Using Case Studies to Navigate a Course to Zero Net Energy

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ABSTRACT

In 2006, the American Institute of Architects (AIA) adopted the 2030 Challenge—an initiative to mitigate greenhouse gas emissions and reach zero net energy by 2030. The AIA has also developed a Case Studies Initiative to encourage practitioners to reflect on their designs and to expose students to issues of professional practice. To support both efforts our research project cataloged the design process and performance of six low-energy buildings in the United States.

The goal of our project was to gain a better understanding of how design intent, team dynamics, and building delivery processes affect long-term building performance. Our research methodology is primarily qualitative; it included gathering metrics of building performance to pre-select each project and then conducting structured interviews with the project architects, engineers, and facilities managers. Interviews focused on: team building, goal setting, technology, process, management and relationships, barriers, and future work.

The analysis of the transcripts revealed nuances in the narrative text and salient themes across the cases. Three themes emerged from the qualitative analysis process: design innovation often requires significant client/owner buy-in; team collaboration fuels goal setting and decision-making processes; and mandates and incentives, although influential, do not drive the decision making process for low-energy buildings.

The methods and results have been disseminated via the internet, a university course, and several conference papers to illustrate the challenges of high performance building design. Qualitative analysis can supplement the building performance case studies already conducted by numerous organizations; the results may be helpful in shaping energy efficiency policy.

Introduction

In 2006, the American Institute of Architects adopted the 2030 Challenge, an initiative that challenged the building community to incrementally reduce the use of fossil fuels and to mitigate greenhouse gas emissions from the built environment. Through the challenge, the design community established fossil fuel reduction targets to achieve carbon neutrality by 2030.

The 2030 Challenge defines carbon neutrality as "using no fossil fuel GHG emitting energy to operate [buildings]" (Architecture 2030b 2011). Participating firms sign a commitment stating that they will: establish leadership structures within their organizations, implement four operational actions within six months of signing, develop a long-term sustainability action plan within a year, and report progress annually (American Institute of Architects a 2012).

In the last six years, the 2030 Challenge (or equivalent) has been adopted by numerous organizations such as the U.S. Green Building Council, The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Royal Architectural Institute of Canada, Ontario Association of Architects, Congress for the New Urbanism, American Solar Energy Society,

Society of Building Science Educators, and Association of Collegiate Schools of Architecture (Architecture 2030a 2011). In addition, the U.S. Conference of Mayors committed to reduce greenhouse gas emissions from the built environment, adopting goals similar to the 2030 Challenge.

The "Case Studies of Carbon Neutrality" research project attempted to strengthen research links between schools of architecture and professional practice, and to contribute to the work being done by the AIA, municipalities, and other organizations to address the goals of the 2030 Challenge. The project cataloged the design and delivery process of buildings that have made significant progress toward achieving carbon neutrality through six case studies of west coast precedents that describe design intent and performance through narratives of interviews with project architects, engineers, and facilities managers.

This study seeks to better understand the ways in which the integrated design process is used in the creation of buildings with aggressive, zero net energy targets. Through explication of challenges faced by project teams during the design process, this inquiry has the following objectives: to reveal examples of innovative practices, strategies, or methods used; to highlight market and other barriers that exist; to use case studies as a means of advancing and enhancing architectural education; and to provide lessons-learned from the design process and post-occupancy evaluation to practitioners.

This paper draws themes and lessons-learned from the social interactions and communications between design team members. The case studies not only highlight the quality of the design firm's work, but provide a chance for practitioners to reflect on their unique approaches to the project. The analysis in this paper advances the discipline of architecture by capturing the commonalities of knowledge, experience, and expertise in an effort to reduce the building industry's dependence on fossil fuels and to mitigate green house gas emissions that the AIA adopted in 2006.

The methods and results of this project have been disseminated through the following venues: the AIA Knowledge Community website, individual design firm websites, the Society for Building Science Educators e-mail listserv, a paper presented at the 2008 Behavior, Energy and Climate Change conference, and a two-credit advanced technology graduate-level course taught at the University of Oregon that asked students to interview practitioners, create narratives, and examine salient themes (Kwok & Rajkovich 2011). The intention was to increase connections between professional practice and schools of architecture by highlighting and successes and lessons-learned in the process of designing and constructing low-energy buildings. By documenting and sharing these design processes, the objective was to better inform and prepare design students for work in the field and to provide opportunities for practitioners to utilize feedback to enhance their design processes on future projects.

While the work is ongoing, we have found that including a qualitative description of "why" and "how" a project team chose to strive for greenhouse gas emissions reductions helps students in selecting technologies and processes for their own studio projects. The experience is also a better simulation of the struggles found in practice, consistent with the collection and analysis of planning practitioner narratives by Forester et al. (2005).

Case Study Selection

To catalog the design and delivery process for carbon-neutral buildings, our team defined the project selection criteria by which the design firms would choose their projects: a project had to have been in operation for at least one year and met the Commercial Buildings Energy Consumption Survey (CBECS) energy consumption performance standard of 50% of the regional (or country) average for that building type. Site Energy Use Intensity (EUI) was used to describe thousands of kilowatt hours of energy use per square foot of building area per year (kBtu/SF-year), an increasingly common metric being used in the building industry and by the 2030 Challenge to describe energy used in buildings. Six firms in San Francisco, California, Seattle, Washington, and Portland, Oregon were invited to participate in the research (Table 1).

Table 1: Case Study Buildings

	Chartwell School Seaside, CA	**Orinda City Hall Orinda, CA**	**Portland State Univ. Stephen Epler Hall Portland, OR**	**Tillamook Forest Center Tillamook, OR**	**The Gerding Theater Portland, OR**	**East Portland Community Center Portland, OR**
Information	21,000 s.f.; completed 2006 Predicted 50% below code Measured EUI 27.9 kBtu/sf/year	13,900 s.f.; completed 2007 Predicted 72% below code Modeled EUI: 59.6 kBtu/sf/year	64,400 s.f.; completed 2003 Predicted 49% below code Measured EUI: 41 kBtu/sf/year	18,800 s.f.; completed 2006 Predicted 30% below code Measured EUI: 99 kBtu/sf/year	55,000 s.f.; completed 2006 Predicted 35% below code Measured EUI: 61 kBtu/sf/year	22,000 s.f.; completed 2008 Predicted and measured data not available
Architect	EHDD Architecture San Francisco, CA	Siegel & Strain Architects Emeryville, CA	*Mithūn Architects* Seattle, Washington	Miller Hull Partnership Seattle, Washington	GBD Architects Portland, OR	SERA Architects Portland, OR
Engineer	Taylor Engineering Alameda, CA	Taylor Engineering Alameda, CA	Interface Engineering Portland, OR	PAE Consulting Engineers Portland, OR	Glumac Engineers Portland, OR	Interface Engineering Portland, OR

Methods

The research team interviewed members of the design teams for each building about the design process for each project. The taped interviews were transcribed and compiled, along with building performance data, into written narratives. These narratives were the primary texts for advanced technology seminars at the University of Oregon. For this paper, the methods were qualitative data analysis procedures: Narrative text coding followed categories derived from our research concerns, recoded to reveal repeating ideas within the categories, and analyzed to reveal emergent themes.

Robust triangulation of evidence was achieved through a variety of methods: structured interviews, physical observation through building walk-throughs, and collection of building energy data. Project investigators conducted twelve structured interviews with architects and engineers who were part of the design team for each of the examined building. We developed a list of questions to maintain consistency among the interviews, while allowing interviewees to describe their unique experiences and design processes in detail. Interviews were conducted primarily in person. The interviews were audio recorded, which freed the interviewer from having to take notes. Interviewers probed issues related to the design process including: team goals, dynamic, and composition; technologies and strategies employed; follow-up and lessons learned; and firm hiring and culture. Interviewees focused on a spoken narrative rather than describing visual props during the interviews that lasted approximately one hour. Each audio interview file took approximately five to six hours to transcribe, ten hours to edit and compose the written narrative drafts, and 15-20 hours for final revisions, edits, and formatting.

To complement these interviews, investigators collected additional evidence for each project. Building walk-throughs at each building allowed the investigators to see and document conditions and to ask the facilities manager's questions adapted from the interview protocol describes above. Descriptive front pieces to each narrative referred to this additional evidence such as drawings, specifications, photos, and building performance metrics data (Kwok & Rajkovich 2011).

Qualitative Data Analysis

To analyze the narrative data, we employed a variety of standard qualitative analysis procedures (Auerbach & Silverstein 2003; Miles & Huberman 1994; Patton 2004; Richards 2004; Saldaña 2009). The data set consisted of twelve interview transcripts ranging from three to eleven pages and averaging seven pages in length. For each of the six buildings, there were two interviews (one with the architect and one with the engineer). Five of the twelve interviews had multiple participants from the design team. Atlas.ti, a computer-assisted qualitative data analysis software (CAQDAS) program, was used to code and analyze the data. CAQDAS software allowed the team to view relationships among the data in more fluid and dynamic ways than are possible using a traditional manual coding and analysis method (Bringer 2003).

Coding is the process by which transcribed narrative data are organized and assigned meaning in qualitative analysis. Miles and Huberman describe codes as "tags or labels" assigned to segments, or "chunks," of text (56). What differentiates qualitative coding from quantitative coding, however, is that the "chunks" of text are not numerically quantified or reduced to numbers.

We employed *a priori* coding procedure as described by Creswell to link our research goals, questions, and concerns to the coding procedure. The team used Creswell's "lean coding" approach: establishing a "start list" of 5-6 codes, expanding these codes into a series of 25-30 sub-categories, and synthesizing these categories into 5-6 emergent themes (152).

Auerbach & Silverstein propose another useful coding and analysis model. Based on a grounded theory approach, they recommend coding as a way to "move from raw text to research concerns in small steps, each one building upon the previous one." Their seven-step process is: raw text, relevant text, repeating ideas, themes, theoretical constructs, theoretical narrative, and research concerns (Auerbach & Silverstein 2003, 35). This study modified the seven-step model to work with an *a priori* approach as described by Creswell. Miles & Huberman argue that "coding is analysis" (56), rather than a prerequisite to it, and our modified model supports their concerns.

The twelve interview transcriptions were imported into Atlas.ti as "primary documents" in PDF format. The research team used a "start list" of predetermined codes that corresponded to our research and interview questions. These codes were: decision, dynamic, delivery, post-construction, and preparation.

There is disagreement among qualitative researchers regarding how much of the raw data to retain (Richards 2005) and how much to reduce (Miles & Huberman 1994) during the analysis process. As such, we took a conservative approach to data reduction by coding the vast majority of the text, eliminating only that text which had very little relevance to our "start list." In some instances, the same "chunk" of text was coded into more than one category.

A second round of coding broke the "start list" into subcategories according to repeating ideas that were found across the groups being interviewed. Repeating ideas are "similar words or phrases [used] to express the same idea (Auerbach & Silverstein 2003, 37). This process generated 31 repeating ideas as sub-codes. The research team further analyzed these repeating ideas for deeper patterns or themes. This process generated three primary themes that emerged across buildings and across interviews. Table 2 outlines the steps in the coding process.

Table 2. Data Coding Process

Research Questions	Code	Repeating Ideas (Sub-codes)	Themes
How and why did people decide to go for a high level of energy efficiency? *(design intent)*	Decision	Decision – Client/Owner Driven Decision – Design Team Driven Decision – Champion/Visionary Decision – Client Buy-in Required Decision – Mandates Decision – Incentives	Innovation requires client buy-in Collaboration fuels goal setting and decision making Mandates and incentives influence, but do not drive, decision making
What was the group or team dynamic like on the project? *(team dynamics)*	Dynamic	Dynamic – Previous Experience Dynamic – Justifying Decisions Dynamic – Regulatory Challenges Dynamic – Team Collaboration Dynamic – Trusting Consultants Dynamic – Team Composition Dynamic – Early Involvement	
What were the key aspects of the project delivery process?	Delivery	Delivery – Construction Delivery – Costs Delivery – Design Phases Delivery – Funding Delivery – Getting the Job	
What kinds of follow-up occurred at the end of the project?	Post-construction	Post-construction – Commissioning/POE Post-construction – Measured/Simulated Data Post-construction – In Hindsight Post-construction – Results Post-construction – Informs Future Process Post-construction – Performance Goals Post-construction – Feedback Loop	
Are schools equipping students with the skills they need to meet the demands of professional practice?	Preparation	Preparation – Skills & Credentials Preparation – Team Players Preparation – Conceptual Thinkers Preparation – Continuing Education Preparation – Integrated Design Thinkers Preparation – Motivation	

Results

In the initial coding procedure, we used a "start list" of five topic categories based upon our research concerns. As we parsed the narrative text, a number of repeating ideas or sub-codes emerged within each topic category that began to reveal nuances and finer-grained characteristics in the data. Direct quotations used in the results described below follow Auerbach and Silverstein's recommendation not to include specific citations for each quote used from the narrative text (2003).

Energy Efficiency Decisions

The primary research question for this portion of the analysis asked, "How and why did people decide to go for a high level of energy efficiency?" In the narratives, we found that clients asked for varying degrees of efficiency, performance, and green building certification, but that the design teams were the primary catalyst in advancing and refining these goals to achieve near zero net energy performance levels.

In some cases, clients embraced these expanded goals, but in others, the design teams had to justify decisions to achieve them. One engineer stated, “The people on the top wanted to make this a green, energy-saving building, but didn’t want to spend money on the energy savings." Several of the architects felt that having an advocate on the client side for energy efficiency and sustainability helped them to achieve their low-energy usage goals. State mandates, such as California's zero net energy goals, affected fewer of the projects, and design teams often found ways to “dovetail” compliance with other requirements.

Incentives were utilized by all projects, although sentiment among the team members in pursuing these resources was mixed. Some of the architects and engineers interviewed felt that the incentives were too small to be worth the effort; others felt that “they helped the owner to look at some of the things they normally wouldn’t have looked at.”

Team Dynamics

The primary research question for this portion of the analysis asked, “What was the group or team dynamic like on the project?” In the narratives, we found that team member collaboration, composition, and involvement played critical roles in the design process for each projects.

Collaboration was the cornerstone of the design process for the teams involved with these buildings. The “team” involved a wider range of players, for example the client/owner and often the contractor, than was typical on traditional projects. All acknowledge the critical role of integrated design team collaboration in solving complex problems, building relationships, and working towards shared goals. “The key was having a core team with the same goals.”

The dynamic between the design team and the client or owner is sometimes characterized by unique interactions distinct from those occurring within the design team. Sometimes there is support within the client camp in form of an advocate, while often the design team must make a strong case for decisions and allow the client to evaluate the options. “Here was a great system that they never heard of before, so they wanted to kick the tires.”

Changing a client’s aversion to something new or innovative can require persuasion, patience, and time from the design team. Some supported getting team members in the design process early. “I think we’re starting to bring our consultants in at a much earlier stage” speaks to both the timing and to the opportunity that the timing presented for a greater degree of involvement in the process. Some architects described regulatory hurdles as challenging, complex, and even “disheartening,” but acknowledged that the key to solving them is through team collaboration and finding synergies between requirements and other design elements or strategies.

Some said that a strong team dynamic can result from relying on the expertise of others the design team, learning from them, and being open to suggestions. “Surround us with consultants that know all of the things we don’t.” The composition of the team is something that nearly all spent time thinking about at the onset of the projects. Previous working relationships with consultancy firms, individuals, clients, and even contractors was common and contributed to team dynamic and rapport. “It was still the best team I’ve ever been a part of.”

Design Delivery Process

The primary research question for this portion of the analysis asked, “what were the key aspects of the project delivery process that constrained or supported design of a zero carbon building?” In the narratives, we found that costs and budgets as well as traditional design-bid-build delivery methods were major constraints to delivering low-energy buildings.

Delivering buildings with ambitious, low-energy goals was “a new thing for a lot of people” involved, particularly on the construction side. Some wished that the contractor would have been part of the design process early-on, but even when that happens it is possible that bids or budgets will lead the client to replace the contractor, which results in lost coordination. For many, costs and budgets had significant impacts on the design-side in terms of design fees collected for the amount of work required to deliver such low energy buildings and on the client side in terms of being able to pay for the desired levels of performance. “The biggest motivator was the challenge to get all these things integrated into the building within the budget that was required.”

Some described the schematic design and design development phases as “more intense than normal,” more time consuming, and more challenging. Since many of the projects were owned by public or non-profit entities, funding came from many sources and was a key factor in being able to implement many of the technologies and strategies intended to maximize energy efficiency, photovoltaic arrays being one example. Design teams obtained these commissions in a variety of different ways including: through a short-lists process, through the Request for Proposals (RFP) process, through invitation, and through previous working relationships.

Post-Construction

The primary research question for this portion of the analysis asked, “What kinds of follow-up occurred at the end of the project?” In the narratives, we found that the design teams valued being able to compare design intent with the built outcome. Such feedback is not always available, but it can reveal surprising insights.

In terms of tracking information after buildings are constructed, some felt that there was “a definite value in knowing what’s actually working.” And, yet, they wish this type of information were more available. Many architects and engineers reflected on missed opportunities, goals they achieved and those they did not, and things they were happy with. Few, predominantly the engineers, admitted that building commissioning and post-occupancy evaluations are critical components of the feedback-loop and actual building performance, but that the processes are complex, challenging, and time consuming.

Many credited the lessons learned from these projects as having improved their internal integrated design processes and as having helped to establish firm sustainability practices, culture, and trajectories. Although energy modeling was widely used, there was mixed sentiment as to whether differences between simulated and measured data helped inform future energy modeling or whether its shortcomings make actual measured data more valuable. Some acknowledged that, while they did not meet all goals, they were satisfied with the high performance of systems and strategies employed in pursuit of goals. Most were surprised, whether in good or bad ways, by unanticipated aspects of the completed buildings or the design process. "Certain things you know intellectually, but it's completely different to experience them viscerally."

Preparation for Students Entering Professional Practice

The primary research question for this portion of the analysis asked, "Are schools equipping students with the skills they need to meet the demands of professional practice?" In the narratives, we found that architecture and engineering firms look for employees with specific skills, experience working on teams, and genuine interests in green design, but that employers weight these characteristics differently in their hiring practices.

The types of skills that architects and engineers look for from students transitioning to professional practice varied widely. Several architects specifically look for students with strong conceptual thinking abilities and that are adept at thinking about complex problems, systems, and ideas. Likewise, some architects seek out students that can think about design, technical issues, and sustainability in integrated ways, skills that can be cultivated in the design studio atmosphere of architecture schools. Some architects and engineers viewed skills developed in school as "just one step in the whole process" and lamented programs that fail to think outside their discipline or to view experience in practice as a continuation of the learning process. Some architects and engineers, alike, felt that specific skills are something that are best learned in practice, but that firms need students with "the right attitude," curiosity, interest, passion, and energy.

Several architects look for students that know how to work as part of a team, skills they seem to be learning well in some design schools. Different professionals look for very different kinds of skills in students they hire, whether technical, graphic, thinking, and/or LEED related.

Key Themes

From the initial analysis using research concerns and repeating ideas, several themes emerged. Three of these themes seemed particularly salient with respect to eliminating barriers to zero net energy buildings and better understanding the integrated design process that shapes these projects.

Collaboration Fuels Goal Setting and Decision-Making

Achieving low-energy goals required that design teams take an active role in setting, refining, and, often, expanding project goals and objectives. "We actually came in and added to the goal setting." Integrated teams, inclusive of design specialists, stakeholders, and others, were critical in working through the complexities inherent in delivering high levels of energy efficiency. "The design process was much more integrated and each person had to step outside of their specialized role to make the project a success."

The earlier team members could be integrated into the design process, the greater the involvement in the goal setting and decision-making activities, a marked difference from traditional building design and delivery processes. "Our involvement at that point was much higher than usual on most projects, and the best early collaborative design that I've seen on green projects."

A key to the success of many projects was the non-hierarchical structure of the teams, which enabled members to take turns advocating or championing specific ideas, strategies, approaches, and technologies employed. “We went back and forth and it was a very open and cooperative arrangement. We never felt that he was telling us, you have to do this.” For many, the composition of the teams often included individuals, firms, or organizations with previous working relationships, which helped to ensure a productive and predictable design processes. “It was probably the greatest asset that we all knew each other and [got] along really well.”

Innovation Requires Client Buy-In

Clients and owners initiated energy efficiency, performance, and green building certification goals, but relied upon the design teams to propose solutions to how to best meet these goals. “Our job is to really make sure that, from the very beginning, clients understand what the give and take will be to deliver a more sustainable building.” Many design teams were sensitive to their client’s reluctance to try something new. “We never want to force something that’s innovative, risky, or challenging on the client.” Some clients were more willing than others to take a risk. “They were open minded to test new ideas.” Achieving buy-in from clients for innovative solutions was a negotiation process. “When you make good projects, you can only go as far as your clients are willing to go.” But, this buy-in process forces the design team to have to justify the merits of ideas and solutions, which strengthens the overall design process.

Mandates and Incentives Influence, but Do Not Drive, Decision-Making

The motivation to seek high levels of energy efficiency came from internal goals set and developed by the teams rather than from external mandates, requirements, rebates, or incentives. “The energy use, particularly the carbon component of that energy, was very important for me.” Teams sometimes found synergies between internal team goals and external mandates and incentives. “It dovetailed into what LEED was at the time.” For some, requirements for mandates and incentives helped pay for design work that directly benefited other aspects of the design process. “It certainly made us more willing to invest more time for the energy modeling because we expected to get some money back.”

Others explained that specific team members handled mandates and incentives; they were not part of the integrated design process. “There were tax credits and incentives; however, we weren’t involved with that aspect of the project.” Some acknowledged that mandates and incentives encouraged teams to think differently about specific aspect of their designs. “Incentives helped the owner look at some of the things they normally wouldn’t have looked at.” Fewer found incentives cumbersome for the rewards they offered. “The project was such a small scale that the incentives…are not worth our time to fill out.”

Limitations

The analysis for this research focused on a small sample size of six case study buildings and twelve interviews of architects and engineers. Furthermore, qualitative analysis of narrative text is predicated on a subjective interpretation of the language used by the participants, which we acknowledge is a very different approach than is traditionally taken in the building sciences which rely on empirical methods and statistical analysis. Nevertheless, the research design was an appropriate fit for the goals and objectives of this study, and is consistent with methods utilized in the social sciences such as urban planning, sociology, and policy analysis.

Discussion

These case studies offer a unique perspective on integrated design; critical to the successful realization of zero net energy buildings. By interviewing practitioners, we found that they engage in the design of low-energy buildings with active participation from clients in the goal setting process. Zero net energy requires an inclusive team that gets members involved early in the process; trust among team members is key to the success of the project. We also found that meeting low-energy targets often requires client buy-in for novel solutions, approaches, or technologies that are outside standard practice. Finally, mandates and incentives influence, but do not drive or dictate, the decisions that design teams make to accomplish energy efficiency goals.

These results suggest that (a) the design of zero net energy buildings has transformed the ways that design firms think about design and do business, (b) design teams are utilizing an integrated design process to address challenges and to break the barriers that exist in the realization of buildings with ambitious, low-energy goals, (c) it is vital that practitioners be able to work collaboratively in team settings, and (d) case studies can be effective in revealing the richness of the design process and the value of lessons-learned through narrative text. While these findings are based on a limited number of cases, it suggests modifications to the current way we educate and train architects and engineers.

For example, the metrics and methodologies taught in architecture and engineering schools tend to be self-reinforcing because students do not typically work in multidisciplinary teams. While this is allows students and faculty to refine the methods they use for building analysis and design, it may not prepare students adequately for working with practitioners outside of the architecture/ engineering/ construction community. Experience through a design-build project such as the Solar Decathlon may provide students with these newly required skills. However, the high cost of having students conduct interviews and narrative analysis may help them to understand some of the barriers they may face in practice.

At the University of Oregon, an upper level graduate seminar has asked students to interview practitioners, transcribe narratives, and then to summarize the barriers practitioners face as they seek to create low energy buildings. While analysis of the effectiveness of this course is preliminary, early results indicate that it exposes students to many of the key issues discussed in this paper: collaboration, client interaction, and the role of financial incentives. This work builds on the case study methodologies common in urban planning and business administration, and augments technical education that shows students how to size and specify building systems.

Our approach, which is grounded in a rich tradition of qualitative methods prevalent in the social sciences, is not intended as a replacement to empirical testing, but rather as an additional approach that should be employed in the evaluation of policies and programs. Beyond technical concepts and principles of building science and technology, case study narratives combine common themes and barriers that cross multiple disciplines; the narratives describe how and why innovation and change occur. This allows educators to reveal nuance, meaning, and patterns embedded in human stories about the design processes, critical to creating low-energy buildings. We feel that this additional information connects with students on a different level, and is an important layer that augments learning beyond the sizing and specification of systems. Our goal is to continue to add examples and narratives to the case study project to eventually build a library of case studies relevant to all practitioners of low energy building design.

Conclusions

In six short years, the 2030 Challenge has been both a call to action and an incremental path to change. Case studies can be an effective instrument in this change toward lower carbon and lower energy in the built environment. This study focuses on six buildings and the stories behind their design and development. We believe that these examples provide an encouraging glance at the future of innovative, zero net energy buildings. We used a qualitative analysis procedure to examine design collaboration, because energy metrics, for all their merits, are unable to adequately describe this process. The methods developed and employed in this analysis have proven robust and illuminating, and we hope that others investigating energy use in buildings will consider this approach to augment technical training.

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