LIFEBUILDINGX©

LIFE BUILDING ***Exchange***:
Investigating the Intersections among
Pro-environmental Behavior,
Place Meaning, and
High-performance Design

A Research and Design Study submitted by:

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2019 Certificate of Research Excellence

The American Institute of Architects
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PREFACE: KRIEGH ARCHITECTURE STUDIOS | RESEARCH + DESIGN

Founded in 2000, KRIEGH ARCHITECTURE STUDIOS is a research, design, and consulting firm located in Seattle, WA. **People; Place; Performance –** these words are at the heart of our firm's philosophy. Using research to deepen our understanding, we design in such a way as to create meaningful places crafted with excellence, meet high-performance Passive House energy standards, and support people's pro-environmental behaviors. By linking high-performance energy-efficient technologies with an informed understanding of the motivations underpinning pro-environmental behaviors, our team arrives at a multi-dimensional approach geared to reach net-positive energy goals as are deemed crucial to meeting the 2015 Paris Agreement on climate change.

We recognize that architectural design requires the coordination and harmonizing of many details in addition to low-energy consumption. Taking a transdisciplinary approach inclusive of clients, architects, artisans, researchers, engineers, planners, builders, developers, and city agencies, KRIEGH ARCHITECTURE STUDIOS integrates details with insight and attention to the art and science of design so that every component works for both our clients and the environment. This process proves both innovative and empowering for clients. As one client recently put it, *"I enjoy working with the team. I admire their expertise and appreciate their individual effort. My Rest of Life house is very important to me, and the process is empowering."*

We work on a diverse range of projects, including the programming, planning, and design of new and renovated structures, with special expertise in residential projects and energy modeling. Out team designs for multiple purposes in support of the environment and pro-environmental behavior. For example, a rain garden on site serving as a stormwater management system may also serve as a psychological cue for water conservation behaviors by the occupant. A roof top solar collection array may supply a renewable energy source to achieve net-positive energy while also cueing energy conservation behaviors for the user.

Our research suggests that both the design of the physical environment and people's relationship with that environment comprise important factors related to energy use. **We believe that user behavior is the next frontier in energy conservation**. As energy codes become more stringent and building envelopes improve, what will most influence impact on the environment is energy use under the direct control of the occupant. Recognizing that an approach incorporating both building science and user behavior is necessary if progress is to be made toward the goals put forward in the 2015 Paris Agreement, Kriegh Architecture Studios | Research + Design undertook the study that follows – **LIFE**BUILDING***X*** | **LIFE** BUILDING ***Exchange***: Investigating the Intersection of Pro-environmental Behavior, Place Meaning, and High-performance Design. The first in-depth, multi-year study on energy use and behavior to be undertaken by our firm, this work was awarded the Environmental Design and Research Association 2019 Certificate of Research Excellence. We are pleased to share the methods and applications to practice provided in this report.

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LIFEBUILDING***X***

LIFE BUILDING ***Exchange***: Investigating the Intersection of Pro-environmental Behavior, Place Meaning, and High-performance Design

A Northwest Net-zero Energy Community. (Source: Retrieved (9.2.18) from Google Images, https://www.google.com/.)

ABSTRACT

Future progress in energy conservation centers on user behavior. As energy codes become more stringent and building envelopes improve, what will most influence impact on the environment are energy-related choices made by the occupant. With regard to the design of the physical environment, we recognize that an approach incorporating both building science and user behavior is necessary if progress is to be made toward the climate change goals put forward in the 2015 Paris Agreement. This study, **LIFE**BUILDING***X*** , offers an integrated transdisciplinary research design approach.

Both the design of the physical environment and people's relationship with that environment are important factors related to energy conservation. While social scientists have developed theoretical frameworks to understand people's pro-environmental behaviors and relationships to place, many have overlooked the role of the built environment—particularly high-performance design—in that relationship. Conversely, architects focused on high-performance net-zero design often do not seek to understand how people live in and make sense of their environments. Drawing together these two approaches, a mixed-methods study comparing two housing communities in the Pacific Northwest was conducted to understand people's residential energy use behavior as it relates to physical and social aspects of their environment as well as to their values, identity, and place attachment. Study sites included a Built Green Community (Site 1) designed to state-of-the-art "green" building standards for

low energy use, and a Code-built Community (Site 2) built according to more conventional minimal energy code standards. Research methods included benchmarking actual household energy consumption, introducing a treatment (a monitoring dashboard showing a household's energy use), and surveying study participants pre- and post-test on perceptions related to energy use, followed by in-depth qualitative interviews of a sub-sample of participants.

KEY FINDINGS

Findings indicated that, while the energy use intensity (EUI) scores for both communities were low compared to national and regional averages, energy use for miscellaneous electric loads and appliances (behavior-related uses) was about on par with those averages, with space conditioning and domestic hot water (building-related uses) responsible for nearly 50% of the total household energy. Additionally, energy use data showed that the Built Green Community participants increased their energy use over the course of three consecutive years, while the Code-built Community participants decreased their energy use. Survey results showed that biospheric values and environmental self-identity ratings increased for the Code-built Community after the dashboard feedback intervention. Interview data suggested that individuals engage with their environment in a way that is likely to be energy conserving when such behavior is supported by their residential setting, they espouse biospheric values, and they are attached to and identify with their homes and communities. Based on these findings, a conceptual framework, LIFE BUILDING ***Exchange***, was developed using Grounded Theory analysis that encompasses the following: LIFE—people's values and place meanings; BUILDING—environmental cues; and EXCHANGE—the locus of reciprocal relationships (buildings and behavior) found in high-performance environments, all of which will play a crucial role in meeting the net-zero climate change goals targeted by the 2015 Paris Agreement.

KEYWORDS

High-performance design, residential energy use, net-zero homes, information feedback, pro-environmental behavior, values, place identity, environmental self-identity, place attachment

THE FOCUS OF THIS REPORT

The AIA Upjohn Research Initiative fund supported exploratory research in pro-environmental behavior in 2013, and applied research in energy use and behavior in 2014. These two initial research endeavors established a foundation for the final research design and dissertation completed in 2018—**LIFE**BUILDING***X*** | LIFE BUILDING *Exchange*: Investigating the Intersection of Pro-environmental Behavior, Place Meaning, and High-performance Design. This report summarizes the mixed-methods, multi-year research study, **LIFE**BUILDING***X*** relates key findings, and highlights applications to practice.

INTRODUCTION

Net-zero energy buildings[1] offer a unique opportunity to research and evaluate the effects of multiple high-performance design features in relationship to occupant behavior. Such an undertaking is needed because, in the realm of net-zero energy buildings and regenerative architectural design, architects and building scientists often pay inadequate attention to the motivations underpinning people's environmental behaviors. Conversely, the literature on pro-environmental behavior in environmental psychology has paid little attention to the physical attributes of building and site design or innovative technologies that might influence people's motivations to act pro-environmentally with respect to energy use. The purpose of this research is to redress this disparity by investigating the intersection among context-oriented and person-oriented variables that inform sustainable development and behavioral research, thereby stimulating design solutions to advance net-zero goals amid climate change as put forward in the 2015 Paris Agreement.[2]

RATIONALE

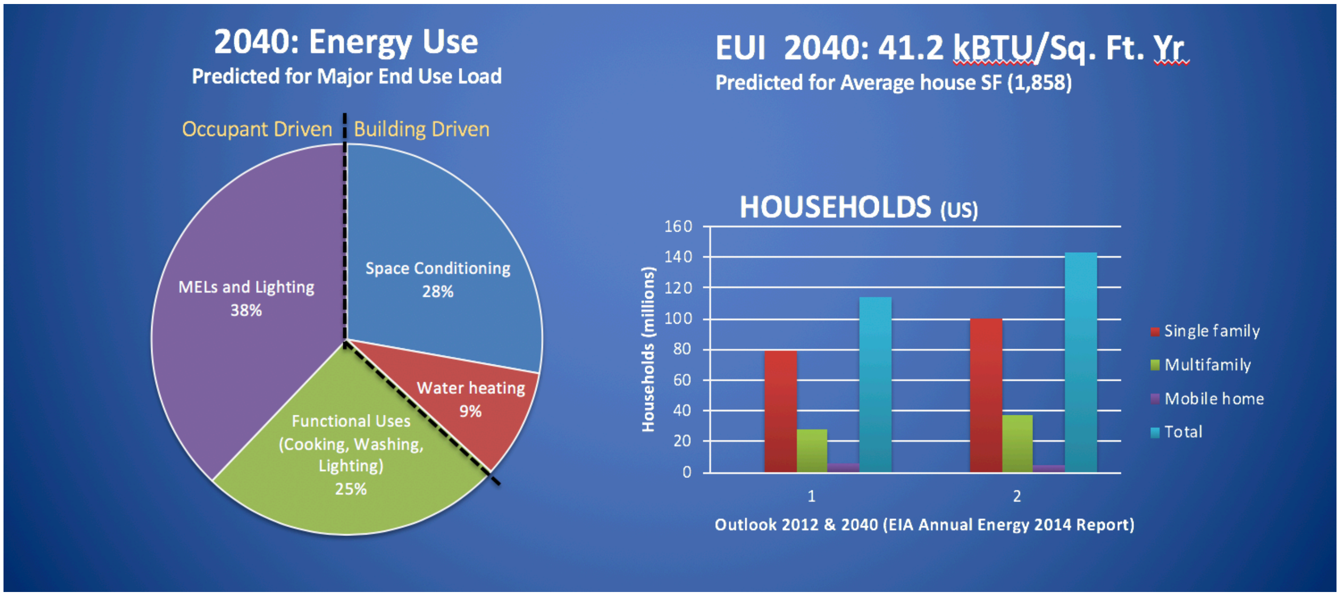
The significant role of residential and commercial buildings in addressing net-zero climate change goals is often underestimated. First, direct GHG emissions from homes account for nearly 50% of all greenhouse gas emissions in the building sector. Second, indirect emissions from electricity used by homes and businesses account for nearly 50% of the total electricity sector. Taken together, residential and commercial buildings account for nearly 30% of all GHG emissions. Furthermore, this number continues to increase (27% since 1990) due to home electricity consumption for space conditioning (heating and cooling), domestic hot water heating, and the rapid rise of miscellaneous electric loads, also known as MELs (EPA, 2016).

Significantly, as the proportional impact of energy used for MELs powering personal electronic devices continues to rise, occupant behavior is likely to define the next frontier in energy use. That is, miscellaneous end-use electric loads such as those drawn by laptops, cell phones, tablets, and monitors are active at the discretion of the building occupant, and the energy consumption associated with these devices continues to increase not only because more are in use per household, but also because they remain powered more of the time. As a result, occupant-driven electric loads are offsetting gains made in building envelop and equipment efficiencies (Kwatra, Amann, & Sach, 2013), thereby rendering net-zero a target that is not only difficult to meet, but also moving. This problem is magnified in light of the 30 million additional housing units anticipated by 2040 (EIA, 2015).

[1] The U.S. Department of Energy defines a net-zero energy building as "an energy efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." Retrieved (August 10, 2018) from https://www.energy.gov/eere/buildings/articles/doe-releases-common-definition-zero-energy-buildings-campuses-and).

[2] The recently ratified 2015 Paris Agreement[2] on Climate Change outlines a clear objective to limit the rise of global temperature warming to 1.5 degrees Celsius over pre-industrial levels. This 2015 imperative is considered an "essentially net-zero goal,"[2] according to Rachel Cleetus, lead economist and climate-policy manager at the Union of Concerned Scientists (Meyer, 2015).

OCCUPANT-DRIVEN-ENERGY



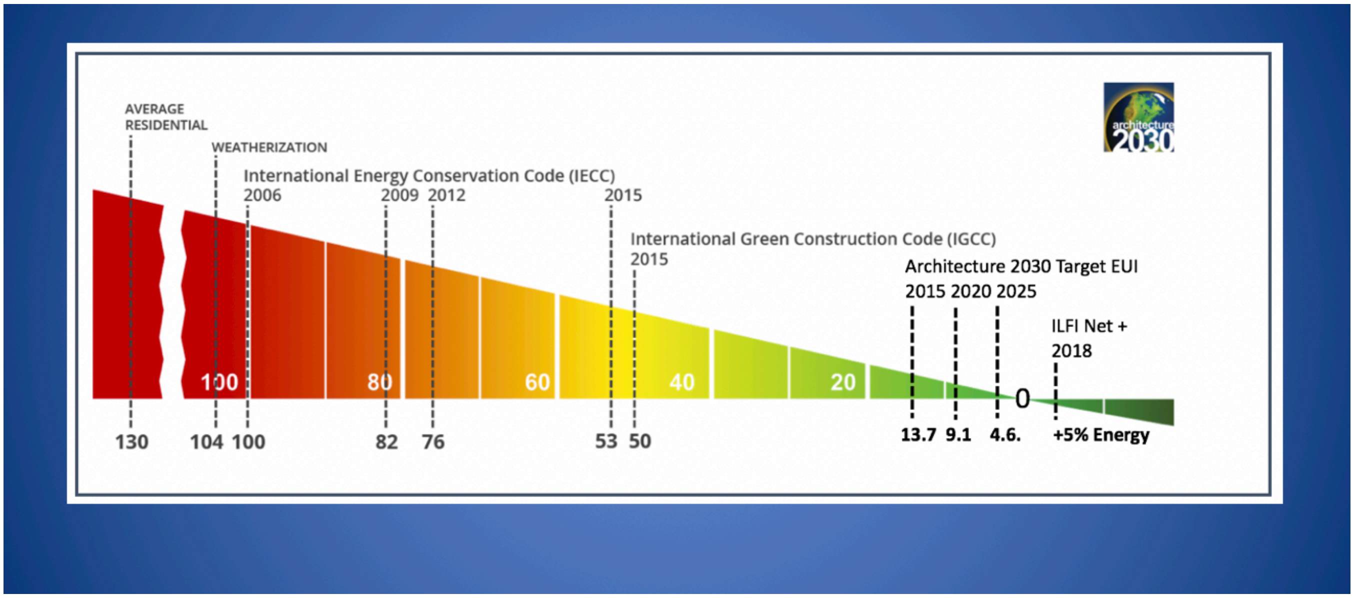
As building energy codes improve, people's choices are predicted to influence a greater share of energy use in typical residential buildings— known as Occupant-Driven-Energy.
(Source: EIA Annual Energy 2014 Report)

Given these factors, what types of innovative pathways are available to spur the transition to net-zero and net-positive energy use? When considering the building sector, the Intergovernmental Panel on Climate Change (IPCC) confirms the need for substantial action, suggesting a parallel multi-track approach that incorporates the following key concepts in sustainable development: 1) advocating the need for improved land use zoning regulations and stringent building code standards; 2) promoting the design of higher-performance buildings and building technological advances; and 3) shifting individual and collective perceptions, beliefs, values, and worldviews (IPCC, 2014) toward sustainable actions. Certainly, great strides have been made independently in all three tracks with increasingly stringent energy codes, advances in high performance net-zero buildings, and a deeper understanding in the field of Environmental Psychology concerning the motivations behind environmental behaviors. Yet the three tracks have not been integrated in a holistic way such that the performance outcomes of for both buildings and human behavior inform and influence higher levels of performance in all three tracks, nor has there been a thorough investigation of the process as a whole, including how to design in support of pro-environmental behavior in the built environment. This study maintains that a holistic approach is essential to spur the transition to net-zero and net-positive energy use in the building sector generally and in residential buildings specifically by 2030.

RESEARCH GAP

This study seeks to fill a significant research gap. That is, it explores how and why architectural design features may, in a dynamic process, support and inform people's depth of place meaning and inspire them to prioritize those values and behaviors that maintain, enhance, and protect environmental

ENERGY USE INTENSITY TARGETS



Residential Energy Use Intensity Score Targets over the last Twenty Years.
(Source: Composite graphic, Architecture 2030, Retrieved (June 22, 2018) from Google Images, https://www.google.com/.)

resources in general and reduce residential energy use in particular. Net-positive energy buildings[3] are designed to achieve or exceed climate change goals through multiple strategies, incorporating performance standards, design features and efficient technologies, as well as on-site renewable resources (e.g., ILFI, iPHA, and OPL criteria[4]). However, these very performance-based architectural features may also offer physical, environmental cues that inform a person's behavior, raising the behaviors themselves to a higher pro-environmental performance level.

Furthermore, while this research investigates the intersections among pro-environmental actions, values, place meanings, and design, it also suggests that the process is neither linear nor sequential. That is, high-performance, in terms of both the building and a given person's behavior, results from a collection of continually evolving relationships found in the dynamic among people, place, and the locus of performance settings. The varying dynamics between people and place may cause people to prioritize certain values, inform their self-concept, enable place attachments, and promote environmental behavior. In this study, these unique combinations related to high-performance or low-performance in terms of energy use. In the best scenario, a person's values and place meanings may promote a higher performance exchange (outcome) that supports net-positive energy developments. This study, therefore, offers a model of people-place interactions in the **LIFE** BUILDING ***Exchange*** framework depicted below:

[3] For more information on the design of passive house and zero net energy buildings see Corner, Fillinger, & Kwok (2018); Eley (2016); and sustainable design philosophy, see McLennan (2004).
[4] For more information see ILFI (International Living Future Institute, 2014, 2016); iPHA (International Passive House Association, 2014); OPL (One Planet Living, Framework, https://www.bioregional.com).

LIFEBUILDING***X*** CONCEPT

LIFE ←→ BUILDING **←→ *Exchange*** ©

LIFE—people's values and place meanings;

BUILDING—architectural design features as environmental cues; and

EXCHANGE—the locus of reciprocal relationships found in higher-performance designs inclusive of both buildings and behavior.

LIFEBUILDING*X* Expression. (Source: Image by author.)

Conceptually, the framework for **LIFE**BUILDING*X* builds on the early work of Kurt Lewin from the 1930s (Gifford, 2014). Lewin saw the relationship between the person and the environment as bi-directional, meaning that, just as the person influences the environment and the environment influences the person, people are active elements in their environments (Clayton, 2012). Hence, the **LIFE**BUILDING*X* framework proposed in this study is similar to Lewin's general model in that it suggests an active relationship between people and place. However, the **LIFE**BUILDING*X* framework stipulates that a number of dimensions in this dynamic process play simultaneous roles, particularly when the outcome is related to energy use in residential settings. Understanding these dynamics is essential if we are to find effective ways to index influential factors, benchmark behavior, and promote higher performance buildings. Importantly, the **LIFE**BUILDING*X* framework builds on the work of other contemporary environmental psychologists and scholars, particularly research on values (Schwartz, 1973, 1977, 1992, 2012; Steg, Bolderdijk, Keizer, Perlaviciute, 2014a; Stern, 2000, 2011, 2014), place identity (Proshansky et al, 1983), environmental self-identity (Van der Werff, & Steg, 2015; Whitmarsh & O'Neill, 2010), and place attachment (Lewicka, 2011; Manzo & Devine-Wright, 2014; Scannell & Gifford, 2010a and 2010b).

In summary, this **LIFE**BUILDING*X* research investigates the intersections among pro-environmental behavior, place meaning, and design in two sites of buildings and communities, intersections described as a whole system that is likely to influence the outcomes of higher-performance buildings and behavior.

TWO COMPARISON COMMUNITIES IN THE PACIFIC NORTHWEST

Images of Built Green (left) and Code-built (right) Communities.
(Source: Top images retrieved (August 2, 2018) from Google Images, https://www.google.com/ and lower photo images by author.)

TWO COMPARISON COMMUNITIES: SIMILAR DEMOGRAPHICS

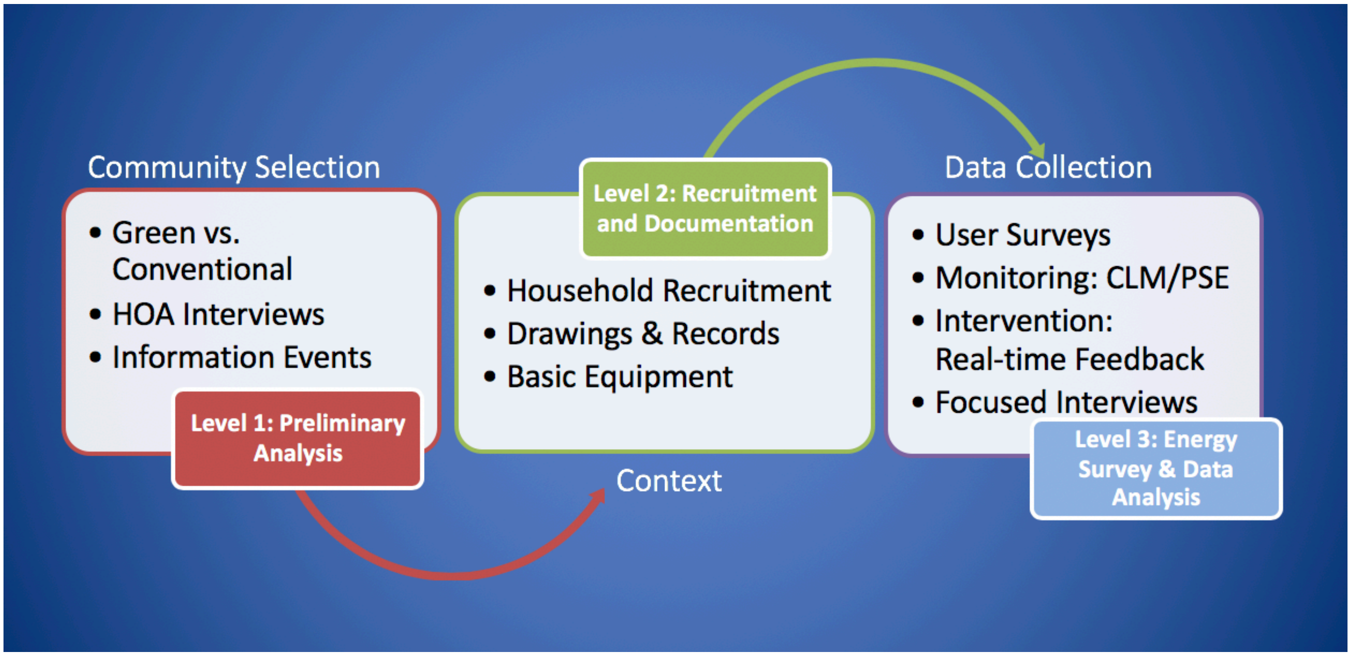
	Green (n = 12)		Code (n = 12)		Combined Sample (N = 24)	
Characteristic	n	(%)	n	(%)	N	(%)
Gender						
Male	6	(50%)	3	(25%)	9	(38%)
Female	6	(50%)	9	(75%)	15	(63%)
Education Level						
2-year Community College	1	(8%)	0	(0%)	1	(4%)
4- or 5-Year College Degree	1	(8%)	5	(42%)	6	(25%)
Graduate Degree	10	(83%)	7	(58%)	17	(71%)
Ethnicity						
Non-Minority (White)	12	(100%)	11	(92%)	23	(96%)
Minority (Asian)	0	(0%)	1	(8%)	1	(4%)
Combined Household Income						
\$100,000 or Less	7	(58%)	5	(42%)	12	(50%)
\$100,001 - \$250,000	5	(42%)	7	(58%)	12	(50%)
Home Ownership						
Rent	2	(17%)	0	(0%)	2	(8%)
Own	10	(83%)	12	(100%)	22	(92%)
Square Footage of Home						
Less than 1,000 SF	2	(17%)	2	(17%)	4	(17%)
1,001 SF - 2000 SF	10	(83%)	10	(83%)	20	(83%)
Age of Head of Household						
26-45	2	(17%)	1	(8%)	3	(13%)
46-65	5	(42%)	10	(83%)	15	(63%)
Over 65	5	(42%)	1	(8%)	6	(25%)

Note. Chi-square tests showed no differences between Grow and Winslow groups ($ps > 0.05$).

Demographics. (Source: Image by author.)

The two Pacific Northwest communities compared were carefully chosen for their similarities in location and demographics (N = 24). The distinguishing factor is that one, the Built Green Community (n = 12) was designed in 2013 using state-of-the-art net zero-energy building technologies and low impact site design strategies, while the other, the Code-built Community (n = 12) was designed in 1991 prior to the development of high performance energy codes or beyond code standards. Demographics show that the two communities are quite similar, both enjoying a high degree of education, income, and homeownership.

RESEARCH METHODS

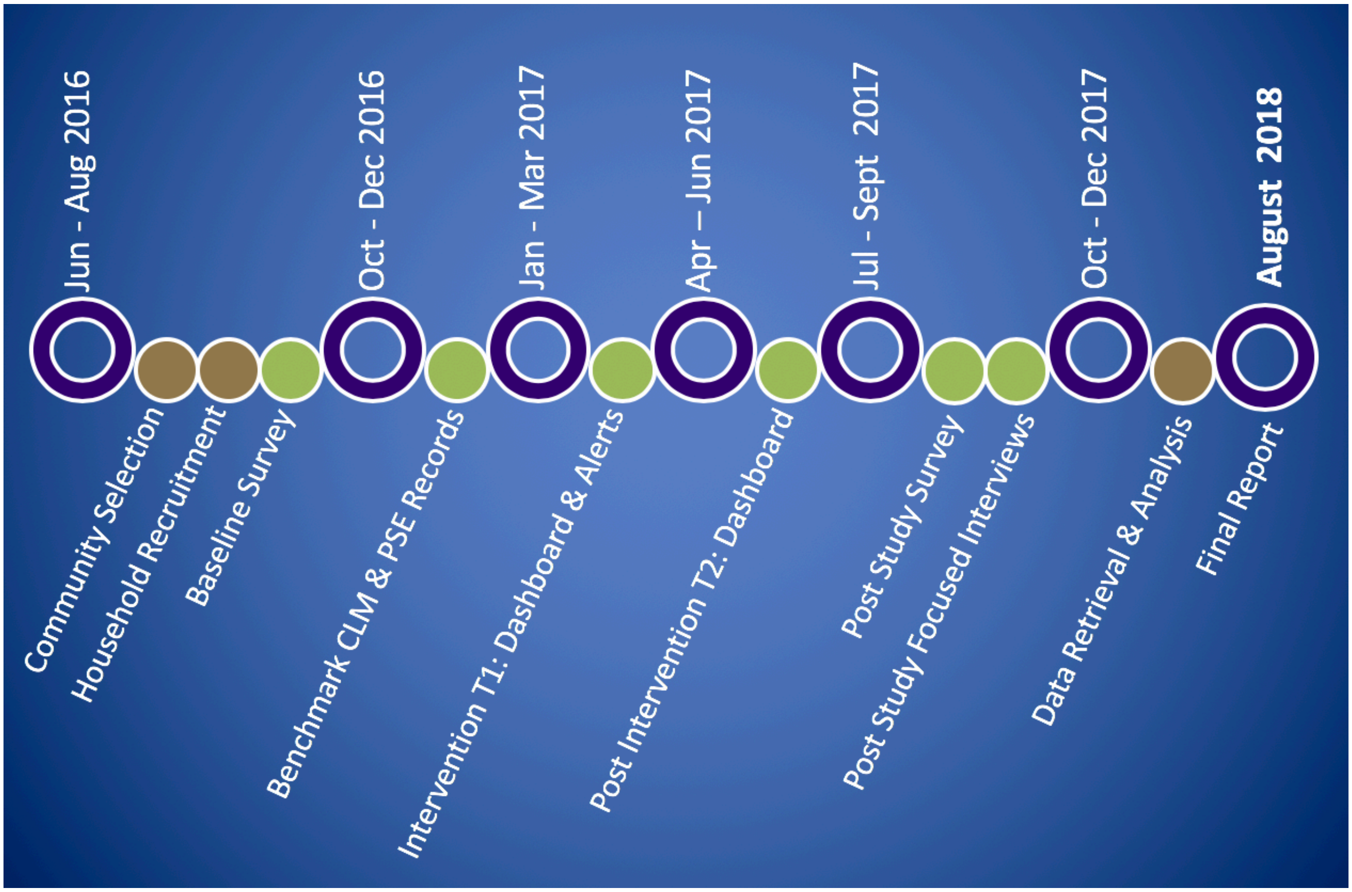


Research Design. (Source: Image by author)

The mixed-methods research design employed in this study used both quantitative and qualitative techniques to investigate people's experiences of their residential energy use in their homes, including their perceived and actual energy use. In addition, the present study examined the patterns, perceptions, and motivations that underlie people's pro-environmental behaviors broadly and residential energy use in particular in two residential communities located in Washington State. The two comparative Pacific Northwest communities were studied via the following steps:

1. Surveyed on their perceptions of energy use and the importance of values, beliefs, goals, place attachment, place identity, environmental self-identity, and design features at pre- and post-treatment study periods.
2. Given a treatment consisting of access to an energy monitoring dashboard in participants' homes that enabled household members to observe and inform their energy behaviors in real-time.
3. Monitored on the households' actual electrical energy use data (three years of utility billing data from Puget Sound Energy [PSE] and one year of circuit level monitoring [CLM]), also measured at pre- and post-treatment (i.e., energy dashboard exposure) periods over the course of the study.
4. Interviewed, following treatment, with a series of focused interview questions that sought to understand residents' perspectives on why they use energy as they do. Additionally, these questions explored possible meanings behind and connections to attachment and identity issues found in the lived experience of place that could potentially promote changes in household energy use.

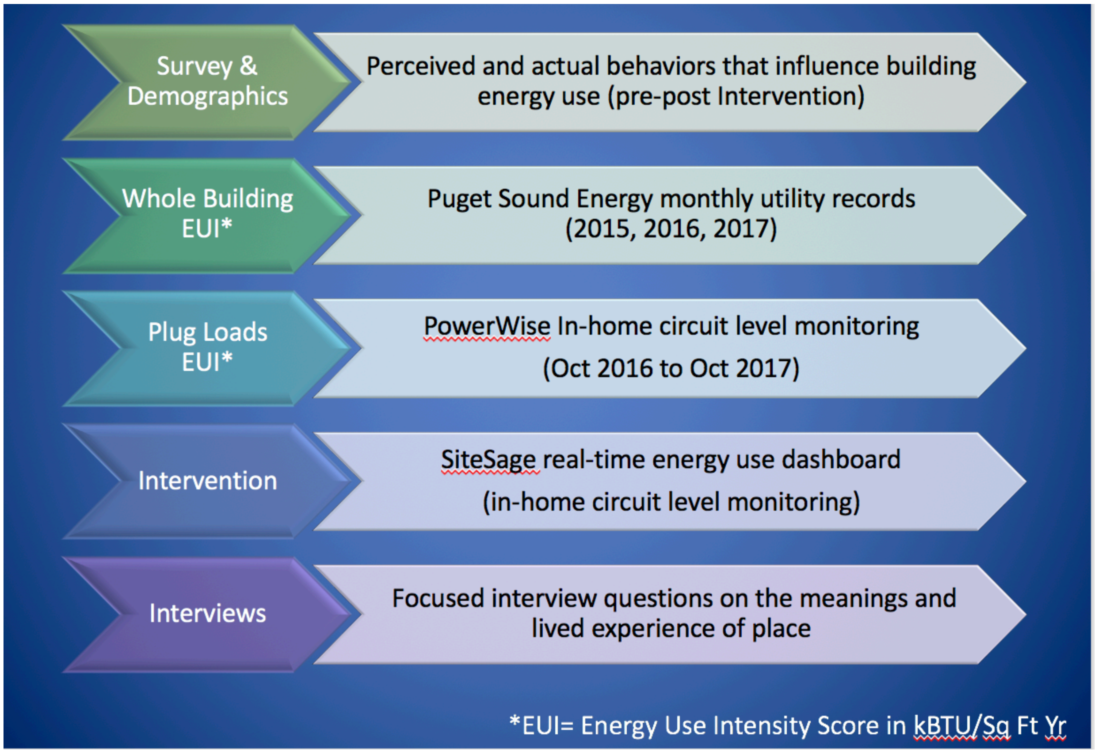
DATA COLLECTION TIMELINE



Phases of Data Collection. (Source: Image by author.)

Research at the two study sites began in June of 2016 with community selection and household recruitment (*N* = 24) and concluded in September of 2018 with the final data retrieval and analysis, culminating in the final report written in August of 2018. Data collection categories, collection systems, intervention dashboard, and interview categories are depicted below.

DATA COLLECTION CATEGORIES



Data Collection Categories. (Source: Image by author.)

DATA COLLECTION SYSTEMS

Data Collection Systems. (Source: Image by author.)

INTERVIEW CATEGORIES

Question Topics	General Interview Responses	
	Green	Code
Background:		
Why this place was chosen	Strongly Sustainability	Strongly Social
Feelings about living here:		
Sense of connection & groundedness	Yes	Yes
Expressions of identity and values	Yes	Yes
Supportive of current lifestyle	Yes	Yes
Caring for place	Taken care of for me	Engaged
Sustainability and environmental behavior:		
Actions and choices on energy behaviors	Taken care of for me	Engaged
Features that influence energy use	Taken care of for me	Engaged
Dashboard feedback:		
Influence on energy use	Not so much	Yes
Usefulness of alerts	Not so much	Yes

Interview Question Categories. (Source: Image by author)

INTERVENTION: DASHBOARD REAL-TIME FEEDBACK

Example of PowerWise / SiteSage Dashboard. (Source: Image by author)

RESEARCH QUESTIONS and ANALYSIS

Specifically, the study investigated the following four elements: 1) participant households' actual residential baseline energy use and whether use differed across the two communities; 2) participant responses to an intervention using real-time feedback on residential energy-related behavior and whether intervention effects differed across the two communities; 3) participant perceptions of their residential energy use and whether perceptions differed across the two communities; and 4) how relationships with the physical context of their residence and community may have been linked with participants' energy use and whether those relationships differed across the two communities. To conduct these investigations, the following research questions and analyses were developed:

1. How do the Built Green (recently built, high-performance buildings) and Code-built (older, lower-performance buildings) communities compare on their actual energy use? (Benchmarking EUI or energy use intensity scores in kBTU/sq.ft.yr.) score variables)

    - Analysis 1a: Mean EUI scores were computed prior to the start of the study in Excel. Two-group t-tests in SPSS were then used to compare and benchmark EUI scores.
    - Analysis 1b: Predicted energy model EUI scores and comparison third party national and regional EUI scores (2009 RECS and 2011 RSBA) were obtained and computed in Excel.

2. What are the effects of real-time feedback (treatment) on actual energy use? (Testing the significance of change in pre- and post-treatment EUI score variables)

    - Analysis 2a: 1-group t-tests were conducted to compare the mean change in PSE EUI scores against a null of zero (no use) from pretest to each treatment period.
    - Analysis 2b: Mean PSE and CLM EUI scores were computed and weather-normalized using 12 months of PSE. 1-group t-tests were conducted to compare the mean change in CLM EUI scores against a null of zero (no use) from pretest to each treatment period.
    - Analysis 2c: Collapsed across both communities, paired-sample t-tests were conducted to test whether PSE and CLM EUI scores differed.
    - Analysis 2d: Two-group t-tests were used to compare communities on mean PSE EUI pre-post changes.
    - Analysis 2e: Two-group t-tests were used to compare communities on mean CLM EUI scores pre-post changes.

3. How do community households compare demographically and on their perceptions of energy use and pro-environment variables? (Testing the significance of change in pre- and post-treatment survey variables on values, place attachments/identities and architectural design features as environmental cues).

- Analysis 3a: Respondents' self-reported survey demographic characteristics were analyzed with SPSS data analysis software using 2-group chi-square tests of independence.
- Analysis 3b: Two-group t-tests were used to compare on pretest (baseline) self-reported survey and pro-environmental variables.
- Analysis 3c: One-group t-tests were used to test the significance of non-zero change on survey rating scale variables on pro-environmental variables from pre- to post-treatment.
- Analysis 3d: Two-group t-tests were conducted to test mean differences among the communities on pre-post changes for each survey rating scale on pro-environmental variables from pre- to post-treatment.

4. What is the relationship among values, attachments, place meanings, and environmental cues on behaviors as they relate to energy use? (Post-study qualitative interviews on how people make sense of their experience of place.)

- Analysis 4a,b,c,d: ATLAS.ti data analysis using grounded theory to determine the role of values and place meanings, physical and social cues, and information on energy use in people's environmental behaviors related to energy use.

KEY FINDINGS

ENERGY USE DATA

Three overarching energy use observations stand out. First, Site 1 had lower energy loads, but Site 2 reduced energy overall more than Site 1. Second, for both Site 1 and Site 2, MELs comprised a high proportion of total energy consumption, followed by space conditioning – two areas where occupants can exercise a high degree control as could be seen in the high degree of variability across the two sites in these categories. Unaccounted for MELs had the greatest variability in terms of end use, with portable space heaters reported most, followed by mobile devices for both entertainment and workstations (laptops, tablets, and cell phones) as well as avocational uses reported by almost every household. Third, treatment exerted a greater effect on Site 2, a pattern perhaps attributable to several causes: a) Site 1 might have been unresponsive because their actual energy use was already very low by virtue of the structural characteristics of their homes; b) the culture of Site 1 might have philosophically maintained that their energy use was low and therefore residents did not feel a need to respond to the treatment; c) Site 2 might have had both physical and social characteristics as well as philosophical perceptions that supported their responses to the treatment.

SURVEY DATA

Noteworthy findings in the self-reported survey data showed that the two sites were quite comparable on demographic information. The two sites were also comparable on pre-treatment environmental, place, and architectural features variables. Over the period of the study, Built Green Community households exhibited a significant decrease on hedonic values mean scores, while the Code-built Community households showed a significant decrease in place identity mean scores. However, there were no significant differences between sites on self-reported changes. In other words, little evidence suggests that the dashboard treatment was associated with changes in people's *perceptions* of their values and behaviors around energy use; however, *actual* energy consumption was affected.

The actual energy used by households did show trends for decreases between baseline and post-treatment for both housing communities (though the Built Green Community used less energy at the outset, and the Code-built Community decreased energy use more than the Built Green Community across time and after treatment.) This decrease supports the idea that behavior may change first, before being perceived to have changed. That is, these findings support the potential for in-home energy dashboards to affect actual energy behavior, especially in the cases of MELs and space conditioning equipment, as these energy expenditures over which occupants can exhibit a high degree control. Importantly, interviews with a broad range of participants in each community on their energy use added to the supporting evidence on why and how people use energy in ways that may not be detectable via survey data or actual energy use.

Moreover, the survey data showed that, over time, the Code-built Community increased on the mean scores for biospheric values whereas the Built Green Community decreased. On environmental self-identity mean scores, again the Code-built Community increased whereas the Built Green Community decreased. On hedonic values mean scores, the Built Green Community decreased more than did the Code-built Community. Both communities increased on mean scores for their perceptions of the importance of being able to accommodate changing needs over time. Taken together, for the Code-built Community, these increases/decreases on perceptions (self-transcendent/self-enhancing values, environmental self-identity, and the importance of accommodating changing needs over time) correlated with the effects of the dashboard treatment and overall reductions in actual energy use.

INTERVIEW DATA

Rather than parsing the data issue by issue or question by question across all interviewees, this study used Grounded Theory analysis to focus on five households that manifested distinct, prototypical ways of interacting with their surroundings, understanding their environments, and using energy. This holistic approach enabled the researcher to draw connections between people's lived experience of place as articulated in the qualitative data with the quantitative data on actual energy use and perceptions of energy use from the survey data. The predominant behavioral trends that emerged from the data illustrate how different person-place process dimensions in different physical and social contexts are likely to underpin a person's motivation to engage in pro-environmental behavior and shape the likelihood of energy conservation behaviors to achieve high-performing buildings, regardless of whether the building envelope itself was structurally built to encourage a low EUI. This alignment of the qualitative and quantitative data allowed a deeper investigation into how people respond to their environments in ways that lead to certain types of prototypical energy use patterns, or profiles. From these five profiles, a conceptual framework for understanding people's energy performance was developed.

A CONCEPTUAL FRAMEWORK

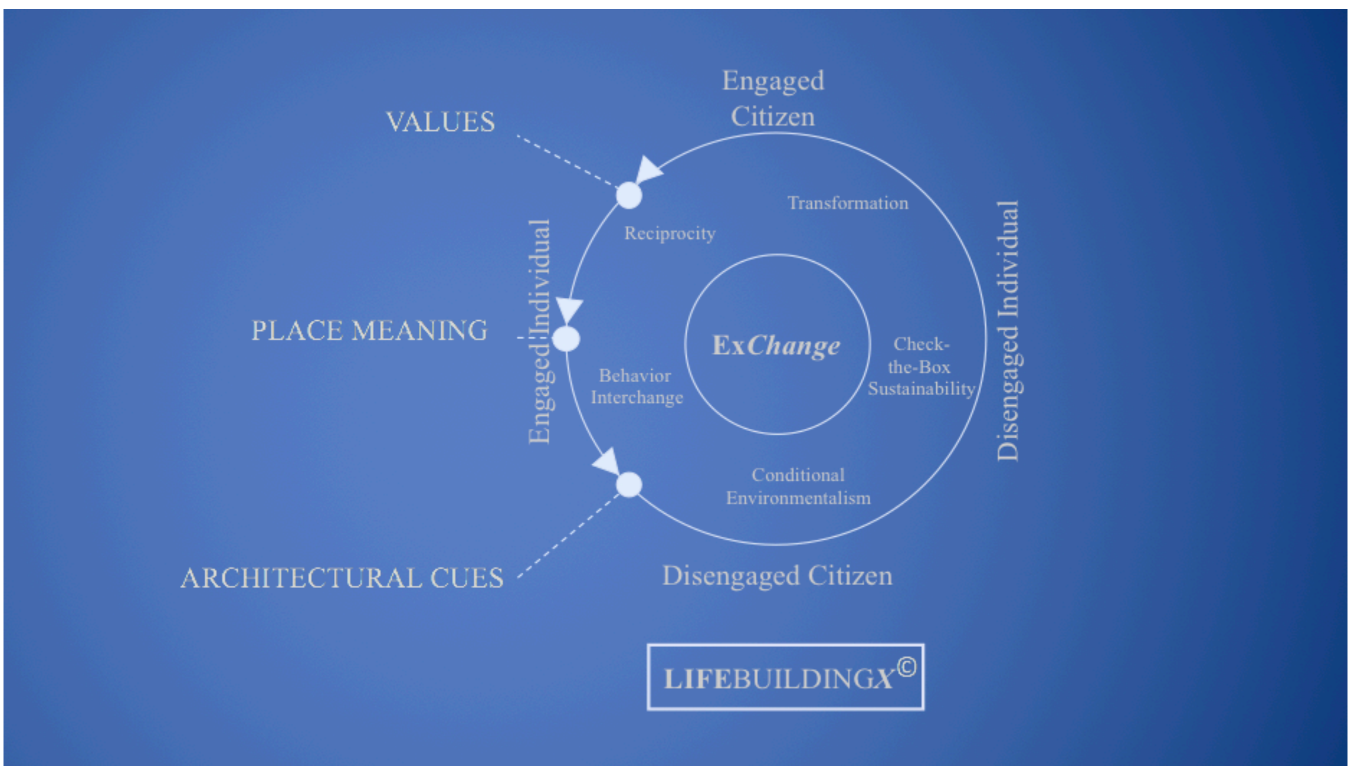
The **LIFE** BUILDING ***Exchange*** or **LIFE**BUILDING***X*** is a conceptual framework developed from the findings of this study that offers a way to understand the dynamic processes likely to shape a person's energy-related environmental behaviors in the place where they live. **LIFE**BUILDING***X*** focuses specifically on the collective significance of values, meaningful person-place relationships and physical and social environmental cues that may elicit a behavioral response and associated EUI. The locus of performance where person-place experiences occur is the residential setting in which a person makes day-to-day choices with respect to home energy. Each of the **LIFE**BUILDING***X*** terms used in the framework is described in greater detail below.

The term **LIFE** is intended to capture the people side of the people-place relationship, including values, place identity, environmental self-identity, and place attachment. It references the processes by which a person evaluates, identifies with, or experiences a bonding relationship to meaningful places likely to influence their behavior. For an individual, these process dimensions may be based on cognitive (biospheric, altruistic, hedonic and/or egoistic values), affective (place attachment), or self-concept (place identity and environmental self-identity) dimensions.

The term **BUILDING** refers to those features and aspects of one's physical and social environments that cue a person's environmental response and enhance or suppress environmentally friendly behaviors generally, and energy conservation behavior specifically. That is, high-performance buildings – and even conventionally built places – can provide cues that prompt inhabitants to favor pro-environmental behaviors that impact their energy use. This connection suggests that high performance outcomes (e.g., low EUI buildings) may depend on the type and quality of a person's experience, with BUILDING and LIFE factors shaping a person's energy-related environmental behaviors in the places where they live.

The term **EXCHANGE** refers to the type, quality, and intensity of people-place interactions and engagements with place. An environmentally friendly behavior likely to make an impact on energy use is indicative of an exchange in which a person makes a commitment to pro-environmental behavior and high-performance outcomes – a process that I call "saturation." Whether enduring (highly saturated) or temporary (low saturation), this commitment entails an active engagement with place. This engagement may furnish a collective benefit for the community, in which case the person can be understood as an engaged citizen. The **engaged citizen** is a person who lives in a particular place and maintains an allegiance to the well-being of that community; that is, their actions support the greater good of the community and collective environment. Alternatively, a person's engagement with place could cultivate more self-oriented benefits, in which case they can be understood as an engaged individual. An **engaged individual** is a person whose actions are based on individualistic or personal reasons to benefit themselves and their personal environments, such as their individual residence. Conversely, a person might not be invested or engaged with their place or community. These individuals can be understood as disengaged citizens and disengaged individuals. A **disengaged citizen** is one whose actions do not support the needs of the community or the greater good of the environment. A **disengaged individual** is a person whose actions are not directed toward the benefit of the environment, community, or themselves with regard to environmental conservation or energy use. Whether a person responds as an engaged or disengaged citizen or individual, findings of this research show that the process is dynamic and combines values, place meanings, and environmental cue dimensions that people access and respond to in order to make sense of their experience of place.

LIFEBUILDING***X*** FRAMEWORK CONCEPTUAL DIAGRAM



LIFE BUILDING ***Exchange*** Framework, condensed. (Source: Image by author.)

KEY FINDINGS FOR CONCEPTUAL FRAMEWORK

The findings of this research showed that relative to environmental actions, particularly those related to energy use, one of five prototypical forms of **LIFE**BUILDING***X*** emerged: (1) reciprocity, (2) transformation, (3) behavior interchange, (4) check-the-box sustainability, or (5) conditional environmentalism. Each of these elements is described below.

RECIPROCITY

Reciprocity is a way of being in the world that is based on an enduring relationship of mutual benefit for self, other humans, other species, and the planet (see also Kimmerer, 2013; Manzo & Perkins, 2006). With regard to environmental behaviors, a reciprocal relationship would "use and replenish but not endanger or deplete" resources, as descried by one resident.

TRANSFORMATION

Transformation refers to a way of living that affirms pro-environmental behaviors captured in the phrase offered by one interviewee: "Be the change you want to see." As implied by this statement, transformation refers to an emerging process that orients a person in a new direction, toward behavioral change, focusing their attention on pro-environmental behaviors at the community level.

BEHAVIOR INTERCHANGE

Some interviewees' narratives demonstrated a particular dynamic in which they engaged in specific actions themselves or encountered others in the community engaging in pro-environmental behaviors that inspired them to take further environmental actions (see also Griskevicius et al., 2008; see also Van der Werff, 2013a & 2013b). Behavior Interchange is a way of living that is likely to affirm one's intentions as pro-environmental but is more effective when past behaviors are repeated, as captured in another resident's phrase: "What you practice grows stronger."

CHECK-THE-BOX SUSTAINABILITY

Some study participants exhibited a type of "check-the-box" environmentalism based on a belief that, since their home was already energy efficient by design, no environmentally conscious behavior was required of them as an occupant. "Just by living here, so many aspects of sustainability can be taken care of and we can check-the-box on sustainability [because it's all done for us]," opined one resident.

CONDITIONAL ENVIRONMENTALISM

Conditional environmentalism relates to an exchange, often temporal in nature, that does not require an enduring commitment. For example, the purchase of something that is associated with environmental values (i.e., an electric car) but has a greater association with preserving self-interest such as saving money, time, or convenience (i.e., rationalizing the use of the electric car instead of walking for convenience). Those who exhibited this type of exchange did not express long-term commitment or engagement in their community. Their behaviors tended to be short-term, rationalized, or negotiated in some way.

CONCLUDING SUMMARY

By investigating pro-environmental behavior in residential high-performance buildings and neighborhoods compared to those more conventionally built, this research looked at the dynamics of values, place meanings, environmental cues, and exchange interactions. This approach explored a deeper understanding of the ever-shifting collection of factors therein, an investigation which, to the knowledge of this researcher, had not been conducted in this configuration to date. By linking high performance energy-efficient technologies in the built environment with a deep understanding of pro-environmental human behavior, this study maintains that a multi-dimensional, integrated research and design agenda is needed to answer critical questions about residential energy use in an effort to reach net-zero climate change goals targeted by the 2015 Paris Agreement.

FUTURE DIRECTIONS, LIMITATIONS, AND DISSEMINATION TO PRACTICE

FUTURE DIRECTIONS and LIMITATIONS

Continuing research might seek to investigate a larger more diverse random sample in order to increase the power and significance of findings. Future studies could, for example: 1) collaborate with other researchers conducting residential studies, such as national RECS and regional RBSA that investigate only structural characteristics, by implementing the behavioral survey and interview methods developed for this study on these much larger random samples; 2) continue research to increase the data set on the community level with additional residential communities to capture a wider range of physical and social characteristics; and/or 3) revise the survey to increase power by reducing the number of questions with a greater focus on values, place identity, environmental self-identity, and place attachment as well as consolidating the questions on architectural design features.

DISSEMINATION to PRACTICE

To realize net-zero energy goals and for research like this to exert an impact on practice, it is crucial that researchers collaborate with agencies and organizations that develop energy codes (e.g., City planning departments) and beyond-code organizations (e.g., International Living Future Institute) to incorporate a behavioral component such as the **LIFE**BUILDING***X*** conceptual framework into energy requirements. In this regard, this research and the **LIFE**BUILDING***X*** framework would support the incorporation of a behavioral component for meeting performance and outcome-based codes and standards. As the structural components of building performance increase in efficiency and energy codes move toward more stringent outcome-based standards, perhaps with a requirement for certification of energy performance in residential settings, residents may be given options to change structural (physical building) characteristics or behavioral characteristics to achieve a low energy performance profile.

Understanding a household's energy profile includes establishing a baseline **LIFE**BUILDING***X*** index or profile from which to measure the contribution of behavioral components to energy performance present and future. To this end, it would be productive to create computer coding for the **LIFE**BUILDING***X*** conceptual framework to be coupled with actual energy consumption data in a software program and dashboard display for use by residents, designers, and developers of sustainable design.

CLOSING REMARKS

This research investigated the ability of the physical built environment to play a rich and active role in support of sustainable living and suggested that high-performance buildings (along with place attachment, identity relationships, and values) may act as dynamic, interdependent, and bi-directional constructs. Moreover, both physical and social environments have the potential to create a reinforcing environment (cue) in which to practice sustainable behavior.

This research contributes to the literature in four respects:

- Developing a holistic conceptual framework inclusive of physical and social contexts. The **LIFE**BUILDING***X*** Index describes the intersection among values, place meanings, environmental cues, and actual behavior as a whole, mutually influential system.

- Examining the role of the physical built environment to 1) serve as environmental cues; 2) "house" place meanings; and 3) comprise the nexus of higher performance buildings and behaviors—the locus of performance in an exchange between person and place.

- Investigating meaningful place relationships such as place identity, environmental self-identity, and place attachment as significant to pro-environmental behavior models.

- Encouraging and actively participating in a transdisciplinary approach to the study of pro-environmental behavior in the context of high-performance net-positive energy buildings and sustainable settings in architecture. This approach supports the goals of the 2015 Paris Agreement, 2014 ICPP, and the Architecture 2030 Challenge, all seeking to mitigate the risks of climate change.

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