



Opinion **Dynamics**

# Barriers to Incorporating Passive House Concepts in Residential New Construction

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## Executive Summary

This white paper presents findings from a research effort to identify barriers to, and opportunities for, incorporating Passive House (PH) principles into California's Energy Code. Opinion Dynamics conducted a literature review and interviews with 16 subject matter experts in PH principles, beyond-code programming, and residential new construction to identify such barriers and opportunities.

Several organizations promote PH in the US. The momentum behind PH has given rise to an entire industry with PH training and certification programs for designers, consultants, builders, raters, and verifiers. More widespread application of PH construction principles has the potential to reduce buildings' energy use and help California meet its greenhouse gas reduction goals. At the same time, there are a variety of market, economic, and regulatory barriers that make codification of PH principles a challenge.

## Barriers

Key barriers to incorporating PH principles into California's building code include:

- **Limited building industry awareness, knowledge, and training.** Builders have limited awareness and knowledge of PH principles and how they impact building design and construction, partially stemming from the limited interaction between PH and non-PH practitioners. Builders tend to resist changes in building practices—particularly to changes in long-standing building practices. Additional market effects remove incentives for builders to pursue energy efficiency buildings, such as the falling cost of solar energy and homebuyers' apparent satisfaction with code-built homes.
- **Builders reluctance to design airtight building envelopes.** PH requires an extremely airtight building envelope. Outside of PH practitioners, new construction professionals (both production and custom builders) are reportedly very concerned with the airtightness of newly constructed homes. Builders are reluctant to construct airtight building envelopes due to: (1) past issues with mold and moisture problems; and, (2) a lack of understanding of building science and PH principles.
- **Limitations or Drawbacks of PH:** Other aspects of PH principles may make code developers reluctant to pursue their inclusion in code. One reason is that a building constructed with PH principles cannot curb the energy demand of unregulated plug loads. The building occupants may plug in and run a variety of devices that can increase the buildings' energy use intensity despite the tight and well-insulated envelope. Also, interviewees emphasized that PH principles translate to thicker walls, which means land plots will need to be bigger if the interior conditioned space is to remain the same. The high cost of land and development in California means planners and builders want to maximize livable, conditioned space on available land plots and may resist calls for thicker walls.
- **Code development and update processes.** The incremental California code adoption process—with a new code cycle instituted every three years—brings a lot of uncertainty as to what the next code change/cycle might mean. If a long-term goal was established, the argument is that builders would have a good idea of where they are eventually going to have to get and can plan accordingly. The code process also requires each component to pass a cost-effectiveness test in isolation. PH principles are inherently holistic and leverage the interactive effects among building

components producing tradeoffs and benefits that cannot be captured by the current approach.

- **Complying with Code:** Builders may use one of two pathways to energy code compliance. Nearly all meet code by improving efficiencies of heating, cooling, and water heating equipment instead of improving envelope tightness, perpetuating their unfamiliarity with tight envelopes. The flexibility of the performance approach to compliance appears to come at the expense of enhancements to envelope measures frequently. Builders and tradespeople are gaining little experience with efficient envelopes given their low usage of the prescriptive path, presenting a barrier to improvements in envelope measures in the market. Since the backbone of PH is the building envelope, the use of the performance path is counter to the central theme of PH: super insulated structure, few thermal breaks, and very low infiltration.

## Opportunities

The Utilities could play a role in transforming the market by sponsoring initiatives such as:

- **Demonstrations and Public Education.** Given the lack of familiarity, it is important to demonstrate the various energy efficiency attributes and features of PH structures. Locally built PH structures present opportunities to promote PH to builders and the general public through demonstration homes or case studies. Featuring these homes can address cost-effectiveness and airtightness concerns while highlighting their comfort benefits, GHG reductions, and benefits to the electric grid.
- **Grid-impact research.** With more renewable energy coming onto the grid, when consumers use energy impacts the cost of its delivery. The reduced energy use in PH buildings can lower energy peaks and transmission and distribution costs. GHG reductions and grid cost savings need to be studied to understand the value of any savings to the grid from PH buildings.
- **Workforce education and training.** A myriad of individuals and organizations will benefit from PH education and training. This includes policymakers, code officials, building inspectors, builders/developers, architects, and building tradespeople. The utilities could continue to subsidize PH courses to promote a variety of skills and services related to PH practices. Courses should be available for policymakers, code officials, building inspectors, builders/developers, architects, and building tradespeople to generate a critical mass of trained professionals.
- **Incentives.** Incentives can close the initial increased cost gap associated with PH construction and increase the number of potential demonstration sites available. Incentives could support workforce development or be available for frequently included equipment in PH structures, such as heat recovery ventilators. Incentive can also be based on energy savings over a code-compliant structure. Interviewees also recommended that utility programs with a whole-building approach incentivize high-performance attics and walls to increase builder familiarity with them.
- **Energy Code.** Interviewees also pointed to opportunities to adjust the energy code to reflect PH principles through managing thermal heat gain and reducing cooling loads. They suggested 1) increasing thermal mass on west- and south-facing walls to absorb afternoon heat; 2) orienting rooms not often used during the hottest part of the day to face west or south; and 3) using overhangs and shading to minimize heat gain. In addition, establishing an alternative code compliance pathway that uses PH

principles can lead to more PH buildings, demonstrating it can be done cost-effectively, and facilitating builder familiarity with those construction practices, as has been done in Vancouver, British Columbia, Canada.

## **Conclusion**

In conclusion, lack of builder familiarity and component-based cost-effectiveness tests limit support for code changes that incorporate PH principles. The Utilities, CEC, and CPUC should consider if providing pathways to pursue PH practices and meet building energy codes will help in achieving California's greenhouse gas reduction goals. If PH is incorporated into code, more PH buildings will be built, builders will gain familiarity with tight envelopes, homebuyers will see PH homes in their communities, all of which ultimately support market transformation.

## 1. Introduction

The objective of this whitepaper is to explore barriers to the inclusion of Passive House (PH) design concepts and requirements within residential new construction programs and building energy efficiency standards in California. Toward this goal, the research team interviewed 16 subject matter experts (SMEs) in PH principles, beyond-code programming, and residential new construction, as well as conducted a literature review of relevant articles, whitepapers, and conference proceedings. The primary purpose of the literature review and interviews was to understand the barriers that PH principles (including design and construction) face when seeking to gain traction within residential new construction. We hope that a clear articulation of these barriers will help policymakers understand the issues that may arise during the consideration of PH principles for inclusion in mainstream construction practices and associated code development.

In this paper, we review the current status of the California Energy Code, the PH history, and the currently available certification for passive houses in California. Then we take a deep dive into the barriers to incorporating PH principles into the Energy Code. After that, we describe some successful approaches to updating code with PH principles from Minnesota, New York, and Canada. Finally, we end with opportunities for the California utilities to help advance PH principles in the construction industry and the incorporation of key PH elements into the California Energy Code.

## 2. Background

To set the stage for this whitepaper, we discuss the California Building Energy Efficiency Standards, the history of the PH movement, the definition of PH, and PH in California in the following section.

### 2.1 California Building Energy Efficiency Standards

The 2019 California Energy Code (Title-24, Part 6; Building Efficiency Standards) will go into effect on January 1, 2020, replacing the 2016 code. The California Energy Commission (CEC) estimates that new single-family homes will use about 7% less energy when built under the 2019 Code compared to the 2016 Code. When factoring in required photovoltaics (PV), a single-family home built under the 2019 Code will use about 53% less energy than under the 2016 Code.<sup>1</sup> Notably, the 2019 Code increases energy efficiency while encouraging demand-responsive, grid harmonizing technologies (such as battery storage and grid-connected heat pump water heaters) and improves the building's thermal envelope through high-performance attics, walls, and windows to improve comfort and energy savings.

### 2.2 Passive House History

Several information sources define and explain PH concepts, design principles, and requirements. There are two passive house organizations who have similar goals and principles—the Passive House Institute (PHI) and the Passive House Institute US (PHIUS). According to Passipedia, an online Passive House Resource provided by the PHI, underlying scientific principles used in many parts of the globe were synthesized and codified into the term that now describes the high-performance building

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<sup>1</sup> California Energy Commission Efficiency Division. (March 2018). 2019 Building Energy Efficiency Standards FAQ. Retrieved from: [https://ww2.energy.ca.gov/title24/2019standards/documents/2018\\_Title\\_24\\_2019\\_Building\\_Standards\\_FAQ.pdf](https://ww2.energy.ca.gov/title24/2019standards/documents/2018_Title_24_2019_Building_Standards_FAQ.pdf)

philosophy, methodology, and certification globally referred to as Passive House (or Passivhaus). The codification of the methodology and certification was developed in Germany in the early 1990s by Professors Bo Adamson of Sweden and Wolfgang Feist of Germany. In 1996, Dr. Feist founded the Passivhaus Institut (Darmstadt, Germany) to develop and promote the PH standard using the Passive House Planning Package (PHPP) energy modeling software. It is important to note that PH principles do not—as potentially implied by the term “house”—solely apply to single-family homes. Rather, the original German word “Haus” should be construed as a more global term, extending to multi-family and commercial buildings as well.

The second main organization advancing PH principles is the Passive House Institute US, Inc. (PHIUS). PHIUS roots trace back to 2003, when Katrin Klingenberg designed and built her own passive house residence in Urbana, Illinois.<sup>2</sup> This was the first passive house built in the U.S.<sup>3</sup> Her experience led her to co-found e-ecological Construction Laboratory (e-colab) with builder Mike Kernagis in 2003.<sup>4</sup> As interest in passive house building grew in North America, Klingenberg and Kernagis oversaw the expansion of e-colab into PHIUS in 2007.<sup>5</sup> North American building scientists and builders with funding from the U.S. Department of Energy (DOE) and the Canadian government were the first to pioneer passive building principles in the 1970s. In the late 1980s the German Passivhaus Institut (PHI) built on that research and those principles and developed a quantifiable performance standard that continues to work well in the Central European and similar climate zones. However, in practice, the PHIUS Technical Committee, Passive House Alliance US (PHAUS) members, and project teams building projects in North America learned that a single standard for all North American climate zones is unworkable. In some climates, meeting the standard is cost prohibitive, in other milder zones it's possible to hit the European standard while leaving substantial cost-effective energy savings unrealized.

As such, in cooperation with Building Science Corporation under a U.S. DOE Building America Grant, the PHIUS Technical Committee developed passive building standards that account for the broad range of climate conditions, market conditions, and other variables in North American climate zones. The result was the PHIUS+ 2015 Passive Building Standard–North America, which was released in March of 2015. PHIUS collaborated with Fraunhofer IBP and Owens Corning to develop WUFI Passive, a family of software modeling products that support the PHIUS project certification.

There are at least 15 certified PH buildings in California at the time of this writing, according to the Passive House Institute US (PHIUS).<sup>6</sup> They include both single-family and multi-family and represent a mix of new construction and retrofit projects. The momentum behind PH has given rise to numerous PH organizations, including PHIUS, PHI, the North American Passive House Network, as well as state- and regional-level PH advocacy organizations. An entire industry has developed in the US that includes PH training and certification programs for designers, consultants, builders, raters, and verifiers. There are 14 certified PH builders in California.<sup>7</sup>

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<sup>2</sup> Passive House Institute US. (2019). Retrieved from <https://www.phius.org/about/mission-history>

<sup>3</sup> Passive House Institute US. (2019). PHIUS Milestones. Retrieved from: <https://www.phius.org/about-passive-house-institute-us/phius-milestones>

<sup>4</sup> Passive House Institute US. (2019). Retrieved from <https://www.phius.org/about/mission-history>

<sup>5</sup> Ibid.

<sup>6</sup> Passive House Institute US. (2019). Certified Projects Database. Retrieved from: <https://www.phius.org/phius-certification-for-buildings-products/certified-projects-database?sort=%60Projects%60.%60Stateld%60+ASC>

<sup>7</sup> Passive House Institute US. (2019). Find a PHIUS Certified Builder. Retrieved from: <https://www.phius.org/find-a-professional/find-a-phius-certified-builder#C>

## 2.3 Passive House Definition

A PH is a very well insulated, virtually airtight building that is primarily heated by passive solar gains and internal heat gains from cooking, bathing, electrical equipment, etc. Control of summer heat through shading, window orientation, and passive ventilation helps to limit the cooling load. A smaller source can provide for the remaining minimized heating or cooling demand, rather than a larger conventional HVAC system. For most climates, a heat or energy recovery ventilator will provide a constant supply of tempered, filtered fresh air. Using this ‘fresh air’ system not only saves space conditioning costs by ‘recycling’ indoor energy but also provides premium indoor air quality and consistent comfort.”<sup>8</sup>

Passive House California (PHCA) promotes PH. PHCA is a membership organization with a mission “to promote awareness, understanding, and application of the PH standard through education, events, and advocacy – focused on professionals and policymakers throughout California.”<sup>9</sup> The PHCA website defines PH as “a building standard that relies on a combination of energy efficiency with passive solar and internal heat gains to dramatically reduce space heating demands and allow for simplified methods of providing needed heat.”

According to PHCA, the concept is implemented through stringent performance standards for airtightness and energy consumption and verified with the PHPP software.<sup>10</sup> The energy consumption limits are developed through extensive research on climate change imperatives, economic feasibility, building durability, occupant comfort, and indoor air quality. PHCA and PHIUS identify the following key attributes of the design approach:

- Accurate climate- and site-specific energy modeling with PHPP;
- Superinsulation;
- Minimization of thermal bridges (“short cuts” for heat loss);
- High-performance windows and doors;
- Optimized passive solar design (solar gain in winter, shading in summer); and,
- Airtight shell with mechanical heat recovery ventilation (in typical heating-dominated climates in the U.S, these units can “recycle” 8-15 times the energy used for ventilation).

## 2.4 Passive House Certification in California

While the PH description and attributes provided in the previous section are instructive in helping understand the basic principles and concepts behind a PH, they are not actual performance standards. There are two PH certification programs—PHI and PHIUS. These certification programs have similar goals but are different programs with different energy targets and tools. It is interesting to note that the Passive House California website promotes the PHI certification program. It does not mention the PHIUS program.

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<sup>8</sup> Passive House California. (2018). Passive House Concept & Design Approach. Retrieved from: <http://www.passivehousecal.org/design>

<sup>9</sup> Passive House California. (2018). Mission Statement. Retrieved from: <http://www.passivehousecal.org/passive-buildings-california-committees>

<sup>10</sup> Passive House California. (2018). Retrieved from: <http://www.passivehousecal.org/performance-criteria-certification>

## Performance Criteria for PHI

- Maximum Heating or Cooling Energy: 15 kWh/m<sup>2</sup> (1.4 kWh/ft<sup>2</sup> or 4.75 kBtu/ft<sup>2</sup>) per year
- Maximum Total Source Energy: 120 kWh/m<sup>2</sup> (11 kWh/ft<sup>2</sup> or 38 kBtu/ft<sup>2</sup>) per year (All energy used in the building includes: heating and cooling, hot water, appliances, lighting, and plug loads. Source Energy includes the energy required to produce and deliver the energy to the site and offset with solar thermal. Photovoltaics cannot be included in source energy offset calculations)
- Maximum Air Leakage: 0.6 air changes per hour (ACH) at 50 Pascals (ACH50), ~0.03 ACHNAT

## Certification Process for PHI

- Accurate compliance modeling with PHPP
- Third-party verified blower door test
- Record of adjustment of ventilation system
- Declaration of Construction Supervisor
- Photographic documentation

Compliance modeling is a key aspect of the PHCA certification process, and PHPP is specified as the planning/modeling tool that must be used for PHCA certification. Documentation of the above must be submitted to a PH-approved third-party certifier to receive certification.

As mentioned above, the PHIUS employs a different modeling software that has varying energy targets based on climate and building type. The PHIUS+ Certification Program combines a thorough passive house design verification protocol with a stringent Quality Assurance/Quality Control (QA/QC) program performed onsite by highly skilled and specialized PHIUS+ Raters and Verifiers. The testing requirements of PHIUS+ align with DOE and EnergyStar programs.

## 3. Methods

We interviewed a wide range of professionals, both within and outside of California, who are considered experts in PH design concepts and residential new construction. The interviews were designed to capture each individual's knowledge of and attitude toward PH concepts. More importantly, we asked interviewees about the barriers to the inclusion of PH design principles, concepts, and standards in residential new construction codes and practices. We also asked interviewees how PH concepts might be introduced into future new construction programs, practices, or codes, and the logical order of introduction.

We started with a list of seven individuals to interview and then used a snowball method, identifying further candidates by asking each interviewee for recommendations of other SMEs we should interview. We ultimately interviewed 16 SMEs. Many of these individuals directly provided or steered the research team toward relevant publications, case studies, and related materials that we included in our literature review.

The interviewed SMEs represented viewpoints from a breadth of stakeholders knowledgeable about PH construction techniques, the California energy code, and the California policy context (Table 1). The

building professionals were experienced with Passive House homes or Zero Net Energy buildings and included builders, architects, mechanical engineers, and energy analysts. The Energy Consultants advise policymakers, developers, and builders on energy-saving technologies and PH standards. The representatives from the California Energy Commission included Technical Leads and Advisors working on the Building Energy Efficiency Standards. Three SMEs had leading roles in PH advocacy organizations in California and North America. The representative from a California Investor Owned Utility led a new construction program, and finally, two people were owners of PH-certified homes in California.

Table 1. Expertise of Interviewed SMEs\*

Organization or Expertise	Number of SMEs
Building Professionals	6
Energy Consultants	5
California Energy Commission	4
Director of a PH Advocacy Group	3
PH Homeowner	2
Investor-Owned Utility	1

\*Total does not add to 16 because four people fit multiple roles.

The purpose of a literature review is to describe, summarize, synthesize, and analyze the literature that exists related to a topic area. In addition to the interviewee-directed literature, we also reviewed relevant articles, whitepapers, and conference proceedings to see what challenges to incorporating PH principles into already identified energy codes. Thus, this report represents a synthesis of information obtained directly from interviewees and pertinent literature.

## 4. Barriers to Incorporating Passive House Concepts in Codes

The primary purpose of the research was to identify, explore, and describe the various barriers to including PH design concepts and standards in future code changes or reach codes, as well as opportunities to do so. Given the number of barriers identified, we created categories that encompass several barriers. While the categories outlined below, and the barriers classified within them, may have room for improvement, we think they are a useful way to organize key findings.

### Category 1: Barriers Common to Innovation

The barriers within this category might be similar to the barriers one might expect to see around any new idea or innovation. One might state that these barriers are “to be expected” or “typical” and, therefore, in some ways not unique to PH. Nonetheless, we describe each in some detail here:

- **Lack of Awareness.** Both those involved in the promulgation of California building codes and standards, and those involved in the production and custom building industries, are, for the most part, reportedly unaware of PH. Outside of SMEs who are directly involved in PH, there appears to be little awareness of PH principles and how they impact design, construction, and certification of newly constructed buildings.
- **Lack of Knowledge.** Given the lack of awareness of PH, it follows that non-PH practitioners have limited to no knowledge of PH principles and how they impact building design and construction.

- **Lack of Skills and Training.** PH practitioners frequently mentioned the lack of tradespeople who have the skills and training needed to construct a PH building. Many suggested that such training can be gained through hands-on learning on PH projects. Additionally, many of the PH practitioners we interviewed said that contractors, and their associated subcontractors, can gain the necessary skillset after working on three or four PH buildings. After that, many said that tradespeople both understand and show significant interest in PH design and construction. In short, the learning curve was reported to be relatively quick.
- **Resistance to Change.** Nearly all interviewees said there is a fundamental resistance to change across the building industry—particularly to changes in long-standing building practices. Interviewees reported that this resistance occurs at all levels, from tradespeople (and, in some cases, their unions) to builders and developers. This reported resistance to change was often talked about as something to expect in any industry where innovation and new ideas are being formulated. Beyond this general overarching categorization, there are several specific areas of resistance to PH concepts and principles that we discuss more fully in the sub-sections that follow. One PH advocate said rather than resistance to change, it might be best to label this issue as “fear of the unknown,” which effectively captures many of the barriers listed in this subsection.
- **Homebuyers do not Prioritize Energy Efficiency.** Several interviewees readily acknowledged the point that “current newly constructed homes sell” and that homebuyers do not understand (nor, in many cases, care) about energy efficiency features. Homebuyers focus on curb appeal and other amenities such as appliances, countertops, and cabinetry, for example. Given this, the argument is that there is little incentive for the building industry to embrace significant shifts toward ever-higher levels of energy efficiency.

## Category 2: Barriers Related to Builders’ Reluctance to Make Buildings Tight

The barriers within this category are related to problems caused by previous construction standards or building techniques, whether real or perceived. It is probably fair to say that many of these problems were not very prevalent across all newly constructed homes in the past. However, when they did occur, they reportedly received a significant amount of publicity and associated discussion within and outside of the building industry. Thus, builders and other construction professionals reportedly have taken an extremely cautious approach to any change in practice related to making buildings better insulated and more air-tight. It is notable, upfront, that many of the PH practitioners’ we interviewed stated that sound building science was not prevalent 20 to 30 years ago and has now, in their opinion, sufficiently addressed these moisture and mold issues. That said, most also readily acknowledged that past problems had a lingering and negative impact that persists among many builders today that limit their willingness to pursue energy efficiency.

- **A Desire to Control Moisture, Mold, and Construction Defects.** PH requires an extremely airtight building envelope. Combined with superinsulation, this approach reduces temperature variation, which also prevents condensation and mold issues. Most interviewees agreed that past mold and moisture problems likely occurred on a small percentage of buildings but asserted that they had had a lingering impact on production and custom builder’s willingness to take significant steps toward better insulated and more air-tight structures. PH advocates consistently said that PH’s

focus on sound building science principles controls humidity and moisture and thus avoids poor outcomes such as mold. They also said builders' concerns about airtightness stem from a lack of understanding of building science in some cases, and PH principles and design in nearly all cases. Overcoming builders' concerns about moisture, mold, and construction defects represent a substantial challenge.

High-performance attics, which is a prescriptive measure under both 2016 and 2019 Title-24 code, is one such area of concern. Builders are reportedly concerned that both above- and below-deck insulation, for example, could lead to moisture build-up, mold, and potential construction defects. Similar concerns—though not as acute—reportedly exists with high-performance walls, which are also a 2016 and 2019 Title-24 prescriptive measure. Reportedly, the CEC has gone to great lengths to research and address this concern, toward the goal of gaining the California Building Industry Association's (and associated builder) confidence that moisture, mold, and construction defects will not result from the higher wall and attic efficiency standards.

- **Concerns about Air Tightness.** Outside of PH practitioners, new construction professionals (both production and custom builders) are reportedly very concerned with the airtightness of newly constructed homes. In particular, possible off-gassing, poor indoor air quality, and the associated potential liability is reportedly concerning.<sup>11</sup> Thus, any conversation about increased airtightness is an immediate red flag for many members of the building industry.

PH advocates argue that such concerns are misplaced because sound building science and PH design directly address this issue. The extremely airtight PH structure (0.6 air changes per hour at 50 pascals [.06 ACH50] requirement) coupled with a mechanical ventilation system ensures excellent indoor air quality. In addition, the PH requirements, based on sound building science principles, ensure that moisture migration can happen within building assemblies. Several PH professionals indicated that the indoor air quality within PH structures is far better than the indoor air quality of conventionally built homes for a couple of reasons. First, because continuous mechanical ventilation is required, which ensures constantly and consistently supplied fresh air. Second, indoor air quality is specifically addressed—and often measured—during the certification process.

Notably, several SMEs stated that the “general consensus” is that the ACH within most newly constructed homes in California falls in the range of 4 to 5 ACH50. This compares to the PH standard of 0.6 ACH50. Reportedly, there is a significant proportion of builders who do not want blower door testing (i.e., ACH measurement) performed on their homes because they view any discussion of airtightness and its measurement as providing information that can be used in potential lawsuits. On top of this, as will be discussed later in this report, staff involved in code development at the California Energy Commission (CEC) seem to agree that construction standards that would result in an ACH50 below 4 are not cost-effective. Similarly, several interviewees with PH experience said they think PH puts too much emphasis on airtightness, especially in mild or dry climate zones. Thus, on this issue alone, there

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<sup>11</sup> Off-gassing refers to the release of volatile organic compounds (VOCs) and other chemicals from new, manufactured items in homes and buildings. Common contributors to off-gassing include internal furnishings such as cabinets, tables, couches, mattresses, carpeting, and vinyl flooring. Off-gassing can also come from other building materials such as particleboard, plywood, drywall, and insulation.

appears to be a fundamental level of disagreement between PH advocates and CEC code developers on the value and cost-effectiveness of achieving high degrees of airtightness.

- **Perception that Tight Buildings Compromise Indoor Air Quality.** Closely associated with airtightness is a reported concern among many production and custom builders around indoor air quality. Such concerns include off-gassing of appliances, carpeting, drywall, and other building materials. Many reportedly believe that overly airtight structures compromise indoor air quality. In response, PH advocates stated that mechanical ventilation via heat recovery ventilators provide constant and consistent fresh air to a home relegating concerns around indoor air quality moot.
- **Preference to Pursue the “Pretty Good House.”** Several interviewees mentioned their support for the “pretty good house.” While not specifically related to airtightness, we include it in this category of barriers, as it suggests that there should be realistic limits in the pursuit of energy efficiency. The basic concept is that PH certification is expensive and difficult, while environmental goals may be met more cost-effectively with renewable energy. However, cost-effectiveness (as we address later in this report) is often in the eye of the beholder and not always well defined.

Some environmentalists consider the installation of solar panels (perhaps in lieu of efficiency gains) to be an environmentally responsible behavior. Thus, their narrative is that one should not be asked to become fully energy efficient if they are offsetting their electrical use with PV. This debate becomes more complex as the cost of PV continues to decline; the favorable economics may tilt toward PV over efficiency improvements. Similar to the concept of cost-effectiveness, the definition of “favorable economics” varies from person-to-person and often goes undefined.

## 4.1 Category 3: Barriers Related to the Cost of Development and Construction

The barriers within this category are related to perceptions that PH and PH-related design principles and construction standards will increase the cost of development and related construction of single- and multi-family buildings.

- **Split Incentives Reduces Builder Motivation to Pursue Energy Efficiency.** Several interviewees discussed the barrier of split incentives—especially in the production building and spec home environment.<sup>12</sup> The issue here is that builders/developers are not the ultimate occupant of the home and, therefore, long-term energy bills are of less concern to them. The general feeling reported by interviewees was that builders/developers would show more concern for future energy costs if they were responsible for paying them.
- **Cost of Land and Development.** The cost of acquiring land in California and meeting all the necessary standards and approvals needed for development are substantial. Thus, each plot of land approved for development is treated as an extremely valuable resource. As a result, very precise planning is done with respect to the placement of homes, buildings, and other structures—such that all requirements are met, and the

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<sup>12</sup> Spec home refers to a home that a builder constructs without an identified buyer. Thus, the builder is speculating that the home he/she is building will appeal to potential buyers and be sold upon completion (or, in some cases, at some point in the construction process).

number of buildings is maximized. For example, residential lot lines are set with a very keen understanding of the specific structure that will be built. This approach enables the home to be placed on the smallest lot possible as defined by the smallest distance, or setback, from the neighboring structure or lot line. Changes in building codes, such as those that require high performance walls, result in less conditioned floor space unless the overall building footprint is expanded.<sup>13</sup> Some energy efficiency upgrades then, translate to the need for larger lots (i.e., fewer total lots), if the amount of conditioned floor space is to be maintained.

- **Higher Upfront Cost of Construction.** All but a few interviewees agreed that PH costs more upfront. Among those who ventured an estimate, the increased cost reportedly ranged from 2% to as much as 20%. Notably, however, a few individuals said that PH does not cost more to design and construct than a code-built building. Drivers of the increased cost range from the cost of materials (e.g., more thermal mass/insulation, energy or heat recovery ventilators, triple-pane windows), to practices (e.g., labor dedicated to reducing thermal bridging, proper installation of windows/doors), to the planning, design, and approval process (e.g., design work with PHPP software, construction oversight)—including the cost of final inspections, blower door testing, and certification. A few interviewees pointed out that cost savings in some areas (e.g., need for smaller or no conventional HVAC system) helps offset some of the cost increase.

Our literature review found increased upfront cost estimates in the 8-10 percent range. The PH International website, for example, states that (on average) someone building to PH standards in Germany—with its approximately 20,000 PH structures—should expect to spend about 8% more, and this cost differential is likely greater in countries where PH components (e.g., triple-glazed windows) are not yet readily available.<sup>14</sup> Similarly, the PH Canada website indicates that the incremental cost of PH in Canada would typically be 10%, assuming that the builder has some experience and training in this type of construction. Finally, a Pennsylvania study concluded that PH multi-family low-income affordable housing projects realized construction premiums of 5.8% (versus conventional construction) in the first year, 1.6% in the second, and minus 3.3% in the third year, suggesting that learning and innovation by project teams may be driving down costs over time.<sup>15</sup>

As explained on the PH Canada website, the incremental upfront cost of reaching PH performance standards depends on several factors, including the severity of the climate, the type of building, the availability of high-quality building components, and the experience of local contractors. The cost-effectiveness of constructing a PH building in any location will be affected by the price of the energy and by local building

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<sup>13</sup> Conditioned floor space is an internal measurement. Thus, all else equal, thicker walls (i.e., high performance walls) reduce the conditioned floor space. And, reportedly, the value of such floor space may fall in the \$500-\$600 per square foot range. Thus, moving from 2X4 to 2X6 exterior wall construction will reduce the conditioned floor space by one square foot per 6 lineal feet of exterior wall (24 square inches per lineal foot X 6 lineal feet = 144 square inches or 1 square foot). One could think of this as reducing the sale price of the home (which is essentially based on conditioned square footage) by \$500 to \$600 per 6 lineal feet of exterior wall.

<sup>14</sup> International Passive House Association. (2019). The Passive House – sustainable, affordable, comfortable versatile. Retrieved from: [https://passivehouse-international.org/index.php?page\\_id=79](https://passivehouse-international.org/index.php?page_id=79)

<sup>15</sup> Zemke, Zachary (June 2019). Low Income Housing Tax Credits: The sleeper Stimulant Policy. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

standards.<sup>16</sup> Notably, the consensus among professionals who have designed and built PH structures is that, over time, cost differentials between PH and conventional construction will come down for several reasons. First, there is a learning curve (and cost) associated with designing, building, and certifying a PH structure. However, most interviewees reported this learning curve is relatively brief. Second, as PH becomes more mainstream, the cost of key building materials should come down, especially if US-based manufacturing becomes more common. Third, while mainstream builders might focus on obvious cost increases, they typically don't think about cost decreases associated with PH, such as the ability to use much smaller and lower cost HVAC equipment.

Finally, several interviewees pointed out that hot and humid climate zones and colder climate zones dictate somewhat different approaches to PH construction compared to more mild or dry climate zones. That said, PH construction has taken place in nearly all conceivable climate zones around the world. PH practitioners agree that PH concepts and design ideally suit many, if not most, of California climate zones, and that certification can be achieved with lower incremental cost compared to a PH structure built in, for example, parts of the Midwest that experience both hot and humid summers and very cold winters.

## Category 4: Barriers Related to Code Development Process

The barriers within this category are related to CEC code development processes, code modeling software, and the energy code compliance pathways, which present a barrier to PH design concepts and principles for a variety of reasons.

- **PH Principles Incompatible with an Incremental Approach.** Section 25402 of the California Public Resources Code (the code) authorized the California Energy Commission to develop and maintain Energy Standards for new buildings. The act requires that the Energy Standards be "...cost-effective when taken in their entirety and amortized over the economic life of the structure when compared with historic practice."<sup>17</sup> Similar to many other states, the California code adoption process is incremental, with a new code cycle instituted every three years. PH advocates suggest that this process is sub-optimal because it does not provide the building industry with a clear goal for energy efficiency achievement and when to meet that goal. PH advocates believe it would be easier for the building industry if code officials made it clear where the standards would be 20 or 30 years down the road. The incremental (every three years) approach brings a lot of uncertainty as to what the next code change/cycle might mean. If a long-term goal was established, the argument is that builders would have a good idea of where they are eventually going to have to get and can plan accordingly.
- **PH Principles Incompatible with a Component-Based Orientation.** The California code adoption process consists of assessing the cost-effectiveness of incremental increases in the efficiency level of a set of prescriptive measures, such as wall assemblies, attic insulation levels and assemblies, and windows. Each measure is evaluated essentially in isolation toward the goal of determining if an enhancement

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<sup>16</sup> Passive House Canada. (2019.) What's the extra cost of building a house to the Passive House Standard? Is this a good investment for me? Retrieved from:

<https://www.passivehousecanada.com/passive-house-faqs/>

<sup>17</sup> California Energy Commission. (February 2016). Warren-Alquist Act. (Public Resources Code Section 25402).

to a given prescriptive measure (e.g., higher efficiency wall assemblies) is cost-effective. This component-based orientation is very different than the integrative approach used by PH and, therefore, may present a barrier to considering PH principles.

In effect, PH is wall assembly-, attic assembly-, and equipment-agnostic. Rather, PH focuses on a clear performance target for the entire building and expresses that target on an energy use per square foot metric. Both New York City and British Columbia have passed legislation that sets a clear target and lays out a pathway to get there. This allows the building industry to understand what the future will look like and to chart a course forward. The recently enacted reach codes set performance-based targets instead of prescriptive ones.<sup>18</sup> The argument is that the building industry needs the energy code system to “leapfrog” to performance-based targets (e.g., energy use per square foot) if we are to meet climate change goals.

- **Allowing Tradeoffs Between Equipment and Building Envelope Means Builders Do Not Pursue Building Envelope Improvements.** In addition to mandatory measures, the California Energy Standards allow builders to use either a prescriptive or performance-based approach to compliance.<sup>19</sup> These standards address the building envelope and heating, cooling, and water heating equipment. As outlined in the Residential Compliance Manual, the prescriptive approach—composed of a climate zone-dependent prescriptive package—is less flexible but simpler than the performance approach.<sup>20</sup> Under the prescriptive approach, each energy component of the proposed building must meet a prescribed minimum efficiency.<sup>21</sup> Alternatively, the performance approach is more complicated and requires more effort but offers considerable design flexibility. The performance approach uses an approved software program to model a proposed building. Our interviews suggest that perhaps 95% of all homes built in California, and close to 100% built by production builders, utilize the performance approach.

Due to its prevalence, it is important to understand the performance approach in more detail. The performance approach uses CEC-approved software and prescribes that the building meet both an efficiency energy design rating (EDR) and a total EDR.<sup>22,23</sup> As outlined in the Residential Compliance Manual, TDV energy is the “currency” for the performance approach. TDV energy not only considers the type of energy that is used

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<sup>18</sup> Zakrzewski, Stan. (June 2019). NYC’s Climate Mobilization Act: A brief history. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

<sup>19</sup> Mandatory measures must always be met under both the prescriptive and performance approach. Some mandatory measures deal with infiltration control and lighting, others require minimum insulation levels or equipment efficiencies. However, mandatory measures may be superseded by more stringent (i.e., more energy efficient) measures under either approach.

<sup>20</sup> California Energy Commission. (December 2018). 2019 Residential Compliance Manual For the 2019 Building Energy Efficiency Standards (Title 24, Part 6, and Associated Administrative Regulations in Part 1).

<sup>21</sup> Ibid. Page 1-17, 1-18.

<sup>22</sup> An Energy Design Rating (EDR) is alternative way to express the performance of a home using a scoring system where 100 represents the performance of a building meeting the envelope requirements of the 2006 International Energy Conservation Code (IECC). A score of zero or less represents the performance of a building that combines high levels of energy efficiency and/or renewable generation to “zero out” its TDV energy use. Source:

<http://www.energysoft.com/faqs/what-is-the-energy-design-rating-edr/>

<sup>23</sup> The efficiency EDR<sub>e</sub> is the efficiency of the building without the benefits of any solar generation or batteries. The total EDR (EDR<sub>t</sub>) includes the building and the savings contribution from Solar PV and batteries. New to the California code in 2019, is a requirement for a PV system.

(electricity, gas, propane) but when it is used as well. Energy saved during periods when California is likely to have a statewide system peak is worth more than energy saved at times when energy supplies (i.e., generation) exceeds demand.

To use the performance approach, one must first determine the “energy budget” from the standard design, which is determined by the modeling software. The modeling software effectively estimates the “energy budget” of the proposed building as if it were being built using the prescriptive approach. Once this “energy budget” is established, the performance approach then allows the designer/builder to modify the proposed building’s energy features in the approved computer software to achieve energy code compliance. Effectively, to achieve compliance, the reworked building plan with different energy efficiency features and attributes must meet the “energy budget” target established through what is effectively the prescriptive approach.

The words “performance approach” can be misleading because they would appear to imply “better energy performance” when, in reality, they mean obtaining the same “energy budget” as the prescriptive approach with, perhaps, alternative energy efficiency features. Most importantly, our interviewees—both those involved directly in PH and those that were not—made it clear that most developers/builders/designers immediately look to increase the efficiencies of heating, cooling, and water heating equipment, and reduce the efficiency of envelope components.<sup>24</sup> This is primarily because California Energy Standards for heating, cooling, and water heating equipment are set at the minimum federal standard. Thus, achieving efficiency gains with more efficient equipment is relatively inexpensive compared to the cost of meeting prescriptive requirements, such as high-performance walls and attics. In the end, as described by many interviewees, builders/developers/designers find a way to meet the home’s “energy budget” at the lowest possible construction cost.

Reportedly, the uptake of high-performance walls in 2017 was around 30% of newly constructed homes or buildings. Most of this uptake was for multi-story homes (e.g., 3-story homes with common walls) and primarily done for structural, not energy efficiency purposes. Similarly, the uptake in high performance attics in 2017 in newly constructed homes or buildings was about 20%. Notably, one interviewee stated that moving from 2X4 to 2X6 framing (16” on center) will increase the cost of exterior wood framing by 50%. This same interviewee said that using advanced framing techniques (24” on center) will reduce this additional cost to 10%. That said, advanced framing techniques are not frequently used or understood.

The flexibility of the performance approach to compliance appears to come at the expense of enhancements to envelope measures frequently. Builders and tradespeople are gaining little experience with efficient envelopes given their low usage of the prescriptive path, presenting a barrier to improvements in envelope measures in the market. Since the backbone of PH is the building envelope, the use of the performance path is counter to the central theme of PH: super insulated structure, few thermal breaks, and very low infiltration.

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<sup>24</sup> Notable is that the 2019 Compliance Manual, page 1-23, notes that “Appliances, as defined by the Energy Commission, included everything from dishwashers and refrigerators to air conditioners and boilers. The performance of some appliances, such as air conditioners, water heaters, and furnaces, is critical to the Building Energy Efficiency Standards. The energy efficiency of other appliances, such as refrigerators, dishwashers, and clothes dryers, is important to homeowners but does not affect that Building Energy Efficiency Standards, since they are considered home furnishings.”

We should mention that the 2019 Code includes Quality Insulation Installation (QII) as a prescriptive requirement for single-family homes. This means that, while it is not a mandatory requirement, the base home being modeled to establish the target “energy budget” will be modeled as utilizing QII, which requires a third-party HERS Rater verification on the entire thermal envelope throughout the construction process. This change will likely bring more attention to thermal envelope improvements and corresponding installation.<sup>25</sup>

## Category 5: Barriers Due to Cost-Effectiveness Standards

The “Barriers Related to Code Development” category should probably list this barrier, as cost-effectiveness testing is an integral aspect of the code development process. In fact, statements about “cost-effectiveness”—which incidentally appear to mean different things to different people—is a driving force behind what one person versus another considers to be a valid barrier to PH. However, given the complexity and importance of cost-effectiveness testing, it warrants a category of its own. It is important to note the CEC cost-effectiveness testing process around code development and key inputs have been developed with stakeholder input over many years. As such, determining key inputs and values has been a research process in and of itself.

Given this, we intend to describe current cost-effectiveness testing broadly and introduce ideas shared by various interviewees—primarily PH advocates. It is noteworthy that most of the concerns or suggested barriers around cost-effectiveness testing were given by individuals who, with some exceptions, admitted to having only a cursory understanding of the CEC’s methodology. Additionally, these same individuals introduced concerns and other approaches that they thought should be considered but, without exception, were unable to provide concrete information on how various attributes, such as GHG emission reductions, for example, should be valued. The important takeaway from this section is that cost-effectiveness testing shapes the entire discussion of what measures to update in the code development process. And, given the discussion around GHG avoidance and electrification in California, several thoughts around future cost-effectiveness testing seem worthy of mention and consideration.

- **Belief that PH is not Cost-Effective and, Therefore, is Incompatible with Current CEC Approach.** The CEC’s Energy Standards must have a positive benefit-cost ratio over the lifespan of a building (30 years) from a modified participant cost perspective<sup>26</sup> and bring value to the electric grid and environment. Within this framework, code developers consider all code changes, including those that might meet or exceed PH principles. There are various inputs to cost-effectiveness testing that are too extensive to cover here. However, it is important to note that energy is valued using a TDV methodology. The concept behind TDV is that energy efficiency measure savings should be valued differently depending on which hours of the year the savings occur, to better reflect the actual costs of energy to consumers, to the utility system, and to society. The TDV method encourages building designers to design buildings that perform better during periods of high energy costs.<sup>27</sup>

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<sup>25</sup> In the absence of QII, it is our understanding that rated insulation levels (R-values) will be degraded to 70% of their listed value. As a consequence, a decision to not institute QII standards will have a substantial negative impact on the calculated energy efficiency of a given home and, most importantly, this deficiency will have to be made up through other energy efficiency measures.

<sup>26</sup> Energy and Environmental Economics for California Energy Commission. (February 2017). Time Dependent Valuation of Energy for Developing Building Efficiency Standards. Page 2.

<sup>27</sup> Ibid.

An important backdrop to a discussion around cost-effectiveness is that the focus of PH is on reducing heating and cooling loads to bare minimums through thermal mass, the reduction of thermal breaks, and airtightness. At the same time, most new construction building professionals reportedly disagree (given their knowledge and practice) that PH principles in these key areas are cost-effective. In short, CEC code developers and the building industry appear to claim that sound engineering practices do not support the levels of efficiency that PH demands in a cost-effective manner. This claim represents perhaps the most significant barrier to the inclusion of PH principles in future code development processes.

- **The Grid of the Future Requires New Values for Cost-Effectiveness Tests.** The debate over cost-effectiveness is not one that this research project specifically intended to explore in detail. However, given the discussion in California shifting to a focus on GHG emission reductions, electrification, and 100% renewables, many PH practitioners suggest that cost-effectiveness testing should adapt to the most likely “future state” of the electrical grid. For example, electrification and the use of renewables will likely mean additional strain on the grid and the need for more capacity at all levels (e.g., generation, transmission, and distribution). It may also involve both summer and winter peaks, given a possible goal to replace natural gas water heating and space heating with electricity-driven technologies. In a nutshell, such developments may mean that very different values, compared to the present day, should be placed on future energy efficiency improvements. Many PH advocates think PH best addresses GHG and future costs of delivering energy. For example, they argue that PH delays heating and cooling needs to later in the evening (helping the duck curve) and that current TDV methods do not adequately value this possible future state. They also argue that PH will mitigate the need to re-build or enhance the grid. Whether or not these arguments have value is a complex issue, involving a multitude of research needs. The first step would appear to be determining what metrics and associated values should be in the future to understand the impacts of electrification and its associated costs on the grid, whether or not and how GHG emission reductions should be valued, and what an appropriate, effective useful life should be for building envelope measures (i.e., is 30 years appropriate or should it be longer?).
- **Little Empirical Research of How PH Impacts the Grid and GHG Emissions.** Another key barrier is that there is little empirical research to understand how PH impacts the grid and GHG emissions. PH designs need to be modeled to understand their true grid impact, their value to the grid, how they compare to more conventional designs, and ultimately if PH requirements indeed represent a cost-effective solution. In this regard, our literature review indicates that very little systematic research has been done around how PH buildings impact the grid across the various California climate zones and on how PH impacts compare to code-built structures. Additionally, a changing focus toward electrification and renewables necessitates additional studies to understand the potential grid impacts of such initiatives and their related cost, with an emphasis on understanding the cost savings realized through reducing grid impacts through energy efficiency, customer-sited renewables, battery storage, etc.

## Category 6: Other Barriers

There are additional barriers to PH principles that do not fit very well into one of the previously listed categories. Nevertheless, they have important implications concerning whether or not (and how) PH principles are considered in the future.

- **PH Principles Incompatible with Incremental Change.** As previously outlined, the California code promulgation process is incremental; three-year code cycles are the norm and improvements in code are made on a measure by measure basis. However, with PH, some critical aspects of design and construction cannot be approached in isolation and must be addressed holistically. For example, the airtightness standard of .06 ACH50 dictates the use of mechanical heat recovery ventilation to ensure an adequate supply of fresh air and indoor air quality. Thus, tightening the building envelope and reducing infiltration means that ventilation measures also must be taken. This means that incorporating PH principles into code would represent a significant change from current code update practices and would necessitate the use of a multi-measure approach.
- **PH Cannot Reduce Unregulated Loads.** It seems fair to state that some building professionals, perhaps including the CEC, think that the 2019 code has taken energy efficiency levels about as far as it should go given current cost-effectiveness constructs. And, many energy efficiency experts would likely agree that unregulated loads (e.g., appliances, plug-loads, etc.) represent a significant and growing problem. While one can debate this issue, it is clear that PH has no particular advantage in addressing the issue of unregulated loads. While it is true that PH does consider the overall source energy for appliances, plug loads, etc., building occupants can easily “undo” original estimates of overall building usage by adding appliances, replacing appliances with less efficient models, and adding various plug loads.
- **Advances in Performance and Decreases in Cost of PV + Battery Storage Reduce Need for Efficiency Improvements.** The cost and performance of PV systems and associated battery storage continue to improve and have the potential to change the energy efficiency landscape in California dramatically.<sup>28</sup> Improvements in battery storage may reduce calls for more stringent increases in construction standards (i.e., energy efficiency) in favor of PV generation + storage. Many anticipate that cost-effective PV + storage will limit the acceptance of further, more stringent changes to code as many may view PV + storage to be the more cost-effective alternative to further increases in energy efficiency, reducing the likelihood that PH principles are incorporated into the energy code.
- **Little Cross-Over between PH and Non-PH Building Professionals Prevents Learning.** Reportedly, there is minimal cross-over and constructive dialogue between PH and non-PH building professionals. However, there does appear to be some progress in this area, as evidenced by the fact that the California Codes and Standards Program appears to be considering some PH features for inclusion in future reach codes—particularly in the multi-family sector. Most importantly, perhaps, there seems to be very little understanding among mainstream builders as to PH principles, software, and construction techniques. In many respects, this barrier falls under the broad umbrella of lack of awareness and knowledge (the first barrier category discussed in this paper). However, we give it additional emphasis here as it seems that dialogue between PH and non-PH practitioners is critical for mainstream building industry professionals to understand PH and PHPP and how it might relate to current building standards, current code, and current modeling software. Without this knowledge, it is difficult to conceive of a scenario whereby PH principles could get more thoroughly adopted in the marketplace.

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<sup>28</sup> In the absence of battery storage, PV does not produce electricity at the most optimal time of day relative to residential end-uses with the notable exception of central air conditioning.

- **Incompatibilities Between PH Buildings and Code Compliant Modeling Software.** Little work has been done to understand the difference in energy consumption, grid impacts, and GHG outcomes between PH and code-built buildings. Understanding differences in PHPP modeling software versus California-approved modeling software is equally important in order to understand what is or is not treated in each software package and to know if compliance software would benefit by incorporating aspects of PHPP that are not currently included. For example, as outlined in the paragraph after the next one, a 2019 PHCA study concluded that current California-approved modeling software has no provision for modifying multi-family infiltration rates.

It is important to note here that the CEC approach to home performance modeling has been vetted over many years with input from various industry stakeholders and professionals. Undoubtedly, CEC officials would argue that their approach to energy modeling is sophisticated and aligns with generally accepted engineering principles. Given this, PHPP may have no particular appeal to the CEC, and PH reliance on PHPP may be a barrier to acceptance of PH concepts, design, and principles. It is noteworthy that some practitioners see PHPP software as a “black box,” which will not work in an environment (California) where transparency and open-source software has been the norm for years. Some interviewed PH advocates viewed CEC approved software in a similar light. With this said, passive house principles can be incorporated into code without utilizing any specific tool. The CEC has full latitude to adopt measures and concepts that reflect good design practices that minimize energy efficiency use before adding energy-efficient equipment, whether they are officially called PH or not.

In 2018, the PHCA board of directors approved a study to compare PH buildings to California’s energy code requirements, electing to focus on low-rise multi-family buildings using a gas/electric fuel mix.<sup>29</sup> This was done because the PH board identified these buildings, in terms of quantity of units, as the most common type of permitted building. Further, the study focused on the most heavily populated climate zones—San Francisco, Los Angeles (represented by the climate data for Torrance), and Sacramento. Cost-effectiveness was ignored, due to the complexity, though it was given consideration when selecting building upgrades. The study encountered several challenges. Two particular challenges were: 1) shading and thermal bridges had to be ignored because California-approved modeling software has no way to accommodate them; and, 2) converting between PHPP and California-approved modeling software revealed that the current California-approved modeling software has no provision for modifying multi-family infiltration rates.

The result of the study demonstrated that upgrading low-rise multi-family buildings to PH criteria can result in overall energy savings of 13-20% over the 2019 baseline code, a 50% reduction of heating demand, and a 47-59% reduction in carbon emissions using PHPP metrics. The single biggest factor contributing to these reductions was the combination of low infiltration rates coupled with a medium-efficiency heat recovery ventilator. PHCA’s recommendation to the California Energy Codes and Standards group were to: 1.) include infiltration rates and balanced ventilation equipment in

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<sup>29</sup> Mann, Steven. (June 2019). Reaching for a Passive House Code: California’s Nascent Adoption Journey. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

future Reach Code analysis; and, 2.) factor infiltration rates into multi-family and commercial building analysis and modeling software.

## 5. Examples of Incorporating PH Principles into Code

Numerous interviewees pointed to the City of Toronto, Canada, and, to a lesser extent, New York City as examples of a more holistic and forward-looking approach to code development and adoption. One of the groundbreaking aspects of New York City's recently adopted Climate Mobilization Act (Bill #1253), is that it directly addresses the issue of building owners and developers having to meet ever-changing energy requirements that are updated every few years with each code cycle. The bill sets a clear target and lays out a pathway to get there. British Columbia's recently enacted reach code is similar in that it sets performance-based targets instead of prescriptive ones.<sup>30</sup>

In 2014, Governor Andrew M. Cuomo initiated Reforming the Energy Vision (REV), a comprehensive energy strategy for the State of New York. One of the outcomes of that effort was the creation of an above-code-minimum policy initiative for optional adoption by municipalities. The result was NYStretch Energy Code-2020, which established the residential code, Section R408 Passive House, as an alternative compliance path to be voluntarily adopted by any local municipalities in New York State.<sup>31</sup>

It is interesting to note that the City of Vancouver, British Columbia found that LEED certification in particular (which draws on ASHRAE 90.1) was driving buildings toward cheaper gas and away from electricity use, resulting in higher total GHG emissions from space heating—an increase that was also propelled by these building envelopes often being thermally weak.<sup>32</sup> It became clear to City staff that improved thermal envelopes were needed citywide to achieve lower GHG and achieve reasonable operating costs.

Also noteworthy is an article by Bronwyn Barry, Board President of PHCA, which presents an analysis demonstrating, when viewed from a zero net carbon perspective, the highest carbon emissions from single-family homes come from energy used for space heating and water heating.<sup>33</sup> She argues that reducing carbon emissions due to space heating should be the California Energy Commission's primary concern. The article further notes that reducing space heating demand happens to be a specialty of PH principles. The analysis of the seven Palo Alto PH buildings demonstrates that both time of use and season of use matters—confirming that perhaps the most critical area to reduce carbon emissions is through winter space heating. Use of PH principles for thermal mass and air tightness specifically, Bronwyn Barry argues, would help address this need.

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<sup>30</sup> Zakrzewski, Stan. (June 2019). NYC's Climate Mobilization Act: A brief history. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhqv4TfbdTqhvi0a/view>

<sup>31</sup> Benzing, Andreas M. (June 2019). New York State's 80X50 Progress: Implementing High Performance Codes. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhqv4TfbdTqhvi0a/view>

<sup>32</sup> Higgins, Chris. (June 2019). A Big Bold Idea: The City of Vancouver Sets a Target and Maps the Path. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhqv4TfbdTqhvi0a/view>

<sup>33</sup> Barry, Bronwyn. (September 25, 2018). Can California Decarbonize Electricity Without Improving Building Energy Codes? Why targeting space heating and water heating is the best path toward lowering carbon emissions. Green Building Advisor. Retrieved from: <https://www.greenbuildingadvisor.com/article/can-california-decarbonize-electricity-without-improving-building-energy-codes>

## 6. Possible Utility-Sponsored Initiatives

This section draws upon the research findings and suggests utility-sponsored initiatives that could potentially promote PH principles. In this regard, it seems noteworthy to highlight the City of Vancouver’s experience where success came from “a combination of clear signals about the direction of code, the removal of regulatory barriers, staff training, incentives, leader dialogues, tours, and trainings.”<sup>34</sup> Although utilities clearly cannot set the direction of future code, they can provide input and be a catalyst for future code development. In all other respects, the path taken by the City of Vancouver would appear to be a good guide for potential utility-sponsored actions.

### 6.1 Demonstration and Public Education

Given the lack of familiarity, it is important to demonstrate the various energy efficiency attributes and features of PH structures. Associated with this, it is important to validate through case studies and demonstration projects that PH structures can be built affordably and that they address concerns about indoor air quality and construction defects. In short, advocates need to prove to the public and building community that PH is realistic, scalable, and can be done for little additional upfront cost, while reducing GHG, lessening the impact on the electrical grid, and providing other non-energy benefits (e.g., better indoor air quality) for years into the future. Along these lines, multiple interviewees said that builders/developers are cautious given their unfamiliarity with PH—especially concerning impacts on construction timelines and cost. They need to see PH structures built in the local community and understand the costs associated with their construction. Locally built PH structures also present unique opportunities to promote PH to the general public.

### 6.2 Conduct Research to Understand the Cost and Impacts of Electrification

Utilities have significant levels of expertise around the potential impact of electrification and renewables on the cost of delivering energy, including understanding the cost of upgrading transmission and distribution resources under various electrification scenarios and timelines. Yet, the utilities lack knowledge about the impact and associated cost that a winter peak predominantly driven by renewable generation may have on the grid. Any assessment of the value of PH and how it compares to conventionally built structures should be done with an appropriate understanding of cost avoidance and the incremental cost avoidance provided by PH over conventional construction. Perhaps the most important contributor to any assessment of PH or other energy efficiency efforts is understanding the value of any resulting savings to the grid and how that value may change based on time of year (summer vs. winter peak avoidance) and time of day. Thus, important potential values (e.g., GHG reduction values, grid cost savings, etc.) need to be studied, vetted, and ultimately established.

### 6.3 Workforce, Education, and Training (WE&T)

If PH principles are deemed appropriate for promotion, a myriad of individuals and organizations will need education and training. This includes policymakers, code officials, building inspectors, builders/developers, architects, and building tradespeople. We provide two examples here of WE&T that the California utilities could learn from. The City of Vancouver focused on training their staff

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<sup>34</sup> Pander, Sean. (June 2019). Vancouver’s Zero Emissions Buildings: Accelerating Passive House Uptake. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

(building officials and inspectors) and funded a 50% trades training subsidy to support local industry adoption of PH building envelope best practices.<sup>35</sup> Between 2014-2016, the New York State Energy Research and Development Authority (NYSERDA) initiated a workforce training and development program focused on subsidizing courses to promote a broad array of skills and services related to improving building energy efficiency—contracting directly with fifty training providers. One aspect was a \$500 grant per attendee to directly offset the tuition costs payable towards a Certified PH Designer or Consultant course or PH-specialty training. The grant provided sufficient incentive to commit to taking the eight-day course and helped build a critical mass of trained professionals.<sup>36</sup>

## 6.4 Incentives

Incentives to close the initial increased cost gap associated with PH construction could help to ensure an ample number of PH projects or demonstration sites are available. Incentives could be based on improved energy savings over a code-compliant structure or provided to support the workforce development aspect of PH construction. Another possibility is to provide incentives around frequently included equipment in PH structures, such as heat recovery ventilators. Several interviewees made it clear that equal incentives should not be given to green building programs that achieve wildly different GHG reductions. Rather, incentives should be based on GHG reductions beyond a standard, code-compliant energy budget. Along this line of reasoning, many agreed that it is unfair to assume the market is going to make changes fast enough to impact climate change and that this is where the government should step in to provide incentives that address future climate issues.

## 6.5 Transformation Activities

Several publications and interviewees mentioned that PH construction costs could come down with more US-based manufacturing. Utilities could be involved in sponsoring initiatives that could be construed as transformative to both the conventional building market and PH. Providing incentives for manufacturing skinny triple glazed windows were mentioned as one such initiative. CEC staff are already working with the building industry and other research organization to bring skinny triple glazed windows to market. Triple glazed windows are a frequent component of PH structures, particularly in some of the most challenging climate zones. They provide important benefits to conventionally built homes. Heat recovery ventilation systems are another opportunity; some interviewees reported that the “best” (more efficient, reliable, durable) systems are currently built in Europe. Finally, several PH advocates said that smaller HVAC equipment is needed for PH structures and this equipment is difficult to find in the United States.

# 7. Key Opportunities for Inclusion of Passive House Concepts in Future Code or Reach Codes

Taking into consideration the barriers to PH requirements they identified, we asked interviewees to suggest opportunities for the inclusion of PH requirements in mainstream residential construction practices and future codes or reach codes. We list the key opportunities in the general order of the

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<sup>35</sup> British Columbia Institute of Technology. (2019). CESA 1500 – Passive House Tradesperson Course – Building Envelope Specialization. Retrieved from: <https://www.bcit.ca/study/courses/cesa1500>

<sup>36</sup> Bronwyn. Barry. (June 2019). Utility Programs: NYSERDA’s Strategic Grant Funding. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

frequency in which they were mentioned. We also include ideas and suggestions that were not mentioned with high frequency yet have particular merit.

## 7.1 Orientation and Thermal Mass

Home orientation was mentioned as a PH concept that could be incorporated into new home construction immediately and at little- to no cost. For most interviewees, this meant planning and designing a home to minimize summer heat gain, particularly to the south and west via increased thermal mass and fewer windows. Experts point to higher levels of thermal mass on the west side of homes as a method of “absorbing” the heat and, thereby, delaying interior heat gains until later in the day/evening when the natural atmosphere is cooling. As several interviewees reported, Title 24 compares a home’s design to a building that is appropriately oriented (i.e., to minimize heat gain from the west), which incentivizes minimizing a building’s west-facing glass. The IOU programs that provide design assistance should encourage their designers to advise participants on the benefits of increased thermal mass to minimize heat gain.

## 7.2 Room Configuration by Function and Time of Use

To increase occupant comfort, homes should be designed according to PH principles that pay attention to the function and the time of use of various areas within a home. For example, bedrooms should be oriented to the west and south as they are typically not occupied during the hottest part of the day. Similarly, living rooms and kitchens should be oriented to the east and north to shield them from high daytime exterior temperatures. Experts suggested that overall home orientation and use of thermal mass should include the concept of “internal orientation,”—meaning where specific rooms are placed within the structure. There is opportunity for IOU programs, such as the California Advanced Homes Program, to offer incentives to participants who incorporate internal orientation in their building plans.

## 7.3 Shading

Shading and overhangs should be used to prevent excessive heat gain in the summer while permitting solar gain in the winter to increase occupant comfort. Our research identified this as another low- to no-cost PH concept to potentially incorporate into mainstream residential housing. Utility programs should consider incentivizing these measures.

## 7.4 High-Performance Attics

Generally speaking, interviewees were supportive of the high-performance attics that are part of the current prescriptive code. As previously discussed, however, the challenge has been getting builders to incorporate them into their construction practices rather than trading this energy-saving feature off against higher efficiency equipment. The inclusion of high-performance attics as a mandatory code requirement would push the building industry toward a higher-performing building envelope and, thus, closer to PH principles. Currently, many building practitioners reportedly do not incorporate high-performance attics and, therefore, they are not gaining experience with them. Utility programs could consider incentivizing high-performance attics and providing design assistance to help building practitioners gain experience with this code option.

## 7.5 High-Performance Walls

Similar to high-performance attics, there is a fair amount of support for the inclusion of high-performance walls within existing practices, especially amongst PH advocates. However, there has been little uptake into newly constructed homes because, similar to high-performance attics, many building professionals upgrade equipment efficiencies, allowing them to move away from high performance walls. As outlined earlier, high-performance walls present a particular challenge with developers and builders as they effectively reduce the conditioned square footage of a given structure given the same external dimensions. To use high-performance walls, and to maintain the existing conditioned square footage, it is necessary to increase the overall footprint of the building. Given setback requirements, this means that lots need to be bigger and, therefore, fewer homes can be built on a given tract of land if interior square footage is to remain the same. Utility programs that promote a whole building approach, such as Savings by Design, are well-positioned to adopt enhanced incentives for high performance walls and increase builder uptake and thus experience with them.

## 7.6 Passive House as an Alternative Compliance Path or Reach Code

In a recent article, Steve Mann of Home Energy Services points out that local jurisdictions in California, in addition to enforcing Title-24, have the authority to adopt local energy efficiency ordinances, called Reach Codes. Local jurisdictions “must demonstrate that a proposed Reach Code, typically consisting of multiple components, can be implemented cost-effectively. The jurisdiction must obtain approval from the California Energy Commission and the Building Standards Commission for the ordinance to be legally enforceable.”<sup>37</sup> Further, the article states that “a Reach Code can have multiple pathways. It can include specific requirements or require that a project use an established framework, such as PH, LEED, or other certification.” A clear mechanism for this to happen exists; it is the central focus of the California Energy Codes and Standards Program. This statewide utility program works in partnership with the CEC, local governments, and other stakeholders to identify Reach Codes tailored to each of California’s sixteen climate zones. Once approved by the CEC, individual jurisdictions can adopt one or more Reach Codes into their local energy efficiency code.

As previously outlined, in 2018 the City of Vancouver, British Columbia, started to allow PH as an alternative compliance path to its rezoning policy for larger buildings. Reportedly, city staff were motivated to assist with PH implementation because they had been seeing newly constructed LEED-certified buildings that were not achieving energy use or greenhouse gas reductions.<sup>38</sup> The move toward allowing PH as an alternative compliance approach, leading to more PH buildings that demonstrated the many energy and non-energy benefits of PH, opened the door for further improvements in the base building code.

The overall concept we suggest is that making PH an alternative to code compliance will lead to more homes and buildings built with PH principles, which helps demonstrate that it can be done cost-effectively and will result in GHG reductions and better overall efficiency. In turn, this will make it easier to continue to advance base building codes. For example, in 2016, the Vancouver City Council adopted the Zero Emissions New Building Plan, which clearly articulates the path that new buildings must take

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<sup>37</sup> Mann, Steven. (June 2019). Reaching for a Passive House Code: California’s Nascent Adoption Journey. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

<sup>38</sup> Higgins, Chris. (June 2019). A Big Bold Idea: The City of Vancouver Sets a Target and Maps the Path. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

and outlines the lessons from PH (better envelopes, lower heating energy, less use of fossil fuels).<sup>39</sup> The bottom line is that the city understood that more PH projects would be needed to serve as the icebreakers, making way for all buildings to move toward high-performance outcomes.<sup>40</sup>

Other building practitioners are suggesting the same. In fact, a proposal has been submitted to establish an alternative compliance pathway in the 2022 California energy code for PH-certified single family and low-rise multi-family projects.<sup>41</sup> Under the proposal, PH-certified homes would not have to use the performance or prescriptive pathways but would have to meet additional mandatory and prescriptive requirements. The additional requirements include items such as QII, minimum wall insulation R-value, roof and ceiling insulation, water heating systems, and solar PV. The biggest challenge to offering a PH compliance pathway is that the ventilation requirements for PH-certified homes does not align perfectly with the ASHRAE requirements in Title 24. Another challenge is that PHPP does not produce the output to create CF1R compliance forms. Additional considerations may be needed to avoid noncompliance with Title 24 and updates to PH software tools may be warranted if an alternative compliance pathway is established.

## 8. Summary

This last section summarizes the barriers identified through the literature review and SME interviews and makes suggestions for Utility-sponsored initiatives and specific PH principles to prioritize for code incorporation.

### 8.1 Barriers Summary

**Builders:** Those in the building industry reportedly have little awareness and knowledge of PH principles, partially stemming from the limited interaction between PH and non-PH practitioners. A key principle of PH is airtight buildings, but builders are reportedly reluctant to construct tight buildings for fear that might cause indoor air quality issues such as moisture, mold, and off-gassing. Their concerns are not supported by building science, though, because, with proper ventilation, tight homes do not encounter such issues. There is also reportedly a large fear of the unknown among building professionals and, in some cases, their unions that makes them resistant to changes in their building practices. This fear and the resistance among building professionals cause them to push back against proposed energy code changes.

Builders are also reluctant to pursue highly efficient homes for additional reasons. First, homebuyers do not often prioritize energy efficiency when considering which home features they are willing to pay a premium for. PH homes have a higher upfront construction cost, and homebuyers appear to be satisfied buying code-built new homes. Second, improvements in the cost and performance of solar PV combined with battery storage make pursuing renewables a cost-effective approach to achieving environmental goals, which reduce the necessity of pursuing expensive efficiency improvements. Finally, both building practitioners and homebuyers show a growing preference for the “pretty good

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<sup>39</sup> City of Vancouver. (July 2016). Policy Report Development and Building. Retrieved from: <https://council.vancouver.ca/20160712/documents/rr2.pdf>

<sup>40</sup> Higgins, Chris. (June 2019). (June 2019). A Big Bold Idea: The City of Vancouver Sets a Target and Maps the Path. In North American Passive House Network (NAPHN) Policy Resource Guide. Retrieved from: <https://drive.google.com/file/d/1x49Xmey6qaqfG-XDhzvq4TfbdTqhvi0a/view>

<sup>41</sup> Frontier Energy. (November 12, 2019) Single Family Passive House Prescriptive Pathway Presentation at the California Statewide Codes and Standards Enhancement (CASE) Team’s Stakeholder Meeting.

house” that pursues efficiency to a limited extent and uses renewables to make it a green building. These market effects limit calls for more stringent energy codes.

**Limitations or Drawbacks of PH:** Other aspects of PH principles may make code developers reluctant to pursue their inclusion in code. One reason is that a building constructed with PH principles cannot curb the energy demand of unregulated plug loads. The building occupants may plug in and run a variety of devices that can increase the buildings’ energy use intensity despite the tight and well-insulated envelope. Also, interviewees emphasized that PH principles translate to thicker walls, which means land plots will need to be bigger if the interior conditioned space is to remain the same. The high cost of land and development in California means planners and builders want to maximize livable, conditioned space on available land plots and may resist calls for thicker walls.

**Code Update Process:** Fundamental to this context is the fact that the cost-effectiveness testing inherent in the California code adoption process shapes the entire discussion of code updates. The code development process is incremental and considers the cost-effectiveness of each measure in isolation. PH principles are inherently holistic and leverage the interactive effects among building components—an increase in the expense of one measure can be a decrease in the cost of another. Yet that tradeoff and resulting energy advantages cannot be captured when taking a component-based approach to measuring cost-effectiveness.

**Complying with Code:** The California Energy Standards permit builders to use one of two pathways to energy code compliance. Nearly all buildings take the performance pathway and meet code by improving efficiencies of heating, cooling, and water heating equipment, without improving envelope tightness. The result of the compliance pathway options means designers and builders are not gaining experience with tight envelopes, perpetuating their unfamiliarity, and continuing their fear of the unknown. Moreover, the California-approved modeling software lacks key functionalities that would facilitate accurate modeling of PH buildings. Greater visibility into how the base energy budget is calculated for the performance pathway can help to overcome this hurdle and help promote the use of passive house principles.

## 8.2 Suggested Utility Initiatives and PH Principles to Include in Code Updates

The energy landscape is also undergoing substantial change. The growth in renewable energy supplies emphasizes when energy is used. As such, grid impacts are in flux, and cost-effectiveness tests will require new values and potentially different metrics. The energy industry needs to conduct more research to determine what new values and metrics should be used to accurately model grid impacts and cost-effectiveness of PH principles. In addition, future code developers should reconsider if allowing builders to tradeoff building envelope measures is an effective strategy given California’s aggressive climate and energy goals. The California Utilities can also offer incentives for building-industry professionals to attend training events on PH principles and incentives to offset the higher upfront cost of construction. The Utilities may also consider sponsoring initiatives that encourage domestic manufacturing of ultra-efficient equipment, which could bring down their cost.

The Utilities may also consider sponsoring demonstration homes that provide public education opportunities for the public and building officials. Attracting attention to PH homes in the community should enhance their visibility allowing people to learn that PH homes already exist and are feasible. Our research also uncovered several PH principles that could be incorporated into the building code with low- to no-cost implications for designers and builders. Proper home orientation and internal room

orientation can minimize thermal heat gain and reduce cooling loads. Increased thermal mass on south- and west-facing walls would also mitigate interior heat gains.

Similarly, shading and overhangs can be incorporated into building designs to prevent heat gain. Two elements that may be more challenging to incorporate into the code given builder perspectives, yet merit inclusion, are high-performance attics and walls. If these were included as mandatory components in the code, it would force the building community to become familiar with them, assuaging their concerns over time. Finally, the most ambitious, yet transformative suggestion is to make PH a designated alternative pathway to code compliance. Learning from other cities that have done this demonstrates that it can lead to an increase in PH projects, letting builders gain experience with them, and pave the way for further improvements in building code.

In the end, the lack of builder familiarity and a perceived lack of cost-effectiveness limits support for code changes incorporating PH principles. The Utilities, CEC, and CPUC should consider if providing pathways to pursue PH and meet building energy codes will help in meeting California's ambitious greenhouse gas reduction goals. If PH is incorporated into code, more PH buildings will be built, builders will gain familiarity with tight envelopes, homebuyers will see PH homes in their communities, which all support market transformation.