Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference
IDETC/CIE 2011
August 29-31, 2011, Washington, DC, USA

DETC2011-47748

Co-Design Methodology for the Development of Sustainable and Renewable Energy Systems for Underserved Communities: A Case Study with the Pinoleville Pomo Nation

Ryan Shelby
University of California, Berkeley
Berkeley, CA, USA

Yael Perez
University of California, Berkeley
Berkeley, CA, USA

Alice Agogino
University of California, Berkeley
Berkeley, CA, USA

ABSTRACT

The notion of developing sustainable communities is generally accepted as a way to reduce the negative environmental impacts associated with human activities, increase the health of citizens, and increase the economic vitality of communities within a country. In order to further the development of sustainable communities, federal and local governments have placed significant attention upon designing sustainability and renewable energy technologies, such as photovoltaic (solar) and grey water recycling systems to reduce (1) fossil fuel based energy consumption, (2) water consumption, and (3) climate changing greenhouse gas (GHG) emissions associated anthropogenic activities. The Pinoleville Pomo Nation (PPN) of Ukiah, CA, is an example of a Native American government and community that has embarked upon an infrastructure development program to design and build culturally appropriate, sustainable housing for its members.

This paper describes the co-design methodology created by the authors to partner with communities that have historical trauma associated with working with outsiders on projects that involved substantial usage of engineering and scientific artifacts, renewable energy technologies for example, that have not integrated their value system or has been historically denied to them. As a case study, we present the lessons learned from a partnership with the Pinoleville Pomo Nation and UC Berkeley's Community Assessment of Renewable Energy and Sustainability (CARES) team to develop sustainable housing that utilizes sustainability best practices and renewable energy technologies as well as reflect the long-standing culture and traditions of the PPN. We also present the Pomo-inspired housing design created by this partnership and illustrate how Native American nations can partner with universities and other academic organizations to utilize engineering expertise to co-design solutions that address the needs of the tribes. As a result of this partnership, the Pomo-inspired house design was utilized to secure federal funding to create housing that will aid the PPN in their tribal sovereignty, economic self-sufficiency, and environmental harmony goals.

THE 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" [7]. The PPN has several hundred 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. One is a large parcel, zoned semi-agricultural located in Ukiah, CA and the other is a much smaller housing subdivision located in Lakeport, CA. Rising energy costs associated with heating and cooling in the current houses funded by the U.S. Department of Housing and Urban Development (HUD) are placing an increased burden on residents. Furthermore, the drought conditions within and around the PPN are also taxing the resources of the residents and the local government. As a result, the PPN is seeking to implement sustainable technologies and best practices that will increase their self-sufficiency and meet their housing, energy, and water conservation needs. At the same time, their housing must meet other goals, including the promotion of tribal cultural and social values, affordability, employment creation and expansion of political sovereignty. The PPN, however, neither had the technical expertise, nor adequate funding, to develop and implement the thorough designs they aspired to. In the spring of 2008, the PPN contacted UC Berkeley and CARES in the hope of creating a partnership that would help them achieve their goals [5].

COMMUNITY ASSESSMENT OF RENEWABLE ENERGY AND SUSTAINABILITY (CARES)

The Community Assessment of Renewable Energy and Sustainability (CARES) project is a multidisciplinary team of engineers, architects and environmental specialists at the University of California, Berkeley [6]. CARES was founded in 2007 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.

Under the CARES umbrella, faculty and students at the University of California, Berkeley have been able to work on projects that have allowed students to provide services to local communities and further develop their communication and professional skills. CARES community projects include: Green Dorms, Estidama – Sustainability in the Middle East, and culturally-sensitive sustainable housing and alternate energy for the Pinoleville Pomo Nation – the focus of this paper [20].

RELATED WORK: TRIBAL GOVERNMENTS AND SUSTAINABILITY

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. Native American tribes that are considered to be "federally recognized tribes" or sovereign nations by the United States government have the right to create treaties and have a direct government-to-government relationship with the U.S. government and other local governments [3]. This effectively means that no decisions about the lands and people of a sovereign Native American tribe can be made without the consent of the respective tribal governments. Currently, the Bureau of Indian Affairs (BIA) has granted 562 Native American tribes status as "federally recognized tribes" [3].

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" [16]. 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 [1]. These homes account for approximately 75% of tribal homes in the United States that have not been electrified [1]. The Navajo Nation has also cultivated a partnership with Sandia National Laboratories to address the issues of water and soil contamination by uranium processing [21].

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 lead 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.

Other examples of Native American tribal governments pursuing sustainability endeavors include the Scotts Valley Band of Pomo Indians' Tribal Multi-County Weatherization Program in Northern California, the Confederated Tribes and Bands of the Yakama Nation's hydropower projects in Southern Washington State, the Hope Tribe Clean Air Partnership to create utility scale wind energy farm in Northeastern Arizona, and the Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation geothermal electricity generation projects [10,11,23,**Error! Reference source not found.**].

RELATED WORK: NEW PRODUCT DEVELOPMENT METHODOLOGIES

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 [26]. It should be noted that in this paper, a distinction is made amongst designer, end user, and consumer. A designer is considered to be a person that makes preliminary plans, products, and/or services that have not 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 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 toy for her child, the end user.

Furthermore, needs are defined as the subjective requirements that a customer or the end user has for a product, service, and/or system. These subjective requirements or metrics can be vague and/or do not list exact specification for a product function [26]. For example, an end user might express a need for a lawnmower that is "easy to use"; however, the production specification for that need might be a lawnmower that only requires "3 Newtons to move the lawnmower a distance of 2 ft in less than 90 seconds".

The end goal of NPD is to create products, services and/or systems that the end user will adopt and use. The NPD process typically involves 7 stages: (1) Opportunity Recognition, (2) Idea Creation, (3) Idea Selection, (4) Idea Development, (5) Idea Testing, (6) Idea Implementation, and (7) Idea Expansion & Adoption. Figure 1 provides a graphical representation of the NPD process [26].

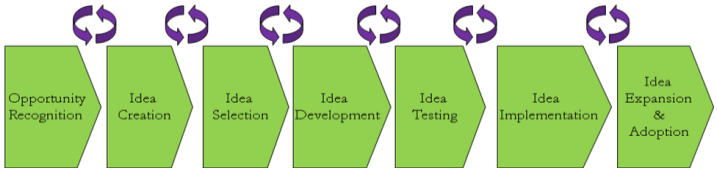

Figure 1: Overview of the New Product Development Process

In New Product Development (NPD), there are two methodologies that are typically utilized: Technology-Driven Design (TDD) and Human-Centered Design (HCD). The TDD methodology advocates for the development of new products, services, and systems based upon the designers/company's technical abilities/core competencies instead of customer demands and end user needs. As a result, importance is placed upon designing products around the objectives of (1) Time to market [reducing time need to introduce the product to the consumer], (2) Price points [determining the price at which consumers will buy the product], (3) Manufacturability [determining how fast the product can be built and mass produced], (4) Performance [determining what standards the product has to adhere to], and (5) Reliability [determining the life span or usefulness of the product]. After it is determined that the product, a piece of technology such as a compact fluorescent lamp (CFL) for example, has been designed to meet the above mentioned objectives of its designers, attention is then given to determining how to modify it so that the targeted consumer and end user groups will adopt and utilize the product.

In contrast, the central tenet of the Human-Centered Design (HCD) methodology is that design should be driven by human needs, with no prior assumptions about solutions or technologies to be applied [18]. As a result, importance is placed upon determining how to design products to meet the needs of the end user instead of determining how to market technologically-driven products to end users. In order to elicit needs from end users, the HCD methodology typically employs qualitative research tools such as customer focus groups and interviews [15, 4]. After conducting a series of focus groups and one-on-one interviews about office equipment design, Griffin and Hauser (1993) determined that there is no 'best' method for eliciting needs and that both interviews and focus groups are valid approaches [9].

METHODOLOGY: CO-DESIGN METHODOLOGY

The Co-Design (CoD) methodology, as presented by the authors, has similar aspects to HCD and its associated qualitative research tools 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 CoD, however, is to create products that meet the full range of consumer requirements/needs while maximizing profits by giving both the end user and the designer shared control during the NPD process. In CoD, the end user has expertise about their needs and determines whether or not a product is appropriate for their needs and environment. Both the end user and design are given agency throughout all stages of the NPD and are allowed to design products that are embedded with the needs of the end user.

The Co-Design methodology has three stages: (1) Trust Building, (2) Split Group User Needs Assessment & Prioritization, and (3) Brainstorming on Conceptual Designs. The underlining principal of CoD is that the residents of the community, the PPN in this case study, are considered to be experts on their needs and therefore should co-design solutions with designers and engineers throughout the NPD to meet their needs. The voice and point of view of the user community is at the forefront throughout the entire NPD process.

The authors have found that CoD is effective at creating a sense of trust between Native American communities that have been historically traumatized when it comes to working with outsiders because the Co-Design workshops create an environment where Tribal members not only express their needs, but also actively utilize their local knowledge to co-design solutions to meet those needs.

In terms of creating participatory workshops and methodologies, Street (1987) and Fraser et.al. (2006) found that community members involved in workshops gained a better understanding of the concerns across their community. Moreover, the community participants felt that they were more empowered to actively address the concerns facing their community when a larger and more complete list of indicators for environment impact assessment (EIA) were generated by both community members and experts in participatory workshops [8, 19].

Ambler (1990) and Nadasdy (2003) point out in their works that Native American nations have a long history of implementing sustainability and environmental endeavors with and without help from non Native members and organizations [1, 16]. In particular, Nadasdy 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

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 energy development to education. It is with this knowledge that the Co-Design methodology was created and used with the PPN.

On April 13, 2008, 40 residents of the PPN in northern California, 14 members from the University of California, Berkeley (UCB), and CARES participated in an innovation workshop to understand the sustainability and environmental needs of the PPN community and to provide recommendations for housing designs for the community.

The innovation workshop began with an ice-breaker session in small groups of 3-5 people. The listening session was then followed by a large group round robin session on good and bad technologies in order to increase the comfort level of discussing technology and to learn the impact of different technologies on different members of the community. In order to increase the comfort level of all the participants, no titles were used during the innovation workshop. Next, the participants were divided into three groups (Elders, Adults, and Youth) and the participants described and/or illustrated specific needs related to sustainability in their current environment (Table 1).

Table 1: Needs Expressed during Split Group User Needs Assessment Sessions

Split Group Needs Assessments			
Elders Group	**Adults Group**	**Youth Group**	
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	Larger working area	Space and storage	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	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		Attractive-ness	Cultural integration

The participants then voted on the top needs identified by the three groups using Post-it notes and markers (Table 2). Finally, the participants were divided into five mixed-age groups on the topics that got the largest number of votes (Traditional Building Techniques, Energy Generation and Conservation, Exercise and Recreation, Privacy, and Heating, Cooling, and Lighting group) to brainstorm on conceptual design solutions based on the needs generated by the Elders, Adults, and Youth group. Figures 1-4 show images and concepts from the first innovation workshop.

Figure 1: Presenting design concepts for the Privacy Group

Figure 2: Presenting design concepts for the Heating, Cooling, Lighting Group

Table 2: Prioritized List of Needs (number of votes)

Top Needs From All the Groups
Privacy (10)
Storage (9)
Safety (9)
Comfort (5)
Exercise (5)
Conserve Energy (5)
Lower Energy Costs (4)
Learn and Use Traditional Techniques (4)
Space (4)

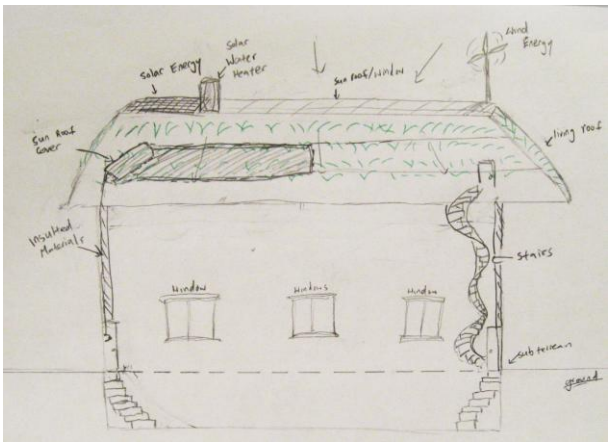

Figure 3: Solar and Wind Power Generation Concept

Figure 4: Wind Power Generation and Grey Water Concept

CLIMATE CHARACTERISTICS AND STRATEGIES

After the innovation workshop, analysis of climatic features of the Pinoleville Pomo Nation land reserve was performed and building strategies were undertaken to refine the co-designed housing prototypes. The California Energy Commission established 16 climate zones to represent geographic areas in California. Ukiah is located in Mendocino County and is situated in California Climate Zone 2. This climate is characterized by cold winters and hot summers with a very small number of days within the comfort zone (75- 100°F). Figure 5 is a psychometric map of California Climate Zone 2 [13]. This chart, produced by "Climate Consultant 4", a software developed at UCLA [14], shows the temperature and humidity for every hour during a full year. The trapezoidal area (highlighted in blue) marked as #1 represents the comfort zone and includes, in this area, only 5.1% of the time.

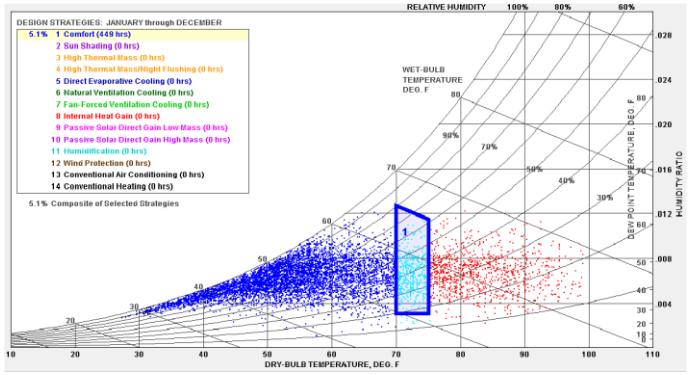

Figure 5: Full year Psychometric map of California Climate Zone 2

During 12% of the time, the temperature range is above the comfort zone (75- 100°F) while during most of the time (81%) the temperature is too cold, ranging between 32-70°F and only

rarely getting even cooler than that. This means that this climate suffers both from cold and hot weather and will need solutions for both situations to make temperatures more comfortable. During the winter months the climate is usually too cold, while during the summer months, temperature ranges from being very hot during the day to too cold during the night (Figure 5, 6). The low range of humidity during the summer months makes the heat easier to overcome with passive cooling solutions; buildings with high thermal mass will reduce the heat load and will add 18.2% of the hours into the comfort zone (marked #3 in Figure 8). The addition of night ventilation to this strategy will help quickly cool down the thermal mass, adding 3.3% more hours into the comfort zone (marked as area #4 in Figure 8).

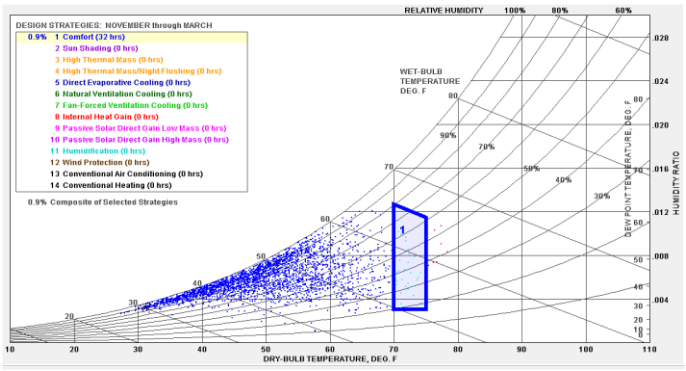

Figure 6: November through March – Psychometric map of California Climate Zone 2 in winter

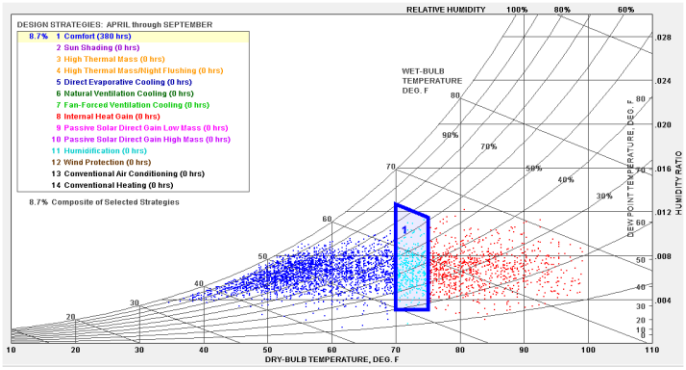

Figure 7: April-September Psychometric map of California Climate Zone 2 in summer

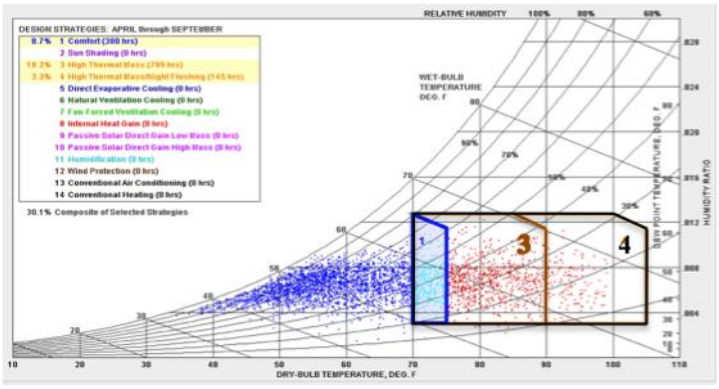

Figure 8: Potential of design strategies for reducing heat load

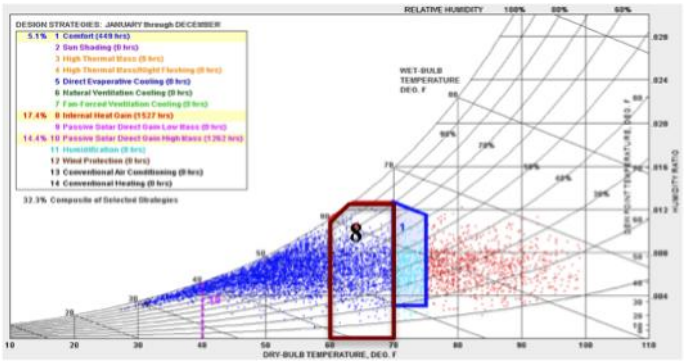

Figure 9: Potential of design strategies for cool weather

These two strategies will take care of nearly all the over-heated hours and can completely eliminate the need for active cooling systems like air conditioning. The cold weather is more difficult to overcome in this climate as it is spread all throughout the year, during both day and night time. Nevertheless, adding direct internal heat gain through southern windows (marked as #8 in Figure 9) as well as passive direct solar gain through high mass (e.g., heavy wall absorbing direct radiation and radiating it back as heat into the house) can cover 32% more of the cold hours through the year. These potential strategies bring us to a total of 68% of the time which will not require active, energy-consuming solutions for gaining thermal comfort at home. The rest of the time requires active heating strategies. However, an efficient heating strategy combined with well insulated walls and energy efficient technology can take care of this with minimum energy use.

CO-DESIGNED POMO-INSPIRED HOUSING DESIGN

Based on the needs and the conceptual home designs co-generated from the innovation workshop and follow up interviews with members of the PPN, a new Pomo-inspired housing design shown in Figure 10 was generated by undergraduate engineering students. A low fidelity prototype was used in order to elicit critical feedback and promote creative changes. The main structure of the design includes a large decagon with five hexagon shaped attachments and a

dome shaped roof. They chose to incorporate one large circular central living space and then smaller add-on private spaces to address the needs of community living and openness, but also to address the need for more privacy.

This quick low-fidelity design concept also takes into account cultural and traditional respect for the four directions of North, South, West, and East in addition to Father Earth (down) and Mother Sky (up) for a total of six. It incorporates these philosophical ideas into the design by integrating five attachments and one main central unit, making six in total. Overall, the design aims to resonate with an historical yurt-like structure while also accommodating for the contemporary needs of larger families, including space for extended family visits. In the Pomo Indian culture, the elder family members will usually not move to nursing homes, rather they typically live with their children. Therefore, the design allows for "granny units" by using attachments for additional living space. The roof is dome shaped but flattens out at the top to increase available space for "living roofs". The living roofs not only have insulating qualities, but also provide space for traditional plants to be grown (addresses needs of optimizing space, energy conservation, and cultural integration). The house includes a large number of windows to take advantage of natural light.

Figure 10: Mockup of the initial prototype house for the PPN

The second project of co-design between the PPN and UC Berkeley was a small neighborhood of 12-15 units on a newly acquired land of the PPN in Ukiah. The early process included a visit to the community and an initial "warm up exercise" to renovate a couple of existing housing. The exercise was intended to help the students become familiar with the current problems and advantages of HUD housing used by the PPN in several locations. It also provided benefits to the existing residents who could get design ideas for easy retrofits by working with the students. Dealing with a project, even in such a small scale, which involves real "clients" turned out to be more complex than initially thought. As before, the students needed to invest time in learning about the cultural aspects of Native Americans in general and the PPN in particular. This process included attending lectures about Native Americans, reading background material and analyzing existing designs used by Native Americans in different locations.

In the third co-design phase of the PPN-UC Berkeley collaboration two prototype houses were to be built on an empty lot near the reservation within the coming year with Housing & Urban Development (HUD) funding and was of great importance to the community as the first sustainable, culturally-sensitive housing project for the PPN. The latest design was detailed by CARES to include sustainable solutions for rain catchment, heating, and cooling.

In this process we brought cardboard cut-outs in different shapes which ware used like a puzzle to produce different floor plans by the community members which were filled with paper-cut furniture to get a better feeling of the ability to furnish different design alternatives. Based on the feedback we received in our previous work with the PPN we included circular shapes for the floor plan (Figure 11). Several members mentioned the importance of circular shapes since "bad spirits" can dwell in corners, according to traditional beliefs. It was important to allow the members to "play" with the circular shapes and to explore their advantages or drawbacks in the house-floor plan. This process produced an "eye-ball" shape floor plan that was rated highly by many members of the community and became the starting point for the detailing stages of the design process.

The design continued for six weeks and included more intensive online interactions that allowed members of the community to evaluate and share with other community members and leave us feedback online. Finally, once a design prototype was agreed upon among the member of the community, we produced a physical and digital mockup as well as more detailed drawings for the different engineering solutions for water and power conservation, which we presented to the community and to a practicing engineering company which was commissioned to construct the house (e.g., Figure 12). This design incorporated practical solutions for sustainable living like straw-bale construction, photovoltaic system, composting toilets, clerestory windows etc. as well as solutions intended to increase the suitability of the house to the particular cultural aspects of the PPN (e.g., a round corner in the kitchen-dining area which gives access to the yard, a central spiritual gathering space, built from earth, which is sunken into the ground and has clerestory windows).

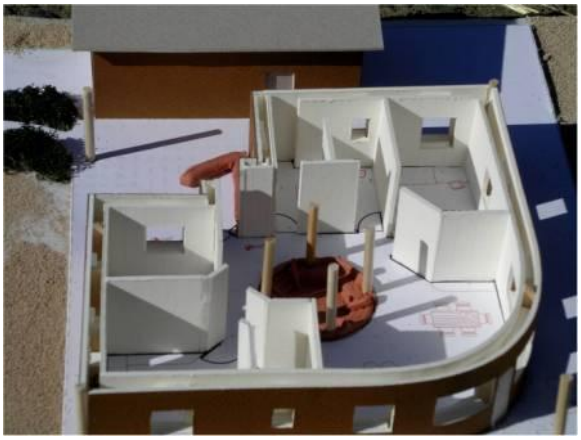

Figure 11: Floor plan view of Pomo-inspired housing

Figure 12: Final mockup of Pomo-inspired housing

PARTNERSHIP SUCCESS

As a result of the work with CARES, the Pinoleville Pomo Nation became empowered to make more informed decisions about renewable energy options and sustainability best practices for their community. PPN used the culturally sensitive home design to apply for and receive federal funding to build more sustainable homes and buildings and perform renewable energy feasibility studies of wind, solar, and biogas technologies [24,25].

The process allowed a greater number of community members to influence community decisions regarding housing. It also introduced community youth to some of the work performed by UC Berkeley students in a way that makes it attractive and encouraging for them to possibly take part in the future.

Qualitative comments from members of the PPN provide more information about the success of the collaboration:

> "*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."*

Another member from the PPN spoke about how this collaboration gave her agency in the 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."*

The UC Berkeley students who worked on the PPN design as a class project also greatly benefited from the collaboration and from learning human-centered design techniques. Adding the actual people influenced by your design adds a major aspect to the design process which is many times ignored in academic studies. One student wrote in his design journal:

> *"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.*
>
> *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."

CONCLUSIONS AND GUIDELINES FOR CO-DESIGN WITH NATIVE AMERICAN TRIBES

This co-design process approach typically involves spending a significant amount of time working directly with members of a community in order to build trust and understand the particular needs of a community as the major generator of the design solution. We have found that the concept of sustainability and the priorities of sustainable living are subjective and therefore must be defined by the end user(s) in a community-context. The co-design approach utilized by CARES changes the power dynamic to the extent that everyone involve in the design process was considered to have expertise in certain domains and the participants collective intelligence was harnessed to produce solutions that meet the needs and requirements of the end users.

The PPN case study is presented here as an example of the co-design of sustainable housing in order to illustrate particular issues that are critical when designing for members of Native American tribes in the United States. We found that the approach of fore-fronting the end user as an expert of their needs and co-designing with members of the community leads to the development of quality designs that share the community's cultural values and are more likely to have high adoption rates as well as post-occupancy satisfaction. One of the biggest lessons learned from this partnership with the Pinoleville Pomo Nation was that, while there was no one standard for sustainability among individual members, there were shared over-arching goals for the community as a whole. During the co-design innovation workshops, the members from CARES and UCB were able to identify three major aspects that frame sustainability for the tribe: Tribal Sovereignty, Economic Independence, Environmental Harmony (Figure 13).

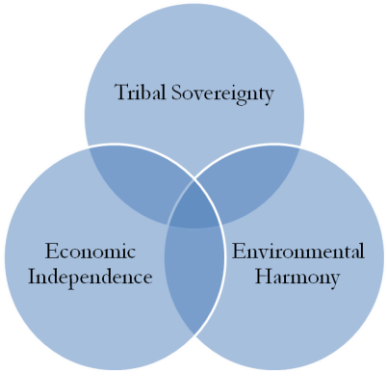

Figure 13: Framing Sustainability

The results of the design have been presented at larger settings with member of other Native tribes in attendance. Feedback was obtained from personal and group meetings, along with use of a project design blog [22] and blogs from the Green Build Conference (e.g., [12]). Lessons learned about use of the CoD methodology for the PPN include:

- Work with members of the Tribal Councils to establish and agree upon goals and processes from the early stages of the design process and through any new major design step.
- Provide non-tribal members with cultural education. This can be done through secondary sources such as books or papers, but also requires active learning from actual Native Americans who are experts in their culture or general members of the community to become familiarize with broad aspects of the community life.
- Compose a team of multidisciplinary specialists to work with community members on the co-design. For sustainable building design we found it valuable to have mechanical engineers, environmental engineers, architects, environmental designers, and landscape architects.
- Acknowledge and treat the tribal members and end users as experts in the domain of their needs and what is appropriate for their environment and community.
- Empower tribal members to share their user needs and provide feedback in a non-threatening setting. We made use of co-design innovation workshops and charrettes on tribal land in which the community worked in small groups. We found that the higher the ratio between community members and UC Berkeley members, the more actively the participation from the community was.
- To enhance the comfort level of the community it was useful to host the co-design workshops in community settings, preferably as community events. The PPN started and ended our innovation workshops with a native prayer in the Pomo language. Native food was cooked and provided by the PPN.
- Begin with trust building exercises, where tribal participants speak early and establish the tone and context for discussions, and where technical specialists acknowledge their own cultural backgrounds and the role these might play in their recommendations,
- Capture as many user needs as possible. In Native tribes, there are protocols for speaking, often with elders being heard first and youth last. In our case, in order to facilitate the capture of needs across all age groups equally, the tribal members were initially broken into age groups.
- Prioritize needs through a combination of democratic processes (e.g., voting with sticky notes) and consultation with members of the Tribal Council.
- Brainstorm as many ideas as possible to meet the prioritized needs. Go into depth on a smaller set as an example of fleshing out promising solutions in the co-design setting.
- Design, development and refinement should fore-front the user needs established earlier and be consistent with the tribe's overarching goals (e.g., Figure 12).
- Community members should be given shared control over the new product development process and have the opportunity to co-design by sketching ideas or "playing"

with the actual forms to get a feeling of the form's constraints.

- Iterate on design solutions and refinements frequently. In-person meetings are always preferable, but tribes are becoming more comfortable with use of collaborative internet technologies. In order to make efficient use of such technology a familiarization session should be done with as many members of the community as possible.
- Make visible the learning process, vocalizing where specialists are learning from and respond to knowledge produced by tribal participants. Online systems are useful for this as they create a collective memory and accumulate information provided throughout the process [22].
- Defer energy analyses to the detailed part of the design process, allowing the cultural concepts and need-driven features drive the early stages of the design process. Costs, regulatory restrictions, energy trade-offs are critical in the iterative redesign process.
- Work with local environmental specialists. Because of the increasing importance of environmental issues on tribal lands, many of the tribes have hired environmental specialists to assist them in developing and evaluating alternatives. These specialists also have experience working with relevant government agencies: Department of Energy, Environmental Protection Agency, and the Housing and Urban Development.

FUTURE RESEARCH

Based on positive feedback from the PPN and other Native American tribes in the Western United States, we are developing a Center for Culturally Appropriate, Sustainable Building Design in UC Berkeley's Center for Information Technology in the Interest of Society (CITRIS). The goal is to expand the software tools developed for the PPN to allow other tribes to reconfigure them for their own needs. We also hope to develop a case base of sustainable housing plans for tribes living in the climate zones of the Western United States. The first case in the database will be the PPN home, along with performance measurements of indoor air quality and energy consumption. Sustainability systems to be included are solar photovoltaic systems, wind turbine systems, passive and active solar water heaters, grey water systems, and passive building design strategies such as passive solar gain and sun shading – strategies that include both renewable energy generation as well as energy conservation. The grey water systems are being considered for its water conservation capabilities, and the passive building design strategies are being considered for their impact on overall household energy usage. The efficacy of the CoD process with the PPN as an underserved community is being evaluated through stakeholders, quantity and quality of the user needs obtained, as well as an evaluation of the final designs.

ACKNOWLEDGMENTS

The authors wish to acknowledge members of the PPN and the PPN Tribal Council for all their expertise and assistance during this partnership: Leona Williams, Carrie Williams, Don Williams, Erika Williams, Deborah Smith, Monica Brown, and David Ponton. We are also grateful for the expertise of Michelle Baker, Cynthia Bayley, Francesca Francia, Rob Laub, Bach Tuyet Nguyen, Che (Tommy) Liu, David Rhoads, Tobias Schultz, Kimberly Tallbear, and Yao Yuan during this partnership and seed funding from the National Collegiate Inventors and Innovators Alliance (NCIIA) for the CARES (Community Assessment for Renewable Energy and Sustainability) Advanced E-team grant [6].

REFERENCES

1. Amber, M., 1990, *Breaking the Iron Bonds: Indian Control of Energy Development*, University Press Of Kansas

2. Battiest, T., 2009,"Navajo Tribal Utility Authority — Wind Energy Feasibility Study", U.S. Department of Energy Tribal Energy Program Review FY 2008, Accessed: 11 December 2009, http://bit.ly/77JGQX

3. Bureau of Indian Affairs, 2009, " Indian Entities Recognized and Eligible To Receive Services From the United States Bureau of Indian Affairs"; Bureau of Indian Affairs; Accessed: 04 December 2009; < www.loc.gov/catdir/cpso/biaind.pdf>

4. Charmaz, K., 2003, "*Qualitative Interviewing and Grounded Theory Analysis*", In Inside Interviewing: New Lenses, New Concerns, (pp. 311-330); Sage Publications, Inc.

5. Cohn, A., 2009, "Student design embraced by Pinoleville Pomo Nation", UC Berkeley College of Engineering's *ForeFront*, Accessed: 13 December 2009; <http://bit.ly/72xkgG>

6. Community Assessment of Renewable Energy and Sustainability, "Advanced E-Team Grant Profile"; National Collegiate Inventors and Innovators Alliance; Accessed: 08 September 2009; <http://bit.ly/Ir134>; CARES website: <http://www.planetcares.org/cares/>

7. Edmunds, D., 2009, "PPN Environmental Program Purpose"; Pinoleville Pomo Nation Environmental

Program; Pinoleville Pomo Nation; Accessed: 10 September 2009 <http://70.90.171.169/departments/env/purpose%20page.htm>

8. Frasera, E., et.al., 2006, "Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management", Journal of Environmental Management, Volume 78, Issue 2, Pages 114-127

9. Griffin, A., Hauser, J.,1993, "The Voice of the Customer", Marketing Science 12(1), 1-27

10. Larson, J., 2010, "Scotts Valley Band of Pomo Indians of California — Tribal Multi-County Weatherization Energy Program"; U.S. Department of Energy Tribal Energy Program Review FY 2009; Accessed: 05 January 2010; < http://bit.ly/4wTm4t>

11. Lewis, C., 2009, "Confederated Tribes and Bands of the Yakama Nation — Yakama Nation Hydropower Projects"; U.S. Department of Energy Tribal Energy Program Review FY 2009; Accessed: 05 January 2010; < http://bit.ly/6vJvuc >

12. Meindl, K, 2009, blog on "Reviving the Oldest Approach to Sustainable Design – How Cultural Values and a Sense of Place Leads to Green Building Designs", November 21, 2009; Accessed: 20 December 2009; < http://bit.ly/5TkVGX>

13. Miline, M., 2009, "Climate Consultant 4"; University of California, Los Angeles; Accessed: 09 December 2009; < http://bit.ly/5bEcOc >

14. Miline, M., 2007, Robin Liggett, and Rashed Al-Shaali; "Climate Consultant 3.0: A Tool for Visualizing Building Energy Implications of Climates"; Proceedings of the American Solar Energy Association Conference, Cleveland, Ohio, July, 2007

15. Morgan, D., 1993, *Successful Focus Groups: Advancing the State of the Art*; Newbury Park, CA: Sage Publications, 1993

16. Nadasdy, Paul, 2003, "*Hunters And Bureaucrats: Power, Knowledge, And Aboriginal-State Relations In The Southwest Yukon*"; Vancouver: UBC Press

17. Navajo Nation, 2009, "Navajo Nation Environmental Policy Act"; Navajo Nation Environmental Protection Agency; Accessed: 04 December 2009; <http://bit.ly/8b74ji>

18. Norman, Donald, 1989, *The Design of Everyday Things*, Bantam Doubleday, New York

19. Street, P., 1997, "Scenario workshops: A participatory approach to sustainable urban living?", Futures. Vol. 29. No. 2. pp. 139-158

20. Oehlberg, L., Shelby, R., Agogino, A., 2010, "Sustainable Product Design: Designing for Diversity in Engineering Education"; Int. J. Engng Ed. Vol. 26, No. 2, pp. 1–10

21. Sandia National Laboratories; 2009, "Navajo Nation National Laboratories Partnership"; U.S. Department of Energy; Accessed: 01 December 2009; < http://bit.ly/66LeLZ >

22. Sustainable Social Design: UC Berkeley – Pinoleville Pomo Nation Collaboration website: <http://pomo.planetcares.org>

23. Tungovia, Roger, 2009, "Hopi Tribe — Feasibility Study for a Hopi Utility-Scale Wind Project"; U.S. Department of Energy Tribal Energy Program Review FY 2009; Accessed: 05 January 2010; < http://bit.ly/7MbVKi>

24. U.S. Department of Interior; 2009, "BIA Awarded $27 Million Reading First Grant by U.S. Department of Education"; U.S. Department of Interior; Accessed:03 December 2009; < http://www.doi.gov/news/firstgrant.htm>

25. U.S. Department of Energy; 2009, "Secretary Chu Announces Funding for Clean Energy Projects on Tribal Lands and Alaska Villages"; U.S. Department of Energy; Accessed: 14 August 2009. < http://bit.ly/146EuW>

26. Ulrich, K. and Eppinger, S., 2004, *Product Design and Development*, 3rd Edition, McGraw-Hill, New York, 2004

27. Walter White Tail Feather, 2009, "Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation Electricity Generation from Geothermal Resources"; U.S. Department of Energy Tribal Energy Program Review FY 2009; Accessed: 05 January 2010; < http://bit.ly/5GGUII >