Co-Designing Sustainable Communities: The Identification and Incorporation of Social Performance Metrics in Native American Sustainable Housing and Renewable Energy System Design

by

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Abstract

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Over the last quarter-century, the twin concepts of sustainability and sustainable development have emerged as a defining imperative of humanity that is situated at the nexus of science, technology, culture, economics, policy and the environment. These twin concepts are both framed as a means to mitigate the negative impacts of natural resource depletion, energy consumption, water consumption, and climate changing greenhouse gas (GHG) emissions associated anthropogenic activities. Since the creation of the term 'sustainable development' in the Brundtland Commission's *Our Common Future* report in 1987 until the present, there has not been a determinate meaning assigned to it. Over the last 25 years, advocates of sustainable development have been trying to assign different frameworks to the ill-defined concept first expressed in the report: that development should "meet the needs of the present, without compromising the ability of future generations to meet their own needs".

When one reviews the Brundtland Commission's report, one finds that (1) 'needs' are not defined, (2) the processes for identifying these 'needs' are not defined, (3) sustainability indicators or performance metrics for measuring these 'needs' are not defined, and (4) there is an implicit assumption that the society of the present will have some idea and understanding of the 'needs' that the society of the future will possess. These voids within *Our Common Future* present a great opportunity for the creation of a methodological framework that allows designers, engineers, and community members to understand the needs and the social performance metrics that local communities utilize to define sustainability and evaluate technology options for their sustainability goals.

This dissertation is a case study of a design research project with the Pinoleville Pomo Nation (PPN), a federally recognized, self-governing Native American tribe located near Ukiah, California, to determine their framework for sustainability framework, to identify their needs as it relates to their sustainability framework, and to co-design housing and renewable energy power systems to meet their needs. The design research was conducted between April 2008 and May 2011 with members from the PPN tribal government, administration, and community members living on and off the primary land base near Ukiah, California. The emphasis of

this research is not about merely providing technological solutions for the PPN to adopt; nor is it about getting the PPN to return to some romanticized way of life in which indigenous people lived with no environmental impact. Instead, this research focuses on the development of the co-design methodological framework that fosters the co-production of knowledge as it relates to sustainable buildings and energy systems design and implementation by situating the concept of sustainability and sustainable development in the local context of the end user community.

The co-design methodological framework presented in this dissertation represents a discourse contribution in the areas of eliciting end user needs/metrics, situating sustainability knowledge bases, the role of citizens in the design of engineering systems, and community-based design approaches for the development of sustainable communities. This dissertation operationalizes the identification of local sustainability frameworks, the identification of needs for sustainability, the identification of social performance metrics for sustainability, and the co-design of solutions to meet local sustainability frameworks within the aforementioned discourse areas.

Acknowledgements

The research presented in this dissertation sits at the nexus of engineering, community-based design, energy science policy, and sustainable development. The nature and the success of such transdisciplinary research is due to the family, friends, and colleagues I have had the distinct honor and pleasure to work, cry, laugh, and co-design with over the last 6 years or so.

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To Dr. Alastair Iles: Thank you for helping try to navigate and make sense of the complex social and cultural norms embedded in engineering, science, and technology. We engineers have a tendency to forget the people side of technology and how society influences and is influenced by technology at the same time.

To Pinoleville Pomo Nation: I wish to thank the entire Pinoleville Pomo Nation and its citizenry for putting their faith and trust in me to work with them as equal partners to aid them in meeting their vision of sustainability as it relates to cultural sovereignty, tribal sovereignty, and economic and environmental stability. You all will always be apart of my life and I will never forget you. A special thanks to Mrs. Leona Williams, Mrs. Lenora Steele, Mrs. Angela James and Dr. David Edmunds for being our champions at the PPN and making the partnership a success.

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Chapter 1: Introduction

1.1 Overview

Engineering design theory and research methods are playing an increasing role in the development and implementation of policies, technologies and best practices that support the creation of sustainable communities around the world. Indeed, many professional and educational engineering organizations stress the need to have sustainability integrated within formal engineering education and call for students to practice sustainable development. For instance, the American Society for Engineering Education states that "engineering graduates must be prepared by their education to use sustainable engineering techniques in the practice of their profession and to take leadership roles in facilitating sustainable development in their communities" (American Society of Engineering Education, 1999). Moreover, the United States of America's Accreditation Board for Engineering and Technology, Inc. (ABET) has a student evaluation or performance metric that states that students should have "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability" (ABET, 2011).

While organizations such as the Bill & and Melinda Gates Foundation have funded projects such as IDEO's Human-Centered Design Toolkit to engineering professionals and others in their development endeavors, there is still a need for methodological and knowledge co-production tools for community based engineering design in which both community and external experts have shared control over the new product development process and are co-designing sustainability systems using subsequent knowledge bases to help situate the twin concept of sustainability and sustainable development. Just as the "dominant discourses of economics, sociology, and political science lack vocabularies to make sense of the untidy, uneven processes through which the production of science and technology becomes entangled with social norms and hierarchies", so too does the engineering discourse lack the language and knowledge production tools *alone* to make sense of sustainability and sustainable development given their entanglement with often conflicting goals such has the preservation of cultural values via oral communication traditions and the usage modern community technology such as Twitter and smartphones (Jasanoff, 2006). This dissertation addresses the shortcomings of our engineering knowledge of partnering with local communities to understand their concept of sustainability, their needs, performance metrics, and indigenous knowledge production methods through a single case study of a specific design methodology called co-design within the contexts of sustainable community development and the co-production of knowledge. This approach involves end user need identification and knowledge production methods for the design and implementation of sustainability systems such housing and renewable energy systems for Native American tribes in California.

The co-design methodology described in this dissertation does not represent an all-encompassing, simple blueprint or formula of community participation/engagement + sustainability + engineering knowledge + knowledge production = comprehensive sustainable community development project. Indeed, it is highly unlikely that such a formula can ever exist given the large variation in sustainability definitions, local community characteristics, goals and social networks, and the performance metrics. Nor does this dissertation seek to provide an engineering abstraction of the local knowledge by separating it from the local context and culture from whence it is produced. Instead, this dissertation seeks to provide a methodological framework in which the co-production of knowledge for sustainability utilizes the geographical, economic and cultural context, theoretical frameworks, and requirements of local community internal experts during the co-design and implementation of sustainable buildings and renewable energy power systems with outside experts.

The co-design methodology, when applied to sustainable community development endeavors, provides a powerful tool in which engineers, designers and community end users can develop a shared understanding of a community's social performance metrics and strike "a balance between environmental concerns and development objectives while simultaneously enhancing local social relationships" during the new product development of sustainability systems (Bridger and Luloff, 1999). This methodological framework seeks to provide an epistemological amalgamation of outside experts and local community experts to create sustainability knowledge bases by bringing "together, rather than separating out, the unique and essential aspects of human behavior, the intermixing of the empirical and the normative" (Fischer, 2000). Engineering, like science, is just a mere amalgamation of local knowledge bases, local innovations, social norms, technical skills, and language assembled over time for the goals of knowledge production, transmission, and usage (Watson-Verran and Turnbull, 1995; Fischer, 2000). The co-design methodology embraces this framework and allows for the creation and usage of situated performance metrics or indicators that aren't easily quantified and situates local innovations that may be produced from methodologies and epistemologies that are foreign to the traditional engineering discourse but still just as valid nonetheless.

This chapter explains the new product development employed within the engineering discourse for knowledge and artifact production. It is then followed by an overview of Native American governments' sustainability efforts and challenges. The chapter concludes with an introduction of the Pinoleville Pomo Nation, a description of the research with the Pinoleville Pomo Nation and the overall structure of the dissertation.

1.2 New Product Development Process

The New Product Development (NPD) describes the process in which a designer creates a product, service, and/or system and introduces it to the market for adoption and usage by an end user group (Otto and Wood, 1995; Ulrich and Eppinger, 2004). The NPD process is also known as the Engineering Design Process (EDP) for new products and it typically involves seven stages: (1) Opportunity Recognition, (2) Idea Creation, (3) Idea Selection, (4) Idea Development, (5) Idea Testing, (6) Idea Implementation, and (7) Idea Expansion & Adoption. It is an iterative process in which each phase refers back to the previous phase to determine if the right design goals, user needs, and assumptions are being followed. The new product development framework presented in this dissertation is merely one of many frameworks for engineering design and product development processes. Dubberly (2005) lists over one hundred frameworks for development and design processes from disciplines including engineering, marketing, architecture, industrial design, and software development. Dubberly (2005) shows in his work that the concept of product development is not beholden to one discipline or that a single discipline contains the methodologically pure, correct form of new product development. He seeks a "sharing of ideas between the disciplines" in an attempt to foster innovation and collaboration amongst the many different stakeholders and practitioners of design (Dubberly, 2005). Figure 1 provides a graphical representation of a typical NPD process.

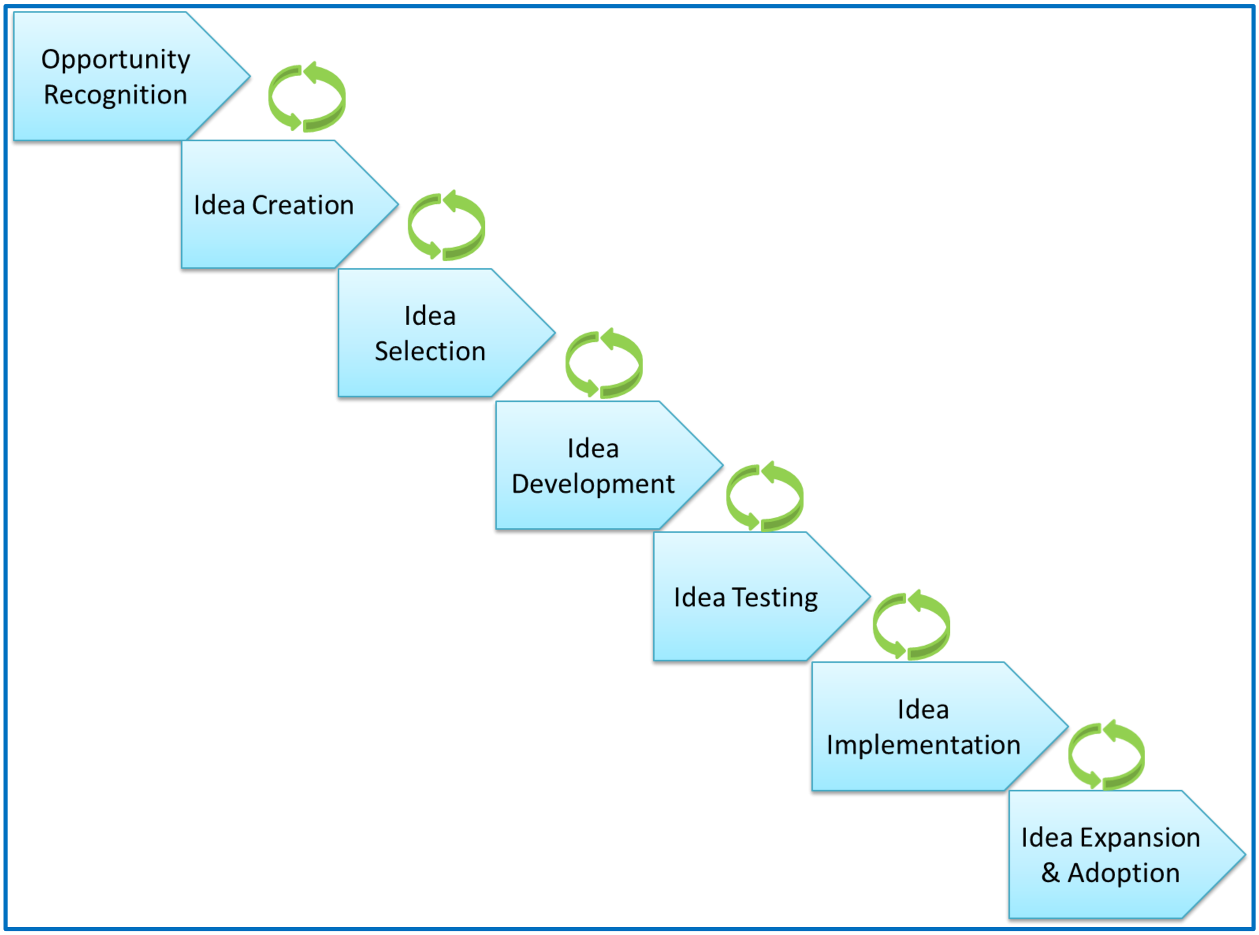


Figure 1: New Product Development Process

It should be noted that a distinction is made in this dissertation amongst designer, end user, lead user, stakeholders, and consumer. A designer or engineer is considered to be a person that makes preliminary plans, products, and/or services to be adopted and utilized by an end user, while an end user is a person that actually uses the product, service, and/or system created by the designer. The customer is the person that purchases or exchanges goods and services in order to obtain the product, service, and/or system created by the designer. The customer and the end user are not necessarily the same person. For example, a mother, the customer, may purchase a laptop for her child, the end user. However, both the mother and the child are considered to be stakeholders as both have a vested interest in ensuring that the laptop being purchased successfully satisfies the requirements of the customer and the end user. Moreover, a lead user is defined an end user who has first-hand, real world experience with a product and faces problems or needs "months or years before the bulk of the marketplace [or community] encounters" (von Hippel, 1986, 1998, 2005). Lead users are generally at the forefront of trends and technology and can provide "new product concept[s] and design data as well" based upon their insights and strong desire to "benefit significantly by obtaining a solution to those needs" they face earlier than the general populous (von Hippel, 1998, 2005). Lead user enable the designer or engineer to create "breakthrough products that tend to have higher performance and marketplace potential than other innovations" in the current marketplace that fail to adequately address the full spectrum of end user needs (Bogers, et.al, 2010).

Furthermore, needs are defined as the subjective requirements that a customer or the end user has for a product, service, and/or system (Ulrich and Eppinger, 2004). Needs are also defined as "a description, in the customer's own words, of the benefit to be fulfilled by the product or service" (Griffin and Hauser, 1993). Sandhu et al. (2007) extends this definition of needs to include ethnographic contributions that may not be directly stated by the end user. In this dissertation, **user needs** follow the format of 'verb' and 'need' such as 'preserve environmental harmony' where preserve is the 'verb' that conveys what actions should be undertaken in relation to the 'need' of environmental harmony. The needs or requirements of the mother and child with respect to the toy are not necessarily mutually exclusive or inclusive. This means that there can be an overlap or intersection between the set of needs possessed by the mother and the child or that none of the set of needs possessed by the mother and child has any connection or intersection in between them. For example, the child's set of needs may include (1) color, (2) ease of use, (3) safety, and (4) fun while the mothers set of needs may include (2) ease of use, (3) safety, and (4) cost. Figure 2 shows the intersection of these two sets of needs between the mother and child: {2. ease of use, 3. safety}.

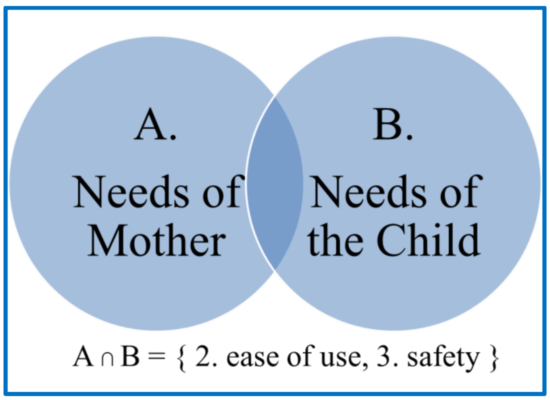


Figure 2: Mother and Child Intersection of Laptop Needs Sets. Please note: safety is defined both physically and in terms of what the technology can access/bring (e.g. via web surfing).

During the opportunity recognition phase of the NPD process, the project idea is pitched to the engineering design team either from an external stakeholder or a member of the design team. Discussions at this stage involve determining the target customer market, end users, and key stakeholders. Moreover, a user needs analysis is performed at this stage in order to determine the product requirements of the end users. Qualitative research tools such as focus groups, ethnography, participant observation, and interviews are typically employed to elicit these needs (Griffin and Hauser, 1993; Morgan and Krueger, 1993; Charmaz, 2003; Lofland, J., et. al., 2005; Boyce and Neale, 2006). The needs generated using these qualitative tools become the imperatives for the concepts created during the ideation phase to address these set of requirements. It is in the idea creation phase that the user needs are transformed into product specifications by detailing that exact functions or procedures that the product, services, or system must follow. The goal of the idea creation phase is to produce as many ideas or concepts as possible to meet the newly defined product specifications. Some ideas may be generated from benchmarking previously existing concepts or merging other ideas together to take advantage of better design features. These product specifications typically involve listing geometric and numeric constraints of time, weight, temperature, distance, length, and size. For example, the safety need that the mother and child possess for the laptop can be transformed into a product specification by assigning a definition that the laptop's battery should not exceed a temperature of 90 degrees F.

The idea or concept selection phase is the decision-making phase of new product development where designers evaluate ideas with respect to end user product. The product specifications in this stage are transformed into metrics or selection criteria by assigning the relative weight/importance (usually on a scale of 0 to 100%) to the specifications. Numerous design methods – such the analytic hierarchy process (AHP), axiomatic design, Pugh's concept scoring, decision analysis, fuzzy set cut-offs, quality function deployment (QFD) – have been created to aid designers during the concepts selection phase (Saaty, 1980; Akao, 1990; Pugh, 1991; Otto and Wood, 1995; Barzilai, 1997; Wang, 2002; Yeo, et.al., 2004; Ficalora, 2009). The goal of this phase is to reduce the large number of concepts created down to a smaller set; thereby, the weak or poorly rated concepts are eliminated from further consideration and analysis. In the idea development and testing phases, low to medium fidelity prototypes of the smaller set of concepts are created and then given to the end user to gauge interactions and reactions to the prototypes. In the idea implementation phase, high fidelity prototypes are created based on feedback from end user testing; these high fidelity prototypes have details and functionality that the final product will possess. Moreover, final design specifications are made and research into manufacturability and reliability are typically explored during this stage. Finally, the idea expansion and adoption phase focuses on price points, business models, and branding needed for the market introduction and acceptance of the final concept by customers and end users.

My research seeks a "more democratic restructuring" of how science and technology are designed and developed by introducing social decision making and its performance metrics at the earlier stage of the new product development process (Beck, 1995; Fischer, 2000). This is akin to Beck's call for the incorporation of non-experts and the public into a highly participatory form of democracy, which he calls "ecological democracy" (Beck, 1995). Co-design is an approach to achieving an "ecological democracy" or at least democratizing how sustainability technology is produced and implemented with end user communities. This is done by creating a public sphere for sustainability in which both the designer and the end user can share their collective intelligence and negotiate on the best solution trajectory to meet end user needs during the design process (Torgerson, 1999). Each participant in this design process frames and communicates sustainability from perspectives based on their social norms and local knowledge (Norgaard, 2004; Sneddon, et.al, 2006). During the translation of end user needs into imperatives or problem definitions, external experts often impose definitions and meanings that are more in alignment with their academic disciplines and their knowledge production norms instead of situating the new product development in the context of the end user (Fischer, 2000). The co-design methodology addresses this facet of design by forefronting end users and their social performance metrics at the beginning of the new product development process, which allows the end user community to proactively guide and situate knowledge production with the scientists and engineers during the design and development of solutions. Co-design is not about just providing technological solutions, but rather assisting “citizens in their efforts to examine their own interests and to make their own decisions”, particularly in the areas of renewable energy systems and sustainable building design and development (Hirschhorn, 1979; Fischer, 2000).

1.3 Native American Governments Sustainability Efforts and Challenges

Native American tribal governments throughout the United States of America have placed great importance upon achieving environmental harmony within their lands. These tribal governments have begun to discuss ways to reduce their tribe’s environmental impacts and improve their overall personal level of sustainability. Examples of Native American tribal governments pursuing sustainability endeavors include the Campo Band of Mission Indians of the Kumeyaay Nation’s 50 MW wind energy facility, Council of Athabascan Tribal Governments (CATG)-Fort Yukon wood energy program, Scotts Valley Band of Pomo Indians’ Tribal Multi-County Weatherization Program in Northern California, and the Elk Valley Rancheria energy efficiency projects (Anderson, 2011; Estes, 2011; Howard, 2011; Maracle, 2011). Ambler (1990), Nadasdy (2003), Brown (2006), Frehner (2010) point out in their works that Native American nations have an extensive history of implementing sustainability and environmental resource management endeavors with and without help from non-Native members and organizations. In particular, Nadasdy (2003) documents the difficulties that the Kluane First Nation in Canada encountered in terms of getting their local knowledge and solutions to their environmental issues accepted and utilized by Canadians officials. Nadasdy (2003) conjectures that the devaluing of the Kluane First Nation’s local knowledge is a mere expression of power that is utilized by paternalistic governments and academic institutions to continue to exert control and influence over the Native people in affairs ranging from sustainability endeavors to energy development to education.

It should be noted that Native American tribes that are considered to be “federally recognized tribes” or sovereign nations by the United States government have the right to create agreements and have a direct government-to-government relationship with the U.S. government and other local governments. Currently, the Bureau of Indian Affairs (BIA) has granted 565 Native American tribes status as “federally recognized tribes” (U.S. Census Bureau, 2011). Unfortunately, the interactions amongst Native American communities, the United States government, and academic communities have not been the most pleasant. Historically, federal laws concerning Native Americans have hindered the ability of Native American tribes to increase their economic and community stability. The initial U.S. Native American laws were based on the doctrine of discovery, which established a legal relationship between European discoverers and the Native American tribes (Allen, 1989; Deloria and Lytle, 1998; Frehner, 2010). This doctrine gave ownership of native lands in the hands of the "discoverers", but allowed the Native Americans to continue to live on the lands. As a result, tribal governments are rather suspicious about federal officials and have a reduced willingness to partner with federal agencies and non-tribal members for fear of not being treated as equal partners. These partnerships failed due to a technology driven approach that is taken to meet the sovereignty, economic self-sufficiency, and environmental goals of the tribal governments. In this technology-driven approach, emphasis is placed on getting the information of the target end user group in order to stay within budgets, fulfill federal policies, and/or meet publication deadlines. Little or no time is spent on understanding the needs of the Native American communities and building trust. However, there are recent examples of successful partnerships between tribal governments and non-tribal organizations as it related to the development of appropriate environmental management solutions.

The Navajo Nation Council, for example, has developed a policy “to promote harmony and balance between the natural environment and people of the Navajo Nation, and to restore that harmony and balance as necessary” (Navajo Nation, 2009). To implement this policy, the Navajo Tribal Utility Authority (NTUA) has been pursuing renewable energy power generation from wind power to provide electricity to 18,000 Navajo homes that currently are not electrified (Battiest, 2009). These homes account for approximately 75% of tribal homes in the United States that have not been electrified (Battiest, 2009). The Navajo Nation has also cultivated a partnership with Sandia National Laboratories and the Environmental Protection Agency to address the issues of water and soil contamination by uranium mining that occurred during the 1940s through the 1980s (Sandia National Laboratories, 2009; U.S. Environmental Protection Agency (EPA), 2008; U.S. Environmental Protection Agency (EPA), 2011).

The roughly four million tons of uranium extracted from the 27,000 square miles of the Navajo Nation provided critically needed material to the United States nuclear weapons program, but left a number of physical structures and water sources contaminated with radiological materials and waste that have been shown to cause chronic respiratory symptoms and act as a reproductive toxicant (Arfsten, et. al., 2001; Hindin, et.al., 2005). In order to address this issue, engineers and scientists from Sandia National Laboratories went into several Navajo communities and met with the people in order to determine which technologies were culturally appropriate and could be transferred to the Navajo Nation to clean up the communities exposed to contamination by uranium and processing chemicals. The Navajo Nation was able to take the lead in defining the scope of the projects and prioritizing the objectives of the projects. This partnership has led to an improvement of the health of the members of the Navajo Nation and also has led to increased discussions about developing the renewable energy potential of the Navajo Nation’s lands. However, 520 abandoned uranium mines still dot the lands of the Navajo Nation and there are concerns that the federal cleanup efforts are stalling due to funding and lack of urgency by government officials (MacMillian, 2012).

1.4 Pinoleville Pomo Nation

The Pinoleville Pomo Nation (PPN) is a federally recognized, self-governing Native American tribe located in Northern California’s Mendocino County on the outskirts of the city of Ukiah; it is dedicated to ensuring that its “members enjoy safe, healthy, and environmentally benign environments, both natural and built” (Edmunds, 2009). The PPN traces its modern origins back to 1878 when a group of Potter Valley Pomos left the Round Valley Reservation due to lack of basic necessities and purchased 51 acres of land north of Ukiah. This land was called ke-buk ke-bul, but was soon known as Pinoleville. Unfortunately, the citizens of Ukiah expressed extreme dissatisfaction of Pinoleville residents’ ceremonial cremation and loud wailing practices that sometimes lasted for several days after a death occurred. In 1893, the 51 acres of land were traded for 100 acres between Ackerman Creek (known as ya-mo bida in Pomo or wind hole creek in English) and Orr Springs Road by the Pinoleville captains and other

Northern Pomo captains. In 1905, the Bureau of Indian Affairs (BIA) deemed the privately owned land overcrowded and utilized a series of Congressional appropriations to acquire additional lands for the families of Pinoleville. This land acquisition was originally known as the Ukiah Rancheria. Later on, it became known as Pinoleville Rancheria (Pinoleville Pomo Nation, 2002). The passage of the Indian Reorganization Act (IRA) in 1934 was aimed at increasing Native American self-governance and resulted in the reorganization of some tribal governments, such as Pinoleville, with a written constitution to manage their internal affairs (Encyclopedia Britannica, 2012).

However, efforts soon began in the 1940s to shift the federal policy of self-governance for Indian tribes to a termination policy of tribes as sovereign nations in order to force tribal peoples to assimilate into the general populous. In 1958, these efforts can to fruition when the U.S. Congress passed the California Rancheria Termination Act in which the federal government absolved its responsibility for managing or financially supporting between 40 and 44 California Rancherias by transferring land ownership directly to respective tribes and not completing agreed upon federal economic, housing and water infrastructure development endeavors within California Rancherias (Government Printing Office, 1958). In 1966, the Pinoleville Rancheria was terminated and the land was deeded to individuals known as allottees. In 1983, Pinoleville was a part of a class action suit called Tillie Hardwick v USA that won federal recognition for 17 terminated tribes (Tillie Hardwick, et.al. v. United States, 1983. Pinoleville completed its reorganization on June 26, 2005 when a constitution was approved. A council of seven elected members now governs the tribe of roughly 250 citizens.

The Pinoleville Pomo Nation (PPN) has members scattered throughout Northern California, and many of these members are seeking to return to their ancestral lands and traditional community. In order to meet the growing demand of people seeking to return to the lands of the PPN, the PPN has undertaken two land purchasing and housing development ventures. Some of the concerns of PPN related to rising heating (Figure 3) and cooling costs associated the current houses funded by the U.S. Department of Housing and Urban Development (HUD) (U.S. Energy Information Agency (EIA), 2012). For most of the PPN’s homes, firewood and natural gas are utilized as the primary sources of space heating. Moreover, the current homes provide basic necessities and no representation of the cultural and traditional values of the PPN. Figure 4 and Figure 5 shows example prefabrication homes and natural gas systems utilized by members of the PPN. As a result, the PPN sought to implement sustainable technologies and best practices that will increase their self-sufficiency and meet their housing, energy, and water conservation needs. It should be noted that the PPN, however, neither had the in-house technical expertise, nor adequate funding, to develop and implement their aspirational designs. In the March 2008, the PPN contacted UC Berkeley and the Community Assessment of Renewable Energy and Sustainability (CARES) in the hope of creating a partnership that would help them achieve their goals (Schultz, et.al, 2010; Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013).

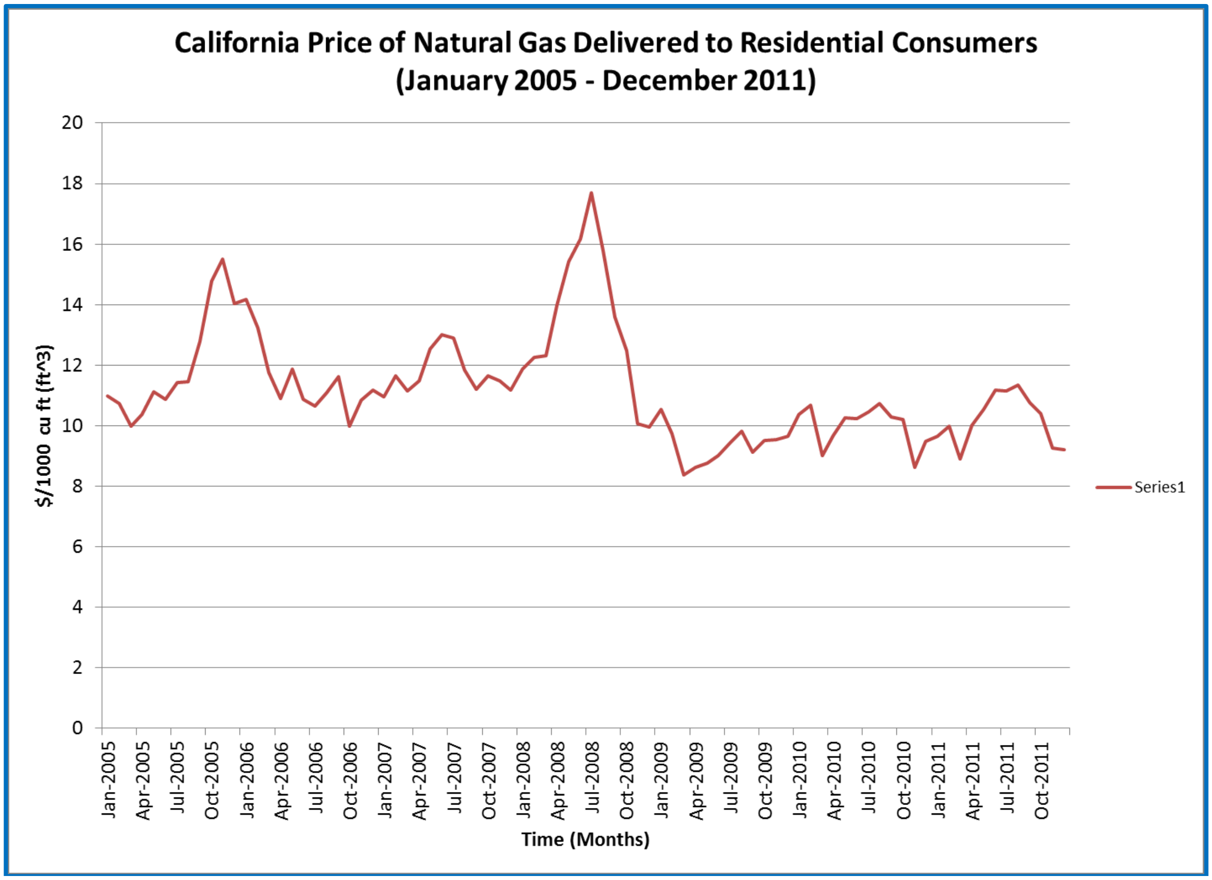


Figure 3: Energy Information Agency (EIA) California Natural Gas Residential Price Estimate

Figure 4. PPN Prefabricate Homes

Figure 5. PPN Natural Gas System

1.5 Organization of Dissertation

Chapter 2 is a literature review focused on defining and challenging the concept of sustainability and sustainable development, the development of indicators or metrics for measuring and modeling sustainability and sustainable development, framing sustainability and sustainable development within Native American and other indigenous communities, community engagement processes for generating sustainability plans, and methodologies for eliciting user needs and metrics.

Chapter 3 contains the principle research questions, research objectives, data collection metrics, and research methods.

Chapter 4 focuses on the co-design methodology and usage of grounded theory and coding procedures for the user needs analysis of PPN case study.

Chapter 5 discusses the conceptual models for culturally-inspired sustainable building design and the whole building energy analysis of the design.

Finally, Chapter 6 addresses the role of outside and inside experts in knowledge production, the relationship of knowledge and power, understanding the situated knowledge bases utilized in this research, and discusses lessons learned about managing sustainable development design research endeavors with communities that have historical trauma working with ‘outsiders’.

Chapter 2: Literature Review

2.1 Introduction

This literature review is grounded in fields ranging from new product development, sustainable development, community engagement processes, environmental policy, co-production , and Native American studies. While the focus of this dissertation centers on new product development and sustainable development, it should be noted that the concept of sustainability has methodological and theoretical connections to fields outside of engineering. This is not to say that these connections indicate that the knowledge production approaches utilized by the fields are identical or that one field is best suited for undertaking sustainability research. Indeed, there is no universal, methodologically pure approach to design and implement sustainability research and technology solutions. The twin concepts of sustainability and sustainable development are just too fluid and multifaceted to be walled off behind discrete epistemological systems of knowledge.

For example, the two essential pieces of literature in this dissertation from Redclift (2005) and Jasanoff (2006) both intersect in how the concept of sustainability (its knowledge base and technological artifacts) is co-produced based upon social norms and local knowledge production systems. Redclift (2005) focuses on how the term 'sustainable development' is used by numerous discourses from engineering to social justice to business to environmental policy without the underlying assumptions and motivations behind the term being fully evaluated. The vagueness and flexibility of the term has allowed the current discourse to ignore the "culturally specific definitions of what is sustainable" and to gloss over the reality that sustainability's "environmental and social objectives are frequently different, and sometimes at odds with each other" (Redclift, 2005). Redclift (2005) acknowledges and argues that sustainability and sustainable development has to be situated or connected to "new material realities, the product of our science and technology, and associated shifts in consciousness". Jasanoff, who is from science and technology studies (STS), argues that scientific knowledge and technological artifacts are "products of social work and constitutive forms of social life". Moreover, scientific knowledge "both embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments, and institutions" (Jasanoff, 2006). Simply put, the process of interpreting or adjusting sustainability and sustainable development to both the local environment (its social norms, practices, and conventions) and the local knowledge is an act of co-production. Viewing sustainability within a co-production framework is one approach that this dissertation employs to "revisit the idea of sustainable development" (Redclift, 2005) and to examine how the Pinoleville Pomo Nation's knowledge and technological artifacts frame the concepts of sustainability and sustainable development.

The purpose of this literature review is to highlight the areas of weakness and overlap in the various fields that address the concepts of sustainability and sustainability development, to illustrate the impact of this work regardless of the disciplinary background in which this research takes place, and to show how the lessons learned and theoretical frameworks from other fields are applicable in this research project.

This chapter begins by defining and challenging the concepts of sustainable development and sustainability. The next section is a discussion related to the development of indicators or metrics for measuring & modeling sustainability. This is then followed by a discussion of Native American sustainable development endeavors and the various frameworks for sustainability utilized by these communities. Finally, this chapter summarizes the knowledge gaps in the current sustainability discourse and the motivation for the research questions presented within Chapter 3.

2.2 Defining and Challenging Sustainability

In 1987, the World Commission on Environment and Development (WCED), also known as the Brundtland Commission, placed the term sustainable development at the forefront of policy discussion as a means to promote economic growth within a country while addressing societal and environmental problems in its report Our Common Future. The Brundtland Commission defines sustainable development as development that “meets the needs of the present, without compromising the ability of future generations to meet their own needs” (WCED, 1987). The Brundtland Commission stated that “it is impossible to separate economic development from environment issues” and viewed sustainable development as a modern approach to resource management that would foster “a new era of economic growth, growth that is forceful and at the same time socially and environmentally sustainable” (WCED, 1987). Some authors state that the concept of sustainable development itself is an oxymoron as development often results in the consumption of goods and services that are produced by processes that can cause irreparable damage and weakness in local social, economic, political and environmental climates (Redclift, 1992; Conca, 2000; Borghesi and Vercelli, 2003; Dawe and Ryan, 2003; Redclift, 2005).

However, sustainable development is not supposed to be a static approach complete with a blanket list of specific needs that covers all of humanity; Indeed, the Brundtland Commission stated that “sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional changes […] that are made consistent with future as well as present needs” (WCED, 1987). This process of constant change and evolution is the development aspect of sustainable development. The Brundtland Commission clearly states that “the concept of sustainable development provides a framework for the integration of environment policies and development strategies” (WCED, 1987). Development is being used by the Brundtland Commission in the broadest sense of the word and can mean any policy intervention or endeavor that has the aim of improving the economic and social well-being (read: equity) of people. It is here where ‘sustainable’ is typically separated from ‘development’ and focuses on the environmental issues while ‘development’ addresses the economic and equity issues. It should be noted that the concept of ‘needs’ plays an important role in driving where and how environment policies and development strategies should be implemented. The Brundtland Commission views that sustainable development should focus on “meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life” (WCED, 1987). When one reviews the Brundtland Commission’s report, one finds that (1) ‘needs’ are not defined, (2) the processes for identifying these ‘needs’ are not defined, (3) sustainability indicators or performance metrics for measuring these ‘needs’ are not defined, and (4) there is an implicit assumption that the society of the present will have some idea and understanding of the ‘needs’ that the society of the future will possess.

The Brundtland Commission seems to indicate that environment and development policies should ensure that the basic needs of food, clothing, shelter, and jobs are met; however, it is unknown why the Brundtland Commission did not lay specific needs of the present and future societies. One can theorize that perhaps the Brundtland Commission understood that needs are unique to each culture and that “it may be defined differently in terms of each and every culture” (Redclift, 2005). Therefore, the Brundtland Commission chose general, non-divisive needs that would give political leaders the flexibility to further refine the definition of ‘needs’ based on local economic, geographic, cultural, and environmental conditions.

Unfortunately, this ambiguity and fluidity about how needs are defined and the processes to meet these needs are the “basis of several confusions about social, economic, and biological systems, and their interrelationship, which need to be explored before we can make satisfactory use of the idea of sustainable development” (Redclift, 1992). Despite the acknowledgement that different societies may have different definitions of needs for sustainability and different priorities for what should be sustained, it is still assumed that all nations or “*civil* societies are pursing the same social and cultural goals” (Redclift, 2005, with emphasis added). Civil societies are those that use the dominant knowledge system (read: scientific method or western science) of the North to create and manipulate knowledge. Other cultures’ epistemological approaches to knowledge production (typically developing countries in the South) are ignored or marginalized in favor of *modern* science which can separate culture from the knowledge it produces (Redclift, 1992; Norgaard, 1988; Dawe and Ryan, 2003). This is most evident in modern attempts to create and determine the meaning of sustainability and sustainable development by framing them both in terms of meeting the Triple Bottom Line (TBL) of people, planet, profit. The TBL was first coined by John Elkington and popularized in his 1997 book *Cannibals with Forks: The Triple Bottom Line of 21st Century Business* as a framework for corporate entities to measure their performance against economic, social and environmental metrics in order to improve their corporate social responsibility. It should be noted that the modern discourse uses both sustainability and sustainable development interchangeably to describe attempts to address these metrics.

These modern attempts to frame sustainability typically involve a Venn diagram that shows an interrelation amongst (1) people, (2) planet, and (3) profit or (1) environment, (2) economics, and (3) society (See Figure 6). Farrell and Hart, 1998 consider these frameworks as competing objectives in which ones tries to balance meeting a broad range of targets or objectives which include “health, literacy, and political freedom as well as purely material needs” (Farrell and Hart, 1998). However, the explanation behind these frameworks is unclear. Are these distinct objects in Venn diagrams the ‘needs’ that the Brundtland Commission refers to or are they just indicators that can be used to measure compliance to a set of ‘needs’? If so, which society do these ‘needs’ relate to?

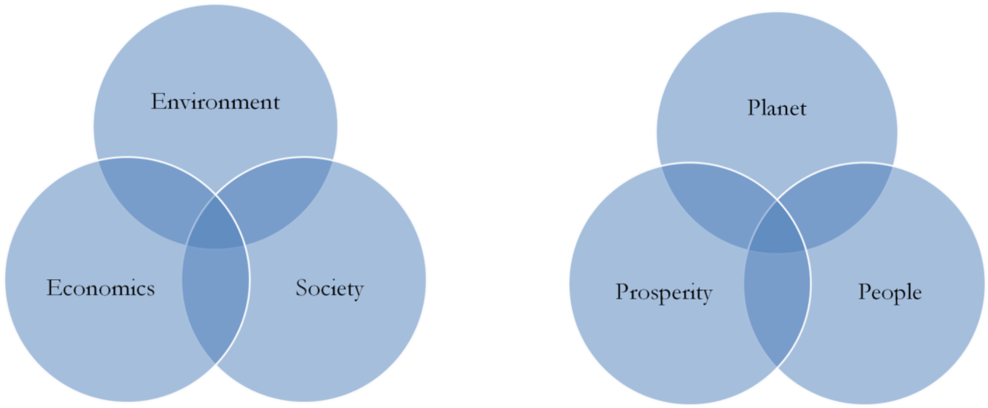


Figure 6: Modern Frameworks for 'Sustainability'

The current discourses in this arena do not explain how these frameworks were created, their interrelationship, and the priorities that these frameworks have with humanity. Instead, it is implied that these two frameworks are related to the whole of humanity because the frameworks focus on general concepts that affect and/or are important to humanity. The Brundtland Commission believes that sustainability is a good thing in which the needs and values of humanity can be met with self-reinforcing economic policies that address societal and environmental needs simultaneously. However, disagreements about how sustainability is defined and which aspect of sustainability should be addressed first does lead to tradeoffs occurring. In the words of Jamieson (1998), "sustainability must sometimes be traded off against other goods, including the welfare of our poor contemporaries. This is the tradeoff that the Brundtland Commission wanted to avoid, but it is inescapable" since there is such a large variation in ideals and values that humans consider most important for their survival. During these tradeoff discussions, those that focus on sustaining natural capital as the primary objective of sustainability are considered to be sustainability consequentialists (Shelby, et.al, 2012) and belong to the weak sustainability (WS) camp (Jamieson, 1998; Neumayer, 2004). Supporters of gearing policy, economics, and equity goals towards protecting the environment belong to the strong sustainability (SS) camp (Jamieson, 1998; Neumayer, 2004) and are called 'environmental primalists' (Shelby, et.al, 2012). Another faction in the sustainability negotiations are the cultural primalists, who believe that sustaining the knowledge base or cultural values of a society should be the main objective of all policy interventions (Shelby, et.al, 2012).

The conflict amongst these groups could most recently be seen in the clash over the expansion of the Keystone Pipeline System to bring oil refined from Canadian Athabasca tar sands oil to the United States. Environmental primalists such as the Natural Resources Defense Council (NRDC) and the Sierra Club oppose the pipeline because it harms the boreal forest environment and the greenhouse gas emissions associated with extracting the oil from tar sands makes the energy produced 'dirty'. On the other hand, sustainability consequentialists like TransCanada support the development of tar oil sands supplies and deliver systems as it meets the global demand for crude oil and can reduce American economic dependence on oil from hostile foreign nations. First Nations in Canada and Native American communities in the United States, whom I consider to be the cultural primalists, oppose the expansion of the Keystone XL pipeline as it could possibly damage their cultural sites and contaminate the local water supplies with harmful by-products that result from extracting the oil from the tar sands. These water systems are used by indigenous people to catch fish that are essential to their normal diets. Given that each group has its set of reasons and concerns for support or rejecting the pipeline, it is hard to understand which group's suggested course of action is the most important and 'sustainable'. A universal definition of 'sustainability' and 'sustainable development' does not exist yet due to the large variability in how one can define these two terms. The definition disagreements as well as the value disputes and uncertainties make the concept of 'sustainability' and 'sustainable development' unstructured (Hisschemöller and Hoppe, 2001) or intractable (Schön and Rein, 1994). In order to overcome these epistemological issues, one must define and situate the concept of sustainability in the "interpretive framework that gives it meaning" (Fischer, 2000) when partnering with a local community to design sustainable development policies and technology (Redclift, 1992; Jamieson, 1998; Redclift, 2005; Cuppen, 2012). The purpose of the dissertation research is to develop a methodological framework to (1) situate sustainability and its performance metrics in the local context of a community, (2) to foster dialogue amongst the stakeholders, and (3) to co-design and implement sustainability innovations based on the knowledge that is co-produced during the dialogue and deliberations.

2.3 Community Participation & Engagement Processes for Generating Sustainable Development Strategies and Designs

End user participation and engagement, as discussed here, is about the deliberation and decision making on the most pressing concerns or needs of a targeted end user/citizen group that will be affected by the choices or solution trajectories being selected. Arnstein (1969) provides a classification of citizen participation with eight ladder levels in order to delineate "the extent of citizens' power in determining the end product". This ladder of participation directly illustrates "the critical difference between going through the empty ritual of participation and having real power needed to affect the outcome of the process" (Arnstein, 1969). While there is some concern that the general public or the end user is not well enough informed to provide meaningful contribution during deliberation and decision making of sustainable development and environment policy (Fischer, 2000), there is a move towards wider "acceptance of stakeholder involvement in policy making" (Connelly & Richardson, 2009) and "enhanced social agency and accountability" (Stirling, 2008) in order to aid in the open innovation flow of diverse ideas from designers and end users that can be used to create new policy, products, and/or services to meet end user needs particularly in the area of sustainable development (Wilsdon and Willis, 2004; Larsen and Gunnarsson-Ostling, 2009; Cuppen, 2012). There are many processes or methodologies utilized for the consideration and involvement of public and end user views in the development of sustainable development strategies and designs. For discussion within this dissertation, I focus on interviews, focus groups, citizen panels/juries, stakeholder dialogues, and scenario or future thinking workshops as described below.

Interviews are open-ended, guided inquiries that explore an interviewees' (usually called an informant) extensive and direct knowledge related to their experiences and viewpoints about a particular subject or situation (Charmaz, 2003; Boyce and Neale, 2006). The greatest strength of an interview is its ability to provide the interviewer with rather detailed, in-depth information from the informant during a conversation. Interviews allow the informant to communicate their responses in a more intimate environment if they are uncomfortable with speaking in public or large groups. Moreover, an interview gives the interviewer the flexibility to further explore comments and responses made by the informant in real time by utilizing follow up and probing questions such as ‘Could you please comment some more on the statement you just made?’ for additional clarification. An interview guide or structured questionnaire consists of open-ended questions and is typically used to direct the conversation between the interviewer and the informant; however, much care has to be taken in the design of the interview guide’s questions in order to avoid terminal yes/no responses and steering the informant into giving responses that s/he thinks the interviewer wants to hear (Lofland, et.al., 2005; Adams and Cox, 2008). Other concerns besides injecting bias into the informant’s responses can include (1) the time intensity associated with conducting the interview, transcribing, coding, and analyzing the results and (2) the lack of generalizing a single, intensive interview to a larger group.

Focus groups are a type of group interviews conducted by a facilitator in which multiple informants that are generally representative of the population under consideration gather together to communicate and discuss various viewpoints (Wilsdon and Willis, 2004; Adams and Cox, 2008). The number of informants within a focus group can vary; however, it is recommended that the maximum size of a focus group should not exceed eight informants and that the minimum size is 3 informants (Adams and Cox, 2008). The advantages of conducting a focus group are that it (1) allows the interviewer to gather a large amount of information and responses from a target population in a single setting without conducting several, separate meetings, (2) facilitates collaborative discussions and responses amongst the informants, and (3) illuminates the power and knowledge differential amongst the informants, decision makers, and the facilitator (Morgan, 1993; Morgan and Krueger, 1993; Wilsdon and Willis, 2004; Adams and Cox, 2008). Some negative aspects of conducting a focus group include (1) one or several person(s) may dominate the conversation and drown out the responses of others in the focus group, (2) groupthink may occur within this gathering of informants due to a tendency for their responses to complement or be synchronized with each other, and (3) some informants may be uncomfortable with speaking in public spaces, particularly if their responses are not similar or in agreement with the other responses being given.

Citizen panels/juries are a collection of lay citizens gathered from a target population that meet, question, discuss, and evaluate designs and proposals submitted to them by experts and other political decision makers in a short time period (Hörning, 1999; Wilsdon and Willis, 2004; Brown, 2006). These lay citizens are typically a randomly selected group of informants that are either convened by local governments or subject matter experts. The purpose of these citizen panels/juries can range from (1) ensuring that the voice of the people who will be affected by the proposed designs or policy is taken into consideration, (2) to ‘stimulating public discourse’, (3) to ‘advising government decision makers’, and (4) to crowdsourcing and designing new options or solution pathways based on civic input and recommendations (Fiorino, 1990; Brown, 2006). However, citizen panels/juries are principally created so the lay citizen may engage in discussions and evaluate the merits or impacts of the designs and policy proposals under consideration. The deliberations and recommendations that emerge during the citizen panels/juries can produce a “common understanding of the issues or the problems based on the joint learning experience of the participants” and can “create opportunities for dialogue between experts and lay citizens” (Renn, 2004; Brown, 2006). However, the discussion documents and recommendations from these lay citizens are not "legally binding decisions" (Brown, 2006) and can be disregarded during final deliberations by the experts or government officials. However, the mere act of the participating in these panels by lay citizens may allow experts or government officials to claim that 'all sides were considered or heard' and could be used to provide some political cover or legitimacy to the final decisions made by them (Arnstein, 1969; Ward, et.al, 2003). This concern about citizen panels/juries legitimatizing or maintaining the status quo is common throughout all the other participatory design processes focused on in this dissertation. Other disadvantages of citizen panels/juries are related to exclusion of other voices by "over-emphasizing rational deliberation", the creation of a shallow consensus by pushing people to ignore or downplay areas of concern in order to achieve convergence a decision, and the power of organizers of the citizen jury to control and change agenda and discussion topics (Ward, et. al., 2003).

Stakeholder dialogues are an organized meetings of affected and interested actors (called stakeholders) that have "different perspectives, knowledge and backgrounds, who would otherwise not meet" without being recruited by an expert using designated best practices, methodological frameworks, and tools (Cuppen, et al., 2010; Cuppen, 2012). These stakeholders can range from individuals, community members, engineers, government representatives, venture capitalists, and other interested parties. (Wilsdon and Willis, 2004). Stakeholders have a vested interest in the designs and policy proposals submitted to them and engage in discussions about the merits or impacts of these submissions. However, these stakeholders may be unaware or unsure of their own and each other's frameworks, perspectives, interests, and user needs (Schön and Rein, 1994; Van de Kerkhof, 2006; Cuppen, 2012). Similar to other participatory processes discussed beforehand, the goals of stakeholder dialogue are to (1) "increase public awareness and acceptance of the problems that society faces and of the measures that need to be taken to solve these problems" (Van de Kerkhof, 2006), (2) to support better, more informed decision-making by incorporating viewpoints and values that may have been overlooked otherwise, and (3) to provide some legitimacy and accountability in the new product development and decision-making undertaken by engineers and policy makers (Fischer, 2000). Moreover, stakeholder dialogue should facilitate and enhance learning about the problem and the solution trajectories being evaluated (Van de Kerkhof, 2006; Cuppen, 2012). Unlike citizen panels/juries, stakeholder dialogues are not created with the principal purpose to elicit a decision or a set of recommendations about proposed policies or designs; however, a discussion document that summarizes the dialogue amongst the stakeholders could be used to inform decision makers about the viewpoints of the affected and interested actors.

Scenario or future thinking workshops are another participatory approach that "involve discussions among a range of local actors [during arranged meetings], with the aim of developing visions and proposals for technological needs and possibilities in the future" (Street, 1990). These scenarios can serve as a "description of the current situation, of a possible or desirable future state as well as a series of events that could lead from the current state of affairs to this future state" (Tress and Tress, 2003). In discourse of sustainability and climate change mitigation, scenarios may be framed as "coherent and plausible stories, told in words and numbers, about the possible co-evolutionary pathways of combined human and environmental systems" (Swart, et.al, 2004). Scenario workshops may employ other participatory processes such as interviews or focus groups to aid in the generation, the integration, and the consistency of scenarios (Borjeson, et.al, 2006). The range of actors involved in the scenario workshops can include, but are not limited to, residents, business representatives, and government officials. In these meetings, the participants imagine, develop, and discuss various future scenarios that illustrate the possible visions and solution trajectories (technology, policy, economic, environmental, etc.) that could come into fruition. These visions and solution trajectories being discussed and evaluated can be generated solely by local actors within the community and/or by outside experts. One of the main goals of these scenario or future thinking workshops is to forecast what are the *local* effects of the proposed environmental, economic, or technology changes under consideration and discuss how these changes support or hinder the *local* vision or goals of the community. Borjeson, et.al (2006) states that scenario or future thinking workshops are geared towards answering one of three questions: “What will happen?”, “What can happen?”, and “How can a specific target be reached?”. The scenario workshops that addressed these questions are classified as “Predictive”, “Explorative”, and “Normative” scenarios (Borjeson, et.al, 2006). In the area of climate change and sustainable development, scenario workshops with visualization have been found to be effective as a means to bridge the climate change science with local activities of a community and “accelerate local capacity-building and policy implementation on climate change” (Larsen and Gunnarsson-Ostling, 2009; Sheppard, et.al, 2011).

Swart, et.al, 2004 cautioned that the key informants or stakeholders, particularly the local communities members, must be “integrated directly into the problem definition, research design and scenario generation components of the research”; otherwise, rather limited scenarios and solutions trajectories will be created that hinder public participation and do not consider the wide range of needs and visions of the public or local actors. While Kallis, et.al. (2006) noted that “scenarios encourage participant appreciation of common ground” through shared discussions during water resource planning sessions, the scenarios workshops were unable to address conflicts that arose during deliberations of proposed scenarios or help lay persons evaluate the different options since they had limited training and knowledge of scientific or political theory being used by the experts to explain their visions and scenarios for sustainable development. Kallis, et.al. (2006) found that participants in scenario workshops “could not propose and vote on measures to achieve the future vision, as they had very limited knowledge of the [scientific and engineering] facts”. This limitation of knowledge and understanding can hinder active participation of lay people in decision making process and create questions about the legitimacy and the capacity of citizens and lay people to undertake sound deliberations and make informed decisions (Hendriks, et.al, 2007).

The abstraction of the concepts of sustainability and sustainable development can lead people to view these twin concepts as meaningless and irrelevant to the public’s daily life (Bridger and Luloff, 1999). Simply put, there is a large disconnect between the engineers and policy makers that conduct research and propose regulation about climate change mitigation and the general public that does not understand how the research and legislation helps this achieve their goals and aspirations. Participatory engagement or design processes are one approach to address this sustainability knowledge and relevance gap and generate more informed deliberations that will ideally result in the creation of solutions and mitigation that have greater public acceptance. While the community participation and engagement processes listed in this section provide several examples of how to elicit information from end user and the public about sustainable development and climate change mitigation solutions, several questions still remain related to “Which end user or stakeholder should be involved in the design process?”, “What is the role of the end user or stakeholder in the design process?”, “What platform or methodology (interviews, focus groups, etc..) is best for eliciting information and public participation?” and “What level of participation and engagement is truly needed with an end user or a community?”

Sanders and Stappers (2008) provide some perspective on various participatory design processes that involve end user and experts by organizing the various methodologies in terms of who leads the research and whether the end user is treated as a subject or a partner. A topography of participatory design research with users is presented that shows a 2x2 matrix with “led by design” and “led by research” on the north-south axis and “user as subject” and “user as partner” on the east-west axis (Sanders, 2006; Sanders and Stappers, 2008). Within this 2x2 matrix, generative design research and Scandinavian are framed as participatory design research processes. Scandinavian uses “physical artifacts as thinking tools” to involve real users “throughout the design development process to the extent that this is possible”, whereas generative design research focuses on the usage of “generative tools” in order to create a “shared design language that designers/researchers and the stakeholders use to communicate visually and directly with each other” (Sanders, 2006). These participatory design processes, according to Sanders and Stappers (2008), have now evolved into the concepts of *co-creation* and *co-design*. *Co-creation* is the “act of collective creativity, i.e. creativity that is shared by two or more people”, and *co-design* is the “creativity of designers and people not trained in design working together in the design development process” (Sanders and Stappers, 2008). Co-design is an example of co-creation (Sanders and Stappers, 2008) and can occur during the interviews, focus groups, scenario workshops, stakeholder dialogues, and the citizen juries that involve the public, designers, and end users during the design and development of sustainability and climate change mitigation strategies. Sanders and Stappers (2008) state that co-design requires that “control be relinquished and given to potential customers, consumers or end-users” and that the people “who will eventually be served through the design process [should be] given the position of ‘expert of his/her experience’, and [play] a large role in knowledge development, idea generation and concept development”. Even with the clarifications of participatory design processes provided by the framework in Sanders and Stappers (2008) it is unclear what generative tools or physical artifacts should be utilized. Moreover, questions still remain about control: what form should it take and how should it be shared?

2.4 Measuring & Modeling Sustainability

Earlier, I touched on how ‘sustainable development’ and ‘sustainability’ are ill-defined concepts that are utilized to place importance upon indicators or factors that pay a critical role in supporting the needs of current and future human populations. I have also touched on the fact that these twin concepts are being applied in arenas outside their original arena of economic development policy without proper consideration of the assumptions and conjectures that underline ‘sustainable development’ and ‘sustainability’. Let us assume for argument’s sake, that we have agreed upon a working definition of sustainability in which the needs for a target end user group or populace have been identified despite the ambiguous origins of ‘sustainability’. If we have an agreed framework for sustainability and a list of user needs, the next question is what are the metrics/indicators that should be utilize to measure and model whether or not these needs are being met? Moreover, who gets to determine what these metrics/indicators are and their relative importance? Methods for selecting sustainability indicators range from expert/professional driven processes in which they decide what are the most important performance metrics to participatory processes where the end user community identifies their own performance metrics and forefronts them throughout the environmental assessment or design process (Chambers, 1994; Hanely, et al, 1994; Rennings and Wiggering, 1996; Freebairn and King, 2003; Bell and Morse, 2003, 2008, 2011). Fraser et al., (2006) tries to address these issues by analyzing the results of the participatory processes undertaken in three case studies ranging from Canada, Botswana, and the United Kingdom. For clarity, a participatory process will henceforth be defined as a methodology in which members from a target end user group have some involvement during the new product development (NPD) of a product or service. Fraser et al., (2006) found throughout the case studies that engaging with the community helped generate "long and complex lists of sustainability indicators that provided a comprehensive assessment of local social, environmental, and economic issues" and that community members involved in the selection of these indicators gained a better understanding of the concerns across their entire community.

Moreover, these community participants felt that they were more empowered to actively address the concerns facing their community and "manage the environment" (Fraser et al., 2006). Furthermore, Fraser et. al., (2006) recognizes the need to "develop a mechanism that brings together experts and community members to develop indicators that measure progress towards sustainability" and that local knowledge from the community – whether it is top-down or bottom-up – should be included in any plans for sustainable development for better decision making. While Morris and Therivel (2009) may agree with this statement, I have concerns about how one actually embeds this local knowledge base of indicators in these sustainable development plans and whether its meaning, if any, is lost during the embedding of the local knowledge. In the Canadian First Nations case study, one of the stakeholders' goals was to use "large amounts of information to make locally-relevant, science based" decisions (Fraser et al., 2006). It seems that there was a strong push from some of the stakeholders to take the local knowledge that First Nation members possessed and embed this knowledge in a scientific framework. Stevenson (1996) points out that while Native peoples may derive some benefits, such as the physical documentation and transmission of knowledge from elders to youth, while doing an environmental impact assessment (EIA) there are also concerns that the knowledge they provide can be misunderstood and misused by non-Native and Native people from other cultures intentionally or unintentionally.

2.5 Barriers to Framing Sustainability in Native American Communities

Knowledge is defined by the Oxford English Dictionary as "facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject". In the current discourse, the knowledge possessed and utilized by Native and non-Native peoples is separated as traditional or indigenous knowledge for Native people and science for non-Native people. The label assigned to knowledge that Native people possess makes it seem that it is not modern or has no value until it is updated and put in a format that acceptable to non-Natives. If scientists and engineers have local knowledge production and manipulation processes that are embedded with social and cultural norms, then why is it valued or utilized more than the local knowledge production and manipulation processes employed by tribal nations? Some say that the dominance of science and engineering as the main knowledge production options is due to the fact that they both are designed to dissociate information from its local knowledge base and the social context in which it was created (Stevenson, 1996; Nadasdy, 2003; Ellis, 2005). Moreover, science and engineering package the information in such a way that it can travel and be used by others without consideration of the social and cultural norms utilized during its production. However, the knowledge produced by science and engineering is "embedded in larger social processes that give it meaning" and thus cannot be truly separated from the cultural and social norms from whence it came (Jasanoff, 2006). In Nadasdy's words, "… it is clear that the idea of trying to understand or make use of *any* knowledge in isolation from its social and cultural context is impossible (even nonsensical)" (Nadasdy, 2003).

There are several barriers, such as the different language, styles, and knowledge creation and collection methods used by engineers and Native people, which can prevent the effectiveness of the participatory processes (Ellis, 2005). Nadasdy (2003) points out that Aboriginal peoples or indigenous populations are at a distinct disadvantage unless they adopt the official language that government officials and academics utilize when discussing resource management and development practices. If these groups do not conform to the formal ways of speaking (scientific or engineering language) or knowledge production processes utilized by scientists and engineers, then they are "effectively barred from participation in these processes" or sentenced "either to silence or to shocking outspokeness" (Nadasdy, 2003). The power dynamics in this relationship are such that the tribal members are reduced to being mere observers in the design process without any power to speak or influence the technology and policy that gets designed and implemented within their lands. What is so distinct or unique about the bodies of knowledge and knowledge creation methods possessed by Native and non-Native people that warrants a separation of the two? It is difficult to understand why the knowledge possessed by Native people is given the definition of "a belief or story or a body of beliefs or stories relating to the past that are commonly accepted as historical though not verifiable" while knowledge possessed by non-Native people has the definition of "an inherited, established, or customary pattern of thought, action, or behavior". Perhaps the local knowledge of science and engineering is valued more than the local knowledge possessed by tribal people because "indigenous knowledge continues to be presented as an object for science rather than as a system of knowledge that could inform science" (Cruikshank, 1998). In order words, tribal people and their knowledge production systems "as objects, 'as things', have no purposes except those their oppressors prescribe for them" (Freire, 2000).

Ambler (1990) and Nadasdy (2003) have the conjecture that this separation of knowledge is a mere expression of power that is utilized by paternalistic government and academic officials and institutions to continue to exert control and influence over the Native people in affairs ranging from energy development to education. There is a history of government officials in the United States and Canada of creating policies, well intentioned or not, that have resulted in negative consequences for Native people simply because these organizations believed that they knew what was 'best' for Native people given Native peoples' lack of capacity and knowledge (Allen, 1989; Coffey and Tsosie, 2001; Ellis, 2005). It seems that the separation of knowledge possessed by Native and non-Native people is an artificial barrier created to exclude parties from participating in certain activities such as environmental management or renewable energy design for example which are typically accepted as within the purview of certain government institutions or organizations.

2.6 What Is Still Missing from the Sustainability Conversation

In analyzing the literature on sustainable development, one sees that there are several limits in the design and implementation of sustainability policies and technologies. First, there is no universal definition of sustainability and sustainable development that is universally agreed upon. However, efforts to understand the vast diversity in defining and framing sustainability are scarce and many of them assume that *civilized* societies will not have significant variation in their needs as they relate to sustainability. Second, the indicators for evaluating and measuring sustainability are not grounded and situated in the local context of community that will be affected by the implementation of environment policies and development strategies. Third, there is a devaluation or marginalization of the knowledge production processes typically utilized by indigenous populations since they are embedded with social and cultural norms that are unfamiliar to the dominate society.

This dissertation seeks to build a mechanism to unite the outside experts' and the community experts' collective intelligence on the concept of sustainability and indicators. This is similar to Fischer's call for a methodological framework that will "bring together, rather than separate out, the unique and essential aspects of human behavior, the intermixing of the empirical and the normative" in order to allow the investigators to "get *inside* the situation and 'understand' the meanings of the social phenomena from the actors' own goals values, and point of view" (Fischer, 2000). Sheppard, et.al, (2011) also shares a similar position to Fischer (2000) and highlights that in the discourses of climate change mitigation and sustainable development, that there is still "an urgent need for better frameworks, tools and processes to help communities and local agencies make sense of and organize emerging information on climate change" and that a "new type of capacity-building process and decision support tools on climate change" are needed. There are still several questions that remain: Which members of the Native American community get to participate in the design process? How are their contributions to development of sustainability indicators or performance metrics valued? What is the framework that Native American tribes utilize for sustainability? What approach is needed to elicit or understand the local concept of sustainability and their indicators? What are the technology solutions and development strategies needed to meet their sustainability needs? Moreover, how does one build a sense of trust and enthusiasm within a community partnership given historical trauma associated with working with outsiders? These are questions that are examined in the following chapters of this dissertation through a presentation of the research questions and co-design methodology created for the completion of the research undertaken.

Chapter 3: Research Design

3.1 Introduction

This dissertation is an extended case study of a research design project with a Native American tribe called the Pinoleville Pomo Nation (PPN) (Burawoy, 1998). This extended case study involves participant observation within the PPN, interviews with citizens, staff and government representatives of the PPN, user needs assessment and community-based design processes. The extended case study method fosters "dialogue between participant and observers [which] "provides an ever-changing sieve for collecting data" (Burawoy, 1998). This chapter lays out the research design for the dissertation, beginning with an overview of the research questions. This is then followed by details on the research location, the data collection methods, and limitations of the research design.

3.2 Research Questions

This research focuses on the development of a methodological framework to elicit user needs and social performance metrics from a target end user group as they relate to sustainable development and climate change. The research addresses the following gaps in the current literature on sustainable development: (1) methods to understand local definitions and frameworks for sustainability and sustainable development, (2) identification of user needs or social performance metrics as indicators of sustainability and sustainable development, (3) amalgamation techniques to merge or incorporation knowledge production processes given variation in social and cultural norms, and (4) processes to design and implement sustainability and climate change solutions.

There are three primary research questions presented in this dissertation. The first question addresses methods for eliciting user needs or social performance metrics with a focus on the co-design methodology. The second question addresses local frameworks and definitions of sustainability and sustainable development. The third question relates to engineering design processes for sustainable development.

Research Question 1: How effective is the co-design methodology in eliciting user needs or social performance metrics from a target end user group such as a Native American tribe?

In order to gauge the effectiveness of the co-design methodology developed in this dissertation, I focused on the number of unique needs or social performance metrics generated during the co-design sessions with the Pinoleville Pomo Nation. I measured the percentage change in the number of needs generated from the co-design sessions and I gathered qualitative comments about the co-design sessions.

Research Question 2: How does a Native American tribe define and frame sustainability and sustainable development?

To answer this question, I participated in several informal and formal interviews sessions with members of the PPN tribal council and administration separately from the larger community. I focused on recording the number of unique needs or social performance metrics generated by the PPN tribal council and administration. I also looked for any overlap or duplication of needs amongst these groups and gathered qualitative comments from PPN community, tribal council and administration members about what they considered the overarching goal or framework for what sustainability and sustainable development should be for the Pinoleville Pomo Nation.

Research Question 3: How should the engineering design process be managed in the field of sustainable development with an end user group that has historical trauma associated with technology, focus groups, and interviews?

To answer this question, I conducted several informal and formal interviews sessions with members of the PPN that focused on the success and failure of the co-design methodology in the design and implementation of sustainable homes within their lands.

3.3 Research Case Study with Pinoleville Pomo Nation

When I talk about my dissertation work, several questions inevitably come up during the discussion: Why did you choose to work with Native American tribes on sustainability systems given your more traditional mechanical engineering background? Do these *tribal* people actually understand what sustainability really is? What are the *real* engineering aspects of your work? Are you doing this research because you are Native yourself? Since beginning this research partnership with the Pinoleville Pomo Nation in March 2008, these questions have regularly been asked by professors and students at UC Berkeley. These questions, at times, seemed aimed more at undermining or separating my research from the dominant research undertaken in my department and less about understanding the discourse contribution of my work in the fields of engineering, sustainable development, and community-based design. These questions had the effect of making the *uniqueness* of my work into something that was considered *weird* and *out of place* (i.e., this is research that Berkeley engineers should not being doing) instead of being treated as *novel* and *paradigm shifting*. It is my firm belief that if I was working in a suburban community or a more affluent area that these questions about my engineering abilities or the local community's intellectual and knowledge production abilities would not be questioned in such as belittling and dismissive manner.

This dissertation is based on research carried out near Ukiah, California on the lands of the Pinoleville Pomo Nation (PPN) with members of the PPN serving as research partners or co-designers. When I use the phrases 'members of the PPN', 'Pinoleville' or 'the tribe', I am referring to people that are elected officials of the tribal government, employees that serve in the PPN administration, and people that are officially enrolled as citizens of the Pinoleville Pomo Nation. It should be noted that not all the employees who serve in the PPN administration are PPN citizens; some employees, such as David Edmunds, then the Environmental Director of the PPN, are not Native American at all. When I use the phrases 'PPN citizens' or 'Pinoleville Pomo people', I am specifically only referring to officially enrolled citizens of the Pinoleville Pomo Nation. I make this distinction because at times I wish to make general comments and statements about the people I have encountered during my work with the Pinoleville Pomo Nation. At other times, I only want to focus on the citizens of the Pinoleville Pomo Nation. Unlike the term 'members of the PPN', citizenship in the Pinoleville Pomo Nation is legally and clearly defined. Citizenship is granted if a person has "at least one-quarter

(1/4) degree of Pomo Indian blood" and is "related by blood to a member of the base roll" which is based upon the "Captains and Councilmen listed on the Mendocino County Indenture, dated 1878, 1893, and 1897, for the purchase of land for Pinoleville Indians: Charley, Sam Hale, Napoleon Bonaparte, Jim Reeves, Fuller Williams, Jack Mace and John Stevenson". Moreover, a person may be naturalized into the Pinoleville Pomo Nation if they have "one-quarter (1/4) degree of Native American Indian blood" and "close social ties" to the Pinoleville Pomo Nation. Currently, there is virtually no disagreement amongst the Pinoleville Pomo people about who should be listed as a member of Pinoleville Pomo Nation.

From an interview conducted with Tribal Chairperson Leona Williams, Vice Chairperson Angela James, Tribal Sovereignty Coordinator Lenora Steele, and Environmental Director Dr. David Edmunds in March 2012, I found that the genesis of my research collaboration began in 2007 when members of the Pinoleville Pomo Nation started discussions amongst themselves about green building designs for potential homes for its citizens within months after the arrival of their new Environmental Director. Members of the PPN tribal council and administration met to review their current funding status for infrastructure development and began asking questions about how new homes could be "green", "self-sufficient", and utilize the latest technology to address the power blackouts experienced by the PPN at the time. A "self-sufficient" home according to members of the PPN tribal council was one that had "no PG&E and the ability for the home to keep running when everybody else was shut down". PG&E stands for the Pacific Gas and Electric Company, and it is a natural gas and electricity company that serves most of the Northern California including the lands of the Pinoleville Pomo Nation. The PPN had a desire to "not go that same route with the typical HUD houses" that had been previously built for the PPN citizens. These HUD homes had little to no representation of the PPN's cultural values, provided only basic necessities of shelter, and were suffering from large heating and cooling costs associated with poor construction. Furthermore, family sizes were also of concern given that most people had extended family members living with them which typically led to overcrowding in the HUD homes.

When asked about the decision to work with UC Berkeley, it was stated by Angela James, Vice Chairperson of the PPN, that Dr. David Edmunds took the initiative, with tacit approval of the upper echelon of the PPN government, in spearheading this effort to create the partnership. The new Environmental Director realized early on that the focus on self-sufficiency in the homes was in concert with the PPN mission statement and that the tribe could "advance the cause of self-sufficiency" by "protecting its environment" and controlling "its own affairs, own water, own energy". The general consensus was that since David's wife Dr. Kimberly TallBear was now a professor at UC Berkeley in Environmental, Science, Policy, and Management department, the tribe now had a "connection" to UC Berkeley which it could leverage for support in their endeavors. Despite this new connection, the willingness of the Pinoleville Pomo Nation to work with UC Berkeley was still tenuous given the undesirable relationship and views many Native American tribes have with UC Berkeley particularly as it relates to Berkeley's depictions of Ishi and its compliance with Native American Graves Protection and Repatriation Act (NAGPRA) (Kroeber and Kroeber, 2008; Sackman, 2010; Kroeber, 2011).

Vice Chairperson Angela James captures this sentiment and apprehension with the following section from her 2009 Native American and Indigenous Studies Association paper:

"*When I was first approached about the Pinoleville Pomo Nation collaborating with the University of California Berkeley I was a little nervous. This was about at the same time I became aware of the controversy with UC Berkeley and the Native American Communities. The issue of concern is regarding the 12,000 Native American remains that lie in drawers and cabinets in the gym's basement. Many Natives are skeptical about the way Berkeley has handled this situation. Tribal leaders and representatives argue that under the 1990 federal Native American Graves Protection and Repatriation Act, the museum is required to identify the tribal origins of its bones and artifacts and return them to federally recognized tribes that request them.*

The media covered the story about tribal leaders requesting a meeting with the UC Berkeley Chancellor but the Chancellor did not respond to requests for a meeting. I have family members who attest the issue of UC Berkeley housing the Native American remains. This issue was in the media when Pinoleville Pomo Nation began collaboration efforts with UC Berkeley Engineering Department on the Culturally Informed Sustainable Green Housing. I have family who have strong feelings regarding the remains they want returned to the Tribe for proper burial. My relatives have been fighting for their rights against UC Berkeley. When the collaboration began I felt as if I was betraying my relatives to collaborate with the university.

I had some issues and concerns about the collaboration that I believe stem from my past, the history shared by my grandfather, and my present work as the Tribal Historic Preservation Officer. It was a little difficult for me to accept the UC Berkeley people with all the combined issues I have spoken about."

The mistrust and uneasiness that Angela and many others at Pinoleville had about working with UC Berkeley is based on a long history of historical trauma and prejudice that many Native Americans have experienced in Northern California when interacting with non-natives. Angela recounts some of these experiences in an earlier section of her 2009 Native American and Indigenous Studies Association paper:

"*My grandfather shared a story with me when I was little that told about the prejudice in the Ukiah Valley. He told me about how the Indian people in Ukiah were only allowed to walk down one side of the street and the only place they could stop and rest at was in front of the courthouse on the lawn. There were signs in store windows that read "No dogs or Indians allowed" this was as late as 1950. There was one grocery store and one restaurant in town that allowed Indian people to shop and eat both owned and operated by a Chinese man.*

The second story my grandfather told me about was what the Indian people of the Ukiah Valley call "Ba-lay Ba-lin", translated into English means "Bloody Run." This event took place during the Gold Rush. When gold was discovered in California the Indian people were an obstacle for the White man to mine for gold. My grandfather's story shares that "the white man herded all the Indians like cattle, and if you were too slow you were shot from behind and thrown in the river." There were a lot of young and elderly who couldn't keep up and they were killed.

The Indian people were herded to Round Valley. The reason this event is called "Bloody Run" is for the fact that the bodies of the dead were thrown into the Eel River and the river ran red from the blood of the deceased for 3 days. This was all done in the name of greed. All the white man wanted was the gold that was on the Indian land.
I believe this is where my fear and intimidation of the white race came from. Something I had to work on in my life, and being able to trust the white race. I did finish school and went on to college but I never felt like I fit in at a University."

Overcoming the fears and suspicion about partnering with non-natives and academic institutions like UC Berkeley that had either been historically denied to native people or used to oppress native people was an ongoing, evolutionary process within many members of the Pinoleville Pomo Nation (PPN). It is my view that having a direct, personal connection to UC Berkley through a professor that had done research on the role of science and technology in Native American and other indigenous populations gave the PPN some measure of confidence and reassurance that they could possibly find other academics that wanted to use their skills to help tribal people meet their goals instead of treating tribal people as a data storage and retrieval system whose knowledge is only valuable when it is extracted and analyzed by non-natives. In March 2008, members of the PPN went to UC Berkeley to meet with members of the American Indian Graduate Program (AIGP) to discuss potential collaboration ideas with Berkeley professors and students. One such project ideas pitched by the PPN's Environmental Director Dr. David Edmunds focused on "designing houses that reflect Pomo culture and/or save energy and water". During this meeting, David met Dr. Benjamin Fine, then a Ph.D. student in mechanical engineering at Berkeley, who told him that he had a friend in his department that was working on a community based assessment approach for sustainable design with Dr. Alice M. Agogino, a professor in mechanical engineering. The other student Benjamin was referring to was me.

At that time, I was finishing up my Masters research at Lawrence Livermore National Laboratory (LLNL) on a thermodynamic model and designs for a cryogenic capable pressure vessel to store liquid and compressed gaseous hydrogen for vehicular application. In December 2007, I had also won an Advance E-team grant from the National Collegiate Inventors and Innovators Alliance (NCIIA) for the Community Assessment of Renewable Energy and Sustainability (CARES) project (with Yael Perez and Job Van de Sande). CARES was founded to address the disconnect between the creation of sustainability technological innovations by engineers and the needs of the end users. The mission of CARES is to enable end users to make informed decisions about sustainability and renewable energy technologies by giving them agency during the design, development, and implementation of sustainability best practices renewable energy technologies by using a cycle of *Assess, Advise, Implement, Live*. CARES would (1) assess current energy usage and identify performance metrics based off of functional user needs, (2) advise end users by identifying potential sustainable technology trajectories that meet user needs and decision criteria, (3) partner with key stakeholders to design and implement solutions in local communities and research test beds, and (4) aid communities in living sustainably by providing a feedback loop where end users can gauge their overall improvement in sustainability via appropriate performance metrics. By the time March 2008 rolled around, I was still unable to find any community partners willing to partner with me on community-based assessment and design of sustainable systems. It was by pure happenstance that

Benjamin was serving as my mentor at the same time that both the PPN and I were looking for partners. Both Benjamin and AIGP served as a vital, initial bridge to link me with David and the Pinoleville Pomo Nation. After a series of emails and meetings between my advisor Dr. Agogino and members of the PPN, it was decided that I would be able to work with the PPN on the design of their culturally inspired, sustainable house design as part of a class project in sustainable product design taught by Dr. Agogino. The question that remained was how exactly I would go about working with the PPN to understand their performance metrics and decision criteria for housing.

3.4 Data Collection and Sources

3.4.1 Introduction

During emails and in person conversations with members of the Pinoleville Pomo Nation community and tribal government, it became rather clear that the Pinoleville Pomo Nation (PPN) had several metrics and requirements for the energy and water performance of the future homes. The initial email prompt from the PPN's Environmental Director indicated that the future homes should "save energy and water", but it was unclear as to how much energy and water should be saved relative to a certain base line. Nor was it clear exactly what was the actual "Pomo culture" and what aspects should be integrated into these new homes designs. Moreover, I had no firm understanding of what energy and water efficiency technologies that members of the Pinoleville Pomo Nation were aware of and viewed as culturally acceptable.

3.4.2 Grounded Theory

In order to address this lack of information, grounded theory was utilized to gather and analyze data on the PPN's framework for sustainability as well as the social and technical performance metrics for the future home designs. Glaser and Strauss (1967) developed grounded theory as a systematic approach for collecting and analyzing data in order to develop theories or frameworks based on or 'grounded' or connected to the reality of the qualitative and quantitative data collected. Grounded theory is typically used in research projects in which there is little "known about a particular topic or phenomenon, or where a new approach is needed to garner insights in familiar settings" (Daymon and Holloway, 2010). The main advantage of grounded theory is this dissertation is that it does not force the application of a "preconceived theoretical framework" about sustainability upon the PPN (Glaser and Strauss, 1967). Instead, the PPN's framework and metrics for sustainability are allowed to emerge naturally from the PPN's own approaches to knowledge production through discussion and juxtaposition. In other words, the PPN's metrics and theories related to sustainability "do not spring tabula rasa from the data, but are carried forward through intellectual debate and division" by members of the PPN and the researcher (Burawoy, 1988). Grounded theory "sets out to find out what theory accounts for the research situation" that is being observed, documented, and analyzed by the researcher (Ng and Hase, 2008).

The central stages of grounded theory include (a) simultaneous data collection and analysis in order to determine missing elements for further study, (b) development of analytic codes and categories from the data gathered, (c) usage of the constant comparative method to code, label and frame the data gathered to develop a theory, and (d) the constant refinement of theory with each new stage of data collection and analysis (Charmaz, 2003, 2006). The constant comparative method is a "joint coding and analysis"… procedure designed to … "generate theory more systematically … by using explicit coding and analytic procedures" as well as a literature review as for comparison and analysis (Glaser and Struass, 1967). Coding in grounded theory is the process of defining or labeling the portions of data recorded in field memos; moreover, "qualitative codes take segments of data apart, name them in concise terms, and propose an analytic handle to develop abstract ideas for interpreting each segment of data" (Charmaz, 2006). It should be noted that a special category of coding, known as *in vivo* codes, are used in this dissertation as data labels that are verbatim quotes from the PPN participants (Charmaz, 2006). Creswell (2006), Charmaz (2006), and Corbin & Strauss (2008) describe the typical process of coding in grounded theory as:

1. Open or initial coding: categorizing the data usually line-by-line or incident-by-incident into short phrases or labels; usage of *in vivo* codes

2. Axial coding: determining a central theme or concept in order to unite the separate pieces of data back together after initial coding; identifying and exploring the relationships amongst the data

3. Selective or focused coding: selecting the most significant or frequently occurring codes to develop a framework or a hypothesis; filtering irrelevant codes and concepts via constant comparison of "data with data, data with category, category with category, and category with concept" (Charmaz, 2006).

3.4.3 Data Collection & Sources

Data collection involved the usage of field memos that recorded events and thoughts in engineering design journals. Other data sources included the email exchanges between myself and members of the PPN tribal government, administration, and community, in person meetings and workshops with the PPN, PPN council meetings notes, workshop flip charts, reports to funding agencies, and educational training sessions. The artifacts or media used from these data sources includes videos, paper flip charts, sketches, reports/memos, conferences presentations, conference papers, and emails. Table 1 lists the data sources and the artifacts/media collected from the field work and research with the Pinoleville Pomo Nation.

3.5 Limitations of Research Design

The main limitation of this research design is that it involves a single case study of a sustainable development endeavor in the specific context of the Pinoleville Pomo Nation (PPN). As a result, it is possible that the findings and the lessons learned from this research undertaking may not be applicable to other Pomo tribes or non-Native Americans. Moreover, the data that I gathered was related in part to my situated knowledge and/or who I was, an African American male pursuing a PhD at the prestigious UC Berkeley in mechanical engineering that had little to no direct experience with Native American tribes (Haraway, 1988). It is my view that my situated knowledge and background did shape how members of the PPN perceived me and my efforts to elicit their local concept of sustainability and their performance metrics. The replication of my research design by another mostly likely will result in very different observations about the PPN's framework for sustainability and the social performance metrics for sustainability generated by the members of the PPN due to the subjectivity of the data label and in vivo codes being utilized (Charmaz, 2006). These issues are explored furthered in the implementation of this single case study with the PPN using the co-design methodology developed for my dissertation research.

Table 1: Data Sources and Artifacts Utilized in Dissertation Research

Medium			Artifact/Media					Timeframe
	Flip Charts with User Needs	Sketches	Interviews	Reports/ Memos	Videos	Paper	Emails	
Initial Email from David Edmunds							X	Spring 08
Co-Design Innovation Workshops	X	X		X				Spring 08
CARES Housing Report				X				Summer 08
Co-Design Innovation Workshops	X	X						Spring 09
NREL PPN Site Visit		X						Spring 09
Solar Hot Water Heater Report				X				Summer 09
NAISA Conference						X		Summer 09
CARES Housing Report				X				Summer 09
Francesca Thesis						X		Fall 09
Co-Design Innovation Workshops	X	X		X				Summer 10
PPN Council Meeting		X		X				Summer 10
Co-Design Innovation Workshops	X	X		X				Fall 10
Renewable Energy Co-Design Innovation Workshop		X						Fall 10
PPN Council Meeting		X						Spring 11
Co-Design Innovation Workshops	X	X						Summer 11
One-on-One Meetings with PPN			X					Spring 12
One-on-One Meetings with PPN			X					Summer 12
CARES Videos					X			Summer 12

Chapter 4: Co-design Methodology

4 Introduction

In Chapter 2, I discussed several community participation and engagement processes for eliciting information and engaging end users and the general public about sustainable development and climate change mitigation solutions. However, it is unclear how well these community engagements and participation approaches will work in communities that are concerned about continuous misrepresentation of their culture and history by people that are unfamiliar or are not properly trained in their local knowledge production processes. Ellis (2005) documents the difficulties that Native peoples [First Nations] in Canada face in trying to find people "who are recognized as having traditional knowledge and are also technically able to participate in environmental governance processes". Even when such a person is found, the traditional knowledge approaches utilized by First Nations people are not considered to be based "from an independently viable system of knowledge" or grounded in an intellectual framework (Ellis, 2005). As a result, these traditional knowledge approaches are "commonly ignored, misunderstood … or discarded… because they are incompatible with science and dominant Euro-Canadian values" (Ellis, 2005).

In particular, Nadasdy (2003) points out that many indigenous populations believe that "scientists [I would add engineers as well] and managers have no real intention of trying to integrate traditional knowledge with science, but that they are merely paying lip service to the idea because it has become politically expedient to do so" in order to maintain and legitimize their control of indigenous populations. This is a similar viewpoint that (Freire, 2000) shares about the increasing usage of science and technology as "unquestionably powerful instruments for [the] purpose [of] the maintenance of the oppressive order through manipulation and representation" of less powerful people and their knowledge. As one could imagine, this blatant disregard and devaluing of Native peoples' local knowledge could lead to severe misgivings and a lack of trust related to working and sharing information with non-Natives. In order to address the challenges associated with building a sense of trust and enthusiasm within Native communities that have historical trauma and concerns about working with outsiders, the co-design methodology detailed in following sections was created.

4.1 Defining the Co-Design Methodology

The co-design methodology seeks to empower citizens of a local community, like the Pinoleville Pomo Nation (PPN), to (1) assess their current level of sustainability, (2) utilize input from outside designers/engineers to select sustainability solutions and best practices, (3) design and implement solutions to meet their needs and framework for sustainability, and (4) measure their progress in meeting their sustainability goals (Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013). The co-design methodology has similar aspects to human-centered design in that both methodologies place a high value on understanding the needs of the end users and gathering feedback from the end users and stakeholders throughout the design process. The central tenet of co-design, however, is to create products that meet the full range of end user needs by giving both the end user and the designer/engineer shared control during the new product development (NPD) process (Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013).

For the co-design methodology, the end user is considered to have expertise about their needs and determines whether or not a product is appropriate for their needs and environment

(Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013). In this dissertation, the members of the PPN are considered to be experts because they possess an understanding of facts, historical records, “culturally sanctioned techniques”, and knowledge about “things [related to the PPN] by virtue of being experienced in the relevant ways” of the PPN’s world (Dear, 2004). The designer/engineer in this methodology takes on the role of a “facilitator of public learning and empowerment” that seeks to achieve a “more democratic balance between [the] knowledge and participation” levels of both the community member and the designer/engineer (Fischer, 2000). In other words, the co-design methodology seeks to democratize the engineering of sustainability solutions by allowing both parties to scrutinize and discuss the “expropriated social meanings” and frameworks laden within the engineering design and development of sustainability systems (Fischer, 2000).

The end result of co-design methodology are solutions that meets user needs and that are situated in a knowledge framework that gives it meaning and relevance to the end user, in this case the Pinoleville Pomo Nation (PPN). This co-design methodology achieves that result through a series of meetings with the PPN called co-design innovation workshops. The co-design innovation workshops have three stages: (1) Trust Building, (2) Split Group User Needs Assessment & Prioritization, and (3) Brainstorming on Conceptual Designs. A typical co-design innovation workshop lasted 6 or 7 hours and usually begins on a Saturday in the mornings at 10 am. This day and time was generally chosen as it allowed for the greatest number of tribal members and UC Berkeley engineers to participate in the workshop with limited economic impact on their wages. It should be noted the research undertaken in this dissertation received funding from the U.S. Department of Energy (DOE) via a grant with the PPN, the National Collegiate Inventor and Innovator Alliance (NCIIA), Housing and Urban Development (HUD) via a grant with the PPN, and UC Berkeley.

4.1.1 Trust Building Stage

On April 13, 2008, 40 residents of the PPN in northern California, 14 participants from the University of California, Berkeley (UCB) and CARES met at the PPN and utilized the co-design methodology to understand the sustainability and environmental needs of the PPN community in order to provide recommendations for the community. The first stage of the co-design innovation workshop is called Trust Building and it began with a 20 minute icebreaker session in which self-selected, mixed groups of 3–5 people from the PPN, CARES, and UCB discussed why they were participating in this meeting and their desired outcomes for the meeting. The purpose of this portion of the Trust Building stage was to allow the various parties represented to convey their goals and aspirations for coming together. This ice breaker session was followed by a 10 minute listening session in which participants in the same 3-5 person groups sat and took turns listening to each other’s responses to questions such as (1) What was the hardest challenge you faced in your life? (2) What is the one thing that brightens your day?, (3) Why did you choose your major in college or grad school?, (4) Who was the most inspirational person in your life?, and (5) Who was the most influential person in your life?.

There were some concerns by members of the PPN tribal council and administration that the ‘hardest challenge’ question should be rephrased as it was assumed that the students and faculty from CARES and UC Berkeley most likely came from privileged backgrounds, didn’t have any ‘real’ challenges, and they could not really begin to emphasize or relate to PPN citizens that faced daily concerns related to creating a safe home, maintaining financial stability, and addressing health issues. At the end of the listening session, some members of the PPN tribal council and administration were pleasantly surprised at how easily they could connect with the backgrounds of some the CARES and UC

Berkeley participants and how well the comments and suggestions from the members of the PPN were acted upon. PPN Vice Chairperson Angela James captures some of her thoughts about the Trust Building stage of the co-design methodology's innovation workshop with the following section from her 2009 NAISA paper:

"*When the Pinoleville Pomo Nation agreed to work with UC Berkeley in collaboration for Sustainable Green Housing, I had a lot of questions about what they were going to do, the people they were interested in talking to, and whom they would share our information with. ….I remember we did an icebreaker before we started the meeting. We broke into groups and each person had to speak about a hero in their life and the others in the group had to listen without asking questions or giving feedback. By sharing something personal with the group it helped everyone feel more comfortable with each other. I felt more comfortable meeting and talking with the individuals from Berkeley who were of African American or Asian descent. I could connect with their cultural backgrounds*."….

"*When I met the white female professor for the first time I was uncomfortable with sharing personal parts of my life with her. She was aggressive in her questioning. I felt she was prying; she invaded my personal space by being physically close to my face while asking questions. She is an overall nice lady but there were some cultural norms that she violated….. At our last meeting I noticed an extreme change in the professor. I could tell she had been listening to comments and feedback because her questioning was different along with her physical closeness. There were three of us who noticed the change. I believe this proves the importance of having the planning sessions. They allow for personal growth among all the individuals involved in the collaboration. The white professor gained her knowledge by listening to the people and all of their likes and dislikes*."

"*I felt a personal connection with the African America male and the Asian American male because of the history and cultural backgrounds each possess. In a planning session icebreaker I learned that I had things in common with these two individuals and it made me feel more comfortable. One individual had grown up on a farm and preformed daily duties. I instantly connected, having grown up with my grandfather. He had a vineyard and walnut orchard where all of his grandchildren worked.*".

"*The connection I made with the Asian American male I believe stems from my grandfather's oral history. He shared with me regarding the one Asian American restaurant/store owner who allowed the Indian people to eat and shop in Ukiah when no other business owners would even let them enter. Some of the Asian cultural beliefs are similar to Native Americans. The two male individuals' presence was really important to me and others I have spoken with in the Pinoleville Pomo Nation. They have gained the trust of the Pinoleville Pomo Nation.*"

The listening session was then followed by a 30 minute, full group round robin session on the technologies that the participants considered to be good and bad. 'Technology', just like the twin concepts of sustainability and sustainable development, is a vague, flexible term that typically refers to the usage of tools, devices, techniques, best practices, and machines to design and implement solutions to problems. The main underlying framework of this session was to communicate that everyone has a mental model about what 'technology' is, uses 'technology' in some fashion, and can evaluate its good and bad points from a user perspective. The usage and manipulation of 'technology' is not under the sole dominion of those that hold the title of engineer or the elected officials in the PPN tribal council and administration that deal directly with the engineers from academia and industry. Since everyone has some general experience with "technology', they should be comfortable with expressing their ideas about 'technology' and its usefulness in their everyday lives. This was a light-hearted session in which no titles were used by the participants when they introduced themselves and their viewpoints about technology. During this session, the participants expressed comments ranging from the computer age being a bad technology since it makes people lazy to community gatherings like Big Time at the PPN as good technologies, and admiration for Apple products (much to my dismay as I am personally not a fan of Apple products). Figure 7 shows some of the participants and Table 2 lists the comments that were recorded by me during the round robin session on good and bad technology.

Figure 7: Participants in the Round Robin Session on Good and Bad Technology in 2008

Table 2. Expressed Comments on Good and Bad Technology during 2008 Round Robin Session

	Good Technology	
Attics	Dimmer Lights	Big Bedrooms
Snooze Button on Alarm	Gates	Community Center
Green Materials	Cellphones for Connection with others	Screened Patios
Lots of Electrical Outlets	Motion Sensing Lights	Zapper Lights
Natural Lights in Rooms	Sports	Shed for Tools
Swimming Pools	Baseball	Granny Unit
Lots of Closet Space	Community Gatherings i.e. "Big Time"	Handicapped Accessibility
Patios	Large Living Rooms	Open Houses i.e. Reduce the Number of Walls
Outdoor Space	More Bedrooms	Gym
Shelves	Asphalt	Veggie Roofs
Porches	Big Bathrooms	Greenhouses
Basketball	Carpet	Arcade Rooms
Solar Panels	Big Yards	
Smart Lighting for Homes	More Bedrooms	
Clap On, Clap Off Lights	Water Sprinklers	
Lots of Colors	Basements	
	Bad Technology	
	No Garage	
	Thin Walls	
	Computer Age (Makes People Lazy)	
	Tile Floors	
	Bad Heating System (More Control)	
	Carpets Small Kitchens	
	Flattop Roofs	
	Apple Products	

4.1.2 Split Group User Needs Assessment & Prioritization Stage

When I first encountered the PPN, I learned that the PPN was a matriarchal society and that all the elected members of the PPN tribal council at the time were female. It became apparent that all principal responses to our questions about the PPN's background and recent history, excluding those of Dr. Edmunds, would come from the female members of the PPN tribal council and the administration staff. It seemed as if the males within the PPN community were either disengaged from daily life at Pinoleville or just not comfortable with interacting directly with me and the other participants from CARES and UC Berkeley when PPN women, particularly those from the tribal council and administration, were present. As a result, the co-design innovation workshop was originally designed to have separate groups for men and women in the hopes that the men would be more comfortable speaking candidly with me and other men in the tribe about their user needs. Based on our workshop planning meeting with members of the tribal council, we agreed that it would be important to split part of the workshop into three user groups in order to capture their distinct voices: Elders, Adults, and Youth. The need for this breakdown was played out during the workshop when I observed during the Trust Building stage that PPN citizens would wait until some of the older members spoke first before volunteering their comments and ideas. Moreover, I noticed that PPN youth present during the Trust Building stage would typically wait until everyone older spoke before they would express their thoughts and views. When I inquired about if there was a certain order for speaking in groups, I was informed that PPN culture and community places a great importance on the wisdom and experience of its elders and PPN citizens typically allow the first comments to be expressed by elders. However, I was not able to determine during my conversations with tribal council members and other PPN citizens over lunch if there was an exact age minimum for a PPN citizen to be considered an elder. My observations of and discussions with several tribal members during the Trust Building stage and over lunch lead me to the realization that the PPN was not just a homogeneous end user group, but rather, a multifaceted community that had three distinct end user groups: Elders, Adults, and Youth.

After lunch, I asked all members of the Pinoleville Pomo Nation to self-select and join either the Elders, Adults, and Youth end user groups that they most closely identified with in order to conduct concurrent user needs assessments for the each group. The remaining CARES and UC Berkeley participants then decided which group to join based on their interest and desire to learn more about the respective group's user needs. Dr. Agogino, Yael Perez, and I acted as facilitators of the Elders, Adults, and Youth groups, respectively, and we began the 45 minute split end user group user needs assessments by asking variations of the following prompts: 'What do you all feel is the most pressing concerns in your community?', 'What are the main needs that should be addressed?', 'Could you describe the things that you want to change in your community' and 'What are topics that you are most important to you?'.

It should be noted at this stage of the co-design methodology I was unsure if the citizens of PPN or the members of the PPN tribal council had even an inchoate concept of sustainability or sustainable development. Even though Dr. Edmunds approached me and others at UC Berkeley with the prompt of "designing houses that reflect Pomo culture and/or save energy and water" initially, I was unclear if the members of the PPN tribal council or PPN citizens gathered for the co-design innovation workshops shared that same notion about the purpose of this meeting or if energy and water usage in housing were their primary concerns. Therefore, great care was taken not to ask prompting questions that might bias or push the participants to focus on energy, water, housing, and/or sustainability as their user needs or primary areas of concerns. The facilitators placed great emphasis on capturing any and all statements made by the participants in split end user groups on the large sheets of paper that were placed in the middle of the group. The purpose of this session was to generate any many user needs as possible that the PPN participants believed were important and relevant. No idea or statement was considered to be too wild or not realistic at this stage. At the end of the session, PPN participants from each group gave a 10 minute summary of their findings to the reconstituted round robin group. Figures 8 and 9 shows participants in the Youth and Adults group talked about the needs generated in each group. Table 3 is a collection of all the needs expressed during the split end user group assessment sessions.

Figure 8: 2008 Participant from the Youth Group Presenting Generated Needs

Figure 9: 2008 Participant from the Adults Group Presenting Generated Needs

Table 3. Needs Expressed During 2008 Split Group User Needs Assessment Sessions

Split Group Needs Assessments			
Elders Group	**Adults Group**	**Youth Group**	
Opportunities to Work	Privacy in homes	Cooling	Hunting
Exercise	Activity space (sleeping, playing)	Heating	Lighting
Fresh air	Lower electricity bills	Privacy	Fun
Less overcrowding	Clean road (no dirt when dry/mud in rain)	Sleeping	Individuality
Host visitors for extended time	Larger cooking space	Swimming	Eating
Accessibility for disabled around house	Larger working area	Space	Surviving
Build crafts and designs	Openness in homes	Driving	Convenient
Grow one's own foods and traditional herbs	Protection from strangers	Comfort	Power generation
Places to socialize within community (unplanned and planned)	Privacy between homes	Safety	Shelter
Want youth to get excited about hands-on activities	Protection from animals (dogs)	Showering	Community
Learn and use traditional building techniques	Storage Space	Exercise	Happiness
Buy equipment to teach youth new skills		Personal connection	Transportation
Traditional Pomo housing: Circular		Attractiveness	Cultural integration
		Storage	

At the end of the final user needs summary presentation, the large sheets of papers with the recorded generated needs were collected and placed on the walls of the meeting areas. The PPN participants then were given 15 minutes to review all the expressed needs generated and vote using 5 Post-it Notes on the primary needs for further discussion and analysis in the during the Brainstorming Conceptual Design Stage of the co-design methodology. This multivoting technique was utilized to allow the PPN participants to whittle down their generated list of user needs and converge on the user needs they considered most important to create related conceptual solutions or low fidelity prototypes during the co-design innovation workshops. The PPN participants were allowed the option of placing their 5 votes on one expressed user need or spread their votes across multiple expressed user needs. After the PPN participants voted, Dr. Agogino, Yael Perez, and I gathered their responses and organized the user needs by the number of votes they received. In some cases, prioritized user needs such as "Protection from animals (dogs)", "Protection from strangers", and "Safety" were grouped or coded together under a common title of "Safety" while other prioritized user needs such as "Larger cooking space", "Space", and "Larger working area" for example were grouped as "Space" after consulting with some of the PPN participants. Table 4 shows the list of prioritized user needs from the PPN participants. In should be noted, that the formal coding of the user needs using grounded theory occurs in Section 4.2.

Table 4. Prioritized List of Expressed User Needs Expressed

Expressed User Needs	**Number of Votes**
Privacy	10
Storage	9
Safety	9
Comfort	5
Exercise	5
Conserve Energy	5
Lower Energy Costs	4
Learn and Use Traditional Techniques (Natural Materials and Roundness)	4
Space	4

4.1.3 Brainstorming Conceptual Designs Stage

The newly generated list of prioritized user needs was then presented to the full group of PPN participants and a 20 minute discussion session was held to decide how to organize these prioritized user needs into topic areas for the selection and development of conceptual design and models. The topic areas that emerged from this discussion were (1) Traditional Building Techniques, (2) Energy Generation and Conservation, (3) Exercise and Recreation, (4) Privacy, and (5) Heating, Cooling, Lighting, and Comfort. The PPN participants were then asked to create mixed age groups to brainstorm on conceptual design solutions based on these 5 topic areas. The purpose of this session was to generate any many solutions as possible that the PPN participants believed were viable options for addressing their user needs.

The remaining CARES and UC Berkeley participants were then allowed to join the groups based on their interest and desire to aid in the creation of potential solutions to the PPN's needs. Dr. Agogino, Mr. David Ponton (PPN Housing Director at the time), Ms. Yael Perez, Dr. Edmunds, and I acted as facilitators of the (1) Traditional Building Techniques, (2) Energy Generation and Conservation, (3) Privacy, (4) Heating, Cooling, and Lighting, and (3) Exercise and Recreation groups respectively. We then began the 45 minute brainstorming conceptual design session by asking variations of the following prompts: 'What ideas do you all have about addressing the group topic?', 'What do you think should be done to fix the problems you talked about earlier?', 'Could you draw or sketch what you want to create?' and 'What solutions have you tried before to address these needs?'. Similar to the split group user needs session, the facilitators focused on capturing as many ideas and thoughts the brainstorming groups generated to address the PPN's prioritized user needs. Moreover, the facilitators steered away from trying to coax the brainstorming groups onto or from a particular solution trajectory. It should be noted that the facilitators did ask clarifying and follow-up questions about various solution options to ensure they properly understood what was said and to encourage more detailed discussions amongst the participants about newly suggested solutions. Table 5 and Figures 10 -11 detail the brainstormed concepts from the co-design innovation workshop participants.

Table 5: Brainstormed Solutions and Concepts during 2008 Co-design Innovation Workshop

Traditional Techniques for Buildings	**Save Money on Energy (Energy Generation and Energy Conservation)**	**Having Fun & Exercise**	**Privacy**	**Heating, Cooling, Lighting, Comfort**
Community Center	Cluster Housing	Swimming	Fence (Between Neighbors)	Living Roofs (Native Plants, Insulation)
Fire Pit	Solar Substation	Hunting	Masonry/Block Wall	Sunlights in Homes
Usage of Local Woods (Oak, Cedar, Redwoods)	Sell on Grid	Driving Go Carts	Hedges	Big Kitchen (Counter Space, Room Closets)
Fireplaces	Motion Sensors in Lights	Arcade, Fun Center	Intruders Issue	Underground Rooms (Constant Temperature)
Round Shapes Embedded in Housing Design (i.e. Yurts)	Recharge Batteries with Solar (i.e. radio)	Gym	Signs Are Not Helpful	Mirrors for Light (Day), Privacy (Night)
Large Kitchens	Street Lights Charged with Solar that Comes on at Night	Sports	Electronic Fencing & Gate	Warmer Floors (No Wood)
Dome Shaped Roofs	Native Plants for Cooling	Park	Security Cameras	Human Power Generation
Southwest Designs (Adobe)	Growing Sod Roofs	Fishing	Inside Home Privacy Issue	Building Materials
Patios	Biofuels	Computers	Thicker Walls	Hay
Porches	CFLs for Conservation	Laser Tag	Furniture as Partition	Chicken Wire
Pond for Willow	Window Position for Natural Lighting	Building Things	Put Up Furniture	Straw
Pond for Community	Passive Solar	Auto Stuff	Alcoves (“Half” Rooms, Gives Flexibility)	Wool
Drip system for Watering Plants	Wind Energy for Pumping Water	Baseball Fields	Two Stories (Hard to get Up and Down)	
Big Garages	Rain Harvesting	Drawing & Art Stuff	Garage as Extra Space	
Big refrigerators	Exercise and Human Power Generation		Mirrors (To get feeling of More Space)	
Native Shrubs in the Front Yards	Smart Lighting		Vaulted Ceiling	
Planter Boxes Under Windows	Put Water from Show or Sink to Use in Toilets (Grey Water Recycling)		A Frame	

Large Size Ovens & Stoves	Glowing Material for Lighting		Lofts	
Yurt Homes with a Granny Unit Attached	Use Earth for Cooling and Heat (Subterranean)			
Custom Tiling with Native American Designs	Sustainable Material for Insulation (Save Energy)			
Garden Space with Native Plants	Double Pane Windows			
Large Workrooms for Sewing	No Water Lines in Attic (Freezing)			
Ceremonial Dancing Area	Solar Water Heating			
Roundhouse	Radiant Water Heating in Floors and Walls for Use in Tile and Hard Floors			
Sweat lodge	Allergy (Asthma Problem, No Carpet)			
Skylight in Homes				
Large Windows				
Storage Area				
Misting System for Cooling Patio				
Storage Areas in Homes for Baskets and Outfits				
Climate Controlled Rooms				
Sheds				
Native Stones in Walkways with Clear Finish				
Community Pathways for Biking and Walking				
Built in Cabinets				

Figure 10: 2008 PPN Participant from the Privacy Group Explaining Generated Solutions

Figure 11: 2008 PPN Participant from the Heating and Cooling Group Explaining Generated Solutions

The results from the Brainstorming Conceptual Designs stage seem to indicate that at least some of the participants from the Pinoleville Pomo Nation (PPN) were aware of various renewable energy and passive heating and cooling design strategies that could be employed to address their prioritized user needs. Moreover, these results provided a technology roadmap of potential solutions that the CARES and UC Berkeley participants, working with in tandem PPN participants as evaluators, could then refine, merge, and expand upon in order to create solutions that the PPN could then use to secure funding for implementation. At the end of the 2008 co-design innovation workshop, the lists of generated solutions and user needs were gathered for further analysis and coding in order to identify and co-design solutions that best fit the PPN's goals. Chapter 5 of this dissertation provides further detailed descriptions of the design and implementation of the solutions created during this session.

4.2 User Needs Analysis and Coding Using Grounded Theory

In order to perform the user needs analysis and coding with grounded theory, the Java based mind mapping software called Freeplane was utilized (Polivaev, et.al, 2013). This program aided in the visualization and organization of the short data labels and *in vivo* codes (verbatim quotes from the PPN participants) that I have assigned to the multitude of statements and comments recorded during the co-design innovation workshops in order to identify common themes and develop an emergent framework of the PPN' s user needs. In other words, coding using grounded theory enables this dissertation to "*define* what is happening in the data and begin to grapple with what it means" (Charmaz, 2006).

4.2.1 Initial Coding of Co-design Innovation Workshop Data

In the first step of this dissertation's coding process, the line-by-line approach (Charmaz. 2006) of labeling each recorded statement or comment captured during all stages of the 2008 co-design innovation workshop with the PPN was chosen. The line-by-line coding approach enabled me to highlight and separate important segments of the recorded data into user needs category or codes that could then be refined over time as I gather and identify more implicit and explicit user needs and solution options from the PPN. When possible, the user needs category or codes utilized in this dissertation try to incorporate the exact quote from the PPN participants in order to capture the meaning of the original statement. Moreover, the assigned codes were given various colors and shapes to aid in differentiation. It should be noted that not all statements and comments gathered were assigned codes; in some cases, these statements and comments were given red capital X's as they were not considered to have any germane content. Figure 12 shows an example of the how the Freeplane software was use for coding the Elder's group user needs (Polivaev, et.al, 2013).

The general strategy for line-by-line coding presented by Charmaz (2006) is: (1) break the data up into their component parts or properties, (2) define the actions or needs they relate to or build upon, (3) look for underlying assumptions in statements or comments, (4) expand upon implicit actions and meanings, (5) highlight the significant codes, (6) comparing codes and the foundational data with other codes generated over time, and (7) identify any gaps in the data. In general, the codes that are developed in this dissertation follow the format of (a) **user need**, (b) **action**, and (c) **solution/concept**. For example, in the generated code of "Preserve environmental harmony by increasing usage of green materials", the **user need** is "Preserve environmental harmony", the **action** is "increasing usage", and the **solution/concept** is "green materials". This is similar to Strauss and Corbin's (1998) strategy of using the format of (a) conditions, (b) actions/interactions, and (c) consequences in the axial coding stage to answer the "when, where, why, who, how, and with what consequences" of the recorded data (Strauss and Corbin, 1998; Charmaz, 2006). This dissertation departs from the

Strauss and Corbin (1998) approach by performing this formatting in the open coding stage. It should be noted that not all the recorded comments and statements from every stage of the co-design methodology provide enough detail to distinguish the **action** and **solution/concept** portions of this dissertation's format for generating codes. In these cases, only the **user need** portion of the coding format is presented. In the focused coding stage of the co-design innovation workshop data, this dissertation attempts to show the missing or latent linkages between the **user need**, **action** and **solution/concept**. Tables 6 – 14 show that codes that were developed in this dissertation based on the comments and statements gathered during the 2008 PPN co-design innovation workshop.

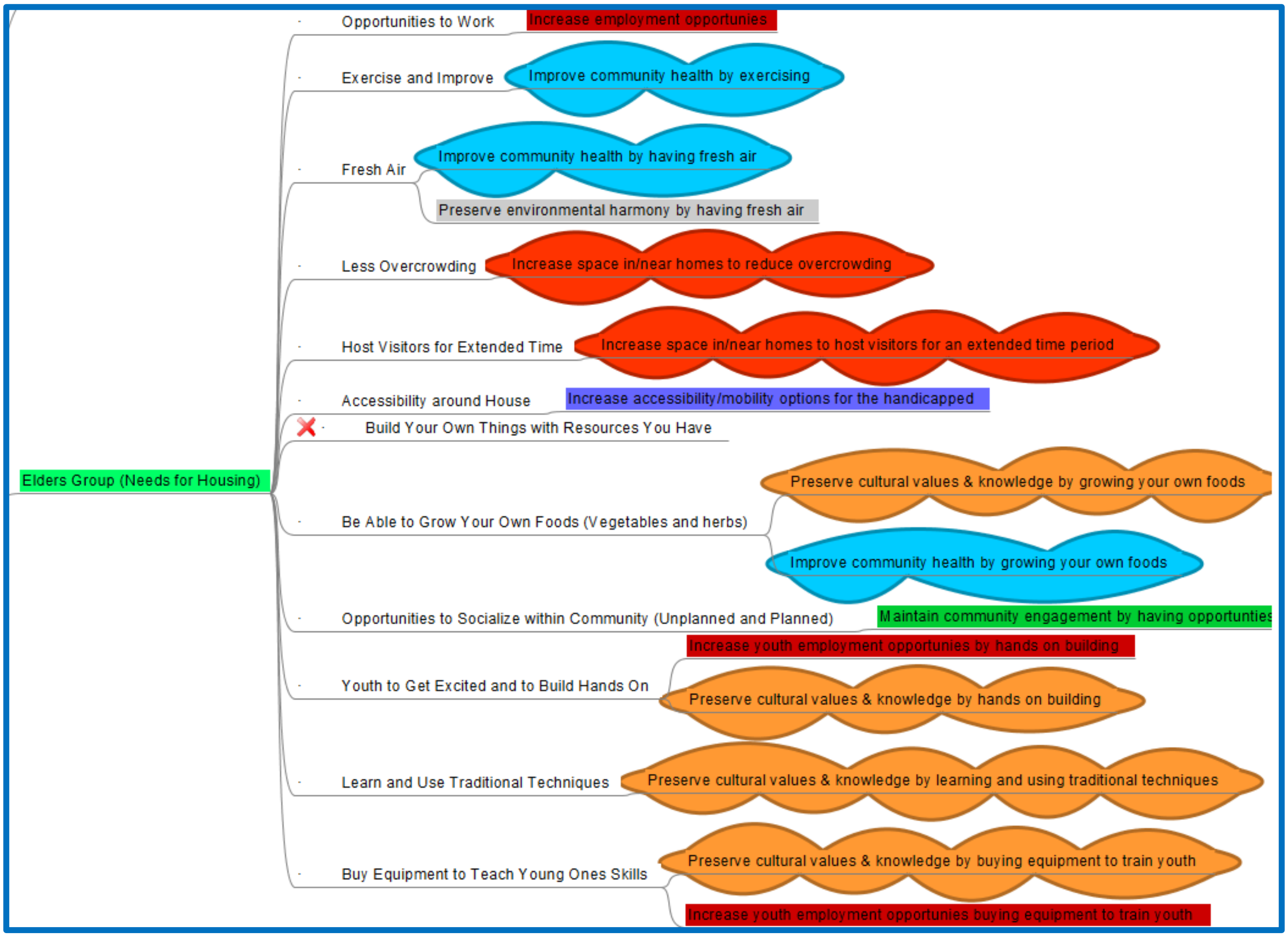


Figure 12. Codes Developed from the 2008 PPN Elders Group User Needs Session

Table 6: Codes Developed from 2008 PPN Good/Bad Technology Sessions

2008 PPN Good/Bad Technology Session
Increase storage options by having an attic
Preserve environmental harmony by increasing usage of green materials
Increase youth entertainment options by having swimming pools
Increase storage options by having lots of closet space
Increase youth entertainment options by having outdoor space
Increase storage options by having a shelves in homes
Increase youth entertainment options by having basketball
Preserve environmental harmony by increasing usage of solar panels
Reduce energy consumption in buildings using smart lighting
Preserve environmental harmony by increasing usage of dimmer lights
Reduce energy consumption in buildings using dimmer lights
Increase community safety by having more gates
Increase privacy by having more gates
Increase communication with others by having cellphones
Increase community safety by having motion sensing lights
Increase youth entertainment options by having sports
Increase youth entertainment options by having baseball
Maintain community engagement by having community gatherings such as Big Time
Increase (family) communication by having large living rooms
Increase privacy by having more bedrooms
Improve road safety by using asphalt
Increase space in/near homes by having big bathrooms
Increase space in/near homes by having more bedrooms
Increase privacy by having a more bedrooms
Increase storage options by having basements
Increase space in/near homes by having big bedrooms
Increase youth entertainment options by having a community center
Maintain community engagement by having community center
Increase storage options by having a shed for tools
Increase privacy by having a granny unit
Increase accessibility/mobility options for the handicapped
Increase family engagement by having reducing the number of walls
Increase youth entertainment options by having gym
Preserve cultural values & knowledge by having veggie roofs
Improve community health by having veggie roofs
Preserve cultural values & knowledge by having green roofs
Improve community health by having greenhouses
Increase youth entertainment options by having arcade rooms
Reduce energy consumption in buildings

Table 7: Codes Developed from 2008 PPN Elders Group Assessment

2008 PPN Elders Group
Increase employment opportunities
Improve community health by exercising
Improve community health by having fresh air
Preserve environmental harmony by having fresh air
Increase space in/near homes to reduce overcrowding
Increase space in/near homes to host visitors for an extended time period
Increase accessibility/mobility options for the handicapped
Preserve cultural values & knowledge by growing your own foods
Improve community health by growing your own foods
Maintain community engagement by having opportunities to socialize
Increase youth employment opportunities by hands on building
Preserve cultural values & knowledge by hands on building
Preserve cultural values & knowledge by learning and using traditional techniques
Preserve cultural values & knowledge by buying equipment to train youth
Increase youth employment opportunities buying equipment to train youth

Table 8: Codes Developed from 2008 PPN Adults Group Assessment

2008 PPN Adults Group
Increase space in/near homes by having more bedrooms
Increase privacy by having a more bedrooms
Reduce energy consumption in buildings in order to lower electricity bills
Improve road safety by using asphalt
Reduce energy consumption in buildings by using natural light
Increase space in/near homes by having a large kitchen
Increase storage options by having a large kitchen
Increase family engagement by having a large kitchen
Increase space in/near homes by having a kitchen island
Increase family engagement by having an open room between kitchen and living room
Increase privacy by having a fence around the community
Increase privacy by having a fence between houses
Increase community safety by addressing stray dog problem
Increase storage options by having a garage

Table 9: Codes Developed from 2008 PPN Traditional Techniques for Buildings Brainstorming Group

2008 PPN Traditional Techniques for Buildings Brainstormed Solutions
Increase youth entertainment options by having a community center
Maintain community engagement by having community center
Preserve cultural values & knowledge by creating a fire pit
Preserve cultural values & knowledge by using local woods
Preserve cultural values & knowledge by using round shapes in homes
Increase space in/near homes by having a large kitchen
Increase storage options by having a large kitchen
Increase family engagement by having a large kitchen
Preserve cultural values & knowledge by using round shapes in homes
Preserve cultural values & knowledge by using creating a pond for willow
Maintain community engagement by having a pong
Conserve water by using a drip system
Increase storage options by a big garage
Increase storage options by a big refrigerator
Preserve cultural values & knowledge by using native shrubs in front yards
Increase privacy by having a yurt (round) home with a granny unit
Preserve cultural values & knowledge by having a yurt (round) home with a granny unit
Preserve cultural values & knowledge by having a Native American art and designs
Preserve cultural values & knowledge by having a garden space for native plants
Increase space in/near homes for sewing
Preserve cultural values & knowledge by having a ceremonial dancing area
Maintain community engagement by having a ceremonial dancing area
Preserve cultural values & knowledge by having a roundhouse
Preserve cultural values & knowledge by having a sweat lodge
Reduce energy consumption by using skylight in homes
Increase storage options
Increase storage options in homes for baskets and outfits
Reduce energy consumption by having climate controlled rooms
Preserve cultural values & knowledge by having climate controlled rooms
Increase storage options by having sheds
Preserve cultural values & knowledge by having native stones
Increase youth entertainment options with community pathways
Maintain community engagement by having community pathways

Table 10: Codes Developed from 2008 PPN Youth Group Assessment

2008 PPN Youth Group
Reduce energy consumption in buildings due to cooling
Reduce energy consumption in buildings due to heating
Increase privacy
Maintain individuality
Increase youth entertainment options by swimming
Increase space
Increase storage
Increase community safety
Increase youth entertainment options by having places to exercise
Increase youth entertainment options by having shooting events
Increase community safety with lighting
Increase youth entertainment options
Increase community safety
Exercise tribal sovereignty
Exercise tribal sovereignty
Increase accessibility/mobility/transportation options
Increase economic development by having power generation
Increase accessibility/mobility/transportation options
Maintain personal communication
Preserve cultural values & knowledge
Exercise tribal sovereignty

Table 11: Codes Developed from 2008 PPN Having Fun and Exercise Brainstorming Group

2008 PPN Having Fun and Exercise Brainstormed Solutions
Increase youth entertainment options by swimming
Increase youth entertainment options by hunting
Preserve cultural values & knowledge by hunting
Increase youth entertainment options with go carts
Increase youth entertainment options with an arcade and fun center
Increase youth entertainment options with a gym
Increase youth entertainment options with sports
Increase youth entertainment options with a park
Increase youth entertainment options by fishing
Preserve cultural values & knowledge by fishing
Increase youth entertainment options with computers
Increase youth entertainment options with laser tag
Increase youth employment opportunities by learning to build things
Preserve cultural values & knowledge learning to build things
Increase youth employment opportunities by learning auto stuff
Increase youth entertainment options with baseball fields

Increase youth entertainment options with drawing and art stuff

Table 12: Codes Developed from 2008 PPN Heating, Cooling, Lighting, and Comfort Brainstorming Group

2008 PPN Heating, Cooling, Lighting, and Comfort Brainstormed Solutions
Preserve cultural values & knowledge by using living roofs
Reduce energy consumption by using living roofs
Reduce energy consumption by using sunlights in homes
Increase space in/near homes having a big kitchen
Reduce energy consumption by using underground rooms
Increase privacy
Increase economic development by having human power generation
Preserve cultural values & knowledge by using hay
Preserve cultural values & knowledge by using straw

Table 13: Codes Developed from 2008 PPN Save Money on Energy Brainstorming Group

2008 PPN Save Money on Energy Brainstormed Solutions
Increase economic development by having a solar substation
Increase economic development by selling on grid (energy)
Increase community safety by having motion sensors in light
Use renewable energy to recharge radio batteries
Increase community safety by having motion sensors in light
Reduce energy consumption for charging street lights with solar
Reduce energy consumption in buildings by using native plants for cooling
Reduce energy consumption in buildings by using native plants for cooling
Preserve environmental harmony by increasing usage of biofuels
Reduce energy consumption in buildings by using CFLs
Reduce energy consumption in buildings for lighting by using natural light
Reduce energy consumption in buildings by using passive solar
Reduce energy consumption by using wind energy for water pumping
Reduce drought conditions using rain water harvesting
Conserve water by using rain water harvesting
Reduce energy consumption in buildings by using smart lighting
Provide exercise options by using human power generation
Reduce energy consumption in buildings by using smart lighting
Conserve water by doing grey water recycling
Reduce electricity consumption in buildings by using earth for cooling and heat
Reduce energy consumption in buildings by using sustainable material for insulation
Reduce energy consumption in buildings by using double pane windows
Reduce energy consumption in buildings by using solar water heating
Reduce energy consumption in buildings by using radiant water heating
Improve community health by eliminating asthma triggers

Table 14: Codes Developed from 2008 PPN Privacy Brainstorming Group

Privacy (From Intruders, Inside and Between Homes) Brainstormed Solutions
Increase privacy by having a fence between neighbors
Increase privacy by having a masonry/block wall
Increase privacy by having hedges
Increase community safety by stopping intruders
Increase community safety by using electronic fencing and gates
Increase privacy by using electronic fencing and gates
Increase community safety by using security cameras
Increase privacy in home by having thicker walls
Increase privacy in home by using furniture as partition
Increase space in/near homes by having alcoves
Increase space in/near homes by having a garage
Increase space in/near homes by having mirrors
Increase space in/near homes by having a vaulted ceiling
Increase space in/near homes by using an A frame
Increase space in/near homes by having lofts

4.2.2Axial Coding of Co-design Innovation Workshop Data

The main point of axial coding is to explore the connections, if any, amongst concepts (user needs and brainstormed solutions in my case) in order to organize the initial codes around a more refined central framework (Charmaz, 2006; Ng and Hase, 2008). I reexamined the data I coded during the open coding stage line-by-line in order to determine the underlying user needs embedded within this dissertation's coding format. Careful attention was paid to the frequent reoccurrence of phrases and statements used by the PPN to express their user needs during the co-design innovation workshop. Table 15 lists the 24 user needs which emerged from the PPN's recorded statements in 2008:

Table 15: 2008 PPN User Needs Incorporated in the Axial Codes

Increase privacy	Exercise tribal sovereignty
Increase community safety	Maintain personal communication
Increase space	Increase accessibility/mobility/transportation options
Improve community health	Increase storage
Reduce energy consumption	Maintain individuality
Conserve water	Maintain community engagement
Reduce drought conditions	Increase family engagement
Preserve environmental harmony	Increase employment opportunities
Use renewable energy	Improve road safety
Increase economic development	Increase family communication
Preserve cultural values & knowledge	Increase communication

Increase youth entertainment options	Increase youth employment opportunities

4.2.3 Focused Coding of Co-design Innovation Workshop Data

During the focused or selective coding phase, irrelevant or redundant codes were filtered out or combined with other codes. At the end of the open and axial coding phase, I discovered that there were several codes that used redundant user needs ('Increase family communication', 'Maintain personal communication' and 'Increase communication' for example) or there were codes that used solutions ('Use renewable energy' for example) instead of an actual user need. Table 16 lists the 15 most significant or frequently occurring user needs that emerged during the 2008 PPN co-design innovation workshop.

Table 16: 2008 PPN User Needs Incorporated in the Focused Codes

Increase privacy	Exercise tribal sovereignty
Increase community safety	Increase tribal communication and engagement
Increase space	Increase accessibility/mobility/transportation options
Improve community health	Increase storage
Reduce energy consumption	Increase tribal employment opportunities
Conserve water	Increase youth entertainment options
Preserve environmental harmony	Preserve cultural values and knowledge
Increase economic development	

4.2.4 Number of Unique PPN User Needs Captured to Date

The co-design methodology, its innovation workshop, and the coding of subsequent user needs using grounded theory were repeated again with members of the PPN in Spring 2009, Summer 2010, and in Fall 2010 in order to determine the effectiveness of the methodology to elicit unique user needs over time. This is similar to Griffin and Hauser's (1993) work to determine the numbers of user needs generated from "30 potential customers of portable food-carrying and storing devices" over time using qualitative methods such as interviews and focus groups. Griffin and Hauser (1993) were able to determine that two one-on-one interviews were just as effective as a single focus group in terms of the percentage (51% vs. 50% respectively) of user needs elicited from the study's targeted end user group. Over the course of research carried out in this dissertation, there were 31 unique user needs elicited from the PPN over time. Moreover, semi-structured interviews guided by an interview guide with a list of open-ended questions about the appropriateness or relevance of the user needs I coded were conducted with members of the PPN during the course of this dissertation research. Table 17 lists the unique PPN user needs gathered over time and coded using grounded theory. Figures 13- 14 shows the number and percentage of unique needs captured during the PPN co-design innovation workshops.

Table 17: PPN User Needs Gathered Overtime from Co-Design Innovation Workshops

Increase privacy (2008)	Exercise tribal sovereignty (2008)
Increase community safety (2008)	Increase tribal communication and engagement (2008)
Increase space (2008)	Increase accessibility/mobility/transportation options (2008)
Improve community health (2008)	Increase storage (2008)
Reduce energy consumption (2008)	Increase tribal employment opportunities (2008)
Conserve water (2008)	Increase youth entertainment options (2008)
Preserve environmental harmony (2008)	Preserve cultural values and knowledge (2008)
Increase economic development (2008)	
Increase water security (2009)	Improve air quality (2009)
Grow traditional plants (2009)	Increase comfort in buildings (2009)
Increase energy security (2010)	Securing financial support for infrastructure projects (2010)
Increase transportation security (2010)	Preserve habitat of local animals (2010)
Reduce pollution on tribal lands (2010)	Increase tribal power generation (2010)
Reduce resource waste (2010)	
Improve image of the tribe (2010)	Educate non-Natives about the Pomo people (2010)
Increase education options (2010)	Increase economic self-sufficiency (2010)

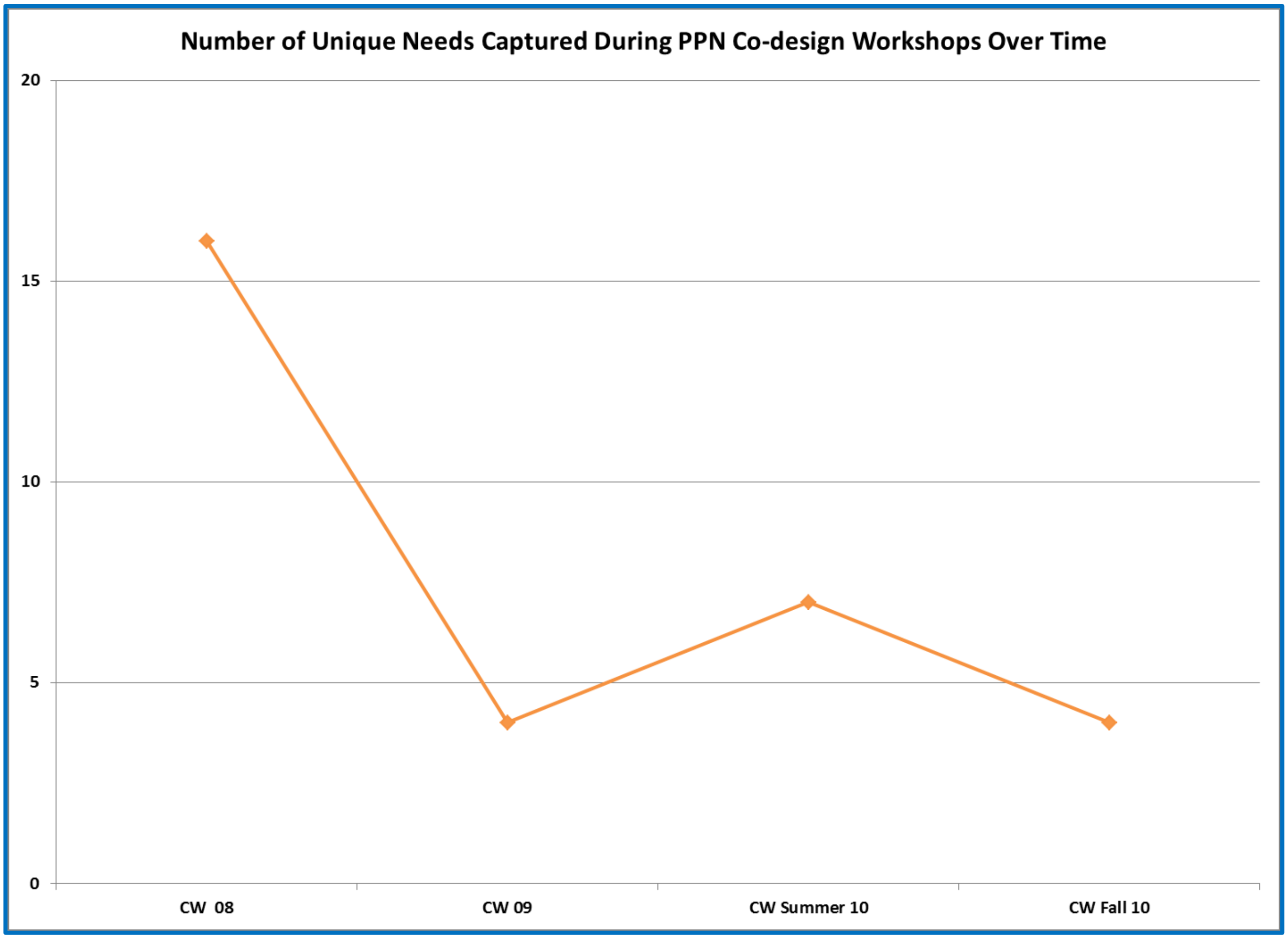


Figure 13. Number of unique needs captured during the PPN co-design innovation workshops

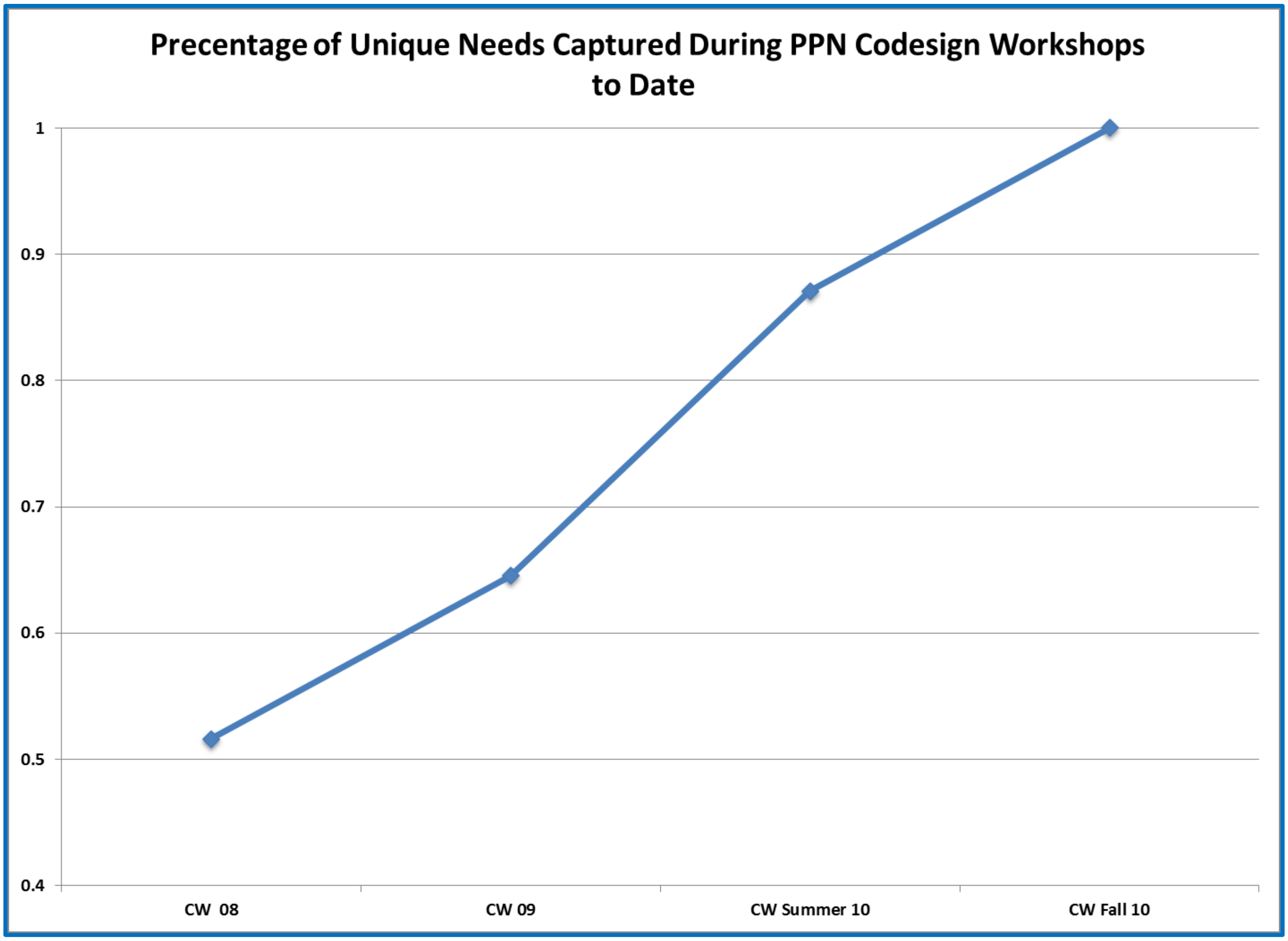


Figure 14. Percentage of unique needs captured during the PPN co-design innovation workshops

4.3 Limitations and Concerns of Co-Design Methodology

The chapter provided a description of the co-design methodology and its innovation workshop utilized to (1) elicit user needs from the Pinoleville Pomo Nation (PPN), (2) identify potential solutions that the members of the PPN identified as most likely to meet their user needs, and (3) lay the foundation for a partnership to work with members of the PPN to evaluate and implement these solutions. The purpose of the co-design methodology is not to create artificial barriers between the knowledge production processes of the PPN and the Berkeley engineers nor is its goal to create "abstractions" that seemingly renders the local knowledge of the PPN moot in a way that "greatly increase [s] the power of scientists [and engineers] vis-a-vis local people" during this design process (Nadasdy, 2003). Instead, the co-design methodology seeks to create a shared understanding of the PPN's needs and create a joint knowledge base that can be utilized by both parties to co-create and implement solutions to meet the PPN's needs. Empowering communities such as the PPN to make informed decisions about which solution trajectory works best for them is at the heart of the co-design methodology. However, there are several concerns about the co-design methodology related to its power dynamics, the co-production of knowledge, and the development of trust amongst the participants.

Nadasdy (2003) has the viewpoint that the production of scientific and engineering knowledge from local knowledge sources using approaches such as the co-design methodology described in this chapter results primarily in scientists and engineers concentrating more power in their “centre [s] of calculation” by manipulating “the abstractions [of local knowledge] brought back to them to form higher- and higher-order abstractions, such as maps, graphs, and theories”. The power dynamics of the relationships amongst the scientists, and engineers, and local community members tend to make a community’s “local knowledge, which is rooted in its own social networks, seem extremely limited and unreliable” Nadasdy (2003) when compared to the knowledge of engineers and scientists that is designed to be flexibly interchanged and remain constant when used by various communities regardless of their cultural background and social networks. As I have pointed out in Chapter 2, it is a fallacy to assume that scientific and engineering can be completely separated from the social and cultural framework from whence it was generated without losing some of its original meaning (Nadasdy, 2003; Jasanoff, 2006; Evans and Collins, 2008). While I do agree that the co-design methodology does create a theory of the PPN’s local knowledge and its evaluation metrics via the concept of user needs, I don’t view that the user needs elicited from the PPN as “abstractions” that merely reduce the “complexities of the local reality” of the PPN to base artifacts that are devoid of any social and cultural connections to the PPN (Nadasdy, 2003). These user needs are designed to be grounded in the local reality of the PPN and represent the concerns that impact the members of the PPN on a constant basis. This grounding of the PPN’s user needs and brainstormed solutions is achieved by giving the members of the PPN shared ownership and control throughout the co-design innovation workshop to directly express topics and propose ideas that the members of the PPN decide is most important to the local community.

The power dynamics in the co-design methodology are such that the participants from the PPN, CARES, and UC Berkeley are considered to be experts in their various knowledge domains and are afforded the same rights and privileges to analyze, question, and produce knowledge. The co-design methodology uses the concepts of “problem setting” (Schön, 1984) or “problem posing” (Freire, 2000) to situate the interaction amongst the co-design participants in the PPN community in order to focus on the identification of the needs, problems, values, and goals that should be addressed and to determine what framework or knowledge base(s) should be utilized to understand and design solutions to meet these needs and goals (Schön and Rein, 1994; Fischer, 2000). In essence, the co-design methodology allows its participants to have a “conversation with the situation” (Schön and Rein, 1994) in order to determine the proper focus of the co-design innovation workshop. By undertaking this co-design process the members of the PPN and the UC Berkeley engineers are able to become co-producers of knowledge that are “jointly responsible for a process in which all grow” in the understanding of each other’s knowledge base (Freire, 2000).

Vice Chairperson Angela James comments on the ability of the co-design methodology to foster this mutual understanding of knowledge bases with the following section from her 2009 NAISA paper:

“After I got over the initial concerns and opened my mind to all the possibilities/opportunities that would open up to the Pinoleville Pomo Nation in collaboration with UC Berkeley. I am comfortable with the students who came for the planning sessions, especially the students who have been involved from the first meeting. They have taken in a lot of information and learned about the Pinoleville Pomo culture. I witnessed one student explaining a cultural aspect to a new student and he was correct with his explanation. I was excited to know that they have compassion for what they are working on and care enough to learn the concerns and needs of the Pinoleville Pomo. I look forward to all of our planning sessions and I try to get as many of our tribal community members involved and explain the importance of this collaboration. The students gather as much information as they can during the planning sessions and create possible solutions to our concerns”.

Chapter 5 provides a detailed explanation of the brainstormed and refined solutions co-designed by members of the Pinoleville Pomo Nation, CARES, and students from UC Berkeley’s E10 class that participated in the co-design innovation workshop in 2008.

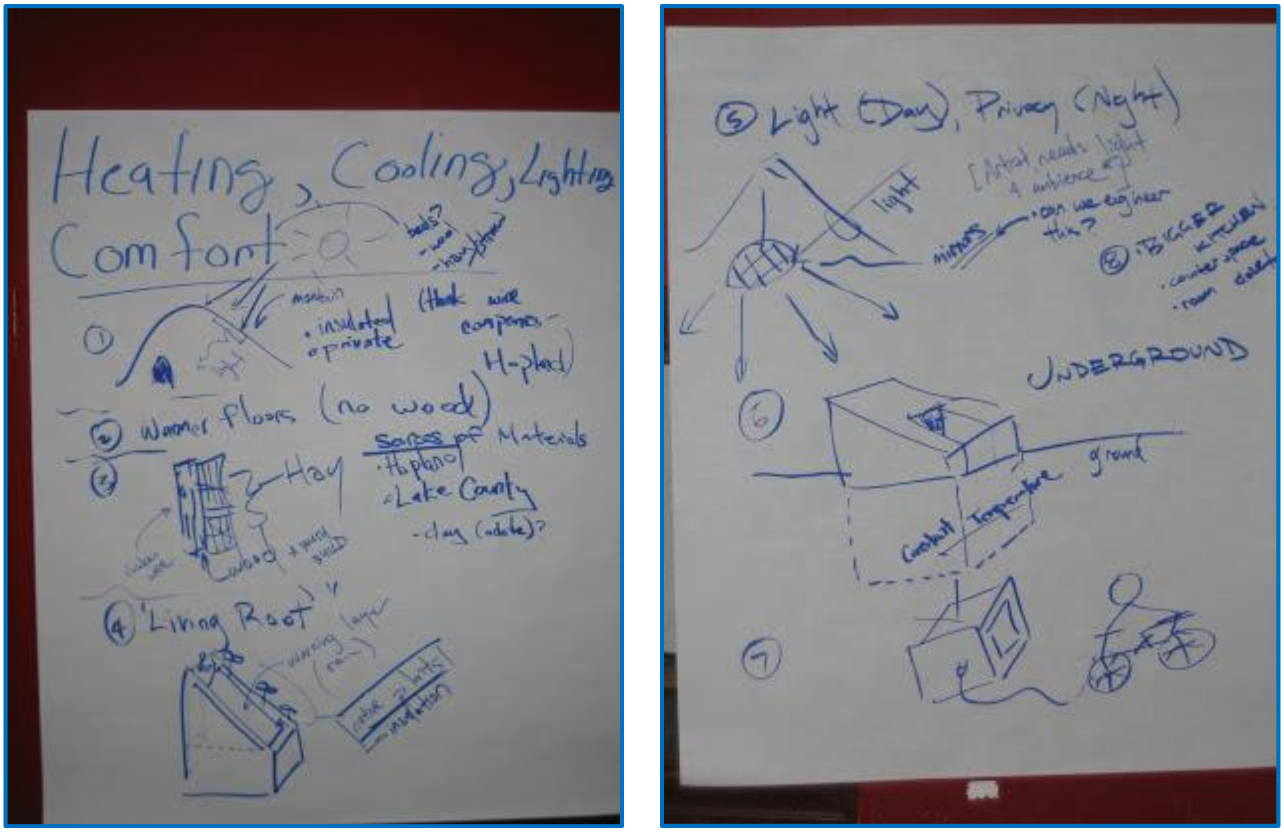
Chapter 5: Culturally-inspired Sustainable Building Design & Energy Analysis

5 Introduction

In Chapter 4, I provided an overview of the co-design methodology created over the course of this dissertation research to elicit user needs and brainstorm solutions to meet the user needs of the Pinoleville Pomo Nation (PPN). The original communications from Dr. Edmunds, PPN Environmental Director at the time, in March 2008 seem to indicate that the PPN wanted to focus on "designing houses that reflect Pomo culture and/or save energy and water" and address the "sustainability…. issues related to housing". During a pre co-design innovation workshop planning meeting with Dr. Edmunds and two PPN tribal council members, I learned that Dr. Edmunds had been framing and "speaking about these issues [of sustainability, environmental impact, and cultural values] specifically as they relate to housing" for the focus of this workshop with the PPN. While the PPN tribal council did sanction Dr. Edmunds's outreach efforts at UC Berkeley, it was unclear if the full PPN tribal council or the PPN citizenry shared a similar framework about sustainable housing as Dr. Edmunds. Moreover, it was unclear what other focus areas or user needs that the members of the PPN possessed. The co-design methodology was designed to aid in the investigation of the PPN's user needs and empowers the members of the PPN to propose technical as well as cultural assertions as experts about which solution options best fits their needs. Chapter 5 discusses in further detail (1) the conceptual designs created during the 2008 innovation workshop, (2) the refinement and selection of the conceptual designs by CARES and E10 UC Berkeley engineering students, (3) the work of CARES and UC Berkeley architecture students to create a high fidelity prototypes of the housing designs, (4) the energy performance of the housing design, and (5) the construction of the co-designed house within the PPN lands.

5.1 Brainstormed Conceptual Designs and Sketches

In the 2008 PPN co-design innovation workshop, 5 mixed age groups labeled as 1) Traditional Building Techniques, (2) Energy Generation and Conservation, (3) Exercise and Recreation, (4) Privacy, and (5) Heating, Cooling, Lighting, and Comfort were formed and composed of self-selected participants from PPN, CARES, and UC Berkeley. Within each group, the participants were encouraged to propose and build upon any ideas that were expressed during this 45 minute brainstorming conceptual design session. At this stage of the co-design methodology, I had a rudimentary idea of the some of the pressing user needs that the PPN participants wanted to discuss further. These recorded user needs statements from the PPN seem to indicate that at least some of the brainstormed solutions would address space, storage, energy, water, and privacy issues particular near, around, or in homes. In particular, Figures 15 -16 show illustrations of several passive heating and cooling best practices and off shelf technologies that members of PPN generated during these brainstorming sessions as possible options to address their user needs.



Figures 15-16 Heating, Cooling, Comfort, and Lighting Brainstorm Solutions and Sketches

In these figures, potential solutions such as creating mound dwellings that would be "private" and "insulated" while still allowing natural day lighting to enter dwelling were pitched. In response to some clarifying questions about why the PPN is considering mound dwellings, it was mentioned that there is a winery in the city of Hopland that has its main facility dug into backside of a hill which allows the winery to reduce its energy usage for heating and cooling. Other potential solutions that were sketched include (1) the usage of radiant floor heating to create "warmer floors", (2) the usage of natural building materials like hay, wood, and clay from local sources in city of Hopland and Lake County, (3) installing a "living roof" on homes in order to produce insulation and a space to growth medicinal and ceremonial native plants, (4) projecting natural day light through an underground dwelling using mirrors, (5) partial submerging a portion of a home in order to utilize the Earth's surface relatively constant temperature at 20 feet, (6) the usage of human power generation for small appliances like microwaves, and (7) the inclusion of a "bigger kitchen" with more "counter space". These concepts indicated to me that there was either a group decision by participants or just an almost natural inclination by several members of the PPN to focus on housing as the platform in which multiple technologies and best practices related to energy and water usage should be grafted upon to address their user needs. The additional sketches, shown in Figures 17-19, illustrate some of these other power generation, water conservation, and passive heating and cooling design features that the participants during the co-design innovation workshop considered viable for usage in a home.

Figure 17 shows an amalgamation of several technologies generated during the Brainstorm Conceptual Design phase in a single family dwelling. Of particular note, this sketch incorporates the usage of a solar hot water heater, a sun roof for natural daylight that is partially covered with a plants, a partially submerged home in the ground for temperature regulation, and power generation systems (wind and solar) that are roof mounted homes.

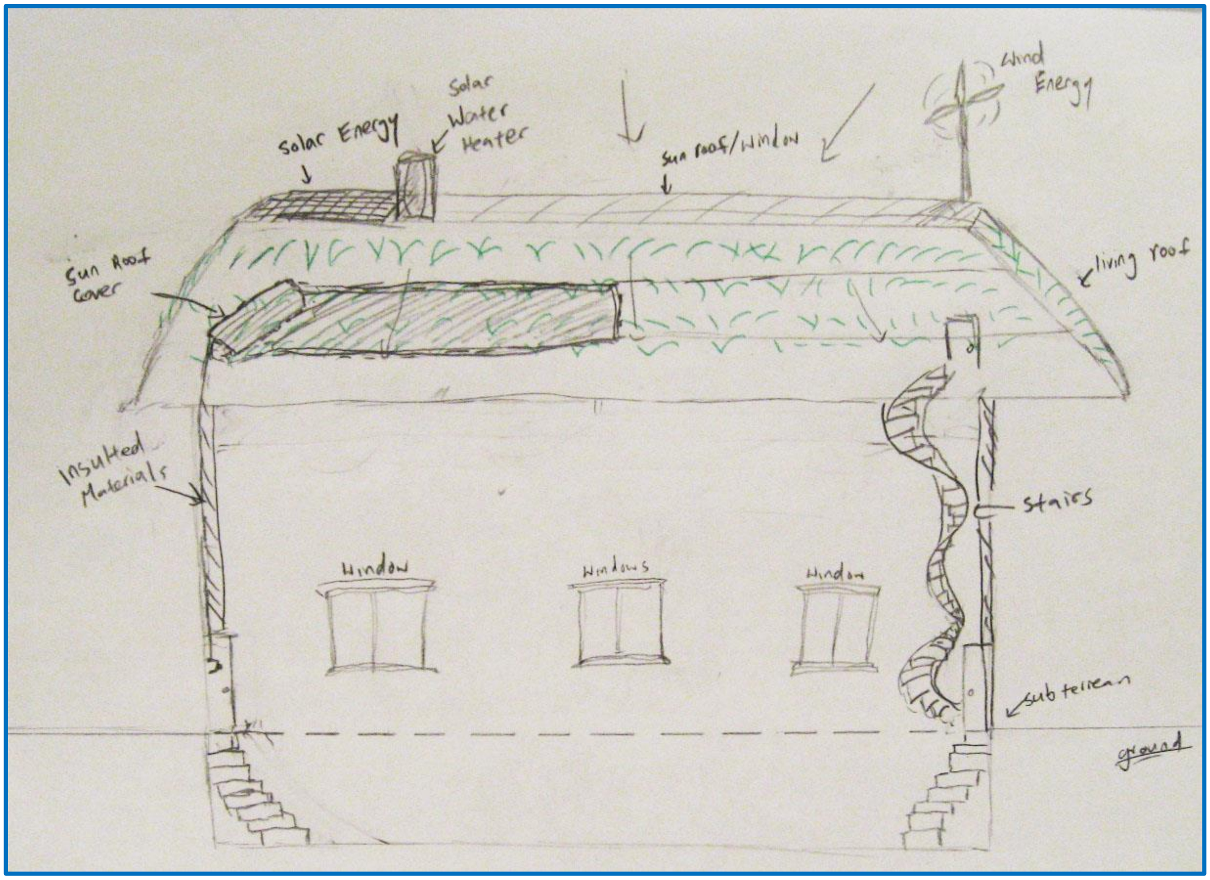


Figure 17: Conceptual home design 1 with green roofs and on house solar & wind power generation

Figure 18 shows another home design created by workshop participants that is partially submerged in the ground behind a hill. This design incorporates the usage of grey water systems connected to a bathroom and a kitchen sink, human power generation via a stationary bicycle, and a green roof. Moreover, this conceptual design features wind and power solar generation systems that are installed on the ground near the home instead of being roof mounted as in Figure 17.

Figure 18: Conceptual home design 2 with grey water & multiple off home power generation systems

Figure 19: Conceptual home design 3 with grey water, plant garden & human powered playground

Finally, Figure 19 shows a vertically vegetated or green wall home design that utilizes human power generation for a playground near the home, a garden for native ceremonial and medicinal plants, grey water system with multiple connections, a biofuel container, a sun roof for indoor natural lighting, and a roof mounted wind power generation system. Of particular note, are the depictions of the fireplace and the exaggeration of the fan inside this home design. When ask to explain the features of this conceptual home design, the some of the PPN participants expressed how several of their current homes used wood burning stoves which necessitated the usage large fans and open windows to ventilate the smoke and reduce breathing issues. Johansson and Arvola, 2007 found that sketches such as those seen in Figures 15-19 can foster "discussion concerning structure, and function at a general level" and that sketches can provide "cues from the work context of the stakeholder group" that can be utilized to further refine designs. The subject of air quality in the homes was a user need that was not previously identified or mentioned until these sketches were created. These low fidelity sketches created by the participants during the 2008 co-design innovation workshop served as a sort of guideline that used by CARES and UC Berkeley engineering and architecture students to model the climatic features of the PPN's land reserve and create prototypes of potential housing and power generation systems to meet the user needs expressed by the members of the PPN.

5.2 Climate Characteristics and Building Design Strategies

After the 2008 co-design innovation workshop, I performed an analysis of climatic features of the Pinoleville Pomo Nation (PPN) land reserve and reviewed energy efficiency building strategies for implementation in the prototype housing designs being created. The California Energy Commission (CEC) established 16 climate zones to represent geographic areas in California and the PPN land area under consideration in this dissertation is located in Mendocino County which is listed as being apart of California Climate Zone 2 (CEC, 2008). This climate zone is characterized by cold winters and hot summers with a very small number of days within the comfort zone (70 °F – 75 °F). The software Climate Consultant 5.4 was utilized to create a psychrometric map, shown in Figure 20, of California Climate Zone 2 that includes the temperature and humidity for every hour during a full year. The trapezoidal area (highlighted in blue, labeled as #1) in Figure 20 represents the comfort zone hours marked as green which only accounts for 449 hours (5.1%) of a full year (8760 hours).

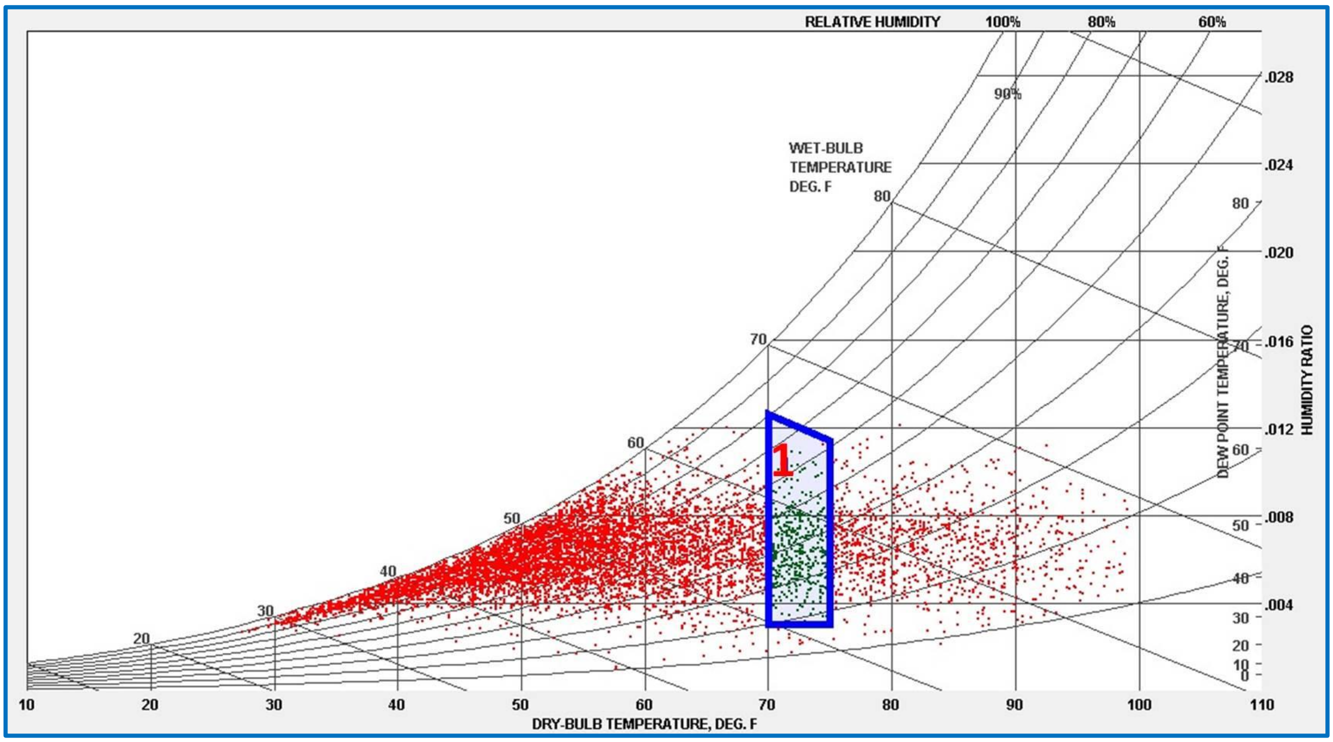


Figure 20: Psychrometric Map of California Climate Zone 2 with Comfort Zone Highlighted

California Climate Zone 2 experiences a temperature range approximately between 28 °F –100 °F and the low range of humidity during the summer months makes the usage of passive cooling solutions ideal to address the heat. In particular, buildings with high thermal mass will reduce the heat load and add 892 hours (10.2%), labeled as #3 in Figure 21, into the comfort zone. Moreover, the incorporation of a night flush ventilation system in a high thermal mass building will result in an additional 1049 hours (12%), labeled as #4 in Figure 21, into the comfort zone hours marked as green.

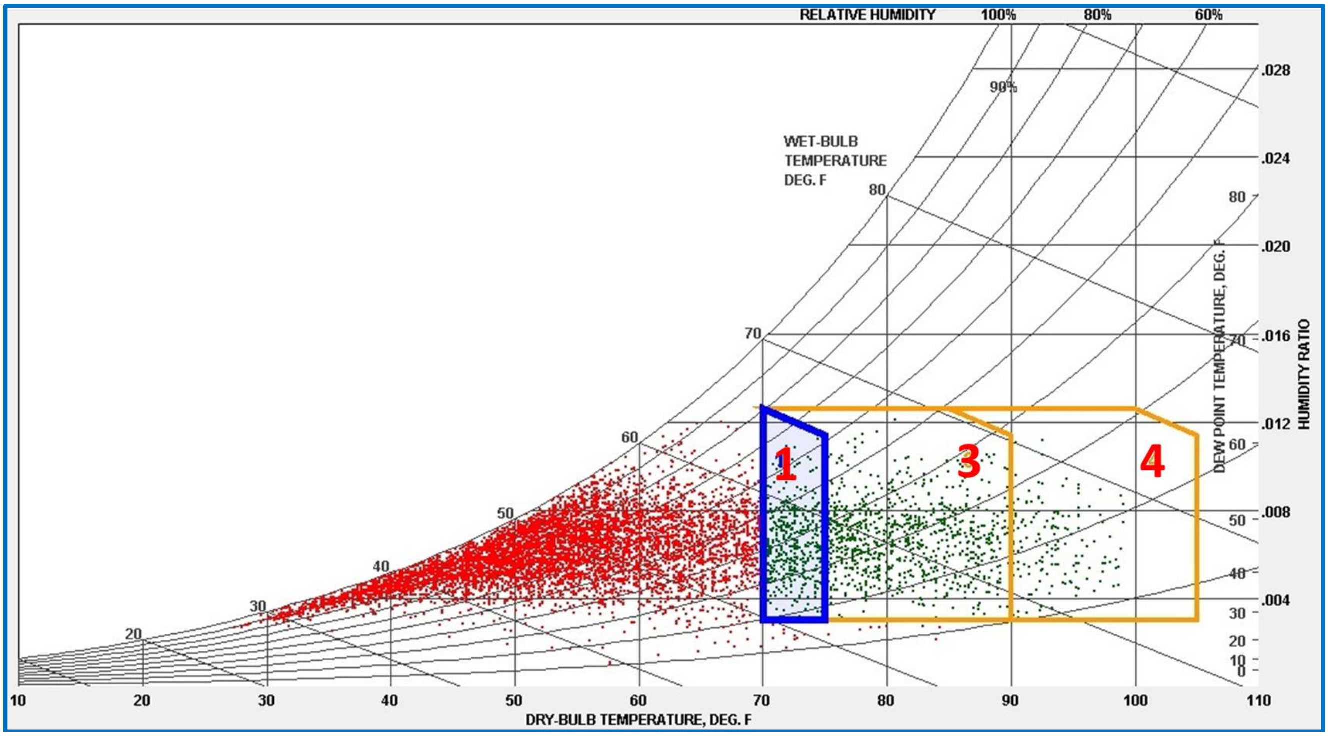


Figure 21: Psychrometric Map of CA Climate Zone 2 with High Thermal Mass & Night Flushing

According to this model, the usage of high thermal mass with night flush ventilation in a building design would address all the heated hours above the 70 °F -75 °F comfort zone and could virtually eliminate the need for active cooling systems like air conditioning. However, the cold temperatures that the PPN experiences in Climate Zone 2 are rather difficult to address as these temperatures are distributed throughout the year during both day and night. Some potential options for overcoming this issue include the addition of direct internal heat gain (labeled as #9 in Figure 22) through southern facing windows for example and the usage of passive direct solar gain through high mass walls (labeled as #11 in Figure 22) which absorbs direct radiation and radiates it into the building as heat. The usage of direct internal heat gain adds 2951 hours (33.7%) and the usage of passive direct solar gain adds 1262 hours (14.4%) into the comfort zone hours marked as green. These above mentioned building design strategies for Climate Zone 2 results in 4929 hours (56%) out of 8760 hours in which the PPN occupants will theoretically not require active, energy-consuming solutions to achieve thermal comfort. The remaining 3831 hours will require the usage of an active heating strategy (labeled as #16 in Figure 22), which would ideally be combined with insulated walls and energy efficient systems.

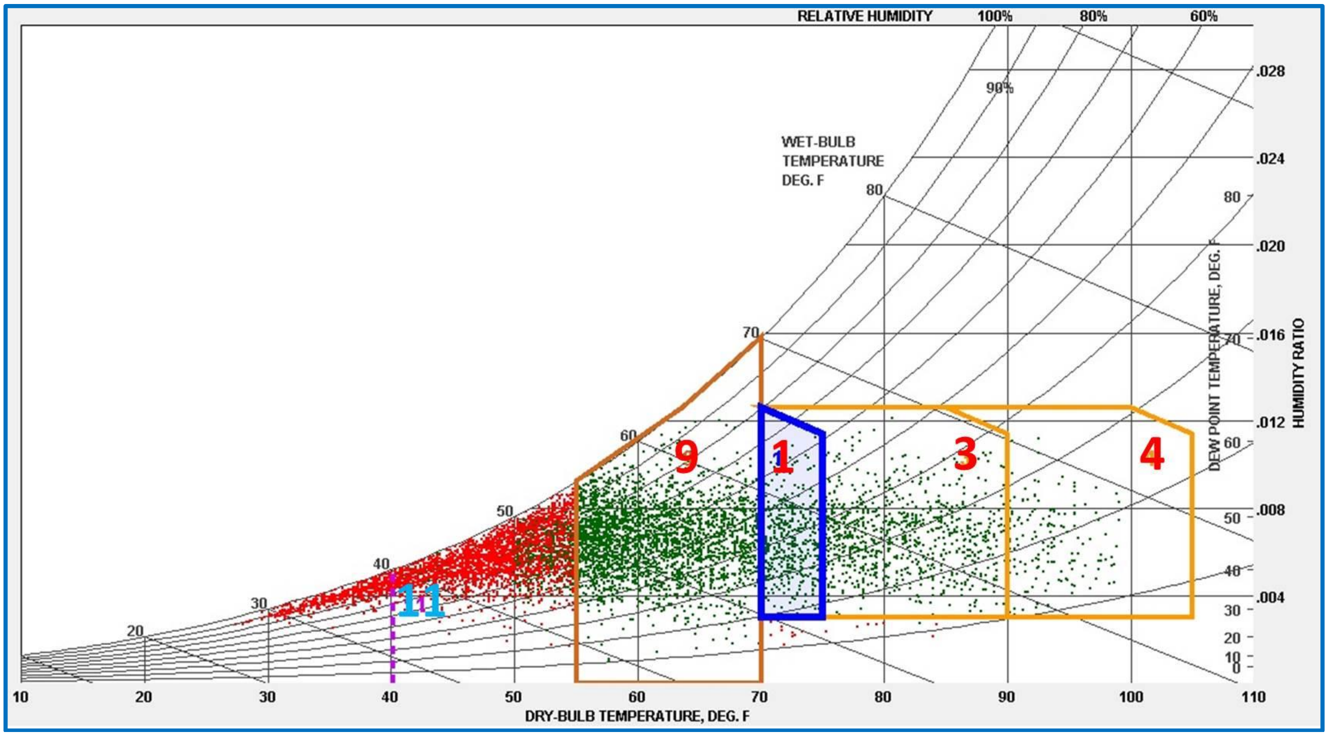


Figure 21: Psychrometric Map of CA Climate Zone 2 with Internal Heat Gain and Passive Solar Gain

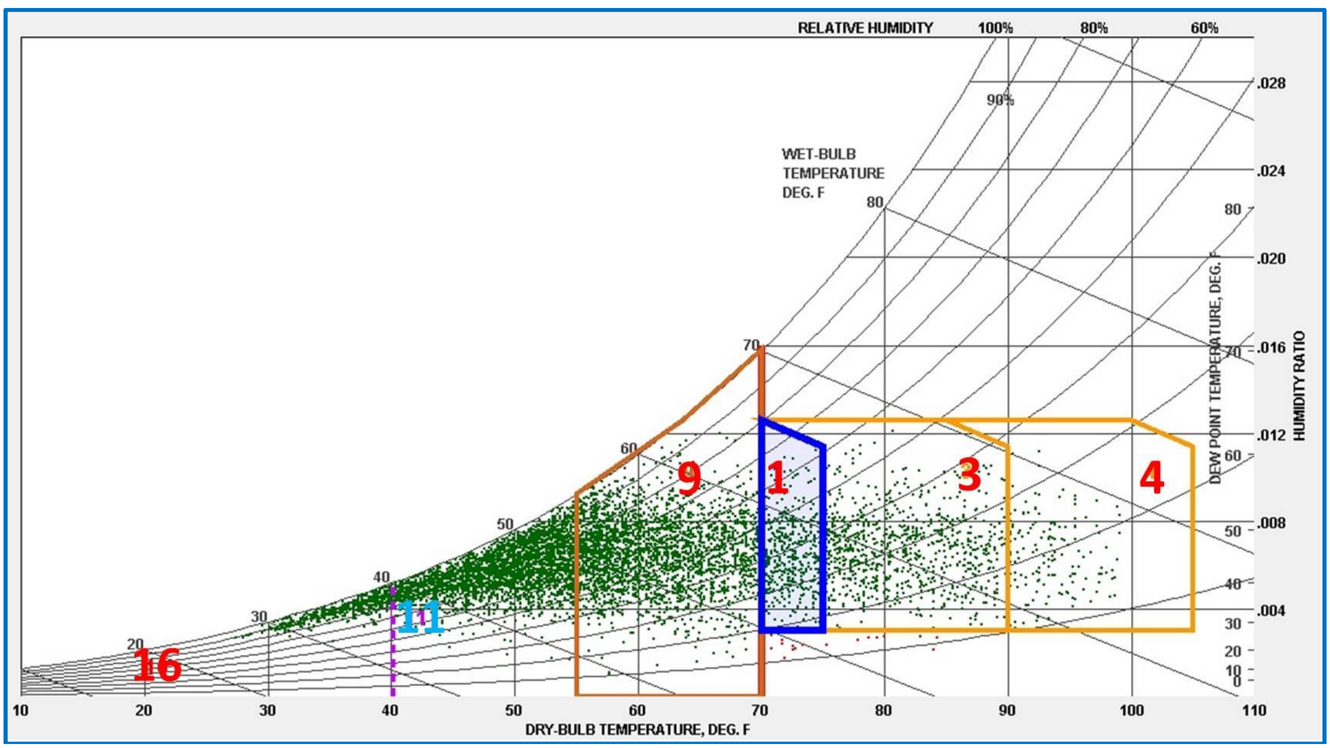


Figure 22: Psychrometric Map of California Climate Zone 2 with Active Heating

5.3 Renewable Energy Resources Assessment

After the various passive heating and cooling building design strategies were identified, I utilized the National Renewable Energy Laboratory's (NREL) PVWATTS Version 2 photovoltaic electricity energy calculator to determine the solar radiation of the land areas identified by the PPN for housing construction and a 3MW solar utility (DOE, 2013). PVWatts Version 2 estimates the energy production performance of locations in the United States 40 km grid cells. It should be noted that each grid cell displayed in the PVWatts Version 2 is a 40km x 40km area of interpolated solar resource data assembled using the Climatological Solar Radiation (CSR) model (Maxwell, et. al, 1998; George and Maxwell, 1999; Perez, et.al., 2002). The locations selected for this assessment of solar resources are located near the PPN tribal office in Ukiah, CA and have coordinates of 39.084 degrees Latitude and -123.295 degrees Longitude. Figure 23 shows the areas analyzed in this study: 2.19 acres (orange), 2.64 acres (yellow), 3.46 acres (green) and 7.12 acres (red).

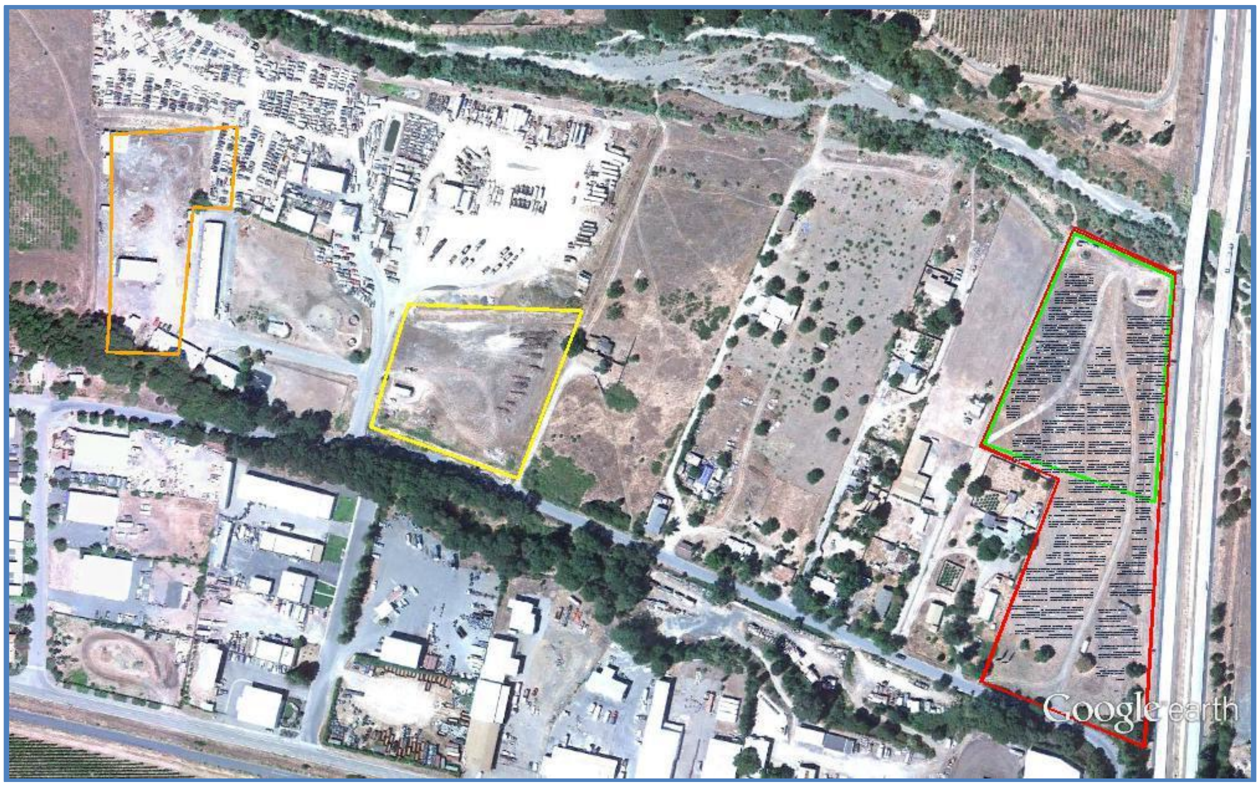


Figure 23: Average Solar Radiation of 5.36 kWh/m^2/yr @39.084 Lat & -123.295 Long

The annual average solar radiation in these areas is estimated to be 5.36 kWh/m^2/day, the total annual energy output is 4,136,319 kWh, and the average monthly energy output is 344,693 kWh (345 MWh) assuming a fixed photovoltaic array fixed facing south. The monthly breakdown of solar radiation can be seen in Table 18.

Table 18: Monthly & Yearly Avg. Solar Radiation for Fixed PV Array Fixed Facing South

Month	Solar Radiation (kWh/m^2/day)	Annual Energy Output (kWh)
1	3.25	220,292
2	4.46	274,598
3	4.98	337,269
4	5.78	373,737
5	6.21	406,748
6	6.35	393,953
7	6.81	432,753
8	6.87	437,957
9	6.64	411,834
10	5.60	368,451
11	4.04	260,048
12	3.29	218,680
Avg. Year	5.36	Total: 4,136,320

It should be noted that both a single axis and a two axis tracking array facing south will result in a higher collection of solar radiation, ~22% and ~27% higher respectively as both arrays can track the sun as it moves across the sky. For 3 MW solar utility with a ***single*** axis tracking array facing south, the annual average solar radiation in this area is estimated to be **6.89 kWh/m^2/day**, the total annual energy output is 5,420,481 kWh, and the average monthly energy output is 451,707 kWh (452 MWh). For 3 MW solar utility with a ***two*** axis tracking array facing south, the annual average solar radiation in this area is estimated to be **7.32 kWh/m^2/day**, the total annual energy output is 5,747,478 kWh, and the average monthly energy output is 478,957 kWh (479 MWh). The monthly breakdown of solar radiation for both a single and two axis array can be seen in Table 19 and Table 20.

Table 19: Monthly & Yearly Avg. Solar Radiation for a Single Axis PV Tracking Array Facing South

Month	Solar Radiation (kWh/m^2/day)	Annual Energy Output (kWh)
1	3.65	249,808
2	5.19	322,026
3	6.13	421,006
4	7.53	496,993
5	8.36	564,153
6	8.92	576,033
7	9.52	624,431
8	9.34	611,477
9	8.58	542,496
10	6.90	456,271
11	4.72	306,365
12	3.72	249,422
Year	6.89	Total: 5,420,481

Table 20: Monthly & Yearly Avg. Solar Radiation for a Two Axis PV Tracking Array Facing South

Month	Solar Radiation (kWh/m^2/day)	Annual Energy Output (kWh)
1	3.78	258,016
2	5.29	327,344
3	6.22	427,523
4	7.87	520,146
5	9.15	616,275
6	10.15	652,206
7	10.64	695,606
8	9.94	651,140
9	8.79	556,383
10	7.05	465,797
11	4.91	316,912
12	3.90	260,131
Year	7.32	Total: 5,747,479

5.3.1 Wind Energy Resources Assessment

From interviews I conducted with members of the Pinoleville Pomo Nation (PPN), I learned that the current PPN Ukiah land reserve that contains the PPN tribal offices an Head Start facilities is known as ya-mo bida in Pomo which translates into 'wind hole near the creek' or 'wind hole creek'. From the PPN oral histories recited to me, I learned that the wind traveling in between the high mountain ridges west of PPN Ukiah land reserve produced wind speeds that "blew away tents and severely bent" the aluminum tent poles used to support the canvases utilized by the PPN during their outdoor ceremonial dances and events. As a result, members of the PPN believed that there was enough wind power potential to install wind turbines near or on new infrastructure development projects. In order to determine if these observable wind speeds were enough to actually support power generation, members of the PPN tribal administration and myself installed a 20 m (60 ft) 3-cup, NRG Systems #40C anemometer (Figure 24) near the PPN tribal administration office that was obtained through the US DOE Wind Powering America's Native American anemometer loan program in September 2010. The NRG Systems Wind Explorer was utilized to record the wind speed and direction data in 10 minute intervals. Figures 25-26 show the annual wind speeds recorded over time (average of 3.95 m/s [8.84 mph]) and the wind power estimate for a 15 ft diameter turbine at those wind speeds.

Figure 24: Anemometer Calibration and Installation on PPN site on September 27th, 2010

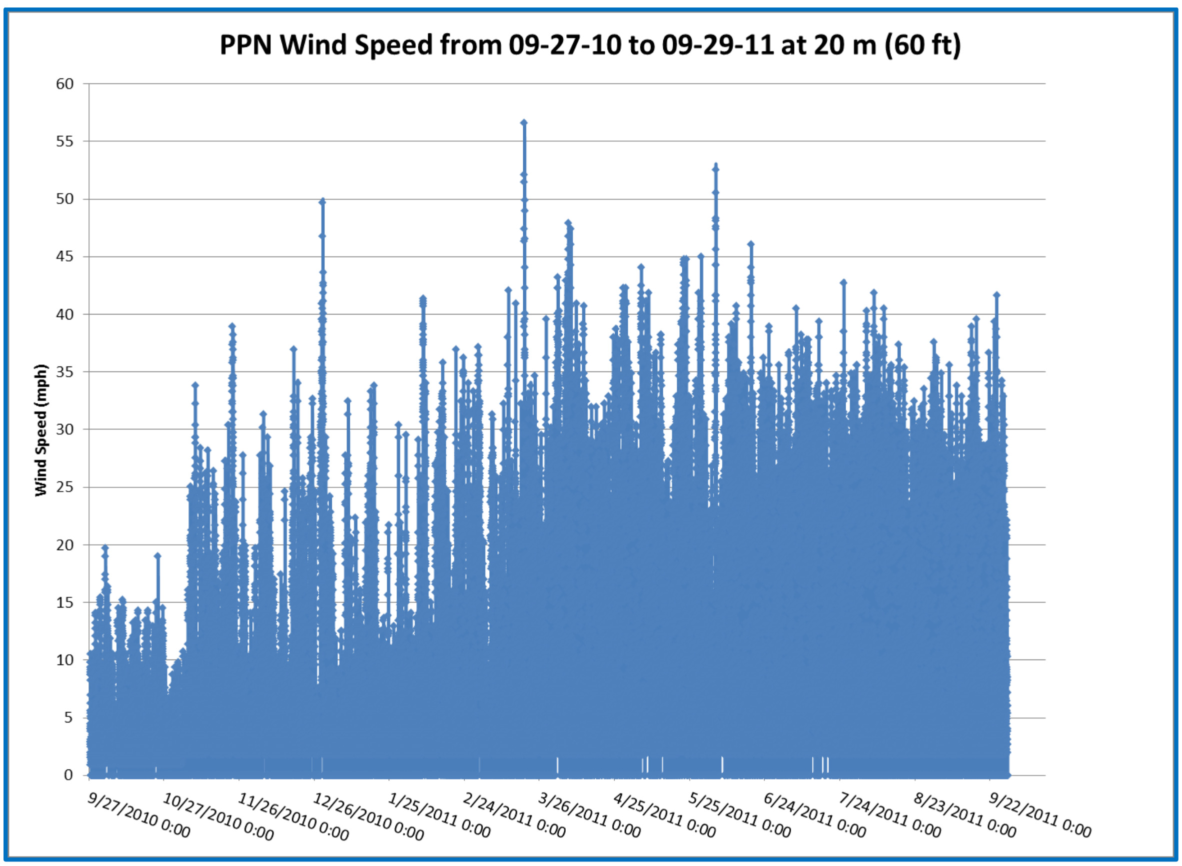


Figure 25: PPN Wind Speed Recorded at 60 ft from September 2010 to September 2011

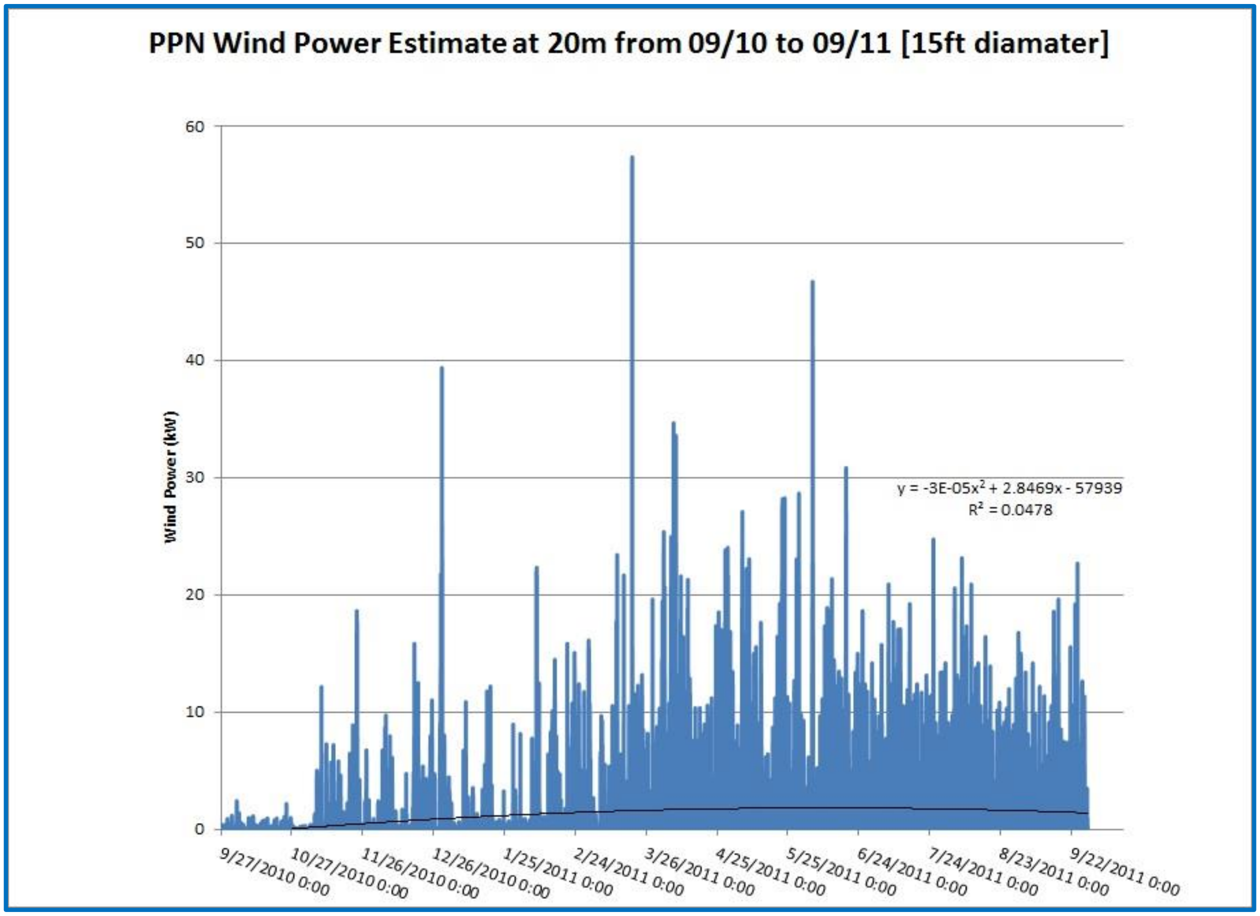


Figure 26: PPN Wind Power Generation Estimate at 60 ft. with a 15 ft. Turbine Diameter

The equation for determining power output from a wind turbine is ($P = 0.5 \times \rho \times A \times V^3 \times C_p \times k$) where P is the power output in kilowatts (kW), ρ (rho) is the density of air in pounds per square feet (lb/ft^3), A is the rotor swept area (ft^2), V is the wind speed in miles per hour (mph) C_p is the coefficient of performance, and k is a constant of .000133 used to yield power in kW. In this analysis, ρ is .0765 lb/ft^3, C_p is .35, and A is 176.715 ft^2. While the highest power output estimated from the recorded wind speed data was ~57 kW in March 2011, the average wind speed recorded at the PPN test site is 3.95 m/s (8.84 mph) which results in an average power output of 0.366 kW. The US DOE's National Renewable Energy Laboratory (NREL) wind energy resources on tribal lands in California assessment lists the PPN as the Pinoleville Rancheria (number 222) with a wind power classification of 1 (Poor) which is generally considered "unsuitable for wind energy development" (US DOE, 2004, 2013). It should be noted that the high mountain ridges west of PPN Ukiah land reserve are listed as Class 2 (Marginal) for wind energy development. See Figure 27 for more detail on the PPN's wind resources.

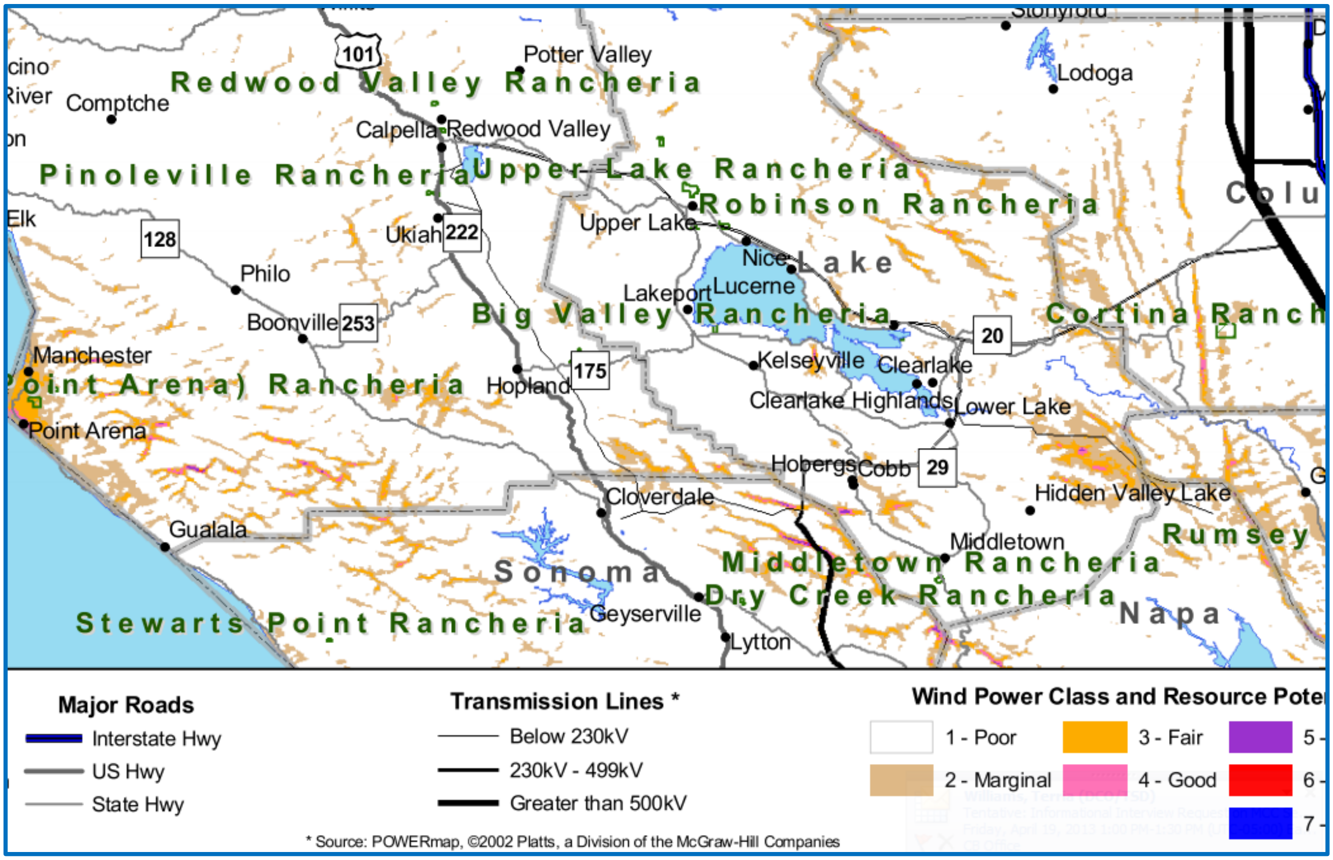


Figure 27: NREL Wind Energy Resources on Tribal Lands in California Assessment

5.3.2 Sub Substation and Transmission Line Location

Utilizing Pacific Gas and Electric's (PG&E) Solar Photovoltaic (PV) and Renewable Auction Mechanism (RAM) program map, I determined that there are two 115 kV substations within four miles of the Pinoleville Pomo Nation (PPN): Capella Substation (ID #: 4341, ~3 miles away) and Ukiah Substation (ID #: 4277, ~3.8 miles away (PG&E, 2013). There are also several transmission lines near the PPN as well: Mendocino-Ukiah, Mendocino #1+, Ukiah-Hopland-Cloverdale+, and the Mendocino-Philo Jct Hopland+ line. In particular, there is a 12kV distribution line (Calpella 1102) that runs into the PPN's land. The presence of these stations and transmission lines near, as well as the strong solar insolation, the PPN makes the development of buildings with roof mounted solar panel and solar power plant ideal for selling excess electricity back to the grid. Please see Figure 28-29 for the substation and transmission line locations.

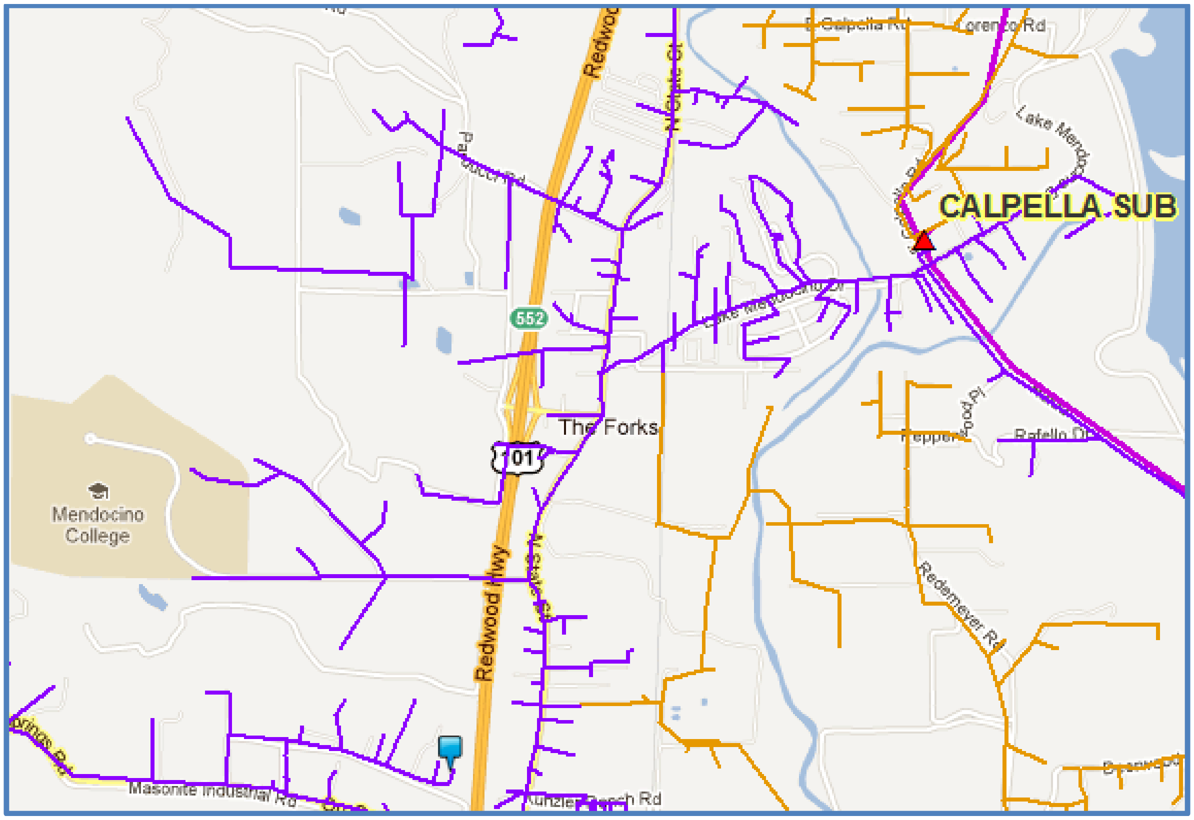


Figure 28: 115 kV Capella Substation (red triangle) & 12kV transmission line near the PPN (blue square)

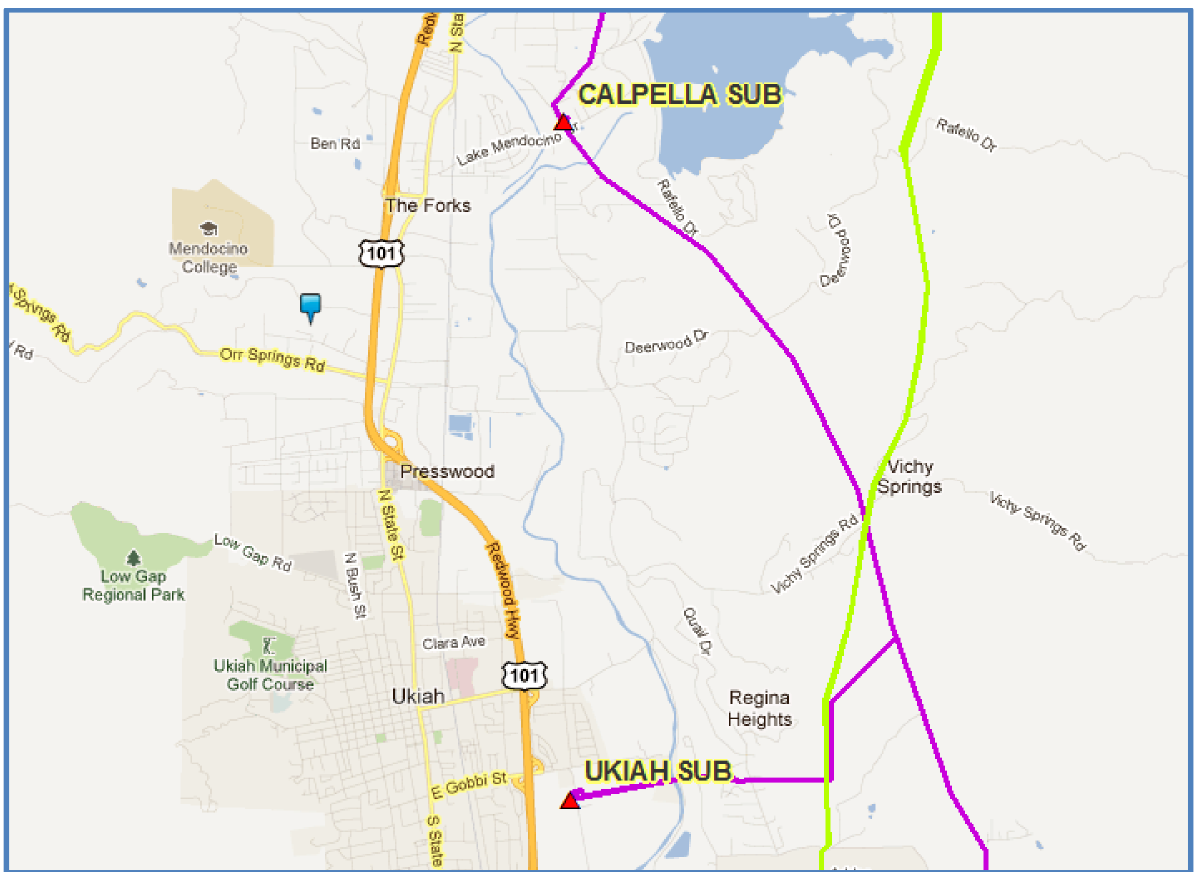


Figure 29: 115 kV Substations (red triangle) near the Pinoleville Pomo Nation (blue square)

5.4 2008 E-10 Pomo Inspired Housing Prototype

After completing the coding of the user needs, modeling of the PPN's land reserve's climatic features, and the assessment of solar and wind power resources, I guided a 2008 freshmen engineering student design team from the E10: Engineering Design and Analysis class at UC Berkeley in the creation of an early conceptual Pomo-inspired housing model (Figure 30) that embedded key user needs identified and coded in Chapter 4 (Oehlberg, et.al, 2010; Schultz, et.al, 2010; Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013). The main structure of the design created by the E10 student team included a large decagon with five hexagon shaped attachments (Figure 31) and a dome shaped roof. This design incorporated one large circular central living space and then smaller add-on private spaces to address the dual needs of community living and communication as well as address the need for privacy.

This early conceptual housing model also takes into account the PPN's cultural and traditional respect for the four directions of North, South, West, and East in addition to Mother Earth (down) and Father Sky (up) for a total of six directions by integrating five attachments and one main central unit (Figure 31). The design draws some of its inspiration from the PPN traditional roundhouses and yurt-like structures while also accommodating for the contemporary needs of larger families, including space for elders and extended family visits. From interviews with members of the PPN, it was determined that elders within a PPN family will live with their children instead of moving into nursing homes. Moreover, the home design includes windows and a sunroof to take advantage of natural light. Finally, this design utilizes a dome shaped, living roof (represented by a green construction paper) with a flat area for growing cultural and medicinal plants. This living roof design feature sought to address the PPN needs of optimizing space, energy conservation, and cultural integration.

Figure 30: 2008 E10 Pomo Inspired Conceptual Housing Model

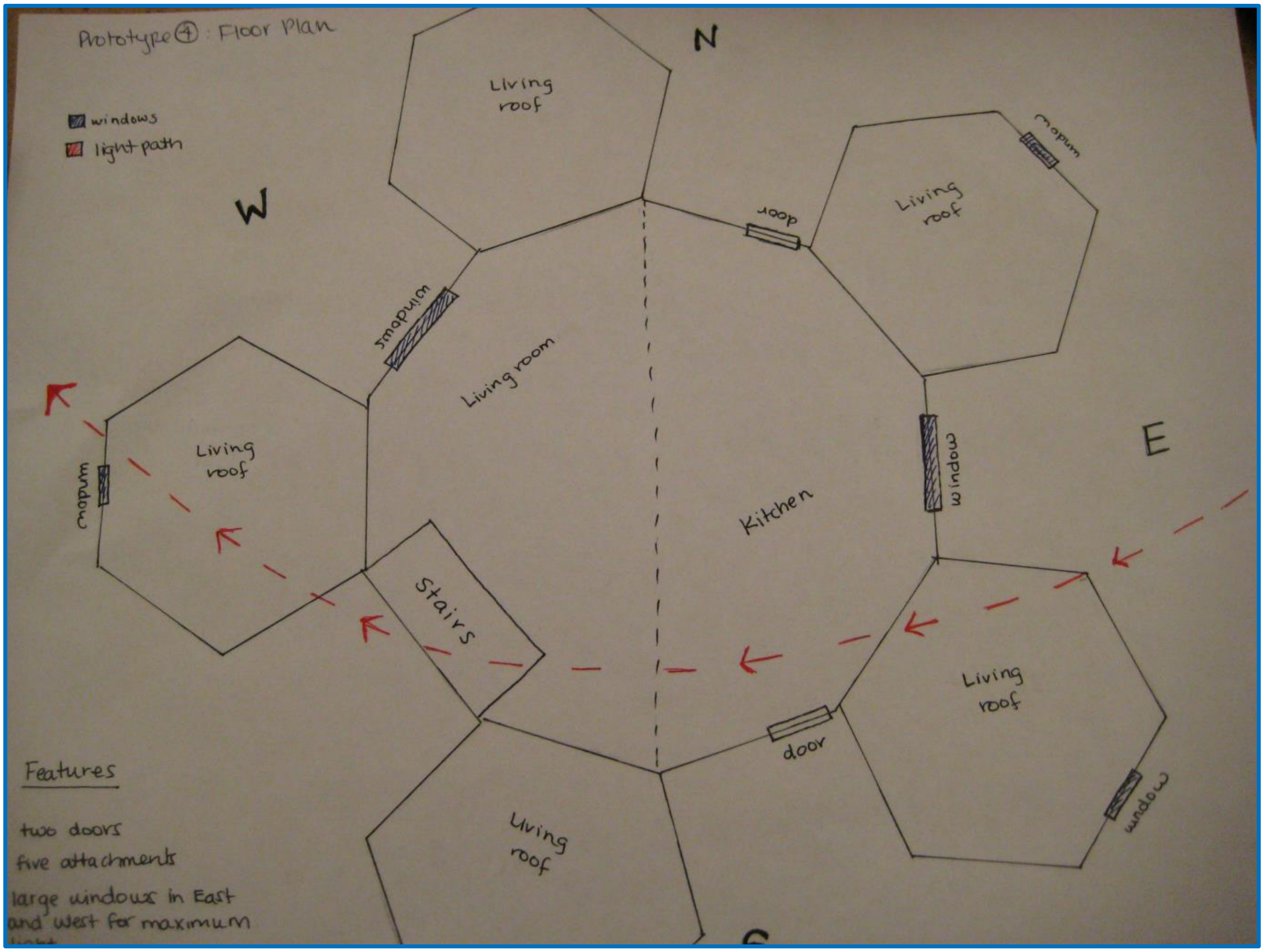


Figure 31: 2008 E10 Pomo Inspired Conceptual Housing Model Floor Plan

This early conceptual housing model shown in Figures 30-31 was created with common materials such as balsa wood, construction paper, duct tape, and a salad container top salvage from a waste bin in order to elicit critical feedback from the members of the PPN. This low fidelity model allows for the quick, early exploration of the basic look and feel features in a new design without heavy investments in full featured designs which will most likely change over time after gathering feedback from members of the PPN. Walker, et.al (2002) found that "quick iterations and modifications are….made easier in low-fidelity prototypes, on paper or computer" and that both low and high fidelity models were equally suited to gauge usability issues in new designs. Some comments provided by a PPN participant about the sketches and prototypes created were:

Personally, I really enjoyed working with all of the UCB and CARES students over the one-year project. To see this project go from an original model all the way through to the completed prototype was amazing. The students worked very hard to create this project. They asked a lot of questions and seemed to take genuine interest in our needs, such as: our energy bills and gray water usage, and to keep this project as green as possible……. We had several meetings with the UCB and CARES students and from these meetings they were able to accurately assess and meet our "green" ideas and traditional needs. Because, of this project, I have become very interested in sustainable environments and architecture. I look forward to working with CARES members Ryan and Tobias on future energy feasibility studies and other projects.

Another member from the PPN spoke about how this collaboration gave her a sense of agency in the co-design process: *"I feel an important part of the collaboration for me, is my voice is finally being heard. We don't have to settle for living in a "box" HUD house. At the conclusion of the planning sessions with Pinoleville Pomo Nation and UC Berkeley, we will have a prototype house that represents Culturally Informed Sustainable Housing, the product of our collaboration. There are many cultural and historical barriers that have appeared during this process. I personally had to take a step back and look deep inside of myself and decide what is best for our next generations. It was difficult to rethink what was taught to me as a child in order to make the best decision for the future of the Pinoleville Pomo Nation. I am satisfied with the outcome of the collaboration and I look forward to more projects in the future."*

Oehlberg, Shelby, and Agogino, 2010 also highlight some of the comments from the E10 engineering student participants about how using the co-design methodology with PPN allowed the students to further development their professional and technical communication skills through a real world engineering project. In particular, one E10 student indicated her reasons for working on the PPN project was that "*it would be really interesting to design an entirely green building; there are so many options it would be fun to come up with the best options that would best fit the needs of the nation….. When I work on a project I like to be physically and mentally engaged. It helps me be more creative. I really do not want to work on a project that is going to be mostly theoretical because I do not find that interesting or engaging"*.

Another E10 engineering student indicated that his work with the PPN really allowed him to explore his fascination with alternative and renewable energy systems: "*Today was essentially the kick-off for our human-centered sustainable design project. To be hones*[t]*, I'm rather excited about it. I was assigned to my first choice project – solar electricity generation for the Pinoleville Pomo Indian tribe. I've been interested in alternate forms of energy for a long time, and am eager to learn more about, not to mention have the chance to work on my first genuine engineering project.* Another entry from this same student conveyed his impressions about the co-design innovation workshop with the PPN: *"Today, we had our innovation workshop at the PPN reservation in Ukiah. Man-where to begin! Overall, I'd have to say the experience was a positive one. I mean yes, it was a bit of a hassle getting there and it was certainly a very long day, but I feel that the knowledge gained about the PPN people and their needs . . . It was a productive/ informative day, and I look forward to beginning the design process with my team mates".*

After gathering this feedback from the E10 students and members of the PPN about the experience of using the co-design methodology to elicit user needs and develop housing prototypes to meet these user needs, the PPN tribal council approved additional co-design innovation workshops to be convened at the PPN in 2009 and 2010 to further refine 2008 E10 housing modeling and gather any additional user needs.

5.5 2009 PPN Greenhouse Design and Structure

One of the goals of the co-design methodology is to democratize the design and implementation of engineering solutions by providing a methodological framework that allows the end user and the outside expert to analyze, share, and build upon each other's respective knowledge bases to identify user needs and implement solutions to meet those needs. Throughout the implementation of the co- design methodology with members of the PPN, I constantly wondered if this methodology actually resulted in transfer of knowledge and expertise amongst the PPN, CARES, and the UC Berkeley participants such that we could create a firm, shared understanding of the PPN user needs that would allow each actor to create and iterate solutions independently. In other words, could the PPN's interaction with CARES and UC Berkeley participants empower the PPN to overcome their concerns about working with outsiders and develop the additional technical expertise to design and build solutions to meet their needs as an expression of their tribal sovereignty? The user need of 'exercise tribal sovereignty' that I identified and coded from 2008 co-design innovation workshop was described to me by some of the PPN participants as the ability of the PPN to govern themselves as "separate political sovereigns with their own territorial boundaries" through a policy known as self-determination or self-governance which allows Native American tribes to create laws to structure its land and guide its citizens according to their cultural and traditional values (Coffey and Tsosie, 2001).

I was able to get an answer to these questions after I arrived at the PPN again in February 2009 to conduct an co-design innovation workshop to further assess the "PPN's spatial needs, energy needs, and gain a better understanding of their housing needs" (Francia, 2009). Once there, I immediately saw a large structure (Figure 30) that bore a striking resemblance to the 2008 E10 Pomo inspired home design. When asked, the PPN's environmental director explained that this large structure was a greenhouse that the PPN constructed with tribal labor in the Fall 2008 with a grant from HUD. The PPN decided to undertake a proof concept project and build a greenhouse that incorporated some of the basic design features of natural daylight, simulating roundness using simple polygons, and reapportion of discarded waste material (in this case, redwood and plastic sheeting) from the original E10 model in order to design a structure that would allow them to grow their native plants and teach their culture and traditions to Native and non-Native peoples. The construction of the PPN greenhouse provided tangible proof that some members of the PPN had gained enough information through the co-design methodology about basic engineering principles that assured them of their abilities to modify the original E10 conceptual model with little to no outside input.

Figure 31: 2009 Greenhouse Created by Pinoleville Pomo Nation

5.6 2010 Co-Design Innovation Workshop & Housing Design

After coding the user needs from the 2008 and 2009 co-design innovation workshops listed in Chapter 4, housing began to emerge as the platform in which various sustainability technologies and best practices could be grafted upon to address the cultural, economic, environmental, political goals of the PPN. By the end of 2009, the PPN was able to utilize the user needs research and the preliminary 2008 E10 culturally-inspired housing design to apply for and receive federal funding from the Bureau of Indian Affairs (BIA) to build three sustainable homes that emphasis cultural values and improve energy and water conservation (Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013). Moreover, the PPN was also able to secure funding from the U.S. Department of Energy (DOE) in 2010 to perform renewable energy feasibility studies of wind, solar, and biogas technologies which resulted in the development of a Native American Energy Plan Analysis (NAEPA) tool (Schultz, et.al, 2010).

In this third co-design session with members of the PPN, CARES, and UC Berkeley, emphasis was placed upon finalizing a medium to high fidelity housing design from which blue prints could be created and utilized for residential housing development within the PPN's lands. To facilitate the visualization of housing floor plans and the placement features and furniture, members of the PPN utilized cardboard 'puzzle pieces' to produce varying, low fidelity floor plans complete with paper-cut furniture (Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013). In reviewing some of the coded user needs related to the PPN's cultural values, feedback was given by several members of the PPN that evil or "bad spirits" tend to dwell into 90° corners, according to traditional beliefs. Therefore, members of the PPN decided to embed circular shapes into the floor plan which resulted in an "eye-ball" shape design (Figures 32-33) that was well received. This co-design process continued for another 6 weeks and involved participants from the PPN, CARES, and UC Berkeley engineering and architecture students creating rapid iterations of conceptual models via online social media interactions that allowed the participants to evaluate, share, and leave feedback online about the various housing designs.

Moreover, the participants were able to use to the NAEPA tool to understand how the various design changes would affect the whole building energy performance (Schultz, et.al, 2010). Once a co-design prototype was agreed upon by the participants, a high fidelity physical and digital prototype, complete with detailed drawings for the different engineering solutions for water conservation and power generation, was presented to the PPN and the construction company selected to build the homes. This housing design, shown in Figures 34- 35, incorporated practical solutions for several of the coded user needs expressed by the PPN since 2008: (1) the usage of straw bale material for insulation, (2) roof mounted photovoltaic system for power generation (Figure 36), (3) composting toilets for water conservation, (4) clerestory windows to increase natural daylight inside the home, (5) rainwater catchment systems, (6) ground-sourced heat pump systems, as well as solutions design to address the cultural aspects of the PPN: (7) a round corner in the kitchen-dining area and fillet walls, (8) a central spiritual gathering space to aid in family communication (Figure 35), (9) the usage of an adobe-like mixture of clay, sand, straw, and water, and (10) a finish layer of earthen plaster that is a clay, fine aggregate, and fiber composite (Seltenrich, 2012; Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013).

Figure 32: PPN members co-designing "eye-ball" housing design with Berkeley architecture student

Figure 33: PPN members and Berkeley architecture student co-designing housing interior

Figure 34: 2010 PPN Culturally Inspired, Sustainable Home Prototype Front View

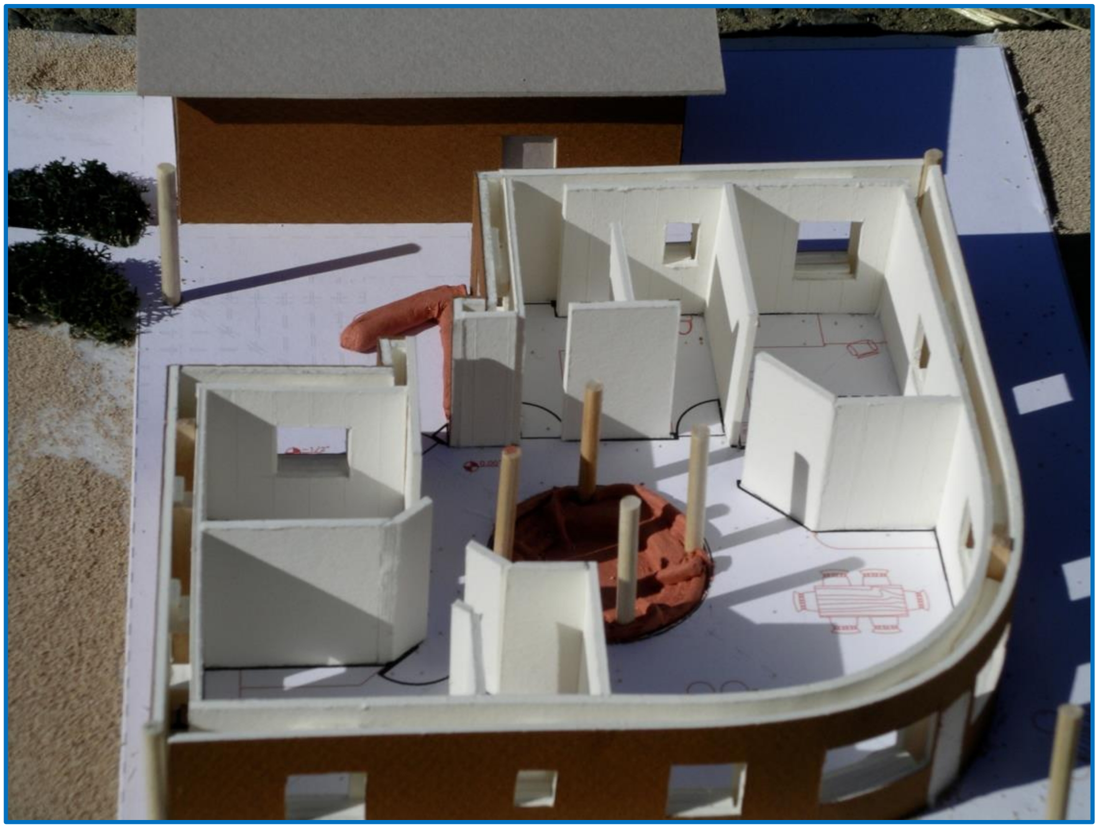


Figure 35: 2010 PPN Culturally Inspired, Sustainable Home Prototype Top Removed

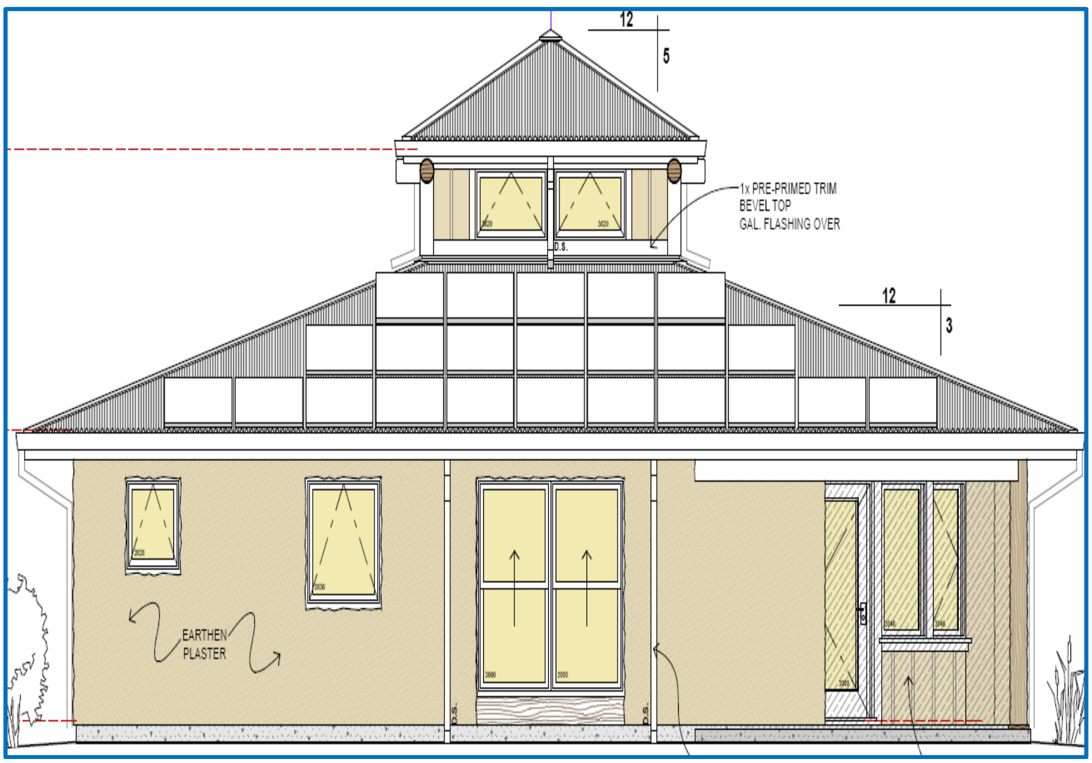


Figure 36: 2010 PPN Culturally Inspired, Sustainable Home Prototype with Roof Mounted Solar

5.7 PPN Co-designed Culturally Inspired, Sustainable Home Construction

In August 2011, construction for two 2,300 ft^2 homes co-designed culturally inspired, sustainable homes began. The framing for the homes and the installations of the straw bale began in late September and ended mid-October 2011. The plastering of the homes' interior was completed in November 2011 and opening ceremonies for the first two homes were held in November 2012. See Figures 37- 40 for more detail images of each construction stage.

Figure 37: Groundbreaking & Site Preparation of Co-designed Culturally Inspired, Sustainable Homes

Figure 38: Foundation Setting and Framing of PPN Home

Figure 39: Straw bale Installation around Kitchen Grey Water System in PPN Home


Figure 40: Straw bale Installation around Kitchen Grey Water System in PPN Home

There are discussions underway by members of the PPN and UC Berkeley to conduct a one year study on the indoor air quality, energy and water usage in these new homes to gauge if they meet performance metrics specified by the PPN. If funds are available, the tribe may move forward with the design and construction of 25 to 30 similar homes on its Sozonni property in Ukiah (Francia, 2009; Seltenrich, 2012).

Chapter 6: Conclusions

6 Introduction

One of the purposes of the co-design methodology is to foster deliberations such that the stakeholders and end user groups in the engineering design process can address and “clarify conflict as well as commonality” amongst their distinct and sometimes overlapping user needs and goals as they related to the concept of sustainability (Mansbridge, et.al, 2010). The co-design methodology seeks to achieve this goal by using its innovation workshops to create a public sphere or a “minipublic” that has “nearly ideal conditions for citizens to form, articulate, and refine opinions about particular issues through conversations with one another” (Fung, 2003). These ‘ideal’ conditions created by the co-design innovation workshops allow its participants to (1) communicate their perspectives on possible solution options based on their social norms and local knowledge, (2) consider each others’ claims, viewpoints, concepts, and designs as valid and germane, (3) transfer knowledge and share lessons learned throughout the engineering design process, and (4) empower each other to design and implement solutions utilizing a shared knowledge base that is an amalgamation of each participants’ local knowledge base. Within this dissertation’s case study with the Pinoleville Pomo Nation (PPN), the members of the PPN as well as the engineering and architecture students from UC Berkeley are considered to have ownership and control through the design of the culturally inspired, sustainable house design, and they are “entitled to make claims on their institutions [background and knowledge base] so as to advance their conceptions of” the best solution(s) to meet the needs identified in this dissertation (Rawls, 1993). The co-design methodology uses an amalgamation of outside experts and local community experts’ knowledge to co-produce solutions, in case sustainable housing and power systems, which meet a variety of performance metrics identified by the PPN and myself. This methodology seeks to empower the members of the PPN that may have some uneasiness or historical trauma associated with working with outsiders to “say in his or her own word[s], to name the world” (Freire, 2000) and implement solutions that meet the PPN’s [and not Berkeley’s or my own] mental model and framework of sustainability or proper building design.

The following sections of this final chapter provides more details on (1) the discourse contributions of this research, (2) understanding the situated knowledge of the PPN, (3) the PPN’s framework for the concept of sustainability, (4) thoughts on managing the research partnership with the PPN, and (5) lessons learned about creating trust during a sustainable development endeavor.

6.1 Discourse Contributions

To restate an earlier point from Chapter 1, this dissertation does not represent a silver bullet or a comprehensive magic formula for understanding the local production practices of various stakeholder groups in order to undertake sustainable community development projects. Indeed, I don’t think that it is possible to create an all-encompassing approach for gathering evaluation metrics for the design of ‘sustainable’ systems due to wide variation in the cultural and social norms utilized to define and evaluate the twin concepts of ‘sustainability’ and ‘sustainable development’.

As single case study, this dissertation focused on addressing the gaps of our engineering knowledge as it relates to the co-production and implementation of residential housing and renewable energy power systems that meets a wide range of performance metrics related to the social, cultural, economic, environmental, and political goals of a target end user community, in this case the Pinoleville Pomo Nation, a Native American tribe in northern California. This dissertation’s discourse contribution was the development of the co-design methodological framework that allowed engineers and community members from a single Native American tribe to elicit end user needs/metrics, situate sustainability knowledge bases within their respective social and cultural norms, and amalgamate these sustainability knowledge bases to co-design community-based infrastructure projects for housing and reliable electricity.

The existing theories [Chapter 2] related to (1) defining and challenging the concept of sustainability and sustainable development, (2) the development of indicators or metrics for sustainability and sustainable development, (3) framing sustainability and sustainable development within indigenous communities, (4) community engagement processes for generating sustainability plans, and (5) methodologies for eliciting user needs and metrics helped guide this dissertation's research questions [Chapter 3]. The findings from this dissertation were then organized in under: the co-design methodology [Chapter 4], culturally-inspired sustainable building design and the whole building energy analysis [Chapter 5], and understanding situated knowledges and managing the research partnership with the PPN [Chapter 6].

Chapter 4 focused on explaining the central tenets of co-design methodology and how it was implemented with the PPN during this dissertation's research to (1) assess the PPN's user needs and performance metrics, (2) identify potential solutions trajectories that meet user needs and decision criteria, and (3) co-create and implement the solutions within the PPN's local community. Moreover, this chapter details the usage of grounded theory to code and analyze data on the PPN's social and technical performance metrics for the future home designs. The end result of co-design methodology was the development of conceptual models related to sustainable, energy efficient building design and renewable power systems that were co-designed in manner that gives it meaning and relevance to the end users within the PPN

Chapter 5 focuses on the steps taken to model the climatic features of the PPN's land reserve, the solar and wind energy potential, and create final, high fidelity prototypes of potential housing and power generation systems to meet the user needs expressed by the members of the PPN. The principle finding in this chapter was that due to the PPN's climate zone, a building that uses high thermal mass with night flush ventilation would be able to address the heated hours above the 70 °F -75 °F comfort zone and could virtually eliminate the need for active cooling systems like air conditioning. Moreover, the additional usage of direct internal heat gain through southern facing windows and the usage of passive direct solar gain through high mass walls would theoretically allow the PPN occupants not to require active, energy-consuming solutions to achieve thermal comfort for approximately 4905 hours (56%) out of the year 8760 hours. The remaining hours would require the usage of an active heating strategy which would ideally be combined with insulated walls and energy efficient systems.

6.2 Situated Knowledge Bases and PPN's Sustainability Framework

In Haraway's (1988) paper, she describes situated knowledge as a "feminist objectivity" which focuses on "limited location and situated knowledge" in order to create a fuller and more accurate perspective of the knowledge production and analysis systems that various communities and cultures possess. Haraway (1988) advocates for the development of "rational knowledge claims" that are not divorced from the complex cultural and social norms that created them, but are instead situated within its original knowledge base. By situating these knowledge claims, one can begin to understand the underlying reasons and assumptions that support these claims and one can develop additional frameworks and assertions that can provide either supporting or contrasting claims. Haraway's (1988) views on separating knowledge and its claims from its source cultural and social norms is similar to Nadasdy's (2003) and Jasanoff's (2006) viewpoints that trying to understand, manipulate, and use knowledge that is separated from its cultural origins is "nonsensical" and will deprive the knowledge of its intended "meaning".

In order to avoid a misinterpretation of the PPN's knowledge, their selection of housing as the platform to address their needs, and their claims for embedding certain design features into the housing, I conducted follow up semi-structured interviews with PPN citizens and members of the PPN tribal council and administration during the spring and summer of 2012. During these sessions, I focused on understanding the underlying reasons and/or framework behind the PPN participants' selection of the final energy systems and passive heating and cooling features by asking the following prompts: 'Why did you decide to choose this technology?', 'What is it about this technology that makes you feel that it is the best solution for you and the PPN?', and 'How do these technologies and design features meet your user needs?'. When I reviewed that comments and statements I recorded from these interviews, several recurring themes or phrases begin to emerge. The comments and statements from the PPN participants tended to be composed of statement such as "These [solar] panels will allow us be self-sufficient and not have to give all or our monies to PG&E or the gas company", "The tribe can live in an environment that is more healthy and balanced", "We can actually put our cultural values and beliefs into practice", "We can now assert our cultural values in this design.", and "The tribe can further exercise its self-governance and sovereignty to have housing that works for us". I began to identify these statements as the PPN framework for sustainability and coded this framework as utilizing four central themes: (1) Cultural Sovereignty, (2) Tribal Sovereignty, (3) Economic Self-Sufficiency, and (4) Environmental Harmony (Shelby, et.al, 2011, 2012; Edmunds, et.al, 2013). Figure 41 shows the PPN's framework for sustainability that I determined during this dissertation research.

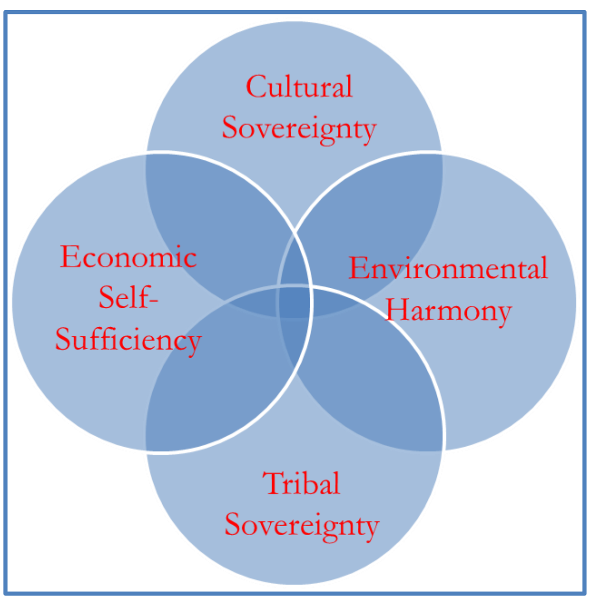


Figure 41: PPN's Framework for Sustainability

After I created this framework, I conducted a final interview with members of the PPN during the summer of 2012 to determine relevant definitions for the four themes I identified. The primary difficulty encountered during this effort was that I had a rather limited understanding of the Pomo language and that there were no direct translation of several Pomo words or phrases into

English. Nevertheless, I was able to develop some definitions for the four themes that I identified. Cultural Sovereignty is defined as the PPN's ability to embed and utilize their cultural values and social norms in their built environment and general interactions with natives and non-natives alike (Edmunds, et.al, 2013). This is similar to Coffey and Tsosie (2001) framework for cultural sovereignty as the "effort of Indian nations and Indian people to exercise their own norms and values in structuring their collective futures".

Tribal Sovereignty is defined within this dissertation as the power of the PPN to develop, implement, and enforce laws and standards, [in this case, standards and/or metrics for building design and power systems] for self-governance and to meet the basic needs of its citizens. Coffey and Tsosie (2001) point out that tribal (political) sovereignty is based on the trilogy of Indian law cases under Chief Justice John Marshall which sets forth the foundation that Native American tribes are "domestic, dependent nations" that can maintain "independent authority within their territorial boundaries" although this authority is subjected to federal oversight and acknowledgement since the "Federal Government has the duty to protect Indian nations and is therefore entitled to exercise authority over Indian affairs" under the Commerce Clause of the Constitution.

Economic Self-Sufficiency is defined as the ability of the PPN to reduce their reliance on outside funds, redirect the transfer of funds from outside of its community to within its community, and to establish stable income generating systems or mechanisms (in case solar PV system whose excess energy can be sold back to electricity grid). This portion of the PPN's sustainability framework further manifests itself through the PPN's usage of tribal members to perform most of the construction of the culturally inspired, sustainable homes in order for PPN tribal members to develop skills in sustainable building design and construction that could be utilized to secure additional job opportunities on and off the PPN reservation. Finally, Environmental Harmony is defined as the PPN's ability to maintain their cultural values, traditions, and lifestyles while minimizing their negative, long term impact within their local and broader environment. This portion of the PPN's sustainability framework can also be seen in the PPN's selection of solar PV systems as they were considered by the members of the PPN as being able to produce clean energy that would not directly harm the environment during its operation.

It is my determination that the PPN is seeking to preserve and grow their culture by utilizing the latest and most effective technology as a means to adapt to the ever changing environmental, economic, and political climate facing the tribe. This adaptive capacity is similar to what Colombi (2012) documents in the Nez Perce efforts to adapt to declining salmon population due their habitat destruction; however, Colombi's (2012) critique of sustainability as a possible signal that tribes want to 'return to their old ways' is not what I have seen in my partnership with the PPN over the last 6 years. It my view that the PPN's pursuit of sustainable buildings and renewable energy systems is about being able to evolve and share their culture and way of life with natives and non-natives alike as an independent, self-sufficient community that utilizes the latest technological, political, and economic tools available to meet their needs and goals. Simply put, the PPN is neither seeking to discard their cultural values and traditions nor are they seeking to return to a lifestyle that is solely dictated by their history. Instead, the PPN seeks to further expand their self-governance and self-determination capabilities to design a built environment that is representative of their culture and values, which are constantly being reinterpreted and applied by members of the PPN to the latest technology and best practices in order to enhance their daily lives.

6.3 Managing the Research Partnership

The ability to maintain this research partnership with the Pinoleville Pomo Nation (PPN) was principally due to the PPN's shared ownership and control throughout the co-design process in which they were able to directly assert their knowledge claims, express new topics for deliberation, and propose alternative solutions that the members of the PPN felt were most important to their local community. This shared ownership and control involved constant email communication, conference calls, as well as physical meetings with members of the PPN tribal council and its citizens. In particular, formal and informal face-to-face meetings were key in allowing the PPN and myself to discuss our concerns and aspirations about the goals of this research partnership. Moreover, the close proximity of the PPN to Berkeley allowed for frequent face-to-face meetings in which the participants from the PPN, CARES, and UC Berkeley were able to work together as partners in real time to iterate on prototypes and design changes to the final sustainable building and energy system design.

It should be noted that while I cited Freire's (2000) work throughout this dissertation, I do not consider the PPN to be an "oppressed" people. The works of Freire (2000) as well as those of Allen (1989), Coffey and Tsosie (2001), Nadasdy (2003), and Ellis (2005) have allowed me to deconstruct and better understand the difficult history that indigenous populations have faced here in the US and around the world to assert more control over their lives. For the co-design methodology to work, the end user, however, should be not viewed as an oppressed, disenfranchised populous that needs to be saved. Labeling the PPN as an oppressed people would devalue their knowledge base, their ability to make knowledge claims about engineering and technology, and relegate the PPN to a mere observer status in the engineering design process. In particular, the PPN had been discussing and reviewing various options for greener buildings and power systems long before they heard of CARES or myself. If I had taken the view that the PPN were a people in need of saving, the end result of this partnership at best would have been a housing and renewable energy power system design that would only be reflective of my view of what is good and right for the PPN. If this had occurred, it would be highly doubtful that the PPN tribal council as well as it citizens would have embraced these solutions. In Freire (2000) words, "many political and educational [I would add engineering and sustainable development] plans have failed because their authors designed them according to their own personal views of reality, never once taking into account (except as mere objects of their actions) the men-in-a-situation to whom their program was ostensibly directed". Simply put, the PPN was not looking for some engineer to liberate them; instead, they were seeking a partner that they could work with as equals, as co-designers, to create a shared understanding of the PPN needs and co-produce solutions using an amalgamated knowledge base to meet those needs. It is my firm belief that if I or any of the other professors and Berkeley students viewed and treated the PPN as an oppressed group, this research partnership would have ended abruptly after the first meeting in March 2008.

6.4 Final Thoughts

The contribution of this dissertation is the development of a methodological framework that provides engineers and end users, in this case Native American tribes, with an approach for (1) eliciting end user needs/metrics, (2) situating knowledge bases as they relate to sustainability, and (3) co-producing knowledge for the development of sustainable communities. The co-design methodology allows its practitioners to frame or situate the engineering design process such that solutions (in the case of the PPN, sustainable building and renewable energy power systems) are designed to meet the needs of the end user. I have learned that working with community leaders and community members to establish and agree upon goals at the early stages of the design process and through each major milestone new major design stage is one of the key step to ensuring acceptance of the final solutions created from the co-design process.

Moreover, non-tribal members should be provided with some cultural education through secondary sources such as books or papers as well as active learning from actual Native Americans who are experts in their culture or general members of the community to become familiarized with broad aspects of the community life. Other key steps include (1) creating a multidisciplinary team of specialists to work with community members during the co-design process, (2) provide opportunism for the tribal members to share their user needs and provide feedback in a non-threatening setting, and (3) iterating on design solutions and refinements frequently via in-person meetings. It is my hope that the co-design methodology could be extended to other Native American tribes, other indigenous communities, and non-Native Americans communities that are interest in working as equal partners to design and implement technological solutions that are co-produced and representative of their user needs.

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