QII requirements were not yet in common use, this served as a valid measuring stick of quality installation).
- Developing a survey for site supervisors to gauge areas of concern in the QII, HPA, and HPW processes.
- Conducting an assessment at 7 sites, including making and documenting observations of insulation installation in homes at various stages of construction, and conducting blower door tests in completed homes where possible. All the sites inspected used the QII credit, but none used HPA or HPW. None of the builders had attended WISE trainings.

Overall, the quality of insulation installation by builders who had not attended training was higher than expected, and many of the quality measures were done well. However, there was a range of specific technical topics where improvements could be made. These topics are all covered — in more or less detail — in WISE trainings.

None of the builders whose sites were assessed had attended WISE trainings. The most commonly found deficiencies involved consistency and attention to detail. Figure 22 shows examples of such deficiencies.

Figure 22: Deficiencies in Insulation Installation

Source: Frontier Energy

On the left is an example of unevenly sprayed insulation, in the center is a missing air barrier behind a tub, and on the right inconsistent insulation around piping. Most of the specific areas where deficiencies were found were covered in WISE trainings, although this kind of attention to detail is not something that can be conveyed in a training. Onsite walkthroughs are the best way to identify these specific areas, although the other training formats can be used to convey the importance of this attention to detail. While the other training formats can be an effective way to show examples where other workers have missed the mark on installing insulation effectively, there is no substitute for showing a worker where they have missed an important detail. This highlights the importance of the onsite walkthroughs and the entire range of types of builder trainings.

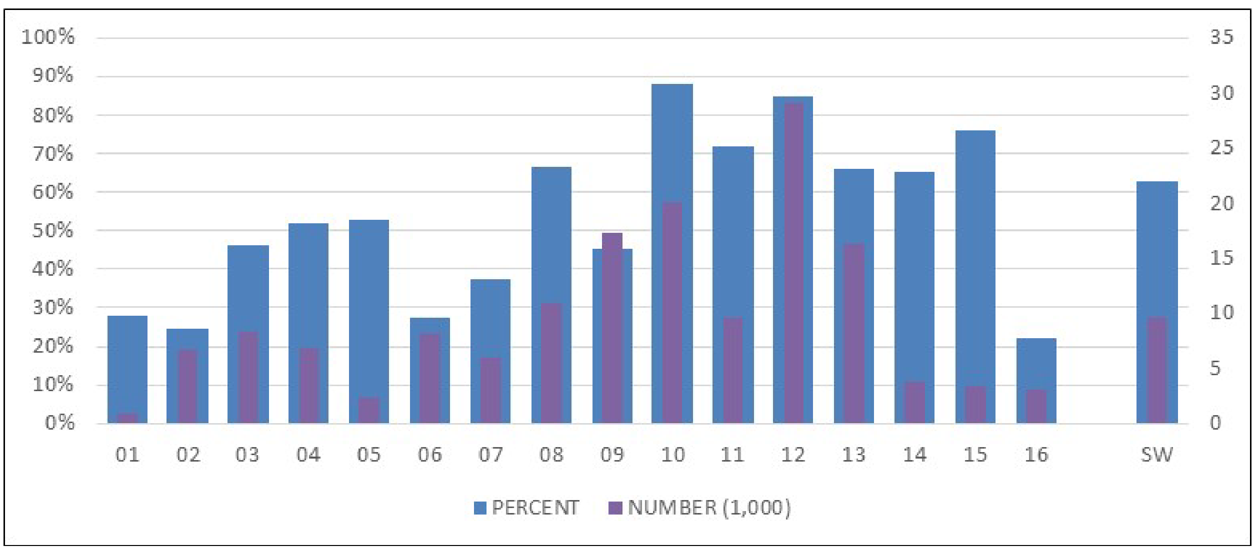
Quality Insulation Installation Registry

The objective of this task was to determine the market share for homes taking QII credit, and the measured air changes per hour (measured at 50 pascals: ACH50).

Frontier Energy obtained HERS registry data from CalCERTS and CHEERS, the two largest HERS registries, for all single-family new homes in the 2016 cycle. From these data, Frontier was able to identify how many homes in each climate zone took QII compliance credit, and what ACH50 measurements were reported.

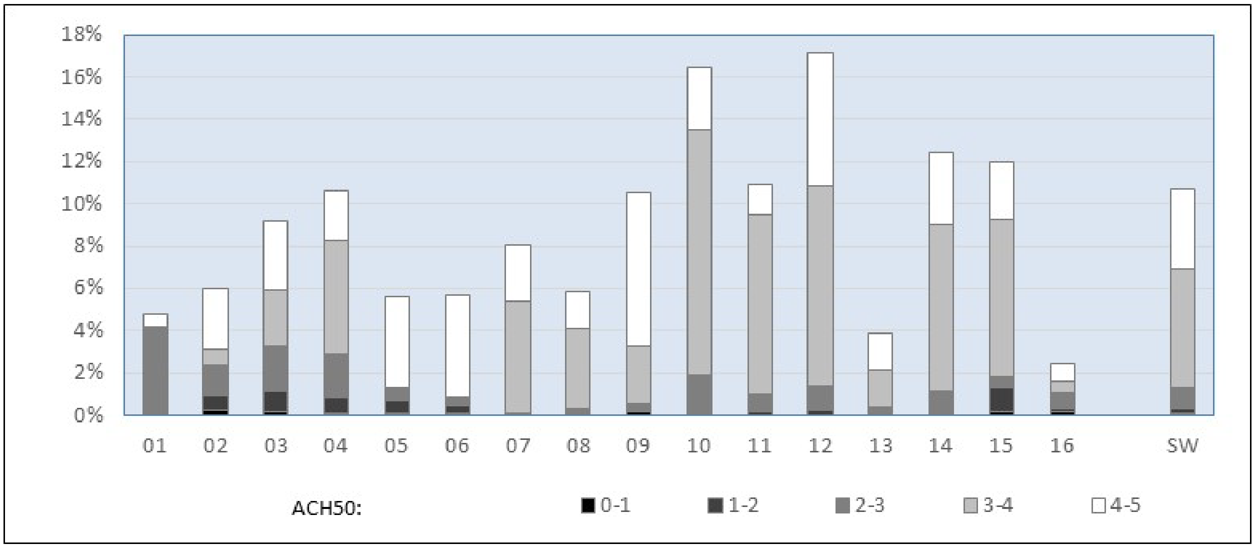
Figure 23 shows that the amount of variation in the percentage of homes taking QII credit by climate zone is surprising, ranging from 22 percent in climate zone 16 to 88 percent in climate zone 10 with an average of 63 percent. Figure 24 shows the air leakage distribution of all new homes which had measured leakage values. Statewide, the average ACH50 across all measured non-QII homes was 3.89. The average for measured QII homes was 3.68 — a 5 percent improvement over non-QII homes. The average for all measured homes was 3.70.

Figure 23: Homes Taking Quality Insulation Installation Credit



Source: Frontier Energy

Figure 24: Air Leakage Distribution



Source: Frontier Energy

Thin TriplePane Windows

The objective of this task was to focus on a significant activity of the WISE team, which was to actively promote the commercialization of thin triple-pane windows ("thin triples") and document the unique process that successfully moved an emerging technology into commercialization and deployment.

Frontier Energy accomplished this by attending two stakeholder workshops and interviewing various stakeholders to identify manufacturers who were considering manufacturing them and builders who were considering using them, and to identify market barriers and other concerns.

Some of the market barriers and concerns that were cited throughout the process were:

- Window manufacturing: Uncertainty over price and market, as well as normal uncertainties when manufacturing a new product.
- First costs: Uncertainty in price combined with the difficulty in overcoming the sticker-shock and explaining that incremental window costs are balanced by savings in construction costs in complying with Title 24.
- Constructability: Concerns about the need for construction changes, inability to include tempered glass, weight differences, should be easy to overcome.
- Information: Builders scrambling to find solutions to code change may not yet be aware of this technology.

Thin triples were in an awkward "chicken-and-egg" dilemma: manufacturers could not commit to producing them unless they had a market, and builders could not commit to purchasing and installing them unless there were already manufacturers ready to provide them. Over the course of months of interactions with the WISE team, a manufacturer decided to add production capability to its factory, a builder decided to implement the windows in upcoming jobs, and PG&E developed a limited incentive to keep the process moving.

The role of the WISE program in moving thin triples from research to production is an informative example in the diffusion of innovation and how to move a market. Some of the critical stages of that process are described in a case study, highlighting the impact that the efforts by the CEC and their contractors can have in helping an innovative new product make its way to market. The stages of engagement that were required to move the market were working with manufacturers, code changes, working with builders, bringing manufacturers and builders together, developing an incentive program, seeing first product availability, and taking the next steps. This was an excellent example of the type of support that is needed to help the suppliers and demanders of an emerging technology come to terms and begin production and installation rapidly.

CHAPTER 4: Conclusions and Recommendations

Conclusions

Over the course of the project, the market penetration of HPA has risen from near zero to approximately half of residential new construction. The market penetration of HPW has not been as significant, although the use of building methods, specifically 2x6 studs and exterior insulation, that are building blocks of HPWs has risen significantly. The use of HPA and HPW is lower than would be hoped for primarily due to the solar trade-off, which has allowed builders to trade off HPA and HPW for solar PV systems.

The training opportunities provided by the WISE team have frequently been used by builders to gather information on HPW, HPA, and code changes to inform decisions for future construction projects. The WISE team was successful in training 87 percent of the leading builders who build more than 40 percent of California new single-family housing. While most avoided HPA and HPW due to the solar trade-off, the exposure significantly increased HPA and HPW market share and made builders aware of HPA and HPW construction options. Based on conversations with builders, the research team expects the use of HPW and HPA to increase significantly from late 2020 forward as projects with submitted permit applications under the 2016 BEES are replaced by projects using the 2019 BEES, which has eliminated the solar tradeoff.

Recommendations

1. The elimination of the solar tradeoff from the 2019 BEES will undoubtedly lead to an increase in the proportion of residential new construction using HPA and HPW. Currently, 80 percent of buildings that do not use the solar tradeoff use a high-performance component. If this fraction is maintained, the researchers expect a spike in demand for trainings as those builders who have not used HPW or HPA begin to integrate them into their developments. The CEC should encourage builders to meet new energy code requirements through training programs supported by the industry.
2. As the WISE program progressed the effectiveness of the training increased when it moved from forums to the builders' offices. Future training for the introduction of new construction techniques should focus on vertical meetings within builder offices which include construction, purchasing, marketing, management, and their trade contractors.
3. The WISE warehouse receives more than 200 queries per month for information on HPA and HPW. The authors recommend that the WISE project website be maintained as a resource.
4. The use of foam sheathing is increasing due to the HPW requirement. Other construction markets use foam sheathing with significantly better R-values. The CEC should support the building industry to move from expanded polystyrene (R-3.6/inch) to polyisocyanurate (R-6/inch) to phenolic foam (R-9/inch) sheathing. This has the potential to triple the R-value of the foam sheathing per inch. The authors recommend that any continuous sheathing be included in the "required special features" section of

the CF-1R, which would lessen the possibility of a project which accidentally included sheathing being submitted. A second option would be for the HERS registries to link the CF-1R and the CF-2R so that any sheathing included in the model used to generate the CF-1R would be automatically flagged if not reported on the CF-2R. This is an issue that should be further investigated by the CEC to determine the most appropriate course of action.

CHAPTER 5: Benefits to Ratepayers

This project has delivered education and training to the building industry for the construction of HPA and HPW. The education of the building industry in construction methods for HPA and HPW offers numerous benefits, such as improved grid reliability, lower energy consumption in homes, and reduced greenhouse gas emissions. The CEC adopted HPW and HPA into the 2016 BEES. This was the first time the California building industry was introduced to HPA and HPW. Through the WISE training program, the building industry was educated in the construction techniques and construction options to achieve HPA and HPW.

Benefits of Experience and Employment

One of the largest benefits of this project is also one of the most intangible. The benefits of learning, of practice and experience are crucial to any economic transition. Market actors, like homebuilders, are generally risk-averse, seeking to maintain reliable profits as easily as possible. A significant shift in construction and procurement practices requires a significant adjustment that in turn requires time and effort. This project was designed to educate stakeholders to minimize that disruption to the extent possible and maximize the ability to share the value of lessons learned.

This project studied and provided detailed construction techniques to build HPA and HPW. The project demonstrated that the construction of HPA and HPW are well within reach and something that current builders can do, with limited support, with the technology available off the shelf today. The benefits of promoting HPW and HPA will lead to additional employment and investment in the growing area of panelized construction. A fully sheathed wall manufactured offsite in an automated factory environment provides tight joints and flush insulation elements minimizing the potential for insulation voids while maximizing cavity insulation and inherently reducing thermal conductivity. One consequence of the introduction of the prescriptive requirements for HPA and HPW in the 2016 BEES has been to influence at least one manufacturer of panelized walls, Entekra,[16] to establish production facilities in California to serve the national market.

Grid Reliability and Emissions

One of the key goals of the BEES is to increase grid reliability. In the early 2000s, California suffered a series of devastating rolling blackouts with millions of dollars in economic damage. A lasting policy change resulting from the rolling blackouts is the use of TDV to assess the effect of building energy use under Title 24, California's building energy code. The purpose of using TDV is the acknowledgment that energy used during different times of the day has a different value. The cause of the summer peak is residential air conditioning. HPAs reduce attic temperature during the summer peak season from 135 degrees to 80-85 degrees depending on installation technique. By significantly cooling attics, HPAs reduce summer peak load, thus

[16] www.entekra.com.

leading to greater grid reliability. In addition to reducing peak load, the use of HPA and HPW in new construction leads to a reduction in energy use compared to similar buildings built with traditional attics and walls. This reduction leads to reduced emissions and contributes to meeting California's goal of carbon neutrality.

LIST OF ACRONYMS

Term	Definition
ACM	Alternative Compliance Manual
BEES	Building Energy Efficiency Standards
BIA	Building Industry Association
BIASC	Building Industry Association of Southern California
BIB	Blow-in Blanket
BITA	Building Industry Technology Academy
CBIA	California Building Industry Association
CDE	California Department of Education
CEC	California Energy Commission
CHEERS	ConSol Home Energy Efficiency Rating Services
CHF	California Homebuilding Foundation
CIRB	Construction Industry Research Board
CTE	Career Technical Education
EPIC	Electric Program Investment Charge
HERS	Home Energy Rating System
HPA	High Performance Attics
HPIP	High-Performance Insulation Professionals
HPW	High Performance Walls
HVAC	Heating, Ventilation and Air Conditioning
IOC	Inches on Center
LBNL	Lawrence Berkeley National Laboratory
MSA	Metropolitan Statistical Area
M&V	Measurement and Verification
NAIMA	North American Insulation Manufacturer Association
PG&E	Pacific Gas and Electric
PV	Photovoltaic
QII	Quality Installation Insulation
SCE	Southern California Edison’s

Term	Definition
SMUD	Sacramento Municipal Utility District's
TDV	Time Dependent Valuation
WISE	Workforce Instruction for Standards and Efficiency
2x4	A common wall stud size used in residential construction. Nominally 2 inches by 4 inches in cross-section, actually 1.5 inches by 3.5 inches
2x6	A common wall stud size used in residential construction. Nominally 2 inches by 6 inches in cross-section, actually 1.5 inches by 5.5 inches