There Goes the Neighborhood: How a NZE Passive House Changed the Culture of a Community

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In 2019 a small, single family house was sold to a family excited to be part of a trailblazing and strangely controversial project. While many net zero energy (NZE) and/or Passive House examples have now been completed across the US, small communities, especially in the flyover country of the upper Midwest, have proudly doubled down against the "unknown" of these new models, reinforcing traditional project delivery and the absence of energy codes. This project and initiative not only serves as an example for students and evolving pedagogy, but also has become a touchstone in the community, challenging the preconceptions of modern design, neighborhood investment, homebuilding practice, and the public image of a university grappling with an evolving "design culture."

The complexities of any architectural project are numerous but often predictable. Like any student design-build project, this house dealt with its share of delays and changes. And like any grant-funded project, it dealt with additional oversight, reviews and red tape. Now in its final phase, the project begins post-occupancy monitoring. Teaching the homeowners about building performance blends the pragmatics of understanding equipment with the global responsibility and mission of NZE and passive house.

An early decision to work within an existing, walkable neighborhood lead unexpectedly to a very public debate on neighborhood design. These and other lessons are a reminder that architectural practice requires teaching your client, and often, your community. This paper will focus on the larger impact that the house continues to have on both the community and university. This includes the cultural challenges of meeting design expectations, the potential of infill as a community revitalization tool, and convincing a skeptical public that energy consciousness and evolving construction techniques have real value. It will also discuss how these issues, understood and accepted as given within the design and academic community, are still radically new in this (and many) regions across the country. A discussion of pedagogy and community design are balanced with quantitative energy data, impact, and continuing observation.

INTRODUCTION

A self-sustaining grant broadly based on passive house strategies as defined by PHIUS (Passive House Institute US) was initiated at the South Dakota State University Department of Architecture (SDSU DoArch) with various curricular, research, and professional goals. Among these, student and faculty training, public dissemination and to the homebuilding industry, adaptation into the curriculum, and continued monitoring of results were most critical. The most visible result of the grant is clearly the design, construction, sale, and monitoring of certified passive houses. At this writing, the first cycle and first house, known as PH01:BRK (Figure 1), is complete and in the post-occupancy monitoring phase. The second and third cycles and houses are in progress, each facing their own challenges while expanding on the passive house research and pedagogical underpinnings described herein.

SDSU DoArch is a new and small professional degree program in Brookings, SD. This is an important factor when considering the context of the passive house grant and initiative. Intentionally small enrollment and class sizes, for example, are a major factor in the "design but not build" approach to the passive house graduate design studio. The small program serves a rural state and region that previously did not have its own professional program in architecture. The growth of DoArch from a single freshman class to a fully accredited four-plus-two Masters program has succeeded in part because of the passive house initiative as a defining and wide-ranging piece of its curriculum. Its influence on course design, community service and outreach, and connection to the profession are all strengths that reinforce a mission of haptic, hands-on learning.

In terms of pedagogy and curriculum alone, the passive house initiative has established a recurring graduate design studio, and anchors successful professional practice and technology courses. Additionally, the emphasis on assembly, hands-on making and materiality reinforce a workshop sequence that supplements traditional studio instruction. An initial community design center called DoArch Public Works established an ethos of connecting students and faculty to underserved towns across South Dakota, and the passive house initiative represents one area of a larger body of DoArch built and award-winning work that has benefitted from these foundational efforts. The range of coursework supports a

Figure 1. PH01:BRK. Photo: Robert Arlt/DoArch.

multi-tiered approach to teaching and pedagogy, and surprisingly may be best exemplified by a four course professional practice sequence that treats theory and practice as one in the same.[1] It has established relationships with the regional building industry and connected students to the profession, approaching architectural theory and practice as inexorably linked. The original grant proposed that passive house teaching would be introduced into the curriculum, and its influence has gone beyond initial expectations. It is now a topic either explicitly or implicitly included in each of the department's curricular sequences.

The passive house initiative is a self-sustaining grant secured from the South Dakota Governor's Office of Economic Development following a series of statewide initiatives implemented by then Governor Dennis Daugaard. Those early projects included a pre-fabricated, income qualified house updated to meet PHIUS certification and a subsidized multifamily passive house project that was completed at roughly the same time as PH01:BRK. The most visible outcome of the DoArch grant is the student designed and contractor build passive house. The sale of the first house funds the construction of the next, and so on. A small collection of industry partners has also been identified, including vendors, consultants, contractors and financial groups. With the completion of PH01:BRK, a final research phase of post-occupancy monitoring has begun. The successor houses are each addressing their own internal and administrative issues and exist in various phases at this time. The goal of course is for all of the design cycles to reach full completion, establishing an array of comparable projects.

The first passive house graduate design studio was conducted immediately following the grant approval. The studio was run like a small design office, with each of the six students responsible for managing components of a shared project. These included 3D and physical modeling, construction documents, energy modeling, site design, permitting, marketing and promotion. Daily meetings were held for progress updates. The early schematic design itself revealed that the students had little experience with residential work, especially single-family houses. Documentation and energy modeling were more easily handled than the initial proposals. Eventually a single design was chosen following a juried review. The learning process of doing a house design, let alone one needing to reach PHIUS certification, became a microcosm of the multitude of lessons and inefficiencies of the PH01:BRK studio and execution. Examples include poor budgeting, inaccurate material and equipment selections, working with an inexperienced general contractor, and administering a building project with the university and third-party financial institution. The successor projects have consciously aimed and largely succeeded at addressing these items. The design of PH02, for example, was largely based on construction cost effectiveness, designed as a "little brother" next door to PH01, with goals of streamlining labor expense, increasing prefabrication, and economizing scale (Figure 2).

The studio-as-office pedagogy continues to serve as a template for the grad studios. Since a single built project is the goal, a dynamic of group work and high production is required. And, in order to achieve equitable, shared student learning, frequent or daily meetings and overlapping tasks remain. This is a common design-build studio pedagogy, always with the risk of students not being involved or "checking out" of critical parts of the process.

The studio held frequent meetings with consultants, contractors, vendors, and representatives from the state and university. Public presentations and a final studio review were held. University faculty partners were identified later in the project as a solar PV system was designed and installed. Students were responsible for coordination with national vendors providing mechanical equipment and materials. Most of the specialty software necessary for PHIUS certification had to be purchased, adding to the learning curve. These include energy and thermal modeling software, site data sets, solar shading equipment and requisite software. Working through embodied carbon quantities began with PH02.

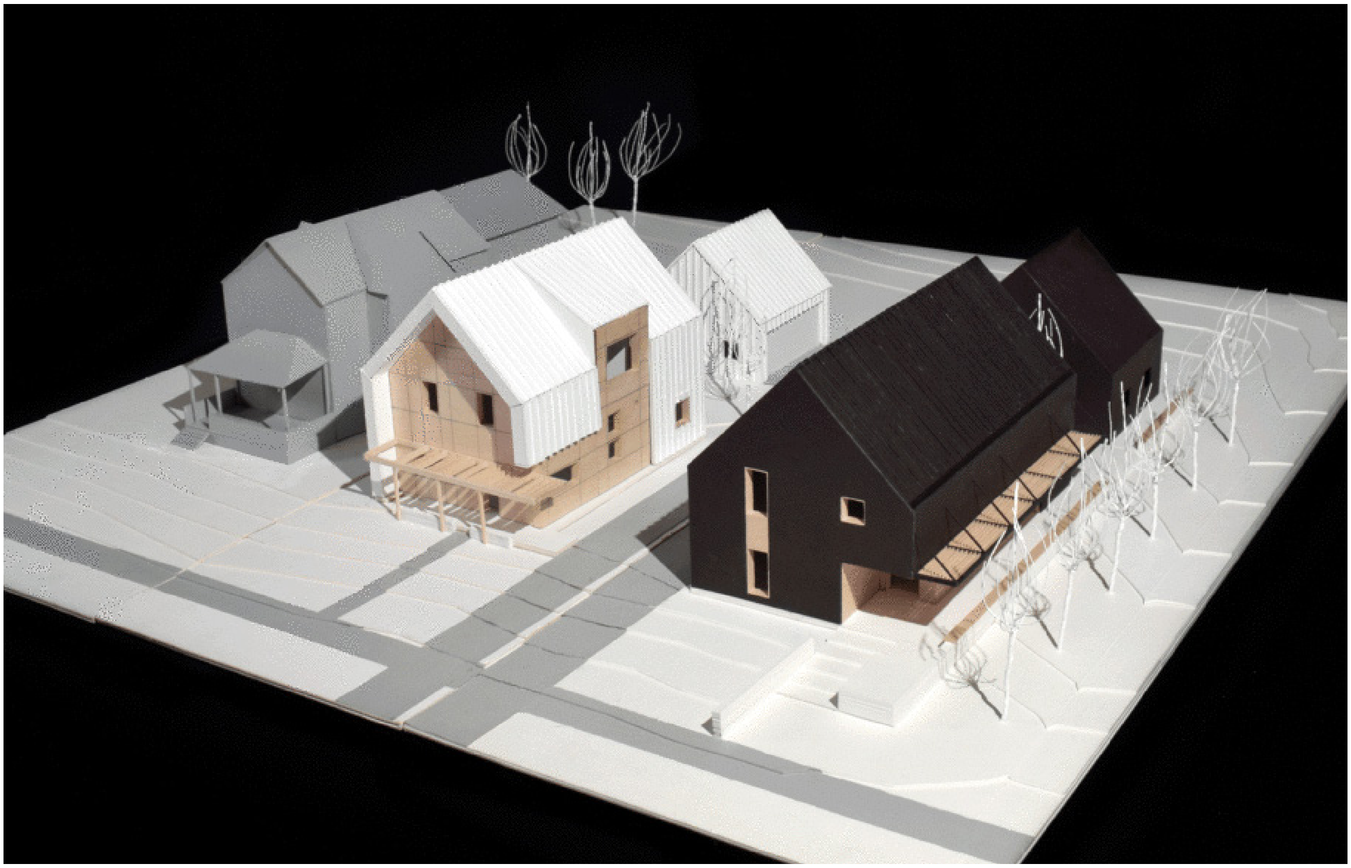

Figure 2. Model of proposed PH02 alongside the earlier PH01:BRK. Photo: Robert Arlt/DoArch.

THERE GOES THE NEIGHBORHOOD

The PH01:BRK site is a low-density residential neighborhood within a few blocks of campus and the downtown Main Street district. It is a walkable, infill location and nearly every building in a 1-2 block radius is poorly maintained leased student housing. DoArch and the grad studio felt strongly about working in an established site, and surprisingly, one of the first decisions in proposing an infill building in an established neighborhood became one of its biggest controversies. In Brookings, like many of the towns across the state, "new" residential construction always means expanding outward into sub-developments and away from the original Main Street. Neither the nostalgia nor the economic viability of the traditional small-town center remains important. While many similar towns are recovering and re-building elsewhere in the US, the pedestrian scaled, walkable community remains undervalued here and does not spur complimentary residential districts or upkeep. The real estate industry and home values reflect this. PH01:BRK, however, intentionally challenged this by identifying an established lot within a transitional neighborhood. A long-term goal is to spur reclamation within the block. Brookings, more than most regional communities, enjoys a thriving Main Street and pedestrian culture due to its student population. Still, a new house in an old neighborhood is unheard of, with the sprawl of new greenfield development attracting the "safer" socio-economic choice.

The house itself is sited on an unusually narrow lot, resulting in a shotgun scheme and detached garage creating a small courtyard. Following the passive house "five principles,"[2] the scheme was modeled to eliminate thermal bridges, increase insulation levels, and control south facing openings. A double height great room led to increased envelope R-values. The 24" thick non-vented roof achieves almost R-100, for example, combining closed cell spray foam with blown-in cellulose. The open plan also led to the use of a steel floor beam supporting upper floor framing, along with the use of a 50-foot dropped glulam ridge beam. The "heroic" framing was certainly an additional expense, but the exposed structure, unusual in residential work here, was meant to challenge expectations.

Construction was not set up as student design-build for several reasons. The original grant recognized conflicts with both the small student enrollment and difficult construction scheduling. Significantly, the initiative projects are meant to serve as demonstration houses undertaken by local homebuilders and, by extension, provide case studies for the financial and real estate industries. A significant inefficiency, and one that caused some conflict from a potential partner, was the decision to

Figure 3. Solar PV installation at PH01:BRK. Photo: Charles MacBride.

stick-frame the house. Avoiding the use of SIP panels (which are specified for PH02) came directly from general contractor as an "unknown" technique. SIP, of course, generally provides faster construction and greater airtightness.

In terms of research, PH01:BRK serves as an internal case study as well. It will act as a baseline house alongside its many inefficiencies, offering a list of "lessons" to be resolved moving forward. Still, it has gone on to win numerous awards including a state AIA Honor Award and recognition from PHIUS. The local and university led controversies revolve around an objectional "modern" style (and color) that have unfortunately exerted an outsized influence on the ability of the initiative to fully proceed.

CULTURAL RESISTANCE

Even before construction on PH01:BRK began, skepticism and resistance were present from many sides. This includes the contractor and subcontractors, the general public, and the university. The house was designed and built "on spec" without an owner/client. Therefore, ongoing design decisions were made completely by the faculty and graduate assistant team (the original student design team had graduated by the time the construction finally started.) Somewhat ironically, the contract and financial issues were fully in place, and the third-party financial institution that held the grant funding were the only stakeholders willing to give the research and design team full reign.

An important contextual and cultural item must be noted in that South Dakota is one of only a handful of states without a residential energy code. The issue is a non-starter in terms of potential, future regulation, and likely would be almost as difficult to enforce.[3] As a home-rule state, there exists a greater chance that the largest cities (Sioux Falls and Rapid City) could enact energy codes. This will remain to be seen. The architectural community are likely the only code or regulatory advocates and are strongly outnumbered.

With few exceptions, the only EnergyStar certified houses in the state are the previously mentioned pre-fabricated "Governors Houses" built by the state itself for income qualified families.[4] This is one of the strongest legacies of Daugaard's passive house initiatives. The South Dakota Housing Development Authority reworked the standard construction of these following a prototype passive house retrofit. Unfortunately, the homebuilding industry is under no obligation and sees no market pressure to match this quality. PH01:BRK, following PHIUS guidelines, required its general contractor to register as an EnergyStar builder and to complete its rating; its final HERS score was 26.

Understandably, the construction industry in the region does things the way they've always been done. An attitude of "good enough" prevails. There exists little to no custom residential work for architects (contractors will handle unusual design items themselves). Any deviation from standard means either increased cost or risk losing a contractor altogether. A lack of skilled tradespeople keeps the building industry very busy, and specialization or calls for high levels of craftsmanship are rare. As part of the preparation for a presentation of the PH01:BRK project, a series of conversations with builders and code officials was conducted. In one instance, a contractor insisted alarmingly that it doesn't matter where the dew point falls in a wall assembly; this status quo unfortunately underscores the state of regional homebuilding: not only a disinterest in craft or housing but also an unawareness of building science.

Achieving PHIUS certification was an important, stated goal of the DoArch initiative. The introduction of performance and energy modeling is clearly an important aspect of this. It wasn't until the design of the successor PH02 that additional metrics beyond the PHIUS requirements were undertaken, however, especially including embodied and operational carbon metrics. The team is retroactively building a comparative series of documents that will include these items plus more, such as budget/cost models, equipment specifications, and an overview of successive PHIUS certifications. PH01 was certified with the PHIUS 2015 Guidelines while PH02 was pre-certified using the 2018 Guidelines.

The PH01:BRK rater/verifier (located three hours away in Omaha) was a PHIUS requirement for final certification. As part of the rater/verifier services, a pre-construction framing workshop was held with the general contractor and framing crew to discuss the importance of airtightness, taping and sealing, advanced framing technique, following a nailing schedule, eliminating penetrations, and more. The workshop started badly and took a turn towards the political, as the framing crew suggested that the students and design team were building something that would never become a standard, and worse, that it supported a progressive agenda of climate change that puts tradespeople out of work. The framing crew was hired from out of state specifically because the raised expectations of quality. Nevertheless, the charged political climate only added to the typical architect-contractor tensions. Specifically, the example of Huber ZIP sheathing, important for simplifying and increasing building airtightness and a new standard in most parts of the country, had never been used on a residential project at this time. The general contractor, despite constant reminders, didn't budget for required tape or adhesives. Another example is the difficult combination and installation of multiple insulation types. Explaining the distinction of closed cell vs open cell, or the window sealing detail, are just two issues that inordinately extended the job schedule based just on insulation design alone.

Within the community, public presentations were given to explain and promote the project. It is not a surprise that the issue of building performance does not register with the public. The presentations touched on issues of energy reduction and air quality, but the "modern" style of PH01:BRK was what garnered most attention. Eventually, the fact that the house did not have a furnace became a lead-in to the radical shift in what the potential of passive house might mean in this region. At the ribbon cutting for the house, then governor Daugaard delivered a talk surprisingly heavy on technical details that went beyond the comprehension of most in the audience. The university dignitaries took the opportunity to discuss the project's significance, but unfortunately their own recognition of the project also starts and ends with its objectionable style, underscored by the perceived difficulties navigating internal funding and legalities.

POST-OCCUPANCY MONITORING

Following completion, PH01:BRK was sold to a family and is now currently occupied. They love the house and have been most supportive of the initial setup and continuing monitoring research. Data collection includes Indoor Air Quality (temperature, relative humidity, CO_2), electrical usage, and PV generation. The PV system was added late in the construction phase, following approval of its own funding sub-grant, and installed by a regional vendor. The IAQ and electrical monitoring system was installed by the electrical subcontractor, during rough electrical and then coordinated with the homeowners upon move-in. Each monitoring system contains a modem connected to the owner-provided Wi-Fi network.

The larger goal of the monitoring research is to develop a comparable data set with the successor houses. The data is also being shared with PHIUS as they continue to update metrics for their own certification guidelines. PHIUS has, notably, taken the position that varying metrics based on climate zone must be considered as a basis for certification. This has been a controversial break from the original, singular metric of the international Passive House Institute.

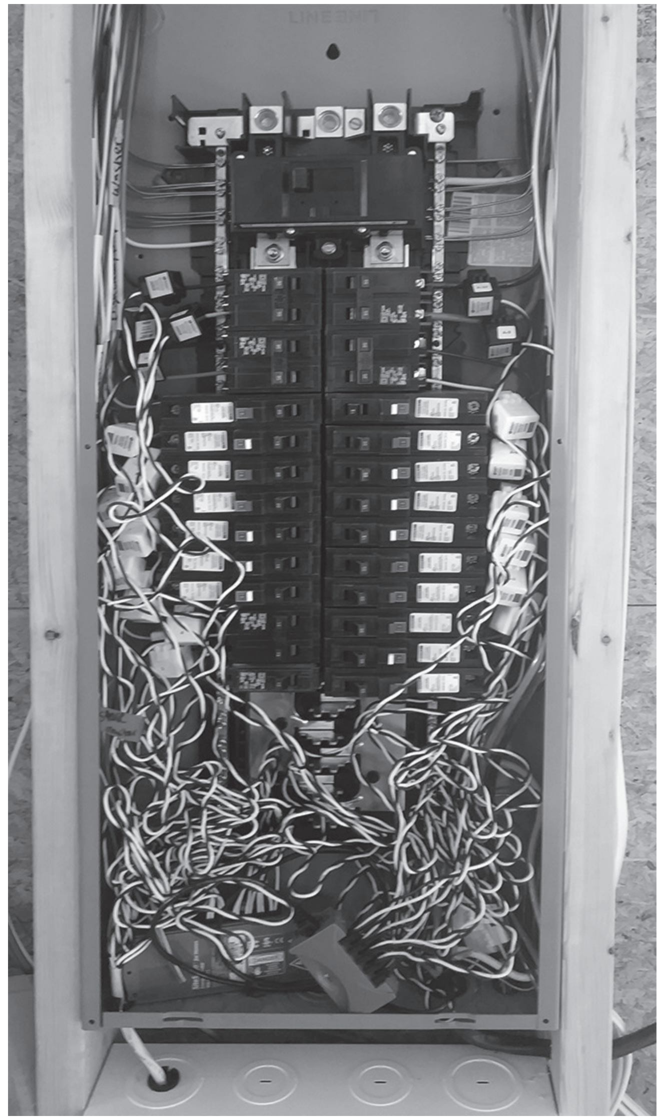

Figure 4. Branch circuit sensors monitoring electrical usage at PH01:BRK. Photo: Charles MacBride.

The house was the first building of any kind in Brookings to install an active PV array. PH01:BRK is sized as a 3.4 KW system (Figure 3). The project taught not only the faculty and students but also the Municipal Utilities Commission themselves. The installation of the system and the administration of the small-generation contract were all new processes. The coordination of schematics and identification of proper metering and shut-off equipment was assisted by research faculty from the SDSU Department of Electrical Engineering, who had practical experience with this work. The vendor is a South Dakota company called GenPro. Following installation, the PV monitoring system identified that one of the micro-inverters

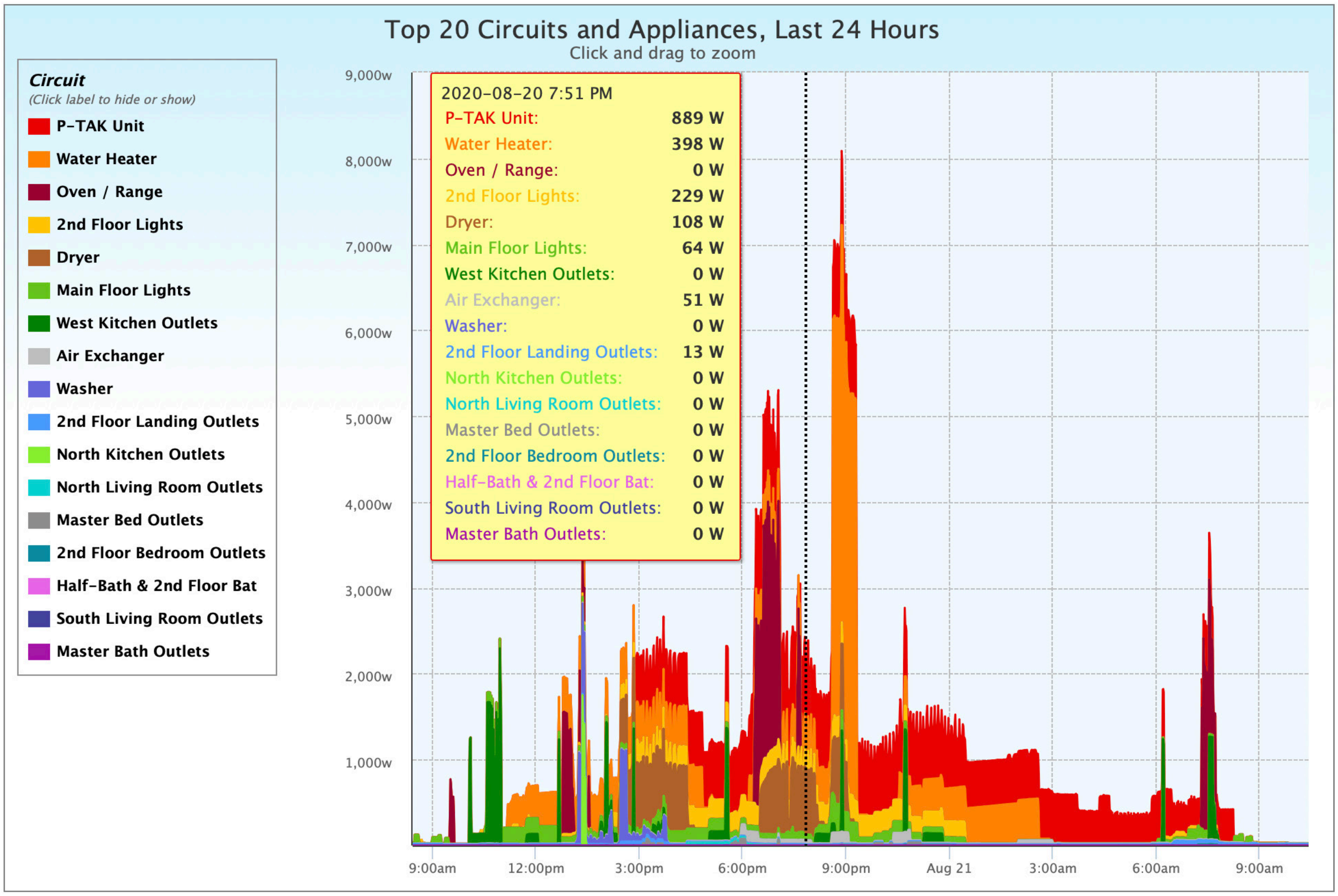

Figure 5. Sample dashboard image capture of the real-time electrical monitoring at PH01:BRK. Source: PowerWise Systems.

was not working and usage was coming from only 11 of the 12 panels. The monitoring system is the only way to have caught this fact; the vendor completed installation prior to the house sale and monitoring data was not accessible until occupancy.

There are many ways to collect and analyze the data. The monitoring of PH01:BRK indicates that summer 2020 required an average daily demand of 24 kWh of electrical use, averaging $2/day. The average daily CO2 emissions were 44 lbs. The PV monitoring indicates that generated electricity from the same time period averaged slightly less than the electrical demand, roughly 18-20 kWh on sunny days. The monitoring of specific electrical circuits reinforces the fact that demand is highest for certain equipment (Figures 4-5). The energy recovery ventilation system (ERV), the high-efficiency heat-pump water heater, the ductless mini-split cassettes, and the house's appliances are all monitored on their own circuits.

Thermal imaging also reinforces the success of the construction with regard to airtightness. The thermal envelope and the south solar shading concept were designed early in the schematic phase of the studio, and now, despite the lengthy process, an analysis of their effectiveness is being made. Therm software was used to identify areas of thermal bridging which is also easily identified using thermal imaging following completion. The most difficult bridging detail during the design phase was the cantilever over the entry landing. This detail required a revised framing strategy both in the south wall and in the upper floor joist sizing. The range of insulation types can also be analyzed. Part of the rater/verifier requirement includes density testing for blown-in cellulose, a blower door test verifying air tightness, and verification of a balanced ERV system.

Because of the delay in the construction of the successor houses, this monitoring data is being collected and analyzed in relation to "typical" builder homes in the area, and as a variable alongside utility and construction costs. The research team's original expectation of comparative analysis now may not be possible. Alternative directions for this data include use by PHIUS as a Climate Zone 6 example and use as a single-family residential building type across multiple climate zones. The design efforts of PH02 and PH03 include a multi-family project, which dramatically increases the efficiencies in passive house design, and retrofitting, which directly addresses issues of embodied carbon through a less efficient construction process.

SPECULATION ON THE FUTURE OF THE INITIATIVE

This discussion has skimmed the surface of the many directions of pedagogy and research involved with the house. As a small department establishing its identity, the project has had an outsized and ultimately positive effect on its culture. One reminder which served as an important lesson for students is that every architectural project itself requires a significant amount of teaching — teaching the clients, community, contractor, and public — and that criticism, warranted or not, will always be present.

The continuation of the grant as a financially self-sustaining project has seen the design but not the construction for the next rounds of houses. Unfortunately, this is largely due to additional oversight and hoops to navigate within the university. The first project awoke the authorities, so to speak, who have now essentially removed the design component from the purview of the students and research team.

Additionally, the studio-centered design phase has introduced a host of new performance software, anticipated by the students and utilized to measure embodied carbon (Tally, EC3), energy and thermal modeling (WUFI and Therm), and now, with the PH03 "retrofit" studio, digital scanning. Where the first project was playing catch-up, the successor projects have taken the opportunity to introduce technology, thereby reinforcing larger topics of curriculum and pedagogy. Monitoring of the first house has been a positive outcome and coincides with a new PHIUS certification standard. These revisions indicate that PH01 (based on PHIUS+ 2021) was over-designed in terms of insulation but lacking in primary and site energy.

The DoArch initiative has left an imprint in many directions. As a pedagogical model, it has shaped the design-build and hands-on approach. As a teaching and research tool it has shaped curriculum and established a model with an as yet unfilled potential. And as a cultural project, it may have created an outsized model considering the limits of the university and the region.

ENDNOTES

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