Can Passive House and Zero-energy Building Standards Promise a Low-carbon Future?

CSHub Research Brief | Volume 2020, Issue 3 | By Jasmina Burek, Ph.D. | jburek@mit.edu

Economically Viable Passive Houses and Zero Energy Buildings

Passive house (PH) and zero-energy building (ZEB) standards aim to reduce the energy consumption and carbon footprints of buildings. The PH concept implies a low energy consumption achieved through passive technology such as insulation and energy-efficient HVAC systems. A ZEB is an energy-efficient building that generates enough renewable energy to offset or even exceed the energy it consumes from the grid.

Previous research has shown higher embodied energy and costs for PH and ZEB compared to conventional buildings. To date, very few projects have shown that a PH could be done within a budget comparable to similar standard homes, which calls into question the economic viability of PH. However, most analyses were done using comparisons of individual designs for specific scenarios, making it difficult to draw broad conclusions.

We conducted an analysis comparing a wide range of conventional, PH, and ZEB designs in order to have a better understanding of the economic and environmental trade-offs of these strategies.

Case Study: San Francisco

Our analysis was conducted using a CSHub-developed probabilistic building life cycle assessment (LCA) tool called the Building Attribute to Impact Algorithm (BAIA). The model predicts embodied (materials and construction) and operational energy-related life cycle impacts based on building geometry, assemblies, system attributes, regional U.S. electricity production, and climate zones.

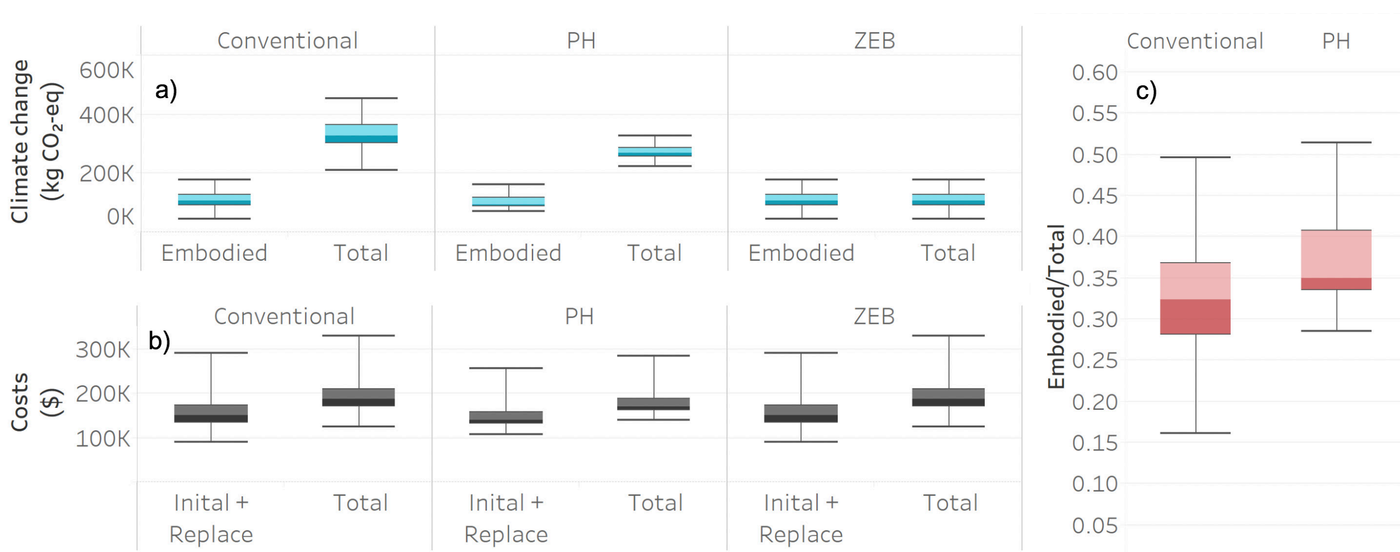

Figure 2a. Embodied and total climate change impact (kg CO_2-eq). **Figure 2b.** Initial, replacement and total cost of Conventional, PH, ZEB (Conventional), and ZEB (PH). **Figure 2c.** Embodied and total ratio for climate change impacts. The plots show the median, interquartile range (within the colored boxes), and upper and lower whiskers.

77 Massachusetts Ave, 1-372, Cambridge, MA 02139 | cshub@mit.edu | cshub.mit.edu

Using these data, the model runs thousands of simulations for an analysis period of 50 years with each simulation culminating in a single, randomly generated building design with a unique combination of attributes. Together, these attributes determine a building's life cycle cost and environmental impact. This research included an environmental and economic assessment of a 172 m^2 (1,851 ft^2) single-family conventional house, PH, and ZEB in San Francisco.

Lower Impacts, Lower Costs

We found that PHs and ZEBs in San Francisco had lower median embodied energy and total life cycle climate change impacts and costs than the conventional house, as shown in **Figure 2a & 2b**. In PHs, though, embodied impacts contributed more to the total climate change impact than use impacts (**Figure 2c**). This is due to a PH's lower long-term energy consumption. While the PH and ZEB have lower median impacts and costs, the range of results for all cases shows that it is possible for them to be higher. Thus, it is important to understand the attributes that would change these relative results. A statistical method was used to rank which attributes have the greatest influence on life cycle costs and impacts for conventional and PH. We found that for the conventional house the key contributors were building systems and for PH were envelope, as shown in **Figure 3**.

The presented PH and ZEB solutions can decrease the climate change impact of the residential sector in San Francisco at a lower life cycle cost, but designs must be developed strategically to achieve this result. Future work will highlight the specific attributes of these low-impact and low-cost designs as a means of incentivizing the transition to a low-carbon society.

Key Takeaways:

- CSHub modeled thousands of potential PH and ZEB designs in the San Francisco Bay Area to validate past research on their economic viability.
- In contrast to past findings, researchers found that PH and ZEB had lower median embodied impacts and costs than conventional designs.

Citation:

Burek, J., Gregory, J., Kirchain, R., (2020). "Can Passive House and Zero Energy Building Promise a Low-carbon Future?", Research brief, Volume 2020, Issue 3.

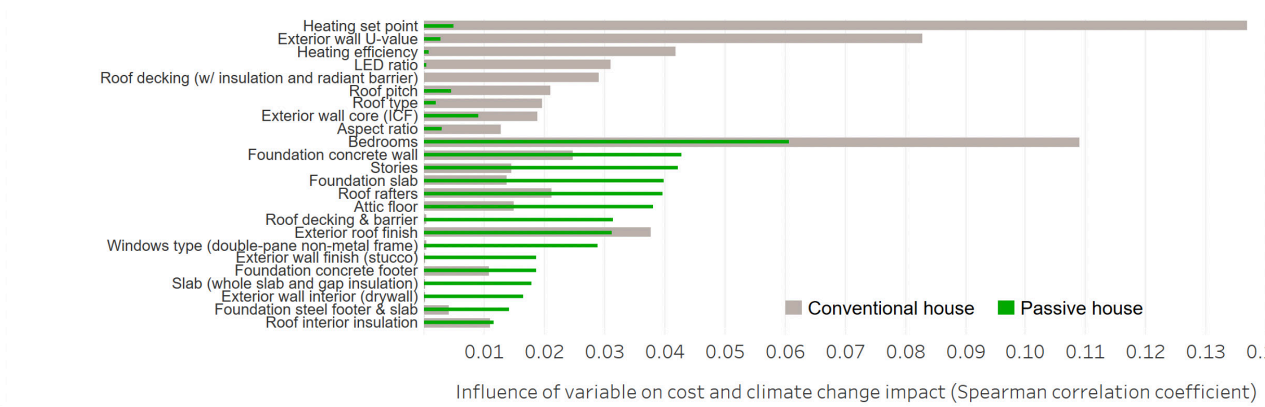

Figure 3. The first column shows the unspecified BAIA building attributes for both the conventional and Passive house (specific attributes for passive house are reported in parentheses). Gray and green bars show the influence of building attributes on cost and climate change impact for a conventional house and PH, respectively. The presented results are statistically significant as $p < 0.5$ (50 per cent chance of being wrong).

This research was carried out by CSHub with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub is solely responsible for content.