

Balancing Act: Seeking Equilibrium Between Cost and Performance in Housing Affordability

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ABSTRACT

Sustainable building certification programs and advanced design tools for modeling assemblies, energy consumption, and embodied carbon have vastly changed the design and construction of high-performance housing. However, in the market sector of affordable, single-family housing¹, the value of implementing high-performance measures can be more difficult to assess. When cost-benefit analysis is critical to project feasibility, design teams need tools to identify which measures generate the most benefit for minimal added investment. Implementation requires responsible translation of modeled performance data into realistic expectations for actual operating cost. Common sustainability “best practices” must be reconsidered and recalibrated to variations in building scale and site context.

This research study seeks to find the balancing point between front-end construction costs of improved performance and back-end performance consequences. The study analyzed the predicted and actual energy usage to heat and cool homes built to specific beyond-code standards: Passive House Institute US (PHIUS) and DOE Zero Energy Ready Homes (ZERH). It evaluates two iterations of a small, detached, single-family home developed for the mixed-humid climate of Alabama. In partnership with Habitat for Humanity (HFH)², the houses were constructed on the same street, with similar orientation but differing energy-related assemblies and details. Initial cost of construction associated with achieving these two performance standards is weighed against the actual energy use in each home. The study also seeks to compare model-predicted energy use and actual energy consumption, with the goal of demonstrating the utility of computational modeling as a resource when evaluating alternative construction approaches.

Introduction

Energy efficiency in residential construction has long been targeted as an opportunity to reduce overall energy consumption, as single-family housing construction comprises 90% of building stock nationwide (Potter 2020). Furthermore, over half of the single-family housing

¹ While the research team acknowledges that higher-density housing is inherently less resource-intensive and potentially more affordable, single-family structures are the predominant form of housing utilized by the not-for-profit housing advocates active in the rural and suburban areas of the Southeastern U.S.

² The Habitat for Humanity (HFH) construction model utilizes primarily volunteer labor with certain scope subcontracted to skilled contractors. Study of homes built under this model limits comparison to other delivery models. For this reason, when comparing the initial cost of construction, the baseline reference will be other HFH homes built with volunteer labor to ensure equitable comparison. This study limits the comparative cost analysis between two homes to costs associated with achieving each third-party efficiency standard, including primarily material costs and taking labor costs into account only where incurred.

stock in the U.S. was constructed pre-1980 (Census Bureau 2022), before widespread adoption of building codes incorporating life safety measures led to standardization and improved construction best practices (Li 2021). These practices include a greater focus on insulation and air sealing prompted by the back-to-back energy crises of the 1970's (Barry 2011). However, in the affordable housing sector³, the initial cost of construction is frequently minimized to maximize the number of units constructed, and, therefore, individuals housed. Decisions that reduce the initial construction cost can negatively impact long-term housing affordability through increased energy consumption and, consequently, utility costs. Conversely, improvements in building performance can lower operational costs and reduce energy cost burden as well as improve health outcomes and increase resilience in the face of uncertain energy and climate futures. The Institute for Market Transformation (IMT) has concluded that default rates on mortgages for ENERGY STAR-certified homes average 32% lower than for non-ENERGY STAR homes (Quercia, Sahadi, and Stellberg 2013), suggesting that improved energy performance contributes to individual economic stability. However, while the benefits of a myriad of energy efficiency upgrades have long been demonstrated, builders often lack the means for evaluating the cost-benefit analysis of upgrades (Walsh, Bashford, and Anand 2003). This pilot project demonstrates tangible outcomes of shifting operational expenses to investment in the asset of the home.

This study is developed and executed by Auburn University Rural Studio's⁴ Front Porch Initiative⁵. This initiative extends Rural Studio's research and holistic approach to housing access and affordability to housing providers well beyond Rural Studio's own service area. Each project offers the opportunity to study issues of efficiency, resilience, wellness, and community building. In this study, a partnership with Auburn Opelika Habitat for Humanity (AOHFH) afforded a unique opportunity for a focused research project on energy performance. Proximity to Auburn University's main campus allowed Front Porch Initiative to harness additional student and faculty resources, enhancing the partnership with AOHFH through academic design-build studios.

Research Design

Frequently, housing "affordability" is addressed by simply reducing up-front construction costs. As such, one of the primary barriers to delivering high-performance homes in the affordable market is the additional up-front cost that these performance "upgrades" necessitate. This research theorizes that targeted increases in construction costs can enhance affordability when they are considered as a variable in the total cost of homeownership.

The primary research objective was to develop an understanding of how the energy performance of small, single-family detached homes could be optimized within an affordable cost-to-construct and cost-to-operate framework. To pursue this question, the research team elected to build two similar homes, shown in Figure 1, constructed on the same street in Opelika,

³ US Department of Housing and Urban Development (HUD) defines affordable housing as "housing on which the occupant is paying no more than 30 percent of gross income for housing costs, including utilities." (archives.hud.gov/local/nv/goodstories/2006-04-06glos.cfm)

⁴ As part of Auburn University's College of Architecture, Design and Construction, Rural Studio educates architecture students by working in partnership with our neighbors in West Alabama in the design and construction of both homes and community facilities. (ruralstudio.org)

⁵ Front Porch Initiative is the outreach arm of Rural Studio's ongoing research to better understand the barriers to equitable housing access and affordability. (ruralstudio.org/frontporch)

Alabama, approximately ten miles from campus. The first home was constructed to the most rigorous single-family residential certification standard: Passive House Institute U.S. (PHIUS). The choice to build to the highest performance standard first is a key element of the research design: this established high energy performance benchmarks for the project and focused the assembly design, engineering, and construction efforts on finding the most affordable way to reach these performance expectations.



Figure 1. Completed houses. House 66, left. House 68, right. Image credit Matt Hall.

The home design chosen for this study was based on Buster's House,⁶ a 900-square-foot prototype house previously developed by Rural Studio. The necessary revisions and construction of each house was the focus of a design-build studio taught in the Architecture program at Auburn University in partnership with Building Science faculty and students. The first house, referred to as House 66, was designed and constructed in the spring and summer semesters of 2018; the second house, House 68, in the spring and summer of 2019.⁷

⁶ Buster's Home was designed and built by a team of 5th-year architecture students at Auburn University Rural Studio in 2017. The student design team for Buster's Home included Olivia Backer, Carley Chastain, Ben Malaier, and Janine Mwenja. The Buster's House prototypes in this study are based on this design.

⁷ The student team for House 66 included: Spring Studio- Lauren Ballard, Meghan Bernhardt, Fox Carlson, Emma Clark, Katherine Ferguson, Jed Grant, Haley Hendrick, Jeff Jeong, Mary Ma, Kate Mazade, Ashley Mims, Walker Reeves, Rowland Sauls, Jordan Staples, and Matthew Wigard. Summer Seminar- Heath Barton, Emma Clark, Noah Dobosh, Melissa Ensley, John Going, Mason Handey, Dee Katoch, Mack Mahoney, Ashley Wiley, Joshua Williams, and Valencia Wilson.

The student team for House 68 included: Spring Studio – Clare Bruce, Justin David, Ozzy Delatorre, Adam Fehr, Jonathan Grace, Emily Hiester, Dongting Huan, Reed Klimoski, Mingtao Liu, and Emma Porter. Summer Seminar – Erik Aguilar, Carol Allison, Craig Baker, Elizabeth Bowman, Caty Bowman, Zack Burrough, McClean Gonzalez, Davis Johnson, Emme Mora, Karmon Sullivan, and Nieman Ugbesia.

The faculty team for House 66 & 68 included Professors David Hinson and Mackenzie Stagg (Architecture) and Professor Mike Hosey (Building Science). The consultant team included David Bitter, CPHC; Bruce Kitchell, PHIUS+ Rater; and Alexander Bell, energy modeler. The team also received generous assistance from Mark Grantham, Executive Director of Auburn Opelika Habitat for Humanity; Jaqueline Dixon, Contractor of Record; Rob Howard of Mitsubishi Electric Heating & Cooling; Alex Cary and Warner Chang from the Institute of Business and Home Safety (IBHS); and Eric Oas of Oasis Heating and Air.

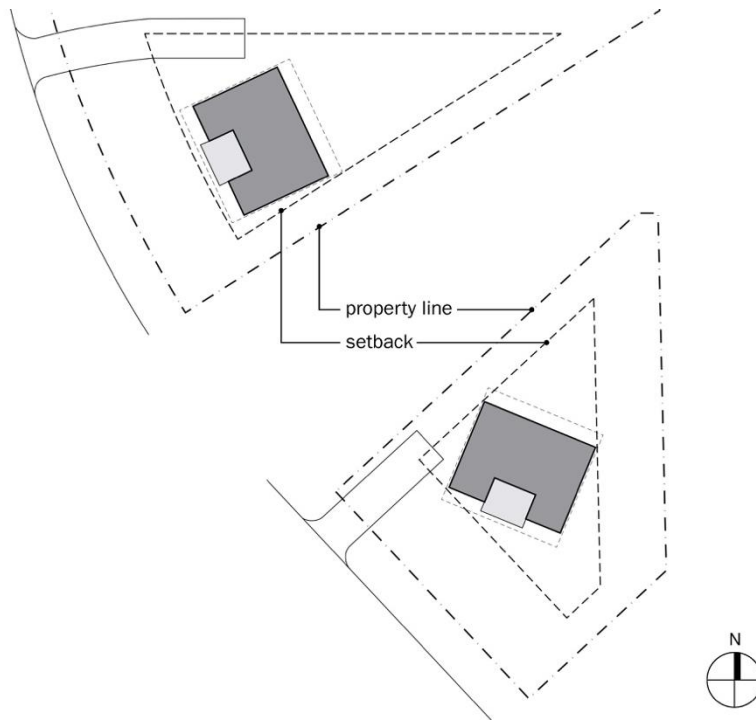


Figure 2. Site plan. House 66, left. House 68, right. Image credit Auburn University.

Each project team worked through the questions of how to modify the construction details of the prototype to ensure each design met the respective standard. The energy study process consisted of four stages. First, for each house, the students, faculty, and energy consultants developed an energy model in WUFI®⁸, working through multiple iterations of key details to optimize assemblies. Second, blower door tests were conducted at critical milestones during construction to ensure the homes met performance targets and to allow for corrections to air sealing. Third, each home sought applicable third-party certifications to verify performance.⁹ And, finally, circuit-level monitoring equipment was installed in each home at the completion of construction to track energy consumption.

Insights gained from the construction of House 66 were subsequently applied to House 68, which aimed to reduce the construction cost while holding closely to the performance achieved by House 66. House 68 was constructed to the Zero Energy Ready Home (ZERH) standard developed by the U.S. Department of Energy. The desired outcomes of ZERH are similar to the more prescriptive PHIUS requirements, but ZERH allows more flexibility in the

⁸ WUFI is a computational modeling software that simulates heat and moisture (hygrothermal) conditions in building components and assemblies and predicts energy consumption over the course of a year. (<https://wufi.de/en/>) PHIUS certification requires design modeling in WUFI. Although the ZERH standard does not require WUFI modeling, the research team utilized the program to model House 68 for more granular predicted energy consumption results, directly comparable to that of House 66.

⁹ House 66 was the first building to achieve PHIUS certification in Alabama (2020). House 68 was designed and constructed to the standards of the Zero Energy Ready Home program but was not certified due to a miscommunication about third-party verification of the slab edge insulation.

These certifications can help housing providers prove to project sponsors that performance criteria have been met; they can provide documentation to homeowners for municipality-sponsored incentives (such as tax credits); and they can equip appraisers with information to appropriately value the home.

approach to detailing construction systems due to its more descriptive nature. This flexibility is a key factor when considering construction approaches across markets and procurement strategies.

For each home, construction costs were tracked and documented, and energy monitoring began post-occupancy. With the permission of the homeowners, the research team installed monitoring equipment in each home that provides detailed, circuit-level information on energy use as well as indoor temperature and humidity conditions throughout the house. The research team monitored energy consumption remotely using SiteSage, a web-based interface. To permit comparison of actual consumption to model predicted energy consumption, raw data was aggregated into six categories determined by the WUFI model: heating & cooling, auxiliary fans (active ventilation system), water heating, major appliances, lighting, and miscellaneous loads. Side-by-side monitoring of the two homes began in February of 2020. This paper reflects data collected through May 2022.

Key Assemblies

Based on the experience of building House 66 to the PHIUS standard, three key construction assemblies were identified as critical opportunities in simplifying constructability and reducing construction cost to House 68 without creating a significant negative impact on building performance. These assemblies are illustrated comparatively in Figure 3.

1. Approach to Under-slab and Slab Edge Insulation / Thermal Breaks

PHIUS standards place significant emphasis on limiting energy transfer through the foundation. The amount of under-slab insulation (4" of extruded polystyrene) and the insulation required to isolate the slab edge from the foundation wall (2" of extruded polystyrene) on House 66 made for a time- and labor-intensive detail at the top of the foundation wall. The necessity of a physical termite barrier associated with the use of under-slab foam products in the "very heavy" termite infestation zone further complicated this assembly.

Given the relative mildness of Climate Zone 3 winters, it was hypothesized that under-slab insulation at House 68 could be eliminated, and the thickness of the slab edge insulation reduced (to ¾" of polyisocyanurate), while maintaining a thermal break. The efficacy of slab edge and under-slab insulation in Climate Zone 3 is ambiguous, so this study offers an opportunity to gather perspective on the actual performance of these two distinct strategies. Analysis and conclusions from this comparative study are forthcoming.

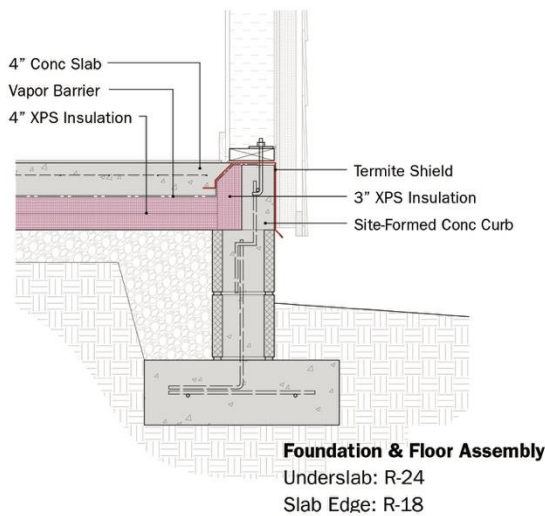
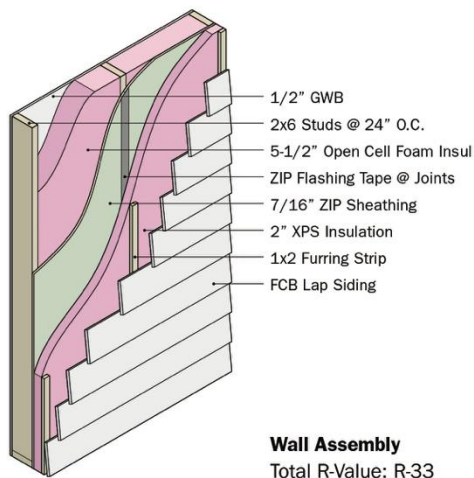
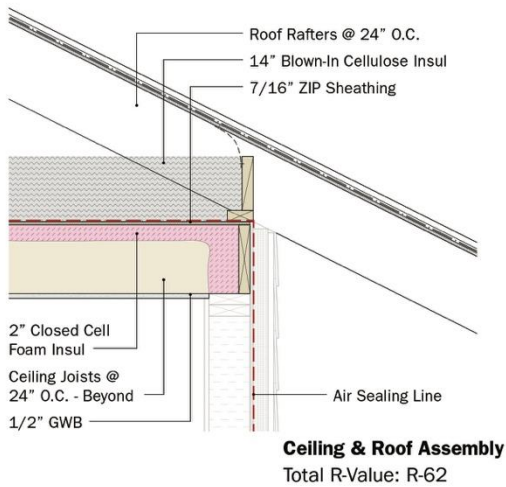
2. Approach to Wall Insulation, Windows, and Exterior Doors

House 66 utilized 5 ½" of open cell spray foam insulation in the stud wall cavity. ZIP sheathing,¹⁰ the primary air barrier, was coupled with 2" of extruded polystyrene (XPS) outboard

¹⁰ ZIP sheathing is a structural wall sheathing with integral water-resistive barrier. When panel joints are taped, the system serves as an air barrier. ZIP-R laminates a layer of rigid polyisocyanurate to the interior face, providing continuous insulation outboard of the studs.

HOUSE 66

PHIUS



HOUSE 68

ZERH

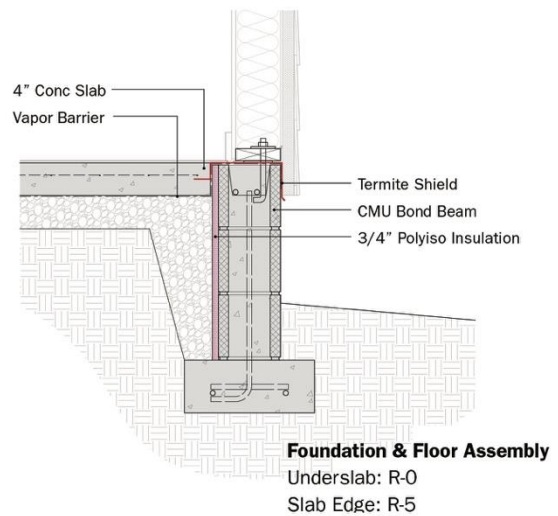
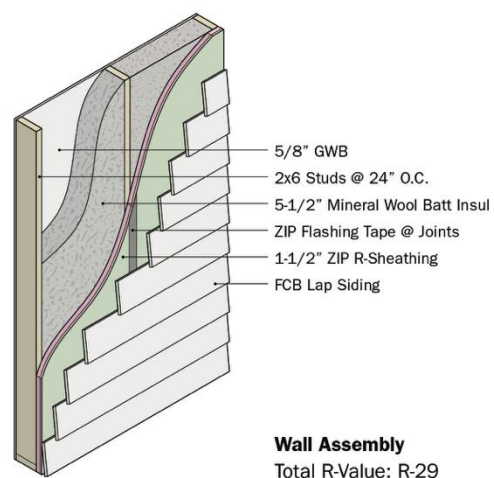
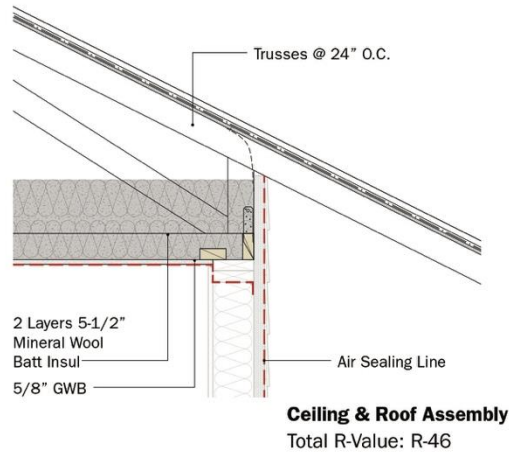


Figure 3. Comparison of key assemblies. Image credit Auburn University.

of the sheathing. This provided the necessary thermal break while simultaneously achieving the R-value required to meet the PHIUS target. Vertical furring and fiber cement lap siding followed. While this approach ultimately created a well-sealed and well-insulated wall assembly, it required the installation of several additional layers of the assembly and special detailing around the window and door openings to accommodate the depth of the continuous insulation. In response to these concerns, House 68 utilized ZIP-R sheathing,⁵ which combined the installation of the sheathing and thermal break into a single step.

Special attention was paid to the fenestration (i.e. exterior doors and windows) at each house, as it tends to be the most expensive and poorest-performing element of the wall system. PHIUS certification is tied to using PHIUS-listed products, and sourcing PHIUS-listed windows can be challenging from a supply and budget perspective, an issue even before the COVID-19 pandemic snarled supply chains.¹¹ House 66 incorporates PHIUS-listed, triple-glazed vinyl windows and upgraded exterior doors. When designing House 68, predictive energy modeling indicated that the ZERH goal could be achieved with locally supplied, double-glazed windows at a significantly lower cost.

3. Approach to Air Sealing and Insulation at the Ceiling Plane

Concerns over meeting the rigorous PHIUS air tightness requirement on House 66 led to a strategy of stick-framing the ceiling joists and enclosing the ceiling with ZIP sheathing, followed by installation of a stick-framed roof. This provided an airtight lid on the house and a ceiling joist cavity to contain ductwork, plumbing lines, and light fixtures within the sealed envelope. The house was then insulated at the ceiling plane, with 2” of closed-cell foam on the underside of the sheathing and an additional 14” of blown-in cellulose in the ventilated attic. While this ceiling assembly provided a clearly defined continuous building envelope for air sealing, it also involved a significant amount of additional framing material and on-site labor.

House 68 utilized prefabricated roof trusses, a more conventional approach. The gypsum board at the ceiling functions as the top-side air barrier. It was determined this approach was more aligned with a typical Habitat for Humanity build and provided the opportunity to explore the management of air leakage that could be applied to future HFH projects. The gypsum board ceiling was installed, then the joint between the gypsum ceiling and the top plate of the stud wall was sealed to ensure an airtight perimeter, and finally the walls were enclosed. All other penetrations through the ceiling plane, such as light fixtures, were carefully sealed as well. While this approach required less framing material and labor, the break in the gypsum board installation necessitated two mobilizations by the installer, increasing time, coordination, and labor cost.

Results

To generate comparable data for the study, the research team documented construction costs for key elements, sought third-party verification of building performance, and installed circuit-level energy monitoring equipment in each home to track costs of heating, cooling, and ventilation.

¹¹ Post pandemic supply chain concerns have only gotten more impactful to the decision-making process (irrespective of cost) and likely will not get better for some time, making availability issues possibly more significant to cost issues (*Economist* 2022).

Figure 4 illustrates how the changes to key assemblies translated to construction costs. As with all Habitat for Humanity projects, while some key work is subcontracted to licensed and/or skilled tradespersons, the majority of the on-site work is performed by volunteers (in this case, students, faculty, and community volunteers). Consequently, the project cost histories do not provide a complete picture of the labor costs as compared to for-profit housing delivery methods. However, cost data presented here reflect a consistent approach regarding volunteer versus subcontracted labor on both homes.

The costs tallied below are isolated to the elements of the building design that relate most directly to performance.¹²

- Foundation
- Framing
- Insulation
- Fenestration (windows and exterior doors)
- Gypsum board at the perimeter of the building envelope
- Active systems (ductless mini-split, ERV, water heater, and dehumidifier)

The cost difference between the two homes comes to about \$10,600, with the largest increase incurred by the costs of the foundation system, insulation, and fenestration at House 66.

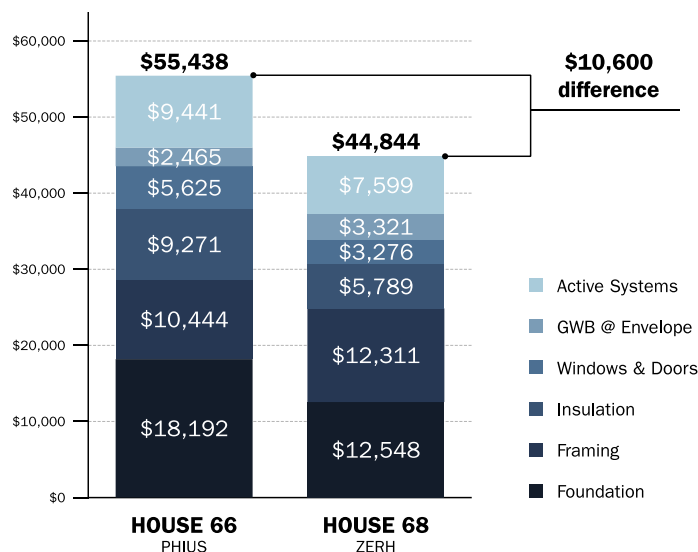


Figure 4. Comparative construction costs of key assemblies. Image credit Auburn University.

The research team measured the cumulative effect of the interventions by comparing air tightness, measured in air changes per hour at 50 Pascals pressure, or ACH50, and HERS (Home Energy Rating System) scores. Upon completion of construction, a final blower door test confirmed air tightness results of 0.37 ACH50 at House 66 and 1.76 ACH50 at House 68.¹³ A more comprehensive measure of performance, the HERS Index score considers assemblies, air

¹² Costs of project components that do not translate to differences in performance, such as those associated with sitework, landscaping, interior millwork, etc., are excluded from this analysis.

¹³ By comparison, the maximum air leakage allowed by PHUS is 0.6 ACH50. The maximum air leakage allowed by 2021 International Energy Conservation Code (2021 IECC) for Climate Zone 3 is 3 ACH50.

tightness, and equipment efficiencies. House 66 achieved a final HERS score of 38, while House 68 achieved a final score of 40. While the results for House 68 indicate a higher infiltration rate than that of House 66, infiltration is still significantly lower than that allowed by code.

The research team collected energy consumption data in each home to determine how alternative approaches to the key assemblies translate into energy use. Side-by-side monitoring began in February 2020, yielding 28 months of comparative data.¹⁴ To compare the energy use of the two homes more closely, the WUFI-modeled and monitored data is grouped into three categories:

- **Category 1 (Heating, Cooling, & Ventilation):** This category of energy use relates most directly to the envelope-driven elements of the house. It includes the energy consumed to heat and cool the home and operate the active ventilation system and the dehumidifier. Additionally, interior temperature and humidity are monitored to understand differences in the interior conditions tied to the associated energy use in this category.
- **Category 2 (Lighting, Large Appliances, & Water Heating):** This category of energy use includes lighting, large appliances, and water heating. These costs are influenced by the efficiency of the equipment specified but are also impacted by variable occupancy patterns and appliance use.
- **Category 3 (Miscellaneous Loads):** This category of energy use includes all the user-connected appliances and fixtures. These “plug loads” are predominately occupant driven. While they can have a significant impact on the total percentage of overall energy consumed—particularly in a high-efficiency house—they have little relation to the way the home was designed or constructed.

Regarding the questions of how the construction cost-reduction strategies (measured by the resulting monthly mortgage cost) impact operating costs, and how this relates to affordability, the data collected is yielding insight. Figure 5 illustrates how the average operational costs of the three categories of energy use add up for each home.¹⁵ Because Categories 2 and 3 are occupant-dependent, this study focuses on Category 1 and changes in the building envelope necessary to affect energy consumption. On average, House 66 requires 30% less Category 1 energy to heat, cool, and ventilate than House 68, an average monthly savings of \$6.77.

Savings due to energy efficiency are most often calculated as an annual cost reduction. However, as most homeowners develop and manage their household budget on a monthly basis, it can be more useful to consider monthly energy savings instead. By transferring monthly energy savings from an expense to an investment—represented by the mortgage payment in the homeowner’s monthly budget — a straightforward cost/benefit analysis can now be considered. For example, in a traditional 30-year fixed-rate mortgage, every dollar of monthly mortgage

¹⁴ A PowerWise SiteSage system installed in each home provides energy consumption data on each circuit within the home. Circuits were organized to align with the major categories of the WUFI model: heating & cooling, auxiliary fans (active ventilation system), water heating, major appliances, lighting, and miscellaneous loads. Side-by-side monitoring began in February of 2020 and will continue through 2022. The data reported here reflects results through February 2022.

¹⁵ The local electric service provider’s residential rate is \$0.135 per kWh.

payment finances roughly \$200 of construction. Therefore, if a homeowner reduces their energy expenses by \$25 per month, they can then invest that same \$25 in their mortgage payment, affording an additional \$5,000 in energy efficient construction with no increase in their total monthly outlay. AOHFH typically utilizes a 20-year zero-percent interest loan; consequently, every dollar added to the mortgage payment finances \$240 of construction. Additionally, such upgrades can increase the appraised value of the home, better protecting the investment of both lender and homeowner. The \$10,600 cost premium on key elements shown in Figure 4 to achieve PHIUS for House 66 (versus ZERH for House 68) conceptually translates to about \$44 per month more in mortgage costs under AOHFH’s 20-year, 0% interest model.

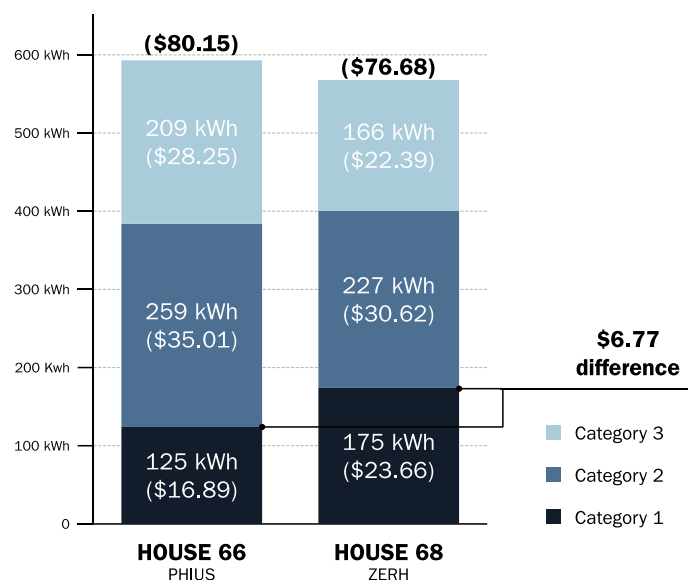


Figure 5. Total average monthly energy use. Image credit Auburn University.

As shown in Figure 5, the cost to heat and cool each house (Category 1 energy use) is less than \$24 per month (\$284/year), compared to just over \$64 per month (\$772/year) for an average home in Alabama.¹⁶ That energy cost savings of \$40 per month can conceptually offset approximately \$9,600 in up-front investments in performance. Establishing such an ambitious goal for operating cost savings is critical to our goal of redefining “affordability” as inclusive of the total cost of homeownership.

When considered as the net monthly cost to the homeowner as illustrated in Figure 6, the cost premium for envelope and systems upgrades in conjunction with average monthly Category 1 energy costs on House 66 do not result in a net savings per month when compared to House 68. Even though House 66 returns a savings in the colder months, the alterations to the key details on House 68 appear to translate to an effective approach to balancing ambitious performance and affordable construction costs.

¹⁶ Source for this figure is the U.S. Energy Information Administration report on “2020 Average Monthly Bill – Residential” (EIA 2020). This report identifies the average monthly energy use for a home in Alabama as 1,145 kWh. At \$0.135/kWh for the local electric provider, this equates to \$155/month and \$1,855/year. The USEIA estimates that 41.5% of energy use in U.S. homes is associated with heating and cooling; therefore, \$64 per month for an average home.

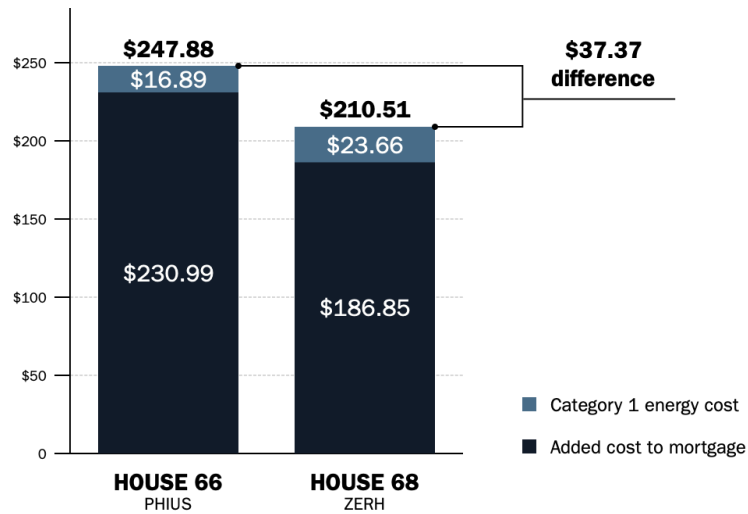


Figure 6. Average monthly mortgage and Category 1 energy cost to homeowner. Image credit Auburn University.

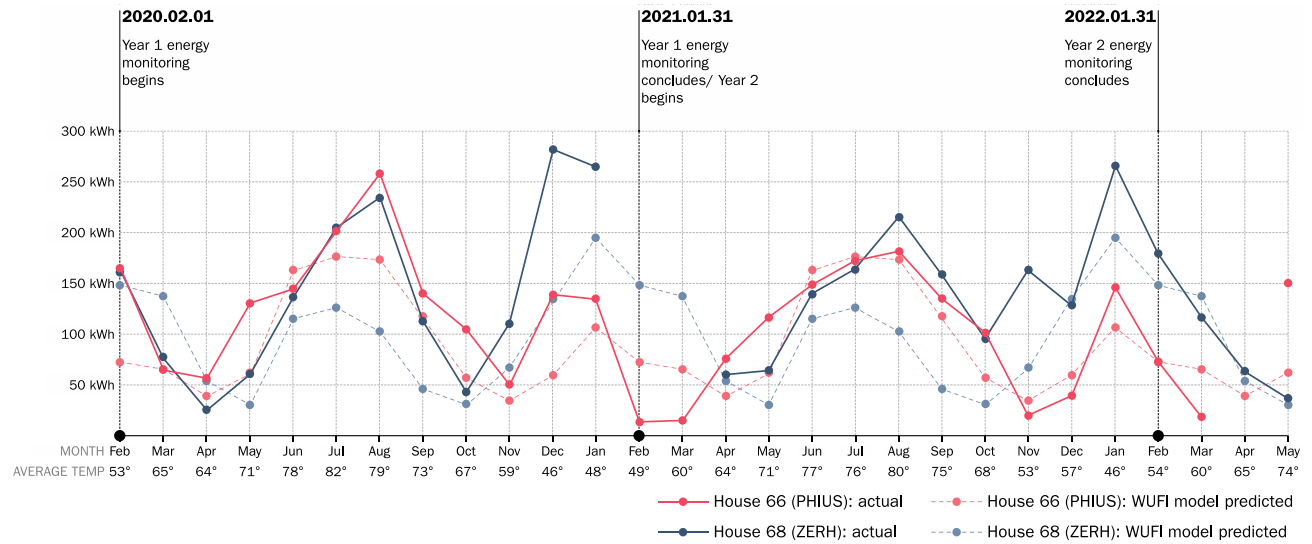


Figure 7. Comparison of modeled and actual HVAC energy use. Image credit Auburn University.

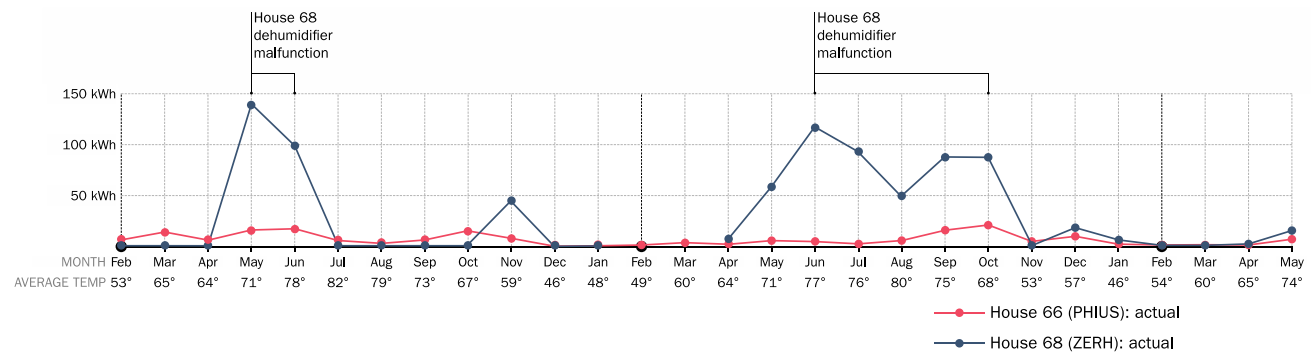


Figure 8. Comparison of modeled and actual dehumidifier energy use. Image credit Auburn University.

Discussion

Figure 7 illustrates how the energy use data for heating, cooling, and active ventilation systems tracks over the 28 months of side-by-side use.¹⁷ An unanticipated finding of the modeled-versus-actual-use comparison was that of its use as a tool for monitoring systems maintenance needs. A faulty humidistat on the dehumidifier at House 68 malfunctioned in May 2020 and again in June 2021, causing a spike in energy use, as illustrated in Figure 8, which compares energy consumption of the dehumidifiers for the two houses. Upon noticing that the dehumidifier in House 68 was consuming ten times more energy than the corresponding equipment in House 66, the research team determined that the humidistat had malfunctioned and repaired it. Were it not for the energy monitoring, the malfunctioning equipment would likely have gone unnoticed by the homeowner and thus unrepaired. After dehumidifier data was removed from Category 1, actual energy use reconverged with the modeled predictions.

Regarding the comparison of model-predicted energy use to actual use, the data for House 66 illustrates that the actual energy consumption for heating and cooling (Category 1) is generally tracking closely with the modeled energy use, as illustrated in Figure 9. The average deviation between predicted and actual use is 20.7 kWh per month (22% higher). Category 2 (lighting, appliances, and water heating) also shows moderate deviation between actual and predicted costs. However, the actual energy consumption for Category 3, which consists of occupant-driven plug loads, greatly exceeds the modeled projections (149% higher). While the design and construction of the building envelope has minimal effect on Category 3 energy use, this category becomes increasingly crucial to address as energy consumption is minimized in Categories 1 and 2.

Next Steps

The research team will continue to monitor energy use on House 66 and House 68 through the summer of 2022.¹⁸ The research team plans to graph interior ambient temperature for comparison with measured energy consumption; temperature setpoints were initially assumed to be within 10% of each other. Visualization of measured setpoints will provide context for variations in Category 1 consumption and insight on how indoor air temperature might influence the comparative costs to heat and cool each home.

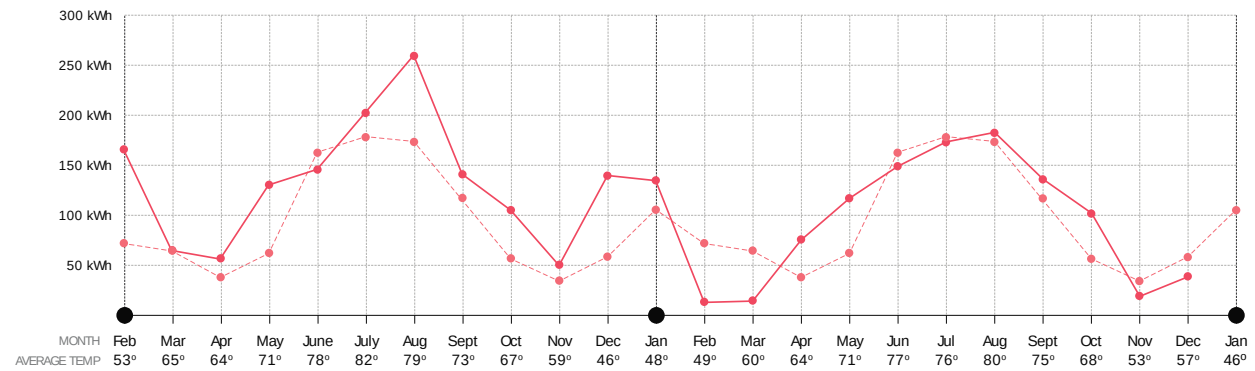
Additionally, the team will monitor energy use in a third AOHFH home known as House 70—based on the affiliate’s standard design and built to meet the locally-adopted energy code (2015 IECC)—to provide a baseline for comparison to the energy use in House 66 and House 68.

The research team will conduct focused investigations into the performance of specific elements of the key assemblies identified above. The first of these investigations will include an analysis of the different under-slab and slab-edge insulation approaches in House 66 and House 68. The team will collect temperature data at key points in the wall and slab edges with the goal of understanding heat flows across the wall and floor assemblies. Sensors mounted at the midpoint of wall and on the floor nearest the exterior wall will be used to register indoor surface temperatures, while infrared camera readings will provide surface temperatures at the exterior.

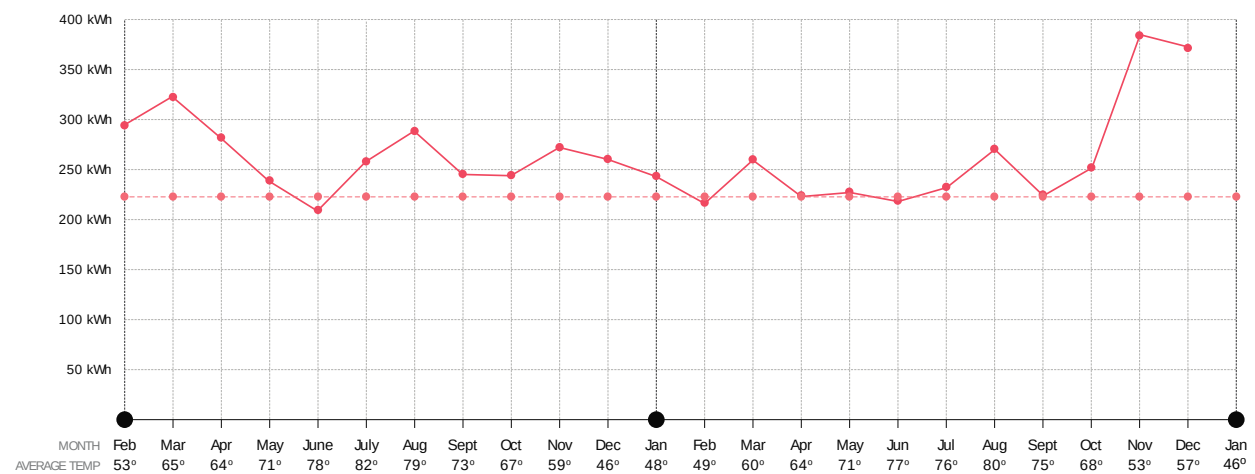
¹⁷ Figure 7 shows a gap in data for House 68 where the monitoring equipment malfunctioned, resulting in a loss of data. This period of time has been removed from the average energy use data for both houses shown in Figure 5.

¹⁸ Data collection was facilitated by Elizabeth Farrell Garcia, Assistant Research Professor, Auburn University Rural Studio, and Anthony Spafford, graduate research assistant, Auburn University.

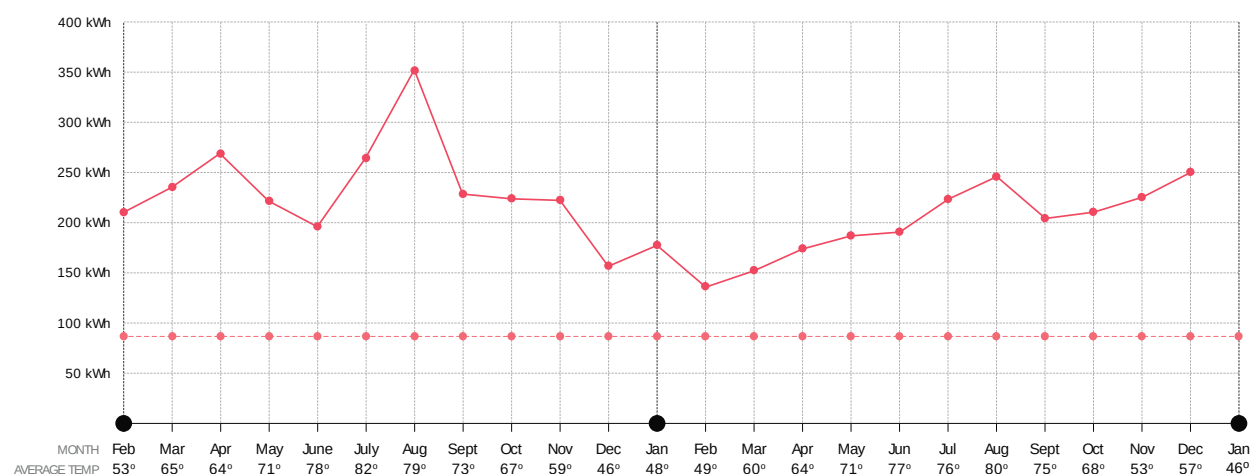
Category 1 (Heating, Cooling, & Ventilation)



Category 2 (Lighting, Large Appliances, & Water Heating)



Category 3 (Miscellaneous Loads)



—●— House 66 (PHIUS): actual - - - - - House 66 (PHIUS): WUFI model predicted

Figure 9. Comparison of modeled and actual energy use in Categories 1, 2, and 3 at House 66. Image credit Auburn University.

From the difference between the two temperatures, one will be able to infer the assembly's resistance to heat transfer. These types of investigations into specific aspects of the building envelope will supplement areas where even a detailed energy model provides limited information as to the efficacy of alternative construction scenarios.

Conclusions and Key Takeaways

The research project questioned whether comparable energy performance between two high-performance houses could be achieved for a lower cost of construction. Specifically, by modifying envelope details where prescriptive PHIUS requirements incurred significant cost impact, could construction cost be reduced while achieving similar performance outcomes under the ZERH standard?

Analysis of construction cost quantified the differences in material and labor to meet the beyond-code standards of PHIUS and ZERH with a savings of \$10,600 on House 68 (ZERH). Measured energy consumption yielded precise data on the cost to heat, cool, and ventilate the houses and found that House 66 (PHIUS) home required 30% less energy than House 68 (ZERH), for an average monthly utility bill reduction of approximately \$7. If the difference in construction cost is extrapolated to a difference in monthly mortgage payment, the House 68 (ZERH) homeowner would pay \$44 per month less than the House 66 (PHIUS) homeowner. The results comparing these two high-performance houses demonstrate savings on initial construction cost without sacrificing performance.

Concrete, field-validated evidence of the operating cost reductions associated with up-front investments in energy performance—and the costs of implementing them—is critical to both Auburn University's efforts to refine and advance the research and outreach to assist not-for-profit housing providers and policy makers. The findings from this study will be folded into future cycles of design/build/evaluate work by faculty and students in the context of the design/build studio, incrementally advancing a comprehensive understanding of how to improve building performance affordably. The perspective and knowledge gained from this work will continue to shape the teaching on the ground at Rural Studio as well as inform the advice and technical assistance provided by the Front Porch Initiative to its partners. Through these activities, the research team will work to provide evidence supporting a definition of “affordable,” inclusive of the total cost of homeownership.

References

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