Development of a decision aid for energy resource management for the Navajo Nation incorporating environmental cultural values

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"My grandchild, education is the ladder. Tell our people to take it" – Chief Manuelito

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Abstract

Decision-making surrounding pathways of future energy resource management are complexity and requires balancing tradeoffs of multiple environmental, social, economic, and technical outcomes. Technical decision aid can provide a framework for informed decision making, allowing individuals to better understand the tradeoff between resources, technology, energy services, and prices. While technical decision aid have made significant advances in evaluating these quantitative aspects of energy planning and performance, they have not been designed to incorporate human factors, such as preferences and behavior that are informed by cultural values. Incorporating cultural values into decision tools can provide not only an improved decision framework for the Navajo Nation, but also generate new insights on how these perspective can improve decision making on energy resources. Ensuring these aids are a cultural fit for each context has the potential to increase trust and promote understanding of the tradeoffs involved in energy resource management. In this dissertation I present the development of a technical tool that explicitly addresses cultural and spiritual values and experimentally assesses their influence on the preferences and decision making of Navajo citizens. Chapter 2 describes the results of a public elicitation effort to gather information about stakeholder views and concerns related to energy development in the Navajo Nation in order to develop a larger sample survey and a decision-support tool that links techno-economic energy models with socio-cultural attributes. Chapter 3 details the methods of developing the energy decision aid and its underlying assumptions for alternative energy projects and their impacts. This tool also provides an alternative to economic valuation of cultural impacts based upon an ordinal index tied to environmental impacts. Chapter 4 details the the influence of various cultural, environmental, and economic outcome information provided through the developed decision aid on beliefs and preferences related to the type and scale of energy development, trust of decision makers, and larger concern for environmental protection. Finally, chapter 5 presents concluding thoughts future research and on how technical-social decision tools can provide a means ensuring effective decision making on the Navajo Nation and other American Indian communities.

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1. Introduction

The Navajo Nation, roughly the size of Ireland, covers 27,425 square miles, across Arizona, New Mexico, and Utah making it the largest reservation in the United States (U.S. Environmental Protection Agency [EPA] 2014). In addition, the Navajo Nations holds some of the most significant renewable and fossil fuel resources of any Tribe in the country (EIA, 2000). The development of these energy resources has been seen as a means of addressing significant levels of unemployment (43% as of January 2015) and poverty (Smith, 2007; Pasuqaletti, et al., 2015). Since the 1920's the Navajo Nation has developed many of its natural resources including petroleum, natural gas, uranium, and coal (Wilkins, 2013).

The first Navajo Nation government, known as the Navajo Business Council, was created in 1922 by the Bureau of Indian Affairs in order expedite oil and gas leasing on the reservation (Wilkins, 2013; McPherson & Wolfe, 1997). This business council was eventually deemed a violation of Title X of the 1868 treaty signed by the Navajo Nation and the United States, which required ¾ of Navajos to approve any cessation of land (Wilkins, 2013). In 1923 the Navajo Tribal Council was formed by the Bureau of Indian Affairs (BIA) as a solution to the issue of representation. The first meeting of this tribal council dealt with two items: elect a Tribal Council Chairman and grant the BIA power-of-attorney for signing oil and gas leases "on behalf of the Navajo People" (Wilkins, 2013; McPherson & Wolfe, 1997). Since this time oil and gas has been developed extensively in the Utah region of the Navajo Nation and led to the creation of one the first for-profit corporations, the Navajo Nation Oil and Gas Company.

While not an energy resource per se, uranium mining across the Navajo Nation after World War II set a precedent for subsequent development of energy resources on the reservation (Eichstaedt, 1994). Uranium mining across the Navajo Nation led to significant consequences for

the health and safety of workers and surrounding communities due to negligent mine safety (Eichstaedt 1994; Brugge, Benally, and Yazzie-Lewis 2006; Brugge, deLemos, and Bui 2007; Bunnell et al. 2010). Still, to this day, many uncontained uranium mining sites remain scattered across the reservation.

Since the 1950's The Navajo Nation has pursued land leasing of coal mining and electricity generation activities across the reservation. The Navajo mine near Farmington, recently purchased by a for-profit subsidiary of the Navajo Nation, has supplied the Four Corners generating station since the 1960's, providing electricity to much of the Southwestern desert (Wilkins, 2013). From 1965 to 2005, coal from the Black Mesa mine was sent via a 273-mile slurry pipeline to the Mojave Generating Station located in Laughlin, NV (Kelley and Francis 1993, Tsosie 2009). Additionally, the Kayenta Mine continues to produce low-sulfur, subbituminous coal for the Navajo Generating Station located near Page, AZ (Pasqualetti, et al., 2015). The royalty and lease payments from these mining and power generation activities comprise a significant portion of the operating budget of the Navajo Nation.

In addition to these significant fossil fuel resources, the Navajo Nation has significant renewable wind and solar resources. These resources have yet to be developed on a significant or widespread scale. A majority of the experience with renewable energy development has been with the electrification of the nearly 18,000 homes across the reservation (Tarasi et al. 2011). Many of these residents live isolated from other homes, miles from existing distribution lines, due to spiritual and ancestral connections to the land (Tarasi et al. 2011; Pasqualetti, et al. 2015). Larger scale renewable projects have been limited to projects between 35kW to 200kW (Gil, Shafer, and Elmer 2012). (A 200kW facility would provide residential electricity for approximately 30-40 typical homes in the US.). Currently the Navajo Tribal Utility Authority is

slated to construct at 27.5MW Solar farm near Kayenta, Arizona and has a power purchase agreement with the Salt River Project, an Arizona utility (Department of Energy (DOE), 2016).

1.1. Energy resource decision making incorporating cultural values

Signification motivations that have spurred the development of energy resources on the Navajo Nation include the need for economic development and the associated payments to tribal coffers (Pasqualetti, et al., 2015). While these motivations may allow such projects to obtain approval within Navajo leadership, these objectives may not be shared completely by the Navajo public - instead research suggests that concerns may focus on protection of land, water, and cultural resources (Pasqualetti, et al., 2015, Piña and Covington 1993; Shirley 2005, 2009; Necefer et al. 2015). These concerns may even hold true for less impactful renewable energy resources as well (Pasqualetti, et al., 2015). Concern for protection of the environment could in part stem from culturally informed values (Schoepfle, et al., 1983; Necefer et al. 2015). The failure to acknowledge and incorporate these cultural values in decision making on economic development has led to many instances of projects failing to be successful or causing long lasting damage to communities (Hall, 1992; Turner-Ruffing, 1978; Nuttall, 1998).

The backdrop of past energy and economic development on the Navajo Nation, which to many degrees failed to incorporate Navajo cultural values, presents a unique opportunity to improve future decision making. Decision making that more fully incorporates a community's cultural values could potentially create frameworks that enable communities to be empowered to manage their energy resources in a broadly beneficial manner. These frameworks could also provide different perspectives to other societies about how resources could be better managed (Brundtland, 1987; Chambers, 1981).

1.2. Public Involvement in Environmental and Energy Decision Making

Decision making on environmental and energy issues are inherently political and involve public and private interests and in a democratic society these decisions cannot be made without consulting all affected parties (Cortner and Shannon 1993; Landy, 1993; Williams and Matheny, 1995; Haggett, 2011; Stern and Dietz, 2008). If people's concerns are not adequately addressed in this process they often become politically involved outside of it through elections, lobbying, judicial action, and social movements (Stern and Dietz, 2008; Powell & Long, 2010). There is significant debate about how the public should participate, if at all, in this decision making as it can present a complex administrate barriers that may outweigh any benefits (Stern & Dietz, 2008). However, structured and thoughtful public engagement in this decision making can both improve decision quality and the legitimacy of the entire process. For example, public engagement can improve the decision making process by clarifying the nature of the problem by identifying outcomes of concern and potential alternatives decision paths (Stern & Dietz, 2008). Additionally, these improvements can also foster greater degrees of perceived legitimacy by identifying and considering the range of decision alternatives and outcomes that that the affected parties want to achieve or prevent (Stern and Dietz, 2008).

Technical and scientific analysis plays a significant role in decision making on environmental and energy issues, yet, this analysis alone is an inadequate guide to determining how the risks, costs, and benefits should be balances or how they should be distributed across the public (Stern & Dietz, 2008). These decisions also depend on values and preferences and the interpretation of the factual information provided by these analysis (Stern & Dietz, 2008). Public input can compliment scientific analysis in addressing these gaps by using public values and concerns to frame the questions being asked and the methods deployed (Stern & Dietz,

2008). Additionally, public engagement can gather useful information about the interconnection of energy and environmental outcomes and their effect on societal consideration such as cultural resources.

1.3. Technical decision making on energy resources

The management of energy resources is complex and requires the consideration and balancing of multiple environmental, social, economic, and technical outcomes. Technical decision tools can provide a framework for informed decision making, allowing individuals to better understand the tradeoff between resources, technology, energy services, and prices. While technical decision support tools have made significant advances in evaluating these quantitative aspects of energy planning and performance, they have not been designed to incorporate human factors, such as preferences and behavior that are informed by cultural values (e.g. resources located on sacred land may constrain their development or individual choices about energy use) (Jefferson, 2014; Sovacool, 2014; Lutzenhiser, 1992). Incorporating cultural values into decision tools can provide not only an improved decision framework for the Navajo Nation, but also generate new insights on how these perspective can improve decision making on energy resources.

In this dissertation I present the development of a technical tool that explicitly addresses cultural and spiritual values and experimentally assesses their influence on the preferences and decision making of Navajo citizens. This dissertation consists of five chapters: Chapter 1 provides an introduction and background to the work. Chapter 2 focuses on interviews conducted on the Navajo Nation to inform the development of technical decision tools for energy resource management. Chapter 3 considers how cultural and spiritual values can be incorporated into a decision tool with specific focus on energy resource management on the Navajo Nation. Chapter

4 considers how the decision tool, presented in Chapter 3, influences the values, beliefs, and perceptions about energy resource management on the Navajo Nation. Chapter 5 presents a brief conclusion.

2. Assessing beliefs and values of the Navajo public through interviews to inform the development of a technical decision tool

This Chapter is based on the following peer-reviewed journal publication:

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2.1. Introduction

Assessing the implications and tradeoffs of different energy technologies, policies, and development pathways requires a deep understanding of their effects locally and globally. The effects of these decisions are often complex and require knowledge of both technical and societal outcomes. Given this complexity, multidisciplinary methods are required to ensure that technical decision tools used for energy resource management more accurately represent both energy systems and the societies they serve.

While technical tools can aid in understanding the tradeoffs between resources, technology, and prices, they are less able to incorporate human factors such as cultural, spiritual and ethical values in their formulation (Jefferson, 2014; Sovacool, 2014; Lutzenhiser, 1992). For example, optimization tools for energy resource management (e.g. MARKAL) generally rely on technical supply curves to model resource availability and end-use demand forecasts (Manfren, et al., 2010). These technical datasets, however, ignore resource constraints that may exist as a result of cultural values. For example, while a supply curve includes resources that are economically recoverable, these resources may in fact be unavailable if they are located in lands that are considered sacred to the community that owns them. In addition, techno-centric approaches can miss cultural and social values that can influence individual choices about energy use such as resistance to certain types of technology and changing levels of energy consumption (Sovacool,

2014; Luzenhizer, 1992). By determining how cultural values relate to energy use and impacts, we can better understand how these perspectives inform preferences about energy resources and thus hopefully develop technical tools more reflective of the decision makers and stakeholders they hope to inform.

Increasingly more attention is being paid to understanding the value of using culturally based knowledge in the evaluation and management of natural systems (LaDuke, 1994; Zafertos, 1998; Berkes, 1999; Huntington, 2000; Jollands and Harmsworth, 2007). For example, culturally based environmental health indicators of freshwater systems, derived from Maori knowledge of the local environment, were found to provide cost-effective, accurate, and accessible methods of environmental monitoring for communities (Harmsworth, et. al. 2011). When coupled with scientific methods of environmental testing, such approaches can enable a broader, more complete worldview on environmental management. Indeed, indigenous people have developed holistic knowledge of the land and ecosystems in which they live that can contribute to environmentally sustainable development practices (Inuit Circumpolar Conference [ICC], 1993; Stevenson, 1996; Huntington, 2000). This knowledge "can offer many modern societies many lessons in the management of resources in complex … ecosystems" (Brundtland, 1987:12). While there has been significant work done to understand knowledge relating to management of environmental systems (Weiss, et al. 2012; Thorpe, N. 1994; Huntington, et al., 2004), there has been very little done in understanding how cultural knowledge and values can inform approaches to *energy* resource management.

As many tribal governments look towards developing technical tools for decision making regarding energy resources, it will be important for these tools to incorporate human factors and cultural values to ensure more effective decision making. The failure to acknowledge and

incorporate these culturally informed values and beliefs in decision making has led to numerous instances in which well intentioned projects operated by non-indigenous entities and governments failed to be successful or sustainable, and even worse, caused long-lasting damages to communities (Hall, 1992; Turner-Ruffing, 1978; Nuttall, 1998). For indigenous communities, improving decision-making means improving decision frameworks that reflect community values and create community ownership over natural resources. More broadly, research into indigenous knowledge with respect to energy systems has the potential to improve existing frameworks of energy resource management beyond the scope of indigenous communities. The incorporation of indigenous knowledge can offer societies different perspectives on the management of resources in complex ecosystems, often enabling more effective management decisions (Brundtland, 1987; Chambers, 1981).

In this paper I aim to further human-centered research methods in supporting technical decision making by more accurately understanding how cultural values can inform the formation of technical decision tools for energy resource management through the design and implementation of a public/stakeholder elicitation protocol of members of the Navajo Nation. The elicitation focuses on understanding Navajo peoples' beliefs regarding technical dimensions of energy development, as well as their values regarding different economic, social, governance, environmental, and spiritual outcomes. This paper provides an analysis of community values, beliefs, and knowledge to aid in the development of technical energy resource management tools. The focus on the Navajo Nation has broader implications for other indigenous communities, and others within developing nations that similarly experience high levels of economic and energy poverty (Tarasi, et al., 2011). Given the Navajo Nation's significant energy resources, development of them has been proposed as a means of addressing both economic and

energy poverty. However, these prescriptive approaches do not necessarily incorporate and embrace cultural values and beliefs; the exclusion of these values and beliefs from formal tools and methods for decision support make these approaches less relevant, effective, and meaningful (Aberle, et al., 1993; Reno, 1981; Ruffing, 1979).

1.1. Context of energy resource development on the Navajo Nation

Many American Indian tribes, including the Navajo, have experienced a tumultuous history of energy development on their lands. Determined and managed primarily by outsiders, many argue that this development has been unreflective of native cultural values, which maintain that ecological systems are sacred and foundational to the integrity of social systems (Reno, 1981; Ruffing, 1979; Cornell & Kalt, 1992; LaDuke, 1994; Aberle, et al., 1993; Eichstaedt, 1994; Brugge and Goble, 2002; McPherson, 1992). Consequently, past energy development on the Navajo Nation has left a legacy of long-lasting ecological damage, adverse health effects, and profound feelings of helplessness and violation among tribal citizens due to the nature of the exploitation of their lands (Eichstaedt, 1994; Brugge and Goble, 2002; McPherson, 1992).

In recent years federal policy has changed to grant tribes greater autonomy over management of their natural resources. Measures have been taken to expedite the development of energy resources on American Indian lands with the dual objectives of economic development and self-determination (Royster, 2009). For example, in 2005 the U.S. Congress passed the Indian Tribal Energy Development and Self-Determination Act, allowing tribal governments to lease and develop energy resources on tribal lands without final approval from the U.S. Department of the Interior (Royster, 2009). Tribal governments, including the Navajo Tribal Council, increasingly view the development of their rich energy resources *by and for* the benefit of the tribes as an important expression of true self-determination (Cornell and Kalt, 1992). These governments

now face a conundrum in managing energy development: continue with the status quo development that is unreflective of cultural values but has provided some economic benefit for the tribal government, or advance a new energy development paradigm more reflective of cultural values while ensuring positive economic outcomes.

Previous work suggests that successful energy resource development on American Indian lands cannot be isolated from the cultural context in which it exists, and that communal concerns should come first (e.g. environmental protection, cultural integrity), while other metrics such as economic efficiency may come second (Duffy & Stubeben, 1998). Furthermore, history suggests that, if not supported by the public, energy projects on tribal lands can face many obstacles to their successful implementation and long-term viability. For example, the proposed 1,500 MW Desert Rock Power Plant that promised to provide 600 long-term jobs and approximately $50 million in annual revenue for the Navajo Nation, failed dramatically due to strong local opposition (NNDED, 2009). Points of conflict included: pressure from the Navajo Nation Government on grazing-rights holders to sign over their land leases, increased air pollution from a third power plant in the region, and concerns about long-lasting impacts on land and water resources from coal mining (Tsosie, 2010; Yazzie et al., 2008). Thus it is important to note that the "success" of energy development projects for American Indian nations is not only measured by employment and revenue. It is also equally measured by the fulfillment of political and social sovereignty, cultural protection, and protection of the environment (Cornell and Kalt, 1992).

A new energy development paradigm that includes community input to be reflective of cultural values could promote public acceptance and thus the long-term viability of energy projects on tribal lands resulting in much-needed economic development. This paradigm would also support tribes' goals of self-sufficiency, self-determination, and political sovereignty (Vinje,

1985; Ruffing 1979a, 1979b; Reno, 1981). Finally, participatory processes of resource management have additional merits as the very process of identifying cultural values can reveal indigenous knowledge that may provide valuable insights into how to manage energy resources in more sustainable ways.

Developing a new paradigm of technical energy resource management decision tools that better reflects cultural values and other social constraints requires understanding the knowledge, interests, and values of the public on issues of energy and the environment. Toward this goal, this paper presents the results of interviews conducted with Navajo citizens, from a broad range of backgrounds, on their beliefs regarding the technical dimensions of energy development and their values in terms of economic, social, environmental, governance, and spiritual outcomes for their community and their land with respect to energy resource management decisions. To investigate Navajo views on energy development, I developed a semi-structured interview protocol, in English, covering five topics: (1) Navajo cultural values and issues of concern, (2) economy and energy projects, (3) environment and energy projects, (4) trust and energy projects, and (5) an energy project case study: the Desert Rock Power Plant. The semi-structured interview protocol ensures consistency between interviews allowing participants to be asked the same questions (Morgan, et al., 2001). In addition, the semi-structured interview protocol has been demonstrated to be an effective method for documenting traditional ecological knowledge in indigenous communities (Huntington, 1998; Neis, et al., 1999).

With topic (1), I aimed to characterize how energy resources relate to Navajo cultural values and issues of concern. Energy projects on the Navajo Nation have been promoted as a source of economic development through employment and increased revenue thus through topic (2) I aimed to assess how these goals fit into the values and concerns of the Navajo public. Given the

significant role the environment plays in Navajo culture (Farella, 1984), with topic (3) I sought to assess how values regarding the environment might inform the selection of energy projects on the Navajo Nation. In topic (4) I aimed to assess respondents' views of different groups who have a significant role in energy development and management on the Navajo Nation, as information that originates from these groups can be interpreted according to their perceived trustworthiness. Finally, topic (5) assessed how views expressed from topics (1-4) translate into stakeholders' views about the failed Desert Rock Coal Power Plant near Burnham, NM. The first section of this paper describes the materials and methods used for the interviews; it is followed by results, then discussion, and a brief conclusion.

2.2. Methods

2.2.1. Pre-interview discussion

Prior to conducting the interviews, I held conversations about non-energy and non-political issues with participants in order to build trust and rapport with participants. A significant part of this conversation revolved around introducing each other's clans, familial relationships, and communities. Within Navajo culture this is an indispensable step when meeting someone new and taking these steps to discuss heritage as it is seen as a sign of respect regardless if one does not have Navajo heritage. This allowed for myself, the interviewer, and the participant to build a sense of commonality and an environment of 'trust' for open discussion.

2.2.2. Interview protocol

Navajo values and issues of concern. After a brief introduction, I asked participants to describe where on the Navajo Nation they are from and how they feel about that place. I then asked what they "value most" about being a member of their current community, as well as what they believe others in their community value. I then asked participants to consider and rank order

flashcards with issues important to Navajo stakeholders related to energy development. These options had been previously identified through a literature review and further defined after pre-testing the protocol with seven Navajo volunteers (Schoepfle, et al., 1983; Ruffing, 1976). The issues presented on the flashcards included: water, employment, environment, energy, cultural continuity (Navajo culture will continue to exist), political sovereignty (Navajo Nation will govern itself), and other (participant identified additional issue). The ranking ranged between 1 for the most important issue and 7 for the least important one (Necefer, et al., 2015). Following the Think Aloud Protocol (Ericsson and Simon, 1980), I also asked participants to describe what they were thinking, feeling, and doing while providing a working definition of what each issue meant to them as a member of their community.

Economy and energy projects. Next, I asked participants to describe how they use energy (such as electricity, propane, diesel, and gasoline) in their daily lives and where they thought this energy came from. We then asked about their views on energy projects (e.g., coal mining, coal power generation, oil and gas drilling, renewable energy) on the Nation as a whole and if they believed these types of projects produced jobs and revenue that benefited the Navajo people.

Environment and energy projects. I then asked participants about their thoughts on possible impacts from having energy projects on the reservation. First I asked about their views regarding land use impacts, their views on land remediation, and how Diné (Navajo) cultural teachings suggest people should relate to the land. Next I asked about their views on the effects of pollution and air emissions on soil, water, and air. Finally, II asked about their views in respect to the amount of water used by various types of energy development projects (e.g., coal mining and power generation, oil and gas operations, solar and wind installations).

Trust and energy projects. I asked participants about their views of the various energy-related stakeholders on the Nation, including the Navajo Nation Government, state (Arizona, New Mexico, and Utah) and federal governments, Navajo environmental non-governmental organizations (e.g., Black Mesa Water Coalition, Diné Care, etc.), and outside companies that operate on or near the Navajo Nation (e.g. Arizona Public Services, Peabody Western Coal Company, Resolute Oil and Gas etc.). I also asked if any of these stakeholders had ever provided them with information about energy projects or their impacts.

Energy project case study: Desert Rock Power Plant. Finally, I asked participants if they knew of any proposed energy project that was not built. For those who mentioned the Desert Rock Power Plant, I continued with questions about the project. For those who had not, I provided a brief description of what the project was – a coal power plant near Burnham, New Mexico - and I mentioned that there was opposition. I then asked why they thought this plant was not built and if this plant should have been built. Participants were further asked if they or their families would have been affected, in any way, by the construction and operation of this plant. Finally, I asked participants if they thought the Navajo Nation should consider another project like it.

At the end of the interview, I asked participants standard demographic questions, and questions about chapter affiliation, participation in traditional medicinal practices, if they or their family owned grazing rights, and if they or someone in their family worked in the energy industry. The protocol was pretested in April and May of 2012 with ten volunteers, seven from the Navajo Nation and three from Carnegie Mellon University. The complete interview protocol can be found in Necefer, et al., 2015. The final interviews took place between June and July 2013.

2.2.3. Participants

I recruited 20 Navajo individuals in Shiprock, NM, Farmington, NM, and Littlewater, NM, and Aneth, UT using snowball-sampling methods (Biernacki and Waldorf, 1981). I first contacted seven individuals, representing a range of social and economic backgrounds, who I knew through acquaintances from previous work in communities. After I interviewed these individuals, I asked them to recommend others who might be interested in participating in this study. Of the 20 participants, 55% were female. Most participants were between the ages of 25 and 54 (45%), followed by those over the age of 55 (30%), and then by those between the ages of 18 and 24 (25%). Our participants represented diverse occupations, with four working in the energy industry, two reporting Hatałii (Traditional Medicine Healers) as their primary employment, two working at the Indian Health Service, one working as an elected Navajo government official, one working at an environmental NGO, four educators, three students, and two who identified as unemployed. Participants were also diverse in where they lived, with individuals from Shiprock, NM, Aneth, UT, Red Valley, AZ, Two Grey Hills, NM, Burnham, NM, Littlewater, NM, and Farmington, NM.

2.3. Results

Participants most frequently mentioned Navajo culture or cultural resources (88 mentions, 100% of participants), and protection of environment and water (50 mentions, 90% of participants) when asked to describe what they "value most" about being a member of their community. Participants brought up other values including concern for future generations (17 mentions, 50% of participants), maintaining rural character (16 mentions, 55% of participants), education (11 mentions, 40% of participants), sovereignty (11 mentions, 45% of participants), and conservation (7 mentions, 20% of participants). When describing these values, participants

often talked about Diné teachings (*Hózhó* and *K'é*), explaining how such teachings guide the way that humans should relate to the natural world and each other.

2.3.1. Economy and energy projects

Views on the contribution of the development of energy resources to job creation on the Nation were mixed. Half of the participants reported that it increased employment (10 mentions - 50% of the participants) and some thought it decreased employment (5 mentions – 25% of participants), whereas some thought it contributed no more and no less to employment (5 mentions – 25% of participants). Some participants expressed concern over how working in the energy industry pulled people away from "traditional values."

We found participants to be relatively well informed about past energy resource management decisions and not opposed to future development *per se.* Rather, they were frustrated with the environmental impacts that large-scale developments of coal, uranium, and petroleum resources have had on the Navajo Nation. Despite high unemployment and the need for revenue, people's concerns about the environment were not allayed by the potential of economic gain from developing the Nation's energy resources. Indeed, some saw this type of development as "selfish" because it would leave a legacy of environmental degradation to be borne by future generations in exchange for uncertain short-term economic benefits. Developing technical decision tools that focus on employment and revenue could further erode trust and credibility of the Navajo Nation government and entities pursuing energy development.

Furthermore, the idea that energy development is good for the economy may not resonate with those whose livelihoods depend on livestock, agriculture, or medicinal practices. Land and water used for or contaminated by energy development could displace people from existing

economies through reduced access to grazing lands and medicinal herb gathering areas or reduced water flows that support ecosystems.

2.3.2. Environment and energy projects

In general, all participants were concerned about environmental impacts and consequent ill-health effects due to the development of energy resources (160 mentions – 100% of participants). Many attributed these impacts to the historic development of non-renewable resources (coal, uranium, oil and natural gas) on the Navajo Nation (147 mentions – 100% of participants), with some expressing the view that these impacts should preclude the future development of fossil fuel resources. With respect to the impacts on scarce water resources and grazing lands used for livestock, participants expressed concerns about both renewable resources - "I think a lot of folks probably at first would get angry about having solar farms covering lots of land" (Participant 8) - *and* non-renewable resources: "Peabody Coal Company that is pumping water through the slurry line to Page and all that. Lots of water moving the coal to Page, so that's probably what depleted the water table and all of that. So there is no more" (Participant 19) (65 mentions – 95% of participants).

As for land remediation, some participants viewed it as being positive with the possibility of returning land to its original state (6 mentions – 30% of participants), but many expressed doubt and concern about whether remediation was truly feasible (15 mentions - 70% of participants). Some expressed concern about lingering contamination from non-renewable resources such as coal, uranium, oil, and natural gas projects and pollution that would remain on the land making it unusable. Others expressed concern about the impacts of water pollution on their livestock, as well as on the quantity of water available (4 mentions, 20% of participants).

With respect to pollutant emissions and natural resource degradation and depletion, participants most often mentioned drought and water scarcity (35 mentions, 80% of participants). Many linked pollution and emissions to health problems such as cancer from past uranium mining and respiratory illnesses such as asthma, bronchitis, cancer, and respiratory infections from coal power generation (160 mentions, 100% of participants).

On balance, most participants supported using land for the development of renewable energy (15 mentions – 75% of participants), while only a few supported development of non-renewable energy (coal, oil, and natural gas) (4 mentions – 20% of participants). Moreover, water use was less of a concern for renewable energy (10 mentions – 50% participants) than for non-renewable resources (14 mentions – 60% participants). In many cases participants described the land and water impacts of oil and gas extraction, coal mining, and uranium mining on the Navajo Nation. Water seemed to be of particular importance, with participants describing its role in the interconnectedness between humans and nature in Diné teachings (Table 1)

Table 1: Total mentions of all codes organized by category.

Category and Code	Total Mentions	% Participants
Drought & water scarcity	35	80%
Climate & environmental change	25	75%
Resource depletion	11	35%
1 - Values		
Navajo culture & cultural resources	102	100%
Protection of environment & water	50	90%
Concern for future generations	21	50%
Rural character	19	65%
Sovereignty & political sovereignty	17	45%
Education	12	40%
Conservation	7	20%
2 - Diné Teachings		
Hózhó - K'é[a]	39	75%

1 - Access to running water & electricity		
No running water	20	60%
No electricity	10	35%
2 - Employment		
Energy Projects	46	80%
Employment - Navajo	10	40%
1 - Energy Resources		
Non-renewable resources	138	100%
Renewable resources	34	85%
2 - Energy Resource Impacts		
Concern for health & environment	180	100%
Concern about land & water use	68	90%
Pollution - Inevitable	4	20%
3 - Non-Navajo Companies		
Impacts on health & environment	29	65%

[a] In Navajo cultural worldview, *Hózhó* is understood to be the concept of maintaining a balanced relationship with the natural world and *K'é* describes the many interconnected relationships that exists in the universe. In this context, it is used to describe the interconnected relationship between humans and the environment and the duty of humans

When asked to rank order the value flashcards (Table 2), participants ranked environment (ENV), water (H2O), and cultural continuity (CUL) as being the most important to them and their community. Concerns about political sovereignty (SOV), energy (NRG), and employment (EMP) followed in order of importance. During this ranking exercise, participants also mentioned values such as education, family, and self-sufficiency.

Table 2: Frequency of rank order of importance using flashcards with topics related to energy resource management, including environment (ENV), water (H2O), cultural continuity (CUL), political sovereignty (SOV), energy (NRG) and others (ETC).

		Count						
	Rank	ENV	H2O	CUL	SOV	NRG	EMP	ETC
Importance Lower - Higher	1	6	4	4	2	2	2	2
	2	5	7	6	5	4	2	1
	3	6	4	4	2	5	5	1
	4	1	4	3	5	4	3	2
	5	1	0	2	2	3	5	2

6	1	0	0	3	0	0	1
7	0	0	0	0	0	2	0

2.4. Discussion

Several thematic patterns emerge from the interview data that have implications for energy development on the Nation. These are: (a) heterogeneity among Navajo in values, beliefs, and trust (b) views on the relationship between intergenerational equity, sustainability and Hózhó–K'é [the interconnected relationships between humans and the natural world (Farella, 1984)], (c) views on the relationship between environmental and human health, and (d) views on the need for reliable electricity.

Heterogeneity among Navajo in values and beliefs. Most participants see a definite lack of Diné teachings in Government policies and practices. Indeed, many feel that the Government does not make decisions according to the values and interests of the Navajo people but rather the financial interests of the energy companies or politicians. Furthermore, there is a perception that, in contrast to the Navajo people, the government values money above human and environmental health. Many participants questioned the competence of public officials, citing high levels of corruption, nepotism, and layers of bureaucracy:

> "Those politics people or the people that are in the Tribal Office, they should use it right. If they think of us people out here – they say it's the Navajo peoples' money, that's what I hear, and they say it belongs to the Navajo people – that's what they say. We need the money but they don't see it. I think they should ... spend the money wisely on the Navajo people, where the people need the money most. Nowadays we don't know who to trust" (Participant 14).

Many of participants believed this way of operating to be true for energy companies (e.g.,

petroleum, mining and utilities) as well, with many blaming them for pollution, ill-health effects, and environmental damage. Not surprisingly, some participants, namely those employed in the energy industry, shared a more nuanced view of current energy development on the Navajo Nation. All cited the lack of employment outside of the energy industry on the Navajo Nation and a desire to remain close to family posing a difficult choice for them. Many recognized the significant role that revenue from these operations has for the Navajo Nation for government coffers, scholarship programs, and employment. Yet, many, including those who were not aware of the revenue, worry about how these operations result in long-term environmental impacts that are not equivalent to the monetary gain:

> "Well it's great and all but I've worked in the coal mine and I see what happens. And the stuff we are put inside – the carbon dioxide, carbon monoxide, the resin, everything that we put into that mining we're putting it into the ground water. It goes past us – we're contaminating it so bad that people don't even realize it. We're affecting the economy right there, we're affecting that. You gotta think – is our royalties going solve that? Are the royalties going to fix that?" (Participant 20).

These results suggest that there may be differing views on energy development projects on the Nation, with those who directly benefit from energy operations, such as through employment, having more favorable views than those who benefit only indirectly. Negative views from those who do not directly benefit may improve if future energy projects have significantly less environmental impacts (e.g., water, land use, and pollution) and are motivated by goals of using energy resources for the long-term benefit of the Navajo Nation. There appears to be meaningful commonality among participants in the concerns about employment options and the environmental impacts of current energy development on the Navajo Nation. In addition,

participants do have similar attitudes in respect to Diné teachings about how the environment should be treated.

Greenberg (2014) suggests that in order to maintain of trust decision makers by the public, economic benefits to society need to be a significant part of decisions surrounding non-nuclear sources of energy. In this particular case many of the participants expressed distrust of the decision makers and entities that operated projects despite the significant revenue, employment, and scholarship money provided by them. A single negative event with regard to an energy system (e.g., a serious oil spill) can temporarily undermine public trust of energy decision makers and companies (Greenburg, 2014). In the instance of the Navajo Nation there have been multiple instances of both nuclear and non-nuclear events that could in part explain the levels of distrust expressed by a majority of the participants. Examples of nuclear events and mismanagement include: the Churchrock Mill Spill in 1979; thousands of abandoned uranium mines and associated uranium contamination (Brugge, 2002); and the displacement of 10,000 Navajos from coal rich and sacred land on the Black Mesa in 1974 (Kammer, 1987). Renewable sources of energy provide an opportunity for a less-polluting and more sustainable experience with energy resource management, though the continuation of past corruption and ineffective management practices could sour the potential for their acceptance.

Views on relationship between intergenerational equity, sustainability, and Hózhó–K'é. Many of the participants related the importance of preserving clean air, water and natural resources to meeting the needs of future generations. This commonality extended across stakeholder groups that included coal miners, oil and gas workers, NGOs, and government officials. Indeed, maintaining resources for future generations is the "duty" of current generations. Moreover, natural resources are also inextricably tied to Navajo culture and identity,

and the preservation of culture depends on the preservation of the environment. Expressing concern about resource depletion, one person said:

> "You don't own Mother Nature and you'll never own Mother Nature because of the fact that you are only here for a temporary amount of time and you should do your best to maintain it because there are other people who are going to come into this world. So don't be selfish with what you have" (Participant 6).

Participants also made frequent references to the earth and water as living, breathing beings, suggesting that they conceptualize the environment through the lens of K'é – the interconnected relationships between humans and the natural world (Farella, 1984). Participants expressed cultural identity through a reciprocal relationship that they have with the land described by Hózhó (Farella, 1984). In describing how the ethic of sustainable practices are established and maintained, one participant described the reciprocal relationship that a person should have with water:

> "In those days way back we used to go to a lake or somewhere to take the cows or sheep to the lake for them to drink. My grandpa used to go there and put an offering [of corn pollen to the water] there for the cattle to drink it. So that way there is more water coming for the animals to drink. Everything that we use in life – fire, water, and air – he used to do that, put offerings to it. That's how it won't hurt you back, he said. Some people nowadays they probably don't do that" (Participant 14).

Our participants expressed views on intergenerational environmental sustainability consistent with those of balance and interconnectedness described by Hózhó and K'é respectively (Tsosie, 2012; Farella, 1984). Many southwestern tribes, including the Navajo, share a belief that when they lose their land, their culture will end (Reno, 1981). Reno (1981), an

economist, argued that because extractive practices disrupt ecosystems and thus traditional economies that rely on those ecosystems, intensive resource extraction is equivalent to "losing the land" and thus represents a loss of culture. As one person said, "If we don't have a clean, stable environment, pretty much my culture would be non-existent" (Participant 7).

Participants expressed concern about the impact of development on the Nation, as well as its impacts on other communities and ecosystems. As one person stated:

> "It is important that we have clean air, and that is why we are working so hard to eliminate coal power plants so that four corners can have cleaner air. Not only for us, but for our children, grandchildren, not only for the Diné children but for all children. We all breathe the same air and we all care about our next generation" (Participant 16).

Participants were not opposed to energy development per se, but to the damage caused by specific types of development such as coal and uranium mining, and western worldviews of the earth's resources as economic commodities. One elected official said:

> "Well to me, the traditionalists' view point, is that the environment and the natural, and cultural setting of the people needs to be considered foremost and that development should follow and be done in such a way that it is at least done in a way that it doesn't upset or interfere with the natural order of things too much" (Participant 17).

These results suggest that energy development can occur on the Nation but should proceed in a manner consistent with and within the boundaries of Navajo cultural values (Vinje, 1985; Ruffing, 1976; Ellis, 1988). Renewable energy resources were seen as more favorable to stakeholders, yet they do not fully address the cultural concerns of maintaining land. Long-term environmental impacts of development and concern for the ability of future generations to live and use land long after a project has been retired directly tie into the cultural "duty" of

maintaining the environment. One coal miner described the importance of considering the long-term implications of renewable energy development both on the Navajo Nation and other communities:

> "If you break a solar panel, and just leave it, there are a lot of things in that panel that are considered hazardous. You got to ask yourself, what were the guidelines in building that panel? What was needed to make it? In the long run it's a good resource, but how much waste is it going to produce? You would need a lot of natural resources for all those panels to energize a whole town. You got to think, do you have enough resources to build all those. They're man-made; you got to think about where they come from and who[m] they're affecting" (Participant 20).

Consistent with these results, for most participants, concerns about the environment and water resources were more significant than the employment and revenue that could result from a project (Table 2). Employment and revenue was seen as important, but did not resonate with everyone. For some, these goals may actually conflict with cultural values of maintaining the land and water resources for generations to come: "Do we want to destroy the land, the air, the water, and everything because we want jobs? We want these big companies?" (Participant 19), and may be perceived as selfish of the current generation, "...you are only here for a temporary amount of time and you should do your best to maintain it because there are other people who are going to come into this world. So don't be selfish with what you have" (Participant 6).

Furthermore, the idea that energy development is good for the economy may not resonate with those whose livelihoods depend on livestock, agriculture, or medicinal practices. Land and water used for or contaminated by energy development could displace people from existing economies through reduced access to grazing lands and medicinal herb gathering areas or

reduced water flows that support ecosystems. One medicine woman explained how drilling has reduced land access and contamination has affected the quality of the herbs: “like when we go out to gather our herbs, they have all those oil companies that are drilling. And the contamination of whatever they are drilling up. Every place we went they are like blocking things off to where you don’t have access to things out there anymore. We see a lot of that. And then even the taste and the smell of the herbs, it changes all that too” (Participant 13). Similarly, one person mentioned how contamination of water resources has affected livestock saying, “I remember we used to go out and herd sheep, and when we did, there used to be probably five different places where you could get fresh well water and whatnot, and now those wells are all contaminated with all sorts of chemicals” (Participant 10).

Decentralized approaches, as opposed to large-scale projects, to energy development, focusing on providing energy for groups of households or communities could receive more support from stakeholders. Such an approach could allow for stakeholders in the community, who are more knowledgeable about the environment, to benefit more directly from a project and thus provide more meaningful contributions in the siting of a project. In addition, such approaches could also foster values of self-sufficiency.

Cultural identity and human health framed by relationship with the environment: All individuals expressed concern about the negative effects of energy development on the environment and human health. Many mentioned respiratory illnesses (e.g., asthma, difficulty breathing, and lung cancer) they believe to be caused by nearby coal power plants, petroleum operations, and prior uranium mining. Some expressed the belief that air and water pollution were significant drivers of increased diabetes and the need for kidney dialysis on the Navajo Nation. Many used symbolism to explain the relationship between environmental and human

health through the lens of Diné cultural teachings. As one person said, "I have heard some of my patients talk about how the land has been desecrated and how that is the reason why we are getting sick. Mother Earth has been cut open and a lot of her heart, like the coal, they say that has been removed. And damming up the rivers, that's why we have high blood pressure, because the water doesn't flow the way it is supposed to be. It's all because of these things" (Participant 19).

Participants also spoke of the role that traditional ceremonies, prayers, and tending to land and water play in maintaining a balanced relationship between humans and the environment (Hózhó). As one person said, "if we don't provide the necessary offering of prayers and songs, then it's not going to continue to be there for us" (Participant 7). Participants also raised the concern that all people, not just Navajo, no longer hold the environment sacred: "We take everything for granted now, nobody knows, they think when it rains it's just rain. The same way with the air that we breathe" (Participant 20). Participants mentioned that the behaviors that reflect a disconnect with nature have had very real repercussions for human health:

> "The earth, the sky, the air, the water, all this environment is given to us. The creator put it in our care, to use it, to take care of it. And what are we doing with it? We are messing it up. We are digging it up. We are making trash, we are polluting everything else. And it's back-firing on us. That's why we're having health problems. The old folks, my father was a medicine man, he used to say that in the long run whatever you do will eventually catch up with you" (Participant 15).

These results suggest that participants use the "cost" of past energy development (e.g., pollution and contamination and health impacts from coal and uranium mining) as an anchor for how they think about future development and new technology. Some participants also interpret the costs of energy development within the context of culturally informed perspectives of human

relationships to the environment. Concern was expressed about the manner in which society as a whole valued the environment and how this valuation led to significantly more damage to the ecosystem, which consequently had a significant impact on human health: "in the long run whatever you do will eventually catch up with you" (Participant 15). From the interviews, we see that these perspectives can inform a longer-term outlook of energy development on future generations.

Views on access to electricity. Many participants reported that they or someone they know lived without electricity at some point during their life either by choice or by circumstance. Somewhat surprisingly, most of these participants suggest that while electricity is a convenience, it is not a necessity. One person said, "we need running water, electricity, to be comfortable. But in the end when you look back on it, more people have lived this lifetime probably without electricity and running water" (Participant 10). Formal reports find that nearly one-third of Navajo households, or about 16,000 families, do not have electricity (representing three quarters of households in the U.S. without access to electricity). These homes have not been electrified for a number of reasons, including geographic isolation, economic barriers, and political and legal issues (Tarasi, et al., 2011). One participant, having recently obtained electricity, explained the reasoning behind her family's decision to live without electricity for many years:

> "With my mom and my dad, they always talked about how they grew up and, you know, how they got water, and they didn't have electricity and stuff. They wanted to give that same teaching to us so that we would understand and have more appreciation for the earth and, not just the earth itself, but everything like animals" (Participant 12).

Participants, while expressing some concern about impacts on grazing lands, saw land used for renewable resources as being acceptable for the purpose of supporting electrification

efforts. These attitudes reflect how some participants are willing to negotiate the tradeoffs being made when balancing cultural values and technological benefits that allow for electrification.

2.5. Conclusions

At hand is an opportunity for a type of energy development that moves the Navajo Nation toward a more socially and environmentally sustainable path. Successful energy resource management will depend upon the extent to which Navajo culture and values can be integrated with advances in energy technology in a participatory process that is well informed by both. Technical modeling efforts can be a useful step in assessing the direction of these different pathways, though without proper incorporation of social and cultural aspects they can fail to be effective and representative (Jefferson, 2014). Cultural values are significant and drive people's preferences about energy resource management decisions and energy use. Understanding these values prior to developing technical models can provide useful insights into their development, such as exclusions of certain technologies, emphasis on certain environmental impacts, and the necessary timeframes needed to understand intergenerational impacts. Likewise, this knowledge can provide a clearer understanding of the reasons for individual energy use patterns and factors that otherwise would not be fully captured by information such as demographic data (Sovacool, 2014; Lutzenhiser, 1992).

Modeling exercises in this context should connect the implications of energy development and subsequent impacts on cultural and environmental resources now and for multiple generations in the future (e.g., hundreds of years into the future). For example, connecting water use and land transformation to impacts on sacred sites and medicinal herbs may be helpful in addressing concerns about the environment and impacts on future generations expressed by the participants. A significant challenge to this approach is the increasing degree of

uncertainty that is introduced by assessing large timescales within these technical models. Despite this challenge, it is important to attempt to model, either qualitatively or quantitatively, the range of potential impacts over these timeframes (e.g., 100–200 years). Including these timeframes within technical models will ensure that cultural perspectives on environmental impacts are maintained despite the challenges they pose to convenience and accuracy of the analysis. Ensuring that these cultural norms are included within technical decision tools could also have meaningful implications for efforts to reduce energy consumption or adopt renewable energy as individuals could feel morally obliged to do so even if it is more costly or involves tradeoffs such as intermittency (van der Werff, 2015).

In this study the views toward variability and costs of specific energy technologies were not explicitly considered, although a number of participants expressed the view of electricity as a luxury. This, combined with cultural values that emphasize environmental protection and spiritual connections with land, suggest that variability in sunlight or wind resources may not be seen as significant an inconvenience to some Navajo citizens as might be the case in other parts of the U.S. The perception of electricity as a luxury instead of a necessity deserves further research so as to better understand the trade-offs Navajos may be willing to accept. Determining whether and how this view might shift among those that are serviced by a more reliable electricity supply will also be important in this analysis (Trentmann, 2009). A greater tolerance for intermittency could, however, result in softer constraints placed on meeting certain types of electrical demands within technical models.

Our findings suggest that energy development that minimizes land transformation and water consumption might be an especially fruitful option for energy resource management on the Navajo Nation. Certain spiritual relationships with the land must be maintained in order to

maintain a larger balance in the Earth's ecosystem. For example, the production and use of some energy resources do not coincide with these beliefs (e.g., coal and uranium). Although people expressed positive opinions about renewable energy, any such development resulting in dramatic transformations or degradation (e.g., large windmill farms or arrays of solar collectors) may reduce support for renewables. Distributed, small-scale systems could be a way forward by providing clean energy with minimal land impacts. The implications of this are that the Navajo public may be receptive to renewable and/or decentralized electricity generation, especially if it is connected in a meaningful way to cultural values. Furthermore, if the Navajo government is interested in increasing electrification, they should consider how various electricity generating technologies, both grid connected and decentralized, could be appropriately integrated into the Navajo way of life. Neglecting these considerations could increase both passive and active resistance of communities to both new energy development and the expansion of electricity supply.

We found participants to be relatively well informed about past energy resource management decisions and not opposed to future development per se. Rather, they were frustrated with the environmental impacts that large-scale developments of coal, uranium, and petroleum resources have had on the Navajo Nation. Despite high unemployment and the need for revenue, people's concerns about the environment were not allayed by the potential of economic gain from developing the Nation's energy resources. Indeed, some saw this type of development as "selfish" because it would leave a legacy of environmental degradation to be borne by future generations in exchange for uncertain short-term economic benefits. Developing technical decision tools that focus on employment and revenue could further erode trust and credibility of the Navajo Nation government and entities pursuing energy development.

This study has a number of limitations including its small sample size from one Agency within the Navajo Nation. This constraint does not allow us to generalize our findings to the rest of the Navajo Nation. This study was geographically limited due to restrictions from the Navajo Nation Health Research Review Board, which requires local Navajo Agencies to pass a resolution of support for any fieldwork in their jurisdiction. The small sample size is reflective of the difficultly of conducting human subject research work in indigenous communities, as detailed in Brugge and Missaghian (2006). As a result of this constraint participants came from one Agency region of the Navajo Nation where significant energy resource development is located and consequently the views of participants living in regions without energy development may not be represented in the present study. Despite the difficulties of conducting interviews on the Navajo Nation, these challenges will likely be lessened in the future as tribal universities on the Navajo Nation (in particular, Diné College and Navajo Technical University) are in the process of implementing institutional research review boards to circumvent intensive tribal research review processes for non-health related human subject research. Further, while we deployed our interview protocol in this limited area, it could further be used as a tool to understand stakeholder values in a process of participatory energy development across the Navajo Nation and in other communities.

3. Development of decision tool for energy resource management with cultural values

3.1. Introduction

Decision-making surrounding pathways of future energy resource management are rife with complexity and tradeoffs. One way to facilitate such decision making is to ensure that stakeholders are well informed about the benefits, risks and uncertainties of options so that they can make decisions that are consistent with their preferences and values (Braddock III, et al., 1999; Fischhoff, 2013). Successful resource management plans will require both short- and long-term perspectives that involve input from a broad range of stakeholders, concerns and disciplines (Fernald, 2012). Toward this goal, it is of critical importance that the information and criteria used to assess the risks and benefits of available decision options are made available and are usable by a range of stakeholders (Wong-Parodi, et al., 2014).

Decision aids have been shown to help laypeople make informed decisions across a range of domains such as such as health, consumer preferences, natural resource management, and climate change (Fischoff, et al., 2011; Häubl & Trifts, 2000; Mayer, et al., 2014; Wong-Parodi, et al., 2013; Tidwell, 2004). Health-related decision-support information has been found to increase knowledge, lower decisional conflict related to feeling uninformed, and reduced the proportion of individuals who remained undecided after an intervention (O'Conner, et al., 2009). Previous studies on decision aids for lay users on energy resource management have focused on respondents creating electricity portfolios to meet low-carbon goals and facilitating dialogue between stakeholders with different idealized energy futures (Mayer, et al., 2014; Trutnevyte, et al., 2013). The tool developed by Mayer, et al., 2014 presented information about CO_2 emissions, electricity and health costs, and land and water impacts. Initial usability studies found that the tool encouraged participants to design diverse portfolios and enabled the public to make

more informed decisions about technologies used for a low carbon portfolio (Mayer, et al., 2014). Trutnevyte, et al. (2013) used stakeholder visions of an idealized energy system to develop energy scenarios with analytical outcomes with multi-criteria assessment of outcomes associated with these visions. As a result of this process most of the involved stakeholders adjusted their initial visions to more economically viable alternatives (Trutnevyte, et al., 2013).

Ensuring that decision aids are adapted to unique cultural contexts has the potential to increase trust and promote understanding of the tradeoffs involved in energy resource management. Inclusion of attitudes, beliefs, and preferences of those who are managing or depending on the resources can engender trust and understanding around decisions potentially increasing chances of success (Lynam, et al., 2007; Ramirez, 1999). For example, tools and information that communicate impacts on cultural resources and spiritual outcomes of interest can ensure that decision makers within these contexts are provided sufficient information to make informed decisions consistent with their values. These connections and outcomes are of particular interest to many indigenous communities where cultural and spiritual values are tied to the environment and may differ significantly from the larger societies in which they reside (Turner-Ruffing, 1976; Heinrich, et al., 1998).

Quantifying cultural and environmental impacts of energy resource development by monetizing these outcomes may be incompatible with certain cultural values (Necefer, et al., 2015; Schoepfle, et al., 1983). We provide an alternative to economic valuation based on willingness-to-pay or related monetization methods by connecting impacts on Navajo cultural resources to environmental impacts that affect them, and creating an ordinal index to reflect the relative magnitude of cultural loss. Additionally, some indigenous groups may not view energy resources as strictly economic commodities, but instead as culturally and/or spiritually

significant resources that must be left undisturbed and undiminished for future generations (Pemberton, 1985; Campbell, 1987; Jett, 1992; Stoffle, et al., 1988). Focusing solely upon economic and environmental outcomes, in these contexts, may not address all of a community's concerns and may be secondary to these cultural and spiritual outcomes (Jett, 1992; Pemberton, 1985).

In this chapter I detail the development of an energy development decision aid for the Navajo Nation for the purpose of informing decision making that is reflective of available technical options, economic constraints, and cultural values. I designed the aid to be realistic and representative of potential paths for energy resource management for the Navajo Nation for electricity and natural gas production. These paths have been developed based upon proposed and current projects for electricity and natural gas generation and distribution supported by the Navajo Tribal Utility Authority (NTUA), the Navajo Nation government, and the Department of Energy's Office of Indian Energy. The design of the internet-based aid was developed from previous research on the Navajo Nation that used open-ended interviews and a survey to understand Navajo values and beliefs about energy (Necefer, et al., 2015; Schoepfle, et al., 1983). Based upon these interviews I developed a decision aid that provides environmental, economic and cultural impacts deemed important by the Navajo public.

In the following section, I describe the methods including the development of the energy decision aid and its underlying assumptions for alternative energy projects and their impacts. Then, I present the results of nine energy development scenarios involving increasing amounts and mixes of fossil fuel and renewable energy development. Finally, I discuss the implications and value of developing a decision aid that includes cultural impacts. First, however, I provide a

brief overview of the importance of including non-monetized cultural impacts in a development decision aid.

3.2. Cultural Resources & Environmental Impacts

Navajo stakeholders expressed significant concern about intergenerational environmental impacts and the effect that these could have on cultural resources and transmissions of cultural values to future generations (Necefer, et al., 2015; Schoepfle, et al., 1983). Scholars have noted that any impact on the environment could be interpreted as a direct impact on culture (Reno, 1981; Schoepfle, et al., 1983). Water withdrawals and consumption can have significant impacts on cultural resources (e.g. agriculture, livestock, and medicinal practices) by impacting both surface and ground water resources (Thomas & Truini, 2000; Brown & Eychaner, 1998). Land transformation can disrupt ecosystems and cultural resources (e.g. scared sites) and the traditional economies dependent upon them (Reno, 1981). Climate change impacts, caused by greenhouse gas emissions, are believed by many to have already had significant impacts on the Navajo Nation. These effects include the movement of plants and animals to higher altitudes and latitudes, increased sand dune migration, increased drought and wildfires, and other impacts on water resources (Redsteer, et al. 2012; Cozetto, et al. 2013). These impacts have had a detrimental outcome for traditional Navajo economies such as grazing and medicinal herbs that rely on these natural systems (Lynn, et al., 2013; Vogesser, et al., 2013).

3.3. Methods

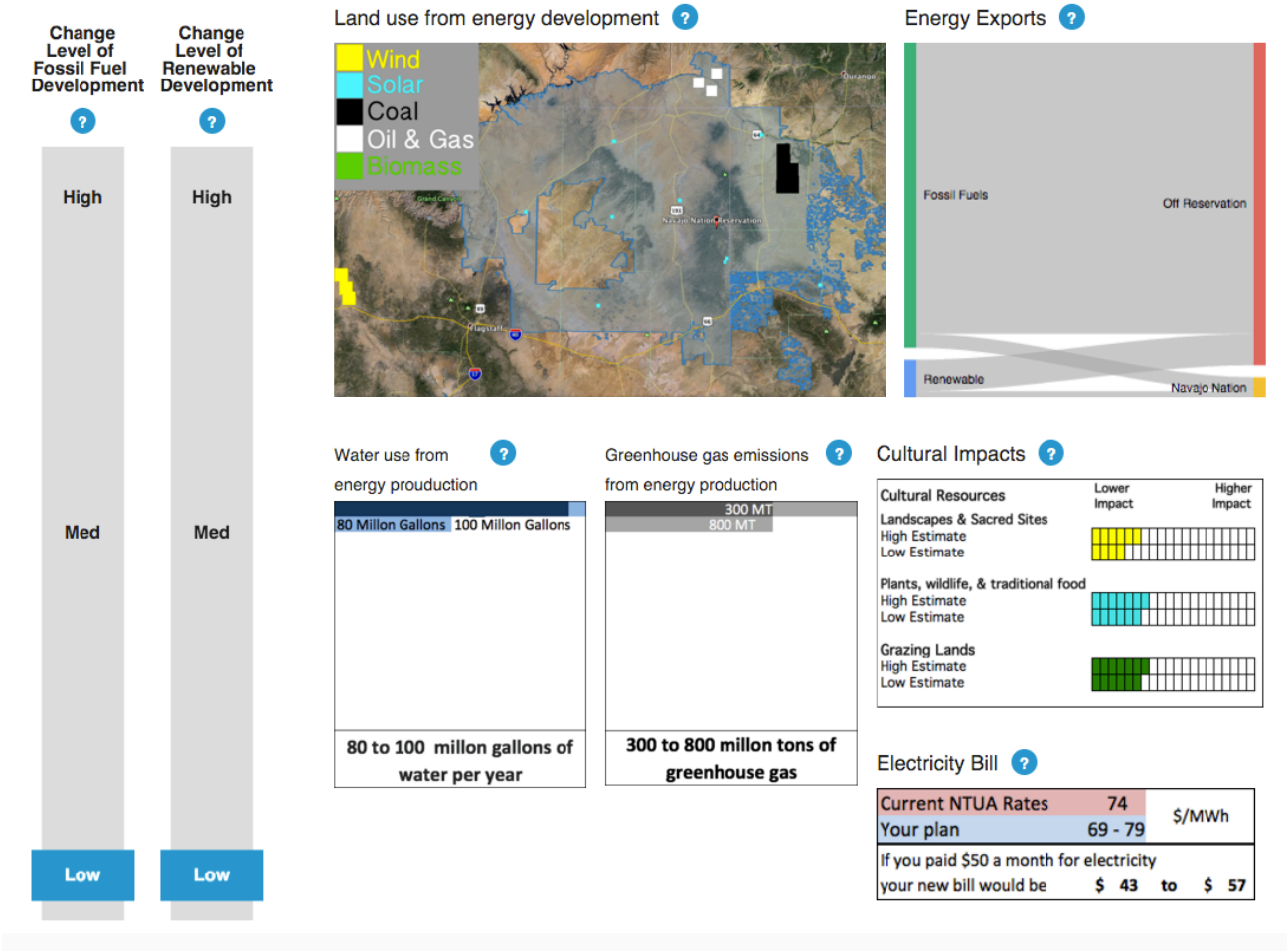
3.3.1. Energy Development Decision Aid

Simple decision aids that provide easily understandable and needed information have been shown to garner more realistic expectations about decision-related outcomes and greater agreement between values and choices when compared to the use of more complex decision aids

(O'Connor, et al., 2009; Murray, et al., 2001; Downs, et al., 2004; Haubl & Trifts, 2004). Indeed, overly complex and detailed aids may overwhelm users with too much technical information leading to cognitive overload (O'Connor, et al., 2009) or resulting in greater vulnerability to framing effects (Kahneman, 2011).

Following Wong-Parodi et al.'s (2014) guidelines for developing usable decision aids, I developed a simple web-based energy development interface and decision aid. This aid allows users to adjust the level of development of: (1) renewable resources (low, medium, and high) and (2) fossil fuel resources on the Navajo Nation (low, medium, and high) for a total of nine possible scenarios (Figure 1). The imbedded scenarios in the decision aid were designed to meet current on-grid demand and increasing levels of electricity service for homes not connected to the grid on the Navajo Nation – estimated to be 18,000 homes or 38% of all homes on the reservation (Begay-Campbell, 2005). I assume full electrification only for the 3 "high" renewable scenarios due to the significant costs of providing all homes with electricity – estimates are upward of $300 million for distributed solar units (Begay-Campbell, 2005). Electricity generated in excess of on-grid demand are considered export and sold off the Navajo Nation. Associated with each of these scenarios are estimated environmental (e.g., land transformation, air pollution, water use, water quality, etc.), economic (e.g., cost of electricity, exported electricity, etc.) and cultural outcomes (e.g., landscapes & sacred sites; plants, animals,

traditional food & medicine; grazing lands).



Information Categories	Outcomes displayed to users
(1) Environmental Impacts	• Land Transformation • Water Consumption • GHG Emissions
(2) Economic Outcomes	• Estimated Utility Bill • Energy sales on and off the Navajo Nation
(3) Cultural Impact Categories	• Landscapes & Sacred Sites • Plants, wildlife, and traditional food & medicine • Grazing Lands

Figure 1: Screenshot of the energy development decision aid. In this case the aid shows results for a medium level of fossil fuel development and a low level of renewable development. Impacts associated with decision aid scenarios

Through an iterative process, I performed in-person user testing of the decision aid with 16 volunteers between May and June of 2015. User-testing was performed using the Think Aloud Protocol (Ericsson and Simon, 1980) where people were asked to express what they were thinking, doing and feeling as they walked through the aid. Participants represented the following backgrounds: 16 participants from the Navajo Nation, five Carnegie Mellon University graduate students, four American Indian (non-Navajo) graduate students focusing on American Indian Energy issues or technical fields such as engineering, and one program manager in the Department of Energy's Office of Indian Energy. From this pretesting I found that visual representation of cultural outcomes from "least impact" to "most impact" was more informative and easier to understand versus displayed text describing the impacts. I found that displaying water consumption visually with text showing the values in both acre-feet and gallons helped participants better understand the differences between the nine scenarios.

3.3.2. Scenario development

I developed nine scenarios for the energy development decision aid: (1) low renewable energy (RE) – low fossil fuel (FF), (2) low RE – med FF, (3) low RE – high FF, (4) med RE – low FF, (5) med RE – med FF, (6) med RE – high FF, (7) high RE – low FF, (8) high RE – med FF, (9) high RE – high FF (Table 3). In the next section I discuss the underlying data and assumptions for the three levels of renewables (section 2.1.1) and fossil fuels (section 2.1.2) development on the Navajo Nation.

3.3.2.1. Three levels of renewable energy development on the Navajo Nation

The Navajo Nation has significant wind and solar resources as well as biomass potential located on tribal land; additionally, there is significant regional transmission capacity available (Acker, 2007; Williams, et al. 2008). Large-scale renewable energy projects on the Navajo

Nation will be built primarily on reclaimed mining land or tribal-fee land as opposed to tribal trust land. Tribal trust land on the Navajo Nation often has competing land use claims such as animal grazing permits that can often compete with other types of land use (Pasqualetti, 2011; Wood, 1995). Reclaimed mining land and tribal fee land, private land purchased by the tribe, often has much fewer land use claims and likely will face less opposition (Pasqualetti, 2011; Pasuqeletti, et al. 2015).

- **Low development** for renewables represents the status quo of renewable energy projects across the reservation. Many projects will be small-scale demonstration projects or installations to meet off grid electricity demand
- **Medium development** is low development plus additional capacity by building renewable resources on existing tribal-fee land and tribal trust land.
- **High development** builds upon the medium development scenario plus significant solar generating capacity through the solar thermal augmentation of the coal fired Four Corners Power Plant.

A. Building Wind Generation Capacity

Future capacity:

Big Boquillas & Grey Mountain Wind Projects (85 MW & 200 MW): Two sites on the Navajo Nation have been proposed for wind resource development. The proposed Big Boquillas project is a two-phase wind project on tribal fee-land owned by the Navajo Nation where the initial phases of project development have begun (Hurlbut, et al., 2012; Ackerman, et al., 2014). Grey Mountain is located on tribal trust land and holds significant wind resource potential (Brummels, et al., 2006; Acker, et al., 2007).

- Low development includes the first phase of the Big Boquillas Wind Project (85 MW).
- Medium development includes the first phases of the Grey Mountain (85 MW) and Big Boquillas (200 MW) Wind Projects (285 MW total).
- High development includes the first and second phases of the Grey Mountain (285 MW) and Big Boquillas (285 MW) Wind Projects (570 MW total).

B. Building Solar Generation Capacity

Current Capacity:

Solar Installations at NTUA Offices (245 kW) & UMTRA Tuba City Site (200 kW):

Currently, large solar installations on the Navajo Nation are limited to seven, 35 kW installations at tribal utility offices and a one 200 kW installation at a former uranium mill superfund site located near Tuba City, AZ (Gil, et al., 2012).

Off-grid solar installations across the Navajo Nation: Currently NTUA leases a combination of 980 W and 1,080 W solar PV systems to around 300 homes located off the grid (Begay-Campbell, 2005).

Future capacity:

Off-grid solar installations across the Navajo Nation:

- Low development assumes that the number of homes with 1,080W systems remains constant at 300.
- Medium development assumes that the number of homes with these systems or connected to the grid is expanded to 3,000 homes (1,500 Solar PV and 1,500 Grid Extension).

- High development assumes that all 16,000 homes off grid are electrified (8,000 Solar PV and 8,000 Grid Extension).

Paragon – Bisti Range Solar Project (100 MW & 500 MW): The Paragon – Bisti Ranch, located on Navajo tribal-fee land in northwestern New Mexico, has been identified as a potential site for developing large-scale of Solar PV capacity (Navajo Hopi Land Commission, 2014; DOE-TEP, 2013).

- Medium development assumes 100MW of solar PV capacity is constructed.
- High development assumes a total site build out of 500MW of solar PV.

Tohajilee Solar Project (55 MW): The Tohajilee solar project is a proposed 55 MW utility scale solar PV installation on tribal trust land (Burpo, 2012; Apache & MacCourt, 2014).

- Medium development assumes 55 MW of solar PV from the project.
- High development assumes 55 MW of solar PV.

Chevron Mine Solar Project (60 MW): The former McKinley Coal Mine located on near Window Rock, Arizona is a potential site for solar development on tribal trust land (Hurlbut, et al., 2012).

- Medium development assumes 60 MW of solar PV at the site.
- High development assumes 60 MW solar PV.

Iyanbito Solar (40 MW): The Iyanbito Chapter located in west-central New Mexico is developing commercial scale solar PV on tribal trust land (Woods, 2013; Hurlbut, et al., 2012).

- High development assumes 40 MW solar PV

Solar Thermal Augmentation at Four Corners Power Plant (250 MW): The Four Corners Power Plant is slated to shut down two boilers as part of an alternative emissions reduction plan (OSMRE, 2014; Hurlbut, et al., 2013). The boilers could be repurposed with solar thermal generation.

- High development assumes 250MW of solar thermal augmentation of the existing Four Corners' boilers.

C. Building the three levels of biomass capacity

Future Capacity:

NTUA Chevron Biomass (20 MW): The NTUA Chevron Biomass power plant is a proposed project that will use a former saw mill in Navajo, NM to generate electricity from the clearing of underbrush and beetle-infected timber (Hurlbut, et al., 2012). This project is located on reservation trust land and will require the expansion of transmission capacity.

- High development assumes the construction of a 20MW biomass generation facility.

D. Geothermal and hydropower capacity

Current Capacity: The Navajo Tribal Utility Authority currently purchases 62MW of electricity generating capacity from the Western Area Power Authority's hydropower tribal allotment to meet a significant portion of the electricity demand on the Navajo Nation (NTUA, 2009).

- Varying capacity purchased is included within each of these scenarios as "electricity purchased from off the reservation."

Future capacity: The Navajo Nation lacks significant proven geothermal and hydropower resources available for commercial production of electricity (USGS, 2008; Hulbert, 2013; New Mexico EMNRD, 2004).

3.3.2.2. Electrical grid storage capacity

I assume that each 1,000 W off-grid solar system have 795 aH storage capacity. Solar panel sizing and battery storage capacities for off-grid residential solar systems were obtained from NTUA's supplier of off-grid energy systems (Sacred Power, 2014). Larger on-grid storage was assumed to be required when renewable generation exceeded 30% of total generation (Table 2).

3.3.2.3. Three levels of fossil fuel development on the Navajo Nation

Fossil fuel resources, specifically coal, petroleum, and uranium have been a significant source of revenue and employment for the Navajo Nation as well as providing electricity, fuel, and nuclear weapons materials for the United States (NNDED, 2009; Brugge & Goble, 2002; McPherson & Wolff, 1997). The Navajo Nation holds significant low-sulfur coal reserves and currently supplies two coal power plants on tribal land (NNDED, 2009). In addition, there are significant oil and natural gas reserves (NNDED, 2009; McPherson & Wolff, 1997). Increasingly stringent emissions regulations for criteria pollutants have led to the closure of coal fired boilers at both of the coal power plants located on the Navajo Nation (EPA, 2015) (Table 3).

- **Low development:** The Four Corners Power Plant will keep two of five boilers in operation for a total capacity of 1,540 MW. In this scenario the second coal power plant, the Navajo Generating Station, will be retired early.

- **Medium development:** This development scenario assumes that both coal power plants will continue to operate with reduced capacity to meet emissions requirements. 200 MW of natural gas generation will be constructed.
- **High development:** Building upon the medium development scenario, the high development adds an additional 1,500 MW of an Integrated Gasification Combined Cycle (IGCC) coal power plant with carbon capture and sequestration technology and a total of 400 MW of natural gas generation.

A. Fossil Fuel Electricity Generation

Four Corners Power Plant (FCPP): Currently this is a coal-fired power plant located on reservation and is served by a Navajo-owned mine (NNDED, 2009).

- Low development assumes a coal generation capacity of 1540 MW
- Medium Development assumes a coal generation capacity of 1540 MW and 200 MW Natural Gas Generation
- High Development assumes a coal generation capacity of 1540 MW and 400 MW Natural Gas Generation

Navajo Generating Station (NGS): Located near Page, AZ, NGS, is a coal-fired power plant that is supplied coal from a non-Navajo owned on the Navajo Nation (Hulbert, et al., 2012).

- Low development assumes early retirement of the plant
- Medium Development assumes closure of one boiler and continued operation of the remaining two boilers – 1500MW
- High Development assumes one boiler closure and continued operation of remaining two boilers – 1500MW

Desert Rock Coal Power Plant: The Desert Rock Power Plant was a proposed 1,500 MW coal-fired, dry cooling power plant located near Burnham, NM (NNDED, 2009; Powell & Curley, 2008).

- High Development assumes the construction of a coal Integrated Gasification Combined Cycle (IGCC) power plant with carbon capture and sequestration emissions technology (50% capture).

B. Petroleum and Natural Gas Production

I consider petroleum and natural gas production to meet the internal demands for the commercial, residential, and industrial sectors on the Navajo Nation. Currently NTUA serves around 10,000 residential customers with natural gas service or 25% of the Navajo Nation (NTUA, 2009). Propane is the primary source of energy for cooking and refrigeration in homes not serviced by natural gas (NNDED, 2009). For these homes I assume energy consumption values for cooking and water heating from the 2014 RECS survey (EIA, 2015). In addition, I include natural gas production to meet demands from a 200 MW and 400 MW natural gas power plant (EIA, 2015).

- **Low development:** 1% growth rate in demand for the entire residential sector and 0.9% growth rate for the commercial sector based upon growth assumptions by the Navajo Tribal Utility Authority (NTUA, 2012).
- **Medium Development:** Low development demand growth projections plus increases in natural gas production to meet the demand of a 200 MW natural gas power plant.
- **High Development:** Low development demand growth projections plus increases in natural gas production to meet the demand of a 400 MW power plant.

C. ***Uranium mining and nuclear power not considered***

The Navajo Nation banned all future uranium mining, milling, and nuclear power generation across the Navajo Nation in 2006 in response to negligent business practices including thousands of abandoned mines, contaminated water resources, and even large scale radioactive releases (Brugge & Goble, 2009; Dawson & Madsen, 2011; Eichstaedt, 1994). These are assumed to play no role in future energy development.

Table 3: Summary of the renewable and fossil fuel capacities at within each of the 9 scenarios. Colors denote type of energy resource: Biomass (green), Coal (grey), natural gas (pink), natural gas production (orange), wind (turquoise), solar (yellow), storage (white)

Low				Medium				High			
Renewable		**Fossil**		**Renewable**		**Fossil**		**Renewable**		**Fossil**	
Wind	85 MW	Coal	1540 MW	Wind	285 MW	Coal	3040 MW	Wind	450 MW	Coal	4540 MW
Solar	0.80 MW	Nat Gas Prod	1.75 MMCF	Solar	216 MW	Nat. Gas	200 MW	Solar	922 MW	Nat. Gas	400 MW
Storage	0.12 kWh			Storage	44.6 kWh	Nat Gas Prod	13.5 MMCF	Biomass	20 MW	Nat Gas Prod	25.2 MMCF
								Storage	2466 kWh		

3.3.2.4. Current electricity mix and demand

On grid: I use a demand estimate of on-grid electricity demands in 2030 based upon the tribal utility's assumed growth factor of 2% per year, to allocate generated electricity (NTUA,2009). Currently the Navajo Tribal Utility Authority purchases generation capacity from surrounding utilities and coops (coal & natural gas) as well as hydropower from the Western Area Power Authority to meet on grid demands (Watchman, 2008). Tribes, such as the Navajo Nation, have the ability to purchase their own electricity through tribal utilities or regulate the electricity generation and sales within their lands (LeBeau, 2001). The lowest development scenario assumes that a majority of electricity is purchased from off the Navajo Nation.

Increasing development of both fossil and renewable resources on the reservation decreases the amount of purchased electricity in the medium and high scenarios (Table 4).

Off-grid: A significant portion of homes in the Navajo Nation are not connected to the grid (18,000 or 38% of all homes on the Navajo Nation). I calculate off-grid electrical and propane demands assuming appropriate sized solar systems are deployed to the portion of homes that remain off-grid and that the homes connected to the grid are incorporated into the overall energy demand for the Navajo Nation (EIA, 2015). Electrification of off grid homes occurs with increasing development of renewable resources as many of these homes are located far from existing transmission and will be served by distributed solar systems (NTUA, 2009). Electrification of all off-grid homes occurs only in the highest renewable resource scenario. (Table 4).

Table 4: Sources of electricity for the Navajo Nation assumed within the nine scenarios of the energy development decision aid. Moving from low to high for the renewable energy and fossil fuel scenarios increases the proportion of renewable energy or fossil fuel derived electricity consumed on the Navajo Nation. In addition, increasing levels of energy development also minimizes the amount of electricity purchased from off the reservation. Colors denote type of energy resource: Solar (yellow), Wind (Turquoise), Hydro (Dark Blue), Coal (Grey), Natural Gas (Magenta), and Biomass (Green).

		Renewable Energy Scenario					
		Low		Medium		High	
		On reservation	Off reservation	On reservation	Off reservation	On reservation	Off reservation
Fossil Fuel	Low	Solar <1%	Coal 42%	Solar 17.2%	Coal 27.2%	Solar 25%	Coal 10%
		300 homes electrified	N. Gas 10%	3,000 homes electrified	N. Gas 6.6%	18,000 homes electrified	N. Gas 5%
			Hydro 48%	Wind 17.2%	Hydro 31.5%	Wind 30%	Hydro 20%
						Bio 10%	
	Medium	On reservation	Off reservation	On reservation	Off reservation	On reservation	Off reservation
		Solar <1%	Coal 25.2%	Solar 17.2%	Coal 12.6%	Solar 25%	Coal 2.5%
		300 homes electrified	N. Gas 6%	3,000 homes electrified	N. Gas 3%	18,000 homes electrified	N. Gas 2.5%
		Coal 17.5%	Hydro 28.8%	Wind 17.2%	Hydro 14.4%	Wind 25%	Hydro 10%

	N.Gas 17.5%		Coal 17.5% N. Gas 17.5%		Coal 15% N.Gas 15% Bio 5%	
High	**On reservation**	**Off reservation**	**On reservation**	**Off reservation**	**On reservation**	**Off reservation**
	Solar <1% 300 homes electrified Coal 45% N. Gas 45%	Coal 1.5% N. Gas 0.5% Hydro 2.4%	Solar 15% 3,000 homes electrified Wind 15% Coal 32.5% N. Gas 32.5%	Coal 1.5% N. Gas 0.5% Hydro 2.4%	Solar 22.5% 18,000 homes electrified Wind 22.5% Coal 25% N. Gas 25% Biomass 5%	

3.3.3. Impacts associated with the nine energy development scenarios

3.3.3.1. Environmental Impacts

A. Land Use & Transformation

I estimated the land required to produce electricity from conventional and renewable-energy options based upon the lifecycle assessment inventory from Fthenakis & Kim, 2009. Here I considered ***only*** direct land use transformations on the Navajo Nation (e.g., construction of plants and supporting infrastructure) and not indirect ones (e.g., obtaining raw materials) (Fthenakis & Kim, 2009). I provide information to users in the tool about land occupation and time required for land to return to its original state after being transformed (Scholz, 2007). Our resulting estimates for the amount of land used are shown in Table 19 - Appendix 3 and summarized below:

- Coal and Natural Gas: Coal power generation considers mining, power generation and waste disposal (Fthenakis & Kim, 2009). Natural gas fuel cycle involves the extraction, refining, transportation, storage, and then electricity generation (Fthenakis & Kim, 2009).
- Solar Photovoltaic & Concentrating Solar: Land transformation within the Solar PV lifecycle includes material acquisition, panel production, operation and maintenance, and

material disposal (Fthenakis & Kim, 2009). I assume solar insulation rates of ~2,400 KWh/m^2/year, typical of the southwest United States, total system efficiency of 10.6%, a packing factor of 2.5, and a project lifetime of 30 years (Table 15 -

- Appendix 3) (Fthenakis & Kim, 2009).
- Wind: The land transformation is estimated based upon land use of two rows of 25 turbines separated by 2.5 rotor diameters between turbines and 20 rotor diameters between rows, with an overall plant capacity factor of 0.3 (Table 15 -
- Appendix 3) (Fthenakis & Kim, 2009). This particular land use requirement can vary significantly depending on the spacing, configuration, and site-specific factors (DOE, 1997)
- Biomass: I assume that the biomass electricity plant employs direct fire to burn the woody materials obtained from underbrush clearing on the Navajo Nation (Fthenakis & Kim, 2009).
- Storage: I do not calculate land use directly for grid electrical storage, assuming that land use for battery storage will accompany that of renewable energy projects.

B. Water consumption

Stakeholders expressed concern about water not being returned to its source from energy development, therefore I track the consumptive use of water for each of the nine scenarios. Water consumption factors for electricity generating technologies were obtained from Macknick, et al., 2011 (Table 1.

C. Greenhouse gas emissions

Emissions from electricity generation are of significant concern to the public and policy makers when deciding which resources should be developed. Greenhouse gas emissions from electrical power generation represent a significant portion of total emissions in the United States and also contribute to climate change. I provide information about total greenhouse gas emissions for each of the nine scenarios in the decision aid. I use lifecycle greenhouse gas emissions values for electricity generation provided by Burkhardy, et al., 2012 and Whitaker, et al. 2012 (Table 21 -

Appendix 3)In addition, I sourced and included lifecycle greenhouse gas emissions for natural gas and petroleum production from Burnham, et al., 2011.

3.3.4. Economic Outcomes

I display projected utility bills and also information about energy exports off the reservation. I assume discrete levels of renewable and fossil fuel sourced electricity within each scenario to calculate the utility bill (Table 22 -

Appendix 3: Environmental impact values and calculation of cultural impact index for chapter 3). Moving from low to high for the renewable energy and fossil fuel scenarios increases the portion of renewable energy or fossil fuel derived electricity consumed on the Navajo Nation (Table 4). In addition, increasing the levels of energy development also minimizes the amount of electricity purchased from off the reservation. The provided utility bill provides a comparison of cost for a $100 utility bill under current NTUA rates ($0.073 per kWh) and the projected costs with the scenario chosen by the users (NTUA, 2009). A difference in costs is also displayed. The cost of electricity was calculated based upon expected annual generation using capacity factors and projected prices of electricity from the 2015 EIA Annual Energy Outlook and NREL (Table 22 -

Appendix 3: Environmental impact values and calculation of cultural impact index for chapter 3). Electricity exports have historically played a significant role for economic development for the Navajo Nation. I provide a basic Sankey energy flow diagram to show the potential of energy sales on and off the Navajo Nation. I allocate energy to the Navajo Nation based upon assumptions made to meet the electricity and natural gas/propane demand on the reservation and I assume the remaining electricity is sold off the Navajo Nation.

3.3.5. Cultural Outcomes

In order to address cultural impacts, I connect the environmental impacts of water consumption, land transformation, and greenhouse gas emissions to impacts on cultural resources such as sacred sites and traditional economies. I provide impacts on the following cultural resources (1) Landscapes and sacred sites, (2) Plants, wildlife, and traditional foods/medicine, and (3) Grazing Lands. I calculated impacts on these resources by creating an index based upon weightings of the environmental impacts. The displayed impacts are proportional to the smallest and largest impacts of all the scenarios. I calculate impacts on (1) Landscapes and Sacred Sites based upon the amount of land transformation. Next (3) Grazing Lands impacts are estimated by proportionally scaling them to the largest and smallest land transformation and greenhouse gas emissions within each of the scenarios. Impacts on (2) Plants, wildlife, and traditional foods & medicine are proportional to an equal weighting of water consumption, land transformation, and greenhouse gas emissions. I calculated the index for these impacts by dividing total land use of each scenario by the total land use for the scenario that transformed the most land – in this instance the High Fossil Fuel and High Renewable energy scenario. I calculated this index by dividing each of the of the environmental impact categories

by the scenario with the largest impact of each category in this instance this was also the “High” Fossil Fuel and “High” Renewable energy scenario.

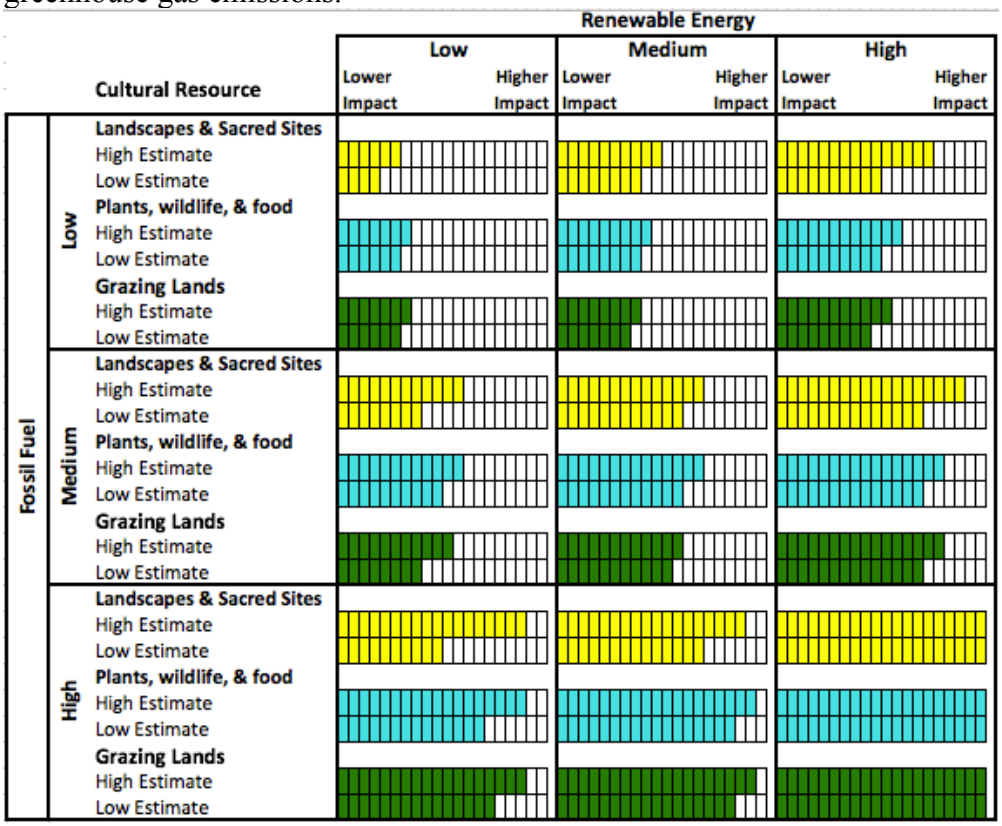
3.4. Results

The decision support tool provides an integrated summary of the different impacts and tradeoffs among energy options available to the Navajo Nation. The most significant land transformation occurs from the development of renewable resources, namely solar and wind. The range of potential land transformation increases significantly in the high renewable development scenario from the lower renewable development scenarios (Table 5). Water consumption is the most significant impact for increasing fossil fuel development (Table 5). Impacts on cultural resources are the most significant in all of the higher development scenarios (Table 6).

Table 5: Displayed are the high and low estimates of the environmental impacts associated with each scenario including land transformation (millions of acres), water consumption (acre-feet), greenhouse gas emission (MT of CO_2e). Estimated price of residential electricity based upon grid mixes from Table 4. Values provided in ($/MWh).

Land Transformation (Millions of Acres)			Renewable Energy		
			Low	Med	High
Fossil Fuels	Low	High estimate	370	1600	9060
		Low estimate	79	440	3050
	Med	High estimate	910	2140	9600
		Low estimate	230	600	3200
	High	High estimate	1450	2680	10100
		Low estimate	390	750	3350
Annual Water Consumption (Acre-feet)			**Renewable Energy**		
			Low	**Med**	**High**
Fossil Fuels	Low	High estimate	330	340	830
		Low estimate	240	240	500
	Med	High estimate	1730	1740	2230
		Low estimate	850	850	1100
	High	High estimate	3130	3150	3630
		Low estimate	1460	1460	1710
Annual GHG Emissions (MT CO2e)			**Renewable Energy**		
			Low	**Med**	**High**
Fossil Fuels	Low	High estimate	790	1040	2000
		Low estimate	320	360	740
	Med	High estimate	3300	3560	4510
		Low estimate	1470	1500	1880
	High	High estimate	5820	6070	7030
		Low estimate	2680	2700	3090
Electricity Prices ($ / MWh)			**Renewable Energy**		
			Low	**Med**	**High**
Fossil Fuels	Low	High estimate	79	88	91
		Low estimate	69	76	79
	Med	High estimate	73	84	88
		Low estimate	63	72	76
	High	High estimate	64	77	85
		Low estimate	56	67	73

Table 6: Displayed are the potential impacts on cultural resources from environmental impacts displayed in Table 5. These impacts are indexed to land transformation, water consumption, and greenhouse gas emissions.



3.5. Conclusion and Policy Implications

3.5.1. Framework for energy resource management for American Indian Tribes

The decision aid outlined in this paper is a tool for identifying tradeoffs and informing decisions about energy development on the Navajo Nation. It includes a method for quantifying cultural impacts, which were shown to be of concern to Navajo citizens (Necefer, et al., 2015). This approach involves using environmental impacts to calculate indexes, which are translated into impacts on cultural resources.

As part of developing this decision aid I engaged with various stakeholder groups to assess attributes and information most relevant to Navajo Nation decision making, including cultural values and information of most interest (Necefer, et al., 2015). From the results of these

interviews I opted to display impacts on cultural resources indexed to environmental impacts instead of monetizing these impacts (e.g., through a willingness-to-pay study) for the following reasons: first there are significant challenges to monetizing impacts on cultural resources, second measuring through monetization could be incompatible with certain cultural values, and lastly environmental quality is closely tied to cultural resources in the view of many stakeholders (Necefer, et al., 2015; Schoepfle, et al., 1983).

There are a number of limitations associated with the model framework. While this decision aid is potentially valuable for stakeholder input, evaluating the understanding and usability of such a tool is an empirical assessment that requires more rigorous testing (details of this testing can be found in chapter 4). From a more technical perspective, feedback mechanisms across environmental and economic systems are not included within this framework (e.g. impacts on hydrology & soil; larger impacts on the economy & human health). Finally impacts on cultural resources are not easily measurable and translation into quantitative measures using environmental impacts may not have a linear relationship as is assumed in this paper. Further study to quantify the connection of environmental impacts to cultural resources of the Navajo people could inform more accurate measures. In a future study, I plan to incorporate this tool into a large sample survey to disseminate to Navajo citizens to assess their understanding of this tool and its usability. This model will be connected with hydrological and economic impacts as demonstrated by Tidwell, et al., 2004 and Fernald, et al. 2012. Providing this connection will allow for a deeper understanding of the impacts to the Navajo Nation and how they are valued across its citizenry.

3.5.2. Public education and engagement on energy and the environment

The energy development decision aid allows for deeper engagement on some of the complexities associated with energy resource management decisions on the Navajo Nation, including environmental, economic, and cultural impacts. This information is complex and during user testing I found providing a tutorial for how to understand, interpret, and use the aid was particularly helpful for many individuals.

In our testing, the process of exploring the complexities within the tool allowed participants to elucidate the associated impacts of both fossil fuel and renewable resources. This process of discovery presented information that, in some instances, conflicted with an individual's mental models on energy and environmental issues. For example, one participant mentioned that their choices were complicated by the realization that while fossil fuel scenarios had high emissions and water consumption, the renewable energy scenarios had an undesirably high impact on cultural resources from land transformation, "its hard to determine what's really best for the Navajo Nation seeing that fossil fuels hurts us with emissions and solar hurts us by disturbing sacred sites."

This type of decision aid has the potential to help people make informed decision, as well as providing an approach for public engagement. The development of the decision aid engaged a number of individuals who have a vested interest in Navajo energy policy. These groups include individuals from the Navajo Medicine Man's Association, employees within the petroleum and coal industries, elected officials, department heads and the general public. Providing these parties with information about the impacts of energy consumption has been shown to enable these types of groups to make more realistic decisions and expectations about energy resources (Trutnevyte, et al., 2013; Mayer, et al., 2014). Such a tool could also be used in guiding facilitated discussions in strategic energy planning sessions for communities. For example, the tool could help in the

assessment of stakeholder positions and facilitate dialogue over the impacts and tradeoffs of various pathways in order to develop a unified vision for future energy resource management (Trutnevyte, et al., 2013).

3.5.3. Energy resource management for future generations

Incorporating cultural impacts into these decisions can provide information about energy resource management pathways, enabling policy makers and citizens to make well-informed choices consistent with their values, thereby fostering environments for future success. Technical modeling of these paths for energy resource management will be a useful tool in assessing the tradeoffs, yet without proper incorporation of social and cultural attributes these models can have significant shortcomings (Necefer, et al., 2015; Pasqualeti, et al., 2015; Lutzenhizer, 1992). History has shown that projects that are not seen to be consistent with the values of a community have faced significant opposition and obstacles in their implementation, and future success depends on the incorporation of these values (Powell & Curley, 2010; Pasqualetti, et al., 2015; Cornell & Kalt, 1992; Turner-Ruffing, 1976). Notably the definitions of success and desired outcomes may place a higher priority on goals of political and social sovereignty and cultural and environmental protection over objectives such as employment, revenue, and economic efficiency (Duffy & Stubben, 1998; Necefer, et al., 2015). One participant elucidated this importance, "The cultural impacts, the amount of water used, and greenhouse gas emissions were the most important. For me, seeing the impact on the way people live and rely on resources is the most important factor in making a decision like this." Determining and incorporating these values in the process of developing technical decision tools can provide useful insights into planning that can increase chances of public acceptance and understanding.

Natural resources are vital for the preservation of the cultural environment on the Navajo Nation. Inevitably energy resource management decisions will have numerous impacts on the environment and thus cultural resources of the Navajo people. Planning with the use of fully inclusive technical-social decision tools can provide a means of ensuring that these cultural practices are maintained in harmony with energy resource management. Phillip Reno, an economist who worked extensively on the Navajo Nation, argued that in order for Navajo resources be developed for the benefit and self determination of the Navajo people, "Planning…will have to combine sophisticated planning technology with traditional Navajo insights, so that planners can take on the task for which Macbeth summoned extrasensory consultants, to 'look into the seeds of time, and see which ones will grow and which will not'" (pg. 155, Reno, 1981). Incorporation of cultural values within technical planning tools can ensure energy resource paths that are both technically viable and ensure that the decisions made are consistent with the values of the Navajo people.

4. Understanding the influence of cultural impact information in a decision tool for energy resource management

4.1. Introduction

Securing a sustainable future requires that people have attitudes and practice behaviors that ultimately result in fewer greenhouse gas emissions, such as installing solar panels on their homes or supporting wind farm development. Among other factors, culture – tradition, common history, language, and values – shape those attitudes and behaviors (Douglas & Wildavsky, 1983; Lutzenhiser, 1992; Sovacool, 2014). For example, a culture of environmentalism may be a hospitable place for the development of renewables versus fossil fuels (Noppers, et al., 2014). Indeed, cultural values and norms has been shown to have a significant influence on individual's preferences and consumption of energy (Lutzenhiser, 1992; Sovacool, 2014). In this study we ask: "How does including culturally relevant information influence preferences with respect to energy development?"

Decision aids may be an effective and low-cost way to deliver culturally relevant information. Indeed, they have been used across a number of fields such as health, consumer preferences, natural resource management, and climate change (Fischoff, et al., 2011; Häubl & Trifts, 2000; Fleishman, et al., 2014; Wong-Parodi, et al., 2013; Tidwell, 2012). Fleishman, et al. (2014) found an energy decision aid helped people carefully balance cost and environmental impact information to develop diverse portfolios that support low-carbon electricity. (Fleishman, et al., 2014). Trutnevyte et al. (2013) found that stakeholder adjusted their vision of idealized energy future after interacting with an analytic energy decision tool. One challenge of conveying energy development information is that there is a lot of uncertainty with respect to different pathways, which may complicate how people understand and use such information. Some

research has found that including uncertainty such as interval estimates of certain impacts can be understood and used by lay audiences in their decision making (Johnson & Slovic, 1995, 1998). Moreover, others have found that it can reduce perceived risk among those with high initial environmental concern (Siegrist, et al., 2010). However, others have found that uncertainty about risks of energy development can be a major stumbling block and can lead to distrust of experts (Greenberg, 2014). Despite this, others argue that including uncertainty information is necessary for the ethnical communication of science (Dietz, 2013). Thus, in this paper we also ask: "How does the inclusion of uncertainty influence preferences with respect to energy development?"

In this paper we present two studies that assess the influence of culturally relevant information on preferences for energy development on the Navajo Nation. The Navajo Nation presents an interesting case study as cultural identity within the Navajo worldview can be interpreted as collectivist, not only among individuals, but also with the wider natural world (Hossain, Skurky, Joe, and Hunt, 2011; Farella, 1988). Thus the natural world (e.g. landscapes, geographic formations, plants and animals, minerals), in this particular cultural understanding, is a significant factor in individual and community identity and has a significant influence on preferences for energy development (Necefer, et al., 2015; Schoepfle, et al., 1984). Here, Navajo citizens used an energy development decision aid showing estimates for either expected (i) environmental, (ii) environmental and economic, (iii) environmental and cultural, or (iv) all three impacts for the Navajo Nation given various levels of renewable and fossil energy development (see Necefer, et al. 2015, Necefer et al., 2016 *(in review*) for more information). In Study 2, citizens were shown the same information with the addition of uncertainty information.

4.2. Study 1 – without uncertainty

4.2.1. Methods

4.2.1.1. Experimental procedures

Participants first read a brief introduction explaining the purpose of the study. To further engage them, participants were asked to express their thoughts about energy issues on the Navajo Nation in one to two sentences.

Baseline preferences. Next, they indicated their baseline preferences for how energy is developed and where it comes from with two statements: "I think the electricity we use in our home should come from" and "Energy resource management on the Navajo Nation should focus on" where 1=Only Fossil Fuels (Coal & Natural Gas), 2 More FF, 3 Slightly more FF, 4=50/50 Mix Renewable & Fossil Fuels, 5 Slightly more RE, 6 More RE, 7= Only Renewable Energy (Wind & Solar). An index of these statements called (a1) *Baseline preference for source of electricity* was created with Cronbach's **α**=.85.

Manipulation. Next, participants were informed that they would be able to choose the sources of energy they desired for the Navajo Nation. They were told the Energy Development decision aid (or tool) would show them the outcomes of their decisions, and to make adjustments until they were satisfied with their choices.

Participants were then randomly assigned to 1 of 4 versions of the Energy Development decision aid: (i) Environmental, (ii) Environmental + Economic, (iii) Environmental + Cultural, and (iv) Environmental, Economic + Cultural (for details on the development of the decision aid see Necefer et al., in review).

(i) Environmental: participants were shown a map of the Navajo Nation with wind, solar, coal, natural gas and oil, and biomass levels of development, an icon graph indicating levels of water used, and an icon graph indicating levels of greenhouse

gas emissions (see Figure 2). Levels could be adjusted with two slider bars, one for fossil fuel development (low, medium, and high) and another for renewables development (low, medium, and high) (see

(ii) Figure **2**).

(iii) Environmental + Economic: participants were shown the same information as those in the Environmental condition, as well as Sankey graph showing the inflow and outflow of revenue due to development and the cost of residential electricity (see Figure 3).

(iv) Environmental + Cultural: participants were shown the same information as the Environmental condition, as well as impact information on cultural resources (grazing lands, sacred sites, plants and wildlife) that are linearly indexed to environmental impacts (see Figure 4).

(v) Environmental, Economic + Cultural: participants were shown the same information as the Environmental, Economic, and Cultural conditions (see Figure 5).

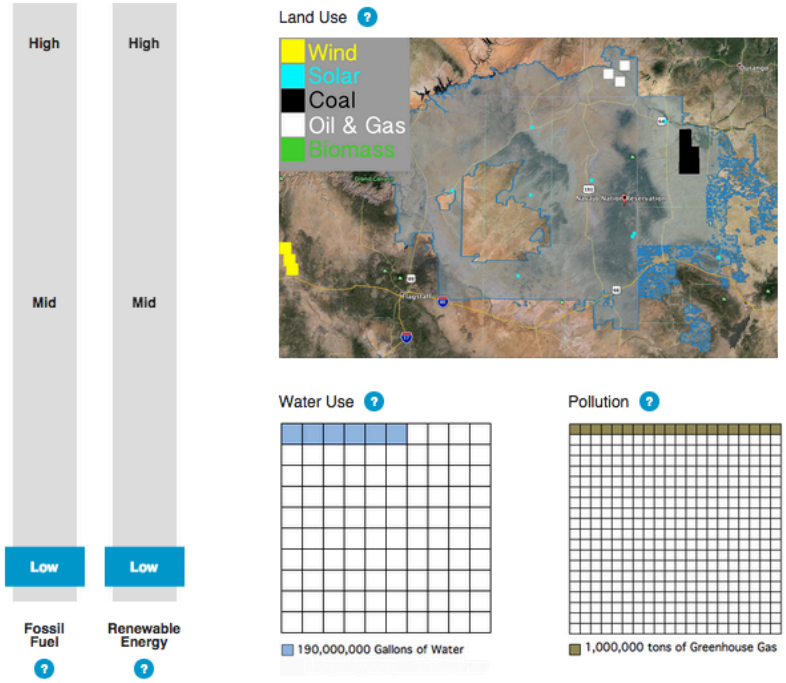


Figure 2: Example screenshot of the Environmental decision aid

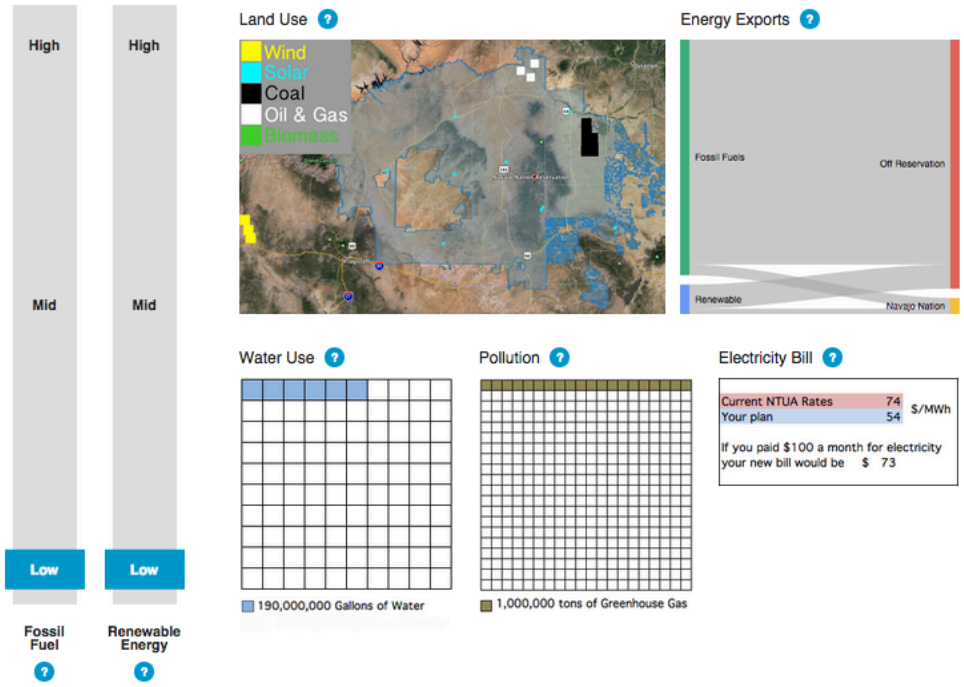


Figure 3: Example screenshot of the Environmental and Economic decision aid

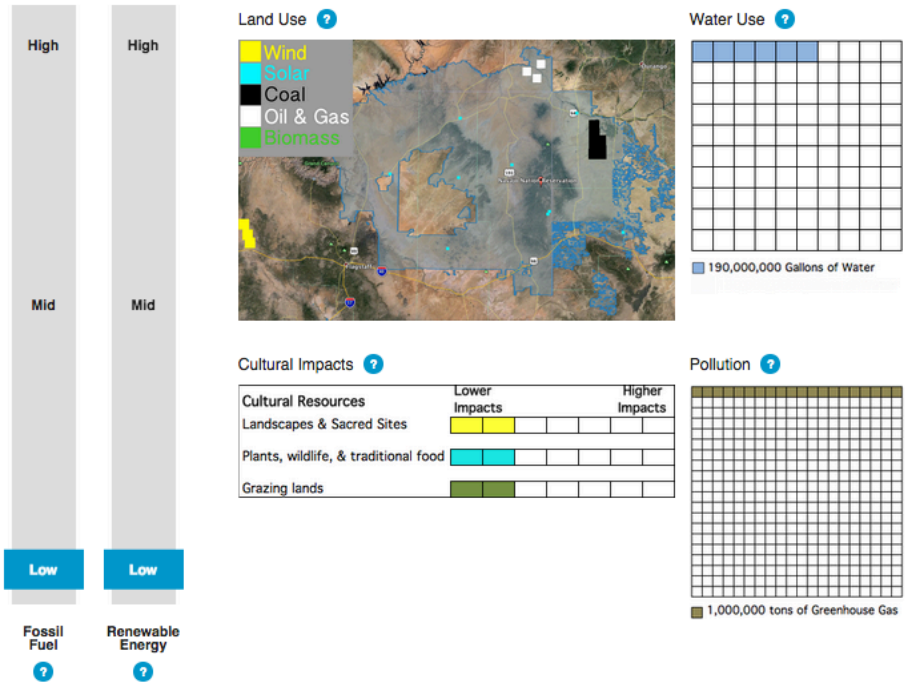


Figure 4: Example screenshot of the Environmental and Cultural decision aid

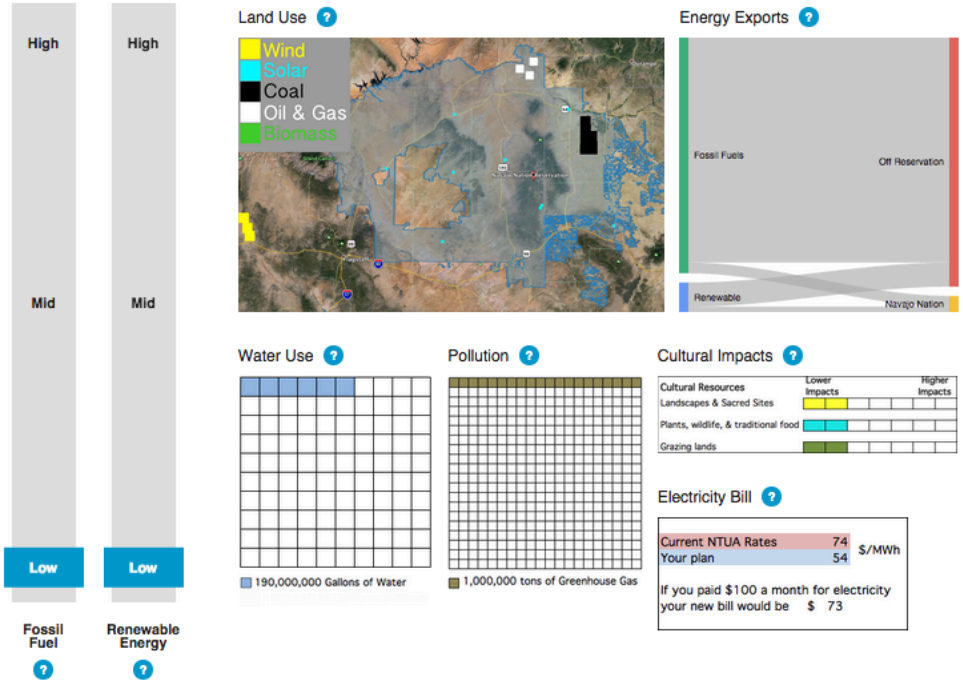


Figure 5: Example screenshot of the Environmental, Economic & Cultural decision aid

Preferences: Next, participants indicated their post-manipulation preferences with two statements: "I think the electricity we use in our home should come from" and "Energy resource

management on the Navajo Nation should focus on" where 1=Only Fossil Fuels (Coal & Natural Gas), 2 More FF, 3 Slightly more FF, 4=50/50 Mix Renewable & Fossil Fuels, 5 Slightly more RE, 6 More RE, 7= Only Renewable Energy (Wind & Solar). An index of these two statements called (a2) *Post tool preference for source of electricity* was created with Cronbach's α=.85.

Views on the energy development tool: Next, participants indicated their views of the tool by their agreement with six statements: "The tool is easy to use," "The tool is easy to understand," "The tool made me more interested in energy," "I learned how sources of energy could change my electricity bill," "I learned about how energy could impact Navajo culture," and "I learned about how energy could impact the environment" where 1=Strongly disagree and 7=Strongly Agree. A mean index of these three statements, (b) *Tool views and learning,* was created with Cronbach's **α**=.87.

Views on the impacts of energy development: Participants indicated their views on environmental and cultural impacts with their agreement with four statements: "Energy development is bad for the environment," "Environmental impacts from energy last a long time, "Navajo culture is threatened by energy development", and "If things continue on their present course we will experience an ecological catastrophe" where 1=Strongly disagree and 7=Strongly agree. An index of these three statements called (c) *Views on environmental and cultural impacts* yielded Cronbach's **α**=.69 and (d) *views on economic impacts* was assessed by agreement with, "Energy development means economic development for the Navajo people" where 1=Strongly disagree and 7=Strongly agree.

Views on size of energy development: Next, participants identified whether they thought images of energy projects were small (decentralized), medium or large (centralized) (Figure 6). We then asked participants to select the size of energy projects that they preferred by using an

aerial map of Shiprock, NM overlaid with either small, medium or large energy projects (Figure 7). We then used participants' responses to create the variable (e) *preference for scale of energy project*, from very decentralized (small) to very centralized (large). Note that each project covers an equal area in aggregate but are distributed at different scales (e.g. rooftop solar versus large land transformation projects) (Figure 7).

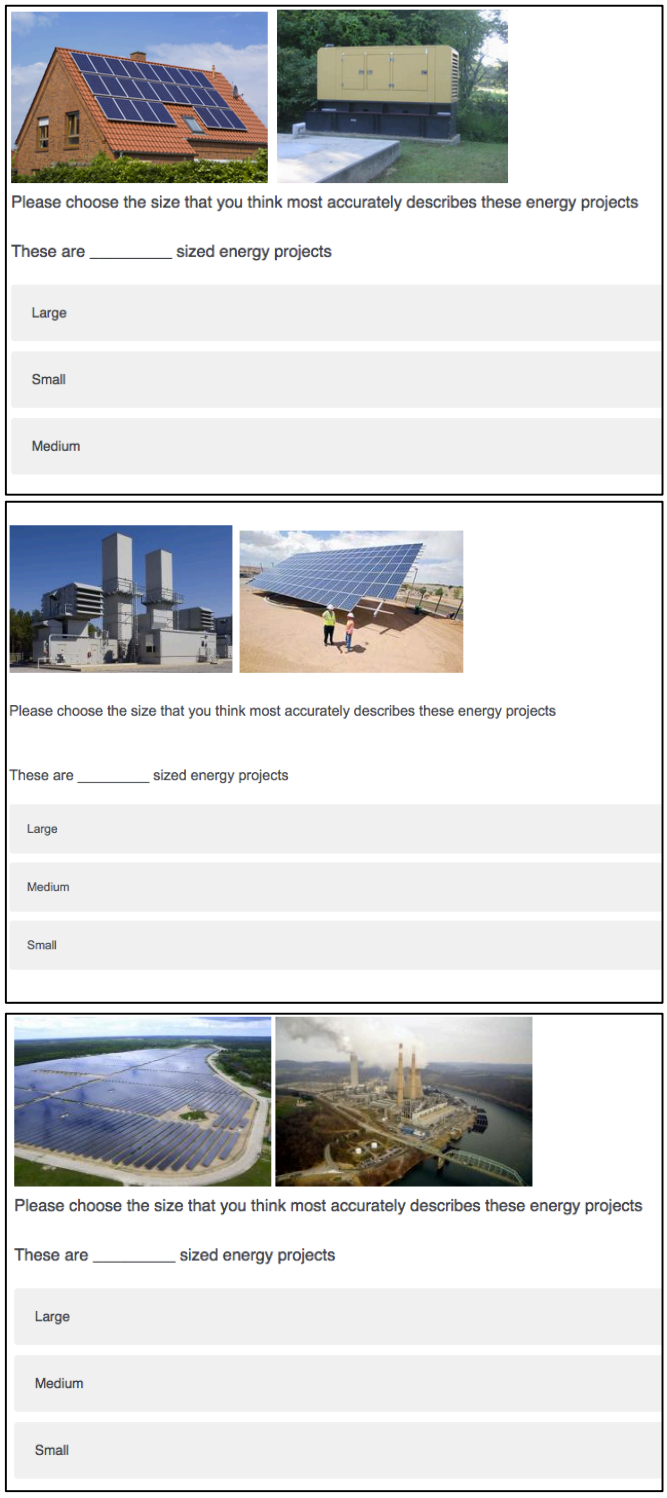


Figure 6: Example of small projects (top), medium (middle), and large projects (right).

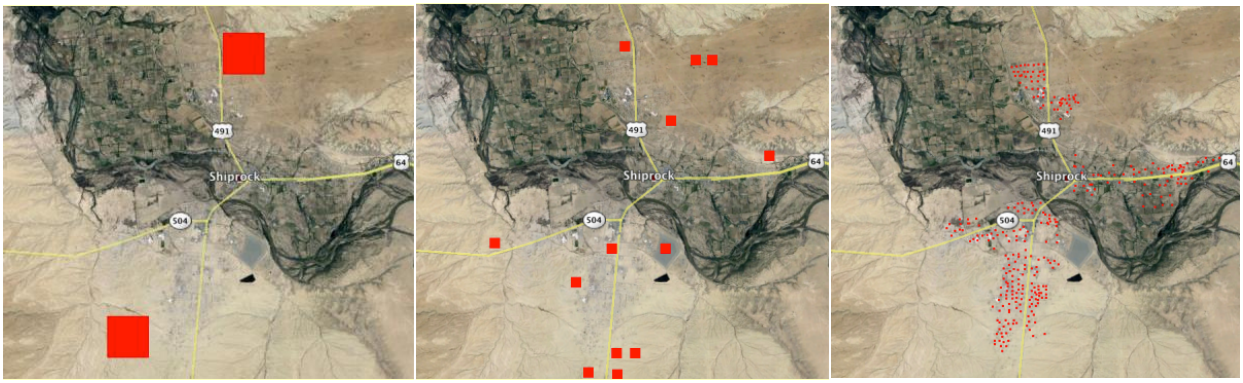


Figure 7: Centralized projects (far left) to decentralized project (far right).

Views on the Navajo Nation government: Next, individuals' views on the Navajo Nation government's handling of energy resource management was assessed with the following statements, "The Navajo government makes good choices about energy," "The Navajo government provides good information on energy," and "The Navajo Nation government uses Diné teachings to make choices about energy." We combined these statements into an index called (f) *Views of the Navajo Nation Government* with Cronbach's **α**=.84.

Views of Non-Navajo companies: Next, individuals' views of non-Navajo companies' handling of energy resource management was assessed with the following statements, "non-Navajo companies makes good choices about energy," "non-Navajo companies provides good information on energy," and "non-Navajo companies uses Diné teachings to make choices about energy." We combined these statements into an index called (g) *Views of Non-Navajo companies* with Cronbach's **α**= .87.

Climate change views: We assessed (h) *climate change views* with two statements: Lastly we combined views about climate change into an index from the following statements: "Climate change is primarily caused by human activities" and "Climate change is a serious threat" (Cronbach's **α**= .84).

Demographics and participation in traditional economies: Finally, individuals were asked standard demographic questions, including what chapter they belonged to, if they currently lived on the Navajo Nation, and if they were involved in cultural practices – such as Navajo medicine, herb gathering, grazing, farming, Native American Church (NAC), weaving, or other artisanal activities.

4.3. Recruitment and participants

4.3.1. Recruitment

Participants were recruited using a combination of snowball sampling and online forums such as social media websites that target a Navajo demographic. We contacted individuals who we interviewed for a previous study on the Navajo Nation (Necefer, et al., 2015), and described the study to them. We then asked these individuals to help us recruit people they know to participate in our study. Participants were also recruited through social media (Facebook: Dusty's Navajo Political Sphere, Navajo in the City, Navajo Post, Navajo Times, Navajo Forward, Being Navajo, DC Tribe, and Wááshindoon Diné bizaad) and two forums (Reddit.com: /r/Navajo, /r/NativeAmerican) that attract a predominately Navajo audience. We administered the experiment online with no compensation, and it took participants approximately 21 minutes to complete.

4.3.2. Participants

A total of 132 individuals were recruited with a median reported age of 30 years old (range of 18 to 65 years old). Most participants self-reported their gender identity as female (62.4%), followed by 36.6% as male, and 2% as transgendered. Most people reported completing a 4-year college education (31%), followed by a master's degree (26%), 2-year college (17%), some college (16%), High School/GED (4%), Doctoral Degree (3%), less than High School

(2%), and professional degree (JD or MD) (1%). For current residence, 35.4% participants reported currently living on the Navajo Nation while 64.6% reported living off the reservation. In addition, participants reported being affiliated with 54 chapters (out of a 110) on the Navajo Nation with the most popular being Shiprock (7 participants), Ft. Defiance (5 participants), Kayenta (5 participants), and Tsaile-Wheatfields (5 participants).

Participants reported being employed educational services (20%), other (not listed) (15.5%), healthcare or social assistance (13.6%), professional, scientific, or technical services (10.9%). arts, entertainment, or recreation (4.5%), finance/Insurance (4.5%), other services (4.5%), accommodation or food services (2.7%), construction (2.7%), mining (2.7%), transportation/warehousing (2.7%), forestry (0.9%), utilities (0.9%), manufacturing (0.9%), retail trade (1.8%), Hatalii – Navajo Medicine (0.9%); other services (0.9%), ranching (0.9%), management (0.9%), and with the remaining being unemployed.

Individuals reported their household income as the following: Below $20,000 (22 people – 19.3%); $20,000 - $29,999 (10 people – 8.8%); $30,000 - $39,999 (17 people – 14.9%); $40,000 - $49,999 (8 people – 7.0%); $50,000 - $59,999 (20 people – 17.5%); $60,000 - $69,999 (4 people – 3.5%); $70,000 - $79,999 (10 people – 8.8%); $80,000 - $89,999 (10 people – 8.8%); above $90,000 (13 people – 11.4%) (Table 11).

Individuals reported participating in the following cultural activities Navajo medicine (62 people – 50.8%); Ranching (41 people – 33.6%); Herb gathering (40 people – 35.7%); Native American Church (27 people – 22.1%); Weaving (21 people – 17.2%); other artisan (22 people – 18%)

4.4. Results

4.4.1. Data analytic plan

To test the affect of cultural impacts on preferences for source of electricity, we conducted a Repeated Measures Analysis of Variance (ANOVA) with (a1, a2) *preferences for source of electricity* in the home and for *energy development* on the Navajo Nation (pre vs. post) by aid (Environment vs. Environment + Economic vs. Environment + Cultural vs. Environment + Economic + Cultural). We then assessed its influence on (b) *tool views and learning,* (c) *views on environmental and cultural impacts,* (d) *views on economic impacts,* (e) *preference for scale of energy projects*, (f) *views of the Navajo Nation Government,* (g) *views of Non-Navajo companies,* and (h) *climate change views* by conducting a series of one-way ANOVAs. In addition, we conducted a Pearson's correlation with age with variables (a-h).

4.4.2. Randomization Check

A one-way ANOVA found no significant difference for pre-tool preferences for the source of electricity by aid (M=5.55, SD=1.57, F(3, 188)=0.80, p>0.05) and the type of energy development on the Navajo Nation by aid (M=5.17, SD=1.63, F(3, 119)=0.31, p>0.05), suggesting successful randomization.

4.4.3. Initial Analysis

A series of one-sample t-tests were conducted as an initial exploration of preferences across all conditions. While participants preferred renewables over fossil fuels, preference weakened after engaging with the decision aid (a2) (Table 1). Participants demonstrated that they learned about energy after using the tool (b), and they expressed the belief that energy development would yield economic benefits (d). As found in previous literature (Necefer, et al., 2015), participants expressed negative views of both the Navajo government (f) and non-Navajo companies.

Table 7: One-sample t-tests of all variables (midpoint=4 unless otherwise specified)

Variable (Response Scale)	Mean (SD)	t (df)
(a1) Pre-tool preference for source of energy (1 FF – 7 RE)	5.41 (1.45)	12.10 (192)**
(a2) Post-tool preference for source of energy (1 FF – 7 RE)	5.27 (1.57)	8.24 (122)**
(b) Tool views and learning	4.82 (1.31)	7.10 (126)**
(c) Views on environmental and cultural impacts (1-7)	4.11 (1.15)	0.93 (122)
(d) Views on economic benefit (1-7)	5.93 (1.09)	17.06 (122)**
(e) Preference for scale of energy projects (1 Sm., 2 Med., 3 Lrg.)[a,b]	2.13 (0.83)	1.53 (103)
(f) Views on the Navajo Nation government (1-7)	2.53 (1.28)	-11.74 (121)**
(g) Views on Non-Navajo companies (1-7)	3.06 (1.47)	-6.55(121)**
(h) Climate change views (1 Definitely True – 4 Definitely False)[c]	1.63 (0.85)	-11.18(117)

Note: Variables presented in order of assessment
*p<.05; **p<.01; ***p<.001
[a] Midpoint 2
[b] We did not find significant difference between participants who correctly identified the scale of projects vs. those that did not F(1, 102)=2.44, *p*=.122
[c] Midpoint 2.5

4.4.4. How does including culturally relevant information influence preferences with respect to energy development?

A repeated-measures ANOVA found no significant interaction between preferences for energy development (pre. vs. post) and tool (Environment vs. Environment + Economic vs. Environment + Cultural vs. Environment + Economic + Cultural), $F(3,119)=2.00$, $p=.12$. However, we did find preference for renewable energy development on the Navajo Nation increased after engaging with any information about energy development (Pre: $M=5.12$, $SD=1.65$ vs. Post: $M=5.39$, $SD=1.51$, $F(1,119)=3.34$, p=.05).

A repeated-measures ANOVA found no significant interaction between preferences for sources of electricity (pre. vs. post) and tool (Environment vs. Environment + Economic vs. Environment + Cultural vs. Environment + Economic + Cultural), $F(3, 119)=.51$, $p=.99$.

However, we did find a decrease in preference for electricity from renewable sources decrease after engaging with any information about energy development (Pre: M=5.51, SD=1.60 vs. post: M=5.14, SD=1.86, $F(1, 119)=6.93$, p=.01).

Table 8 shows choices made by individuals about the level of renewable and fossil fuel development on the Navajo Nation. We found a significant difference between the choices made between the tool types ($\chi^2(9, 136)=60.10$, $p<.01$). On balance, individuals reported preferring higher levels renewable energy development compared to fossil fuel options. Table 9 shows the information that individuals reported using to make selections in the decision tool. Across all tool types individuals reported basing their decisions while using the tool on environmental impacts specifically land use, water use, and greenhouse gas emissions.

Table 8: Expressed preferences for fossil fuels versus renewables made by individuals by tool type

Tool 1 - Environmental without uncertainty

		Fossil Fuel			
		None	Low	Med	High
Renew. Energy	None	4	0	0	0
	Low	0	0	1	0
	Med	1	1	5	1
	High	1	10	3	0

Tool 2 - Environmental & economic without uncertainty

		Fossil Fuel			
		None	Low	Med	High
Renew. Energy	None	0	0	0	0
	Low	0	0	1	0
	Med	1	1	4	0
	High	1	13	4	4

Tool 3 - Environmental & culture without uncertainty

		Fossil Fuel			
		None	Low	Med	High
Renew. Energy	None	0	0	0	0

	Low	0	2	1	0
	Med	0	4	3	0
	High	2	8	9	2

Tool 4 - Environmental, economic, and culture without uncertainty

		Fossil Fuel			
		None	Low	Med	High
Renew. Energy	None	0	0	1	0
	Low	0	0	1	2
	Med	0	5	2	1
	High	1	8	3	4

Table 9: Information participants reported using to inform their decisions about energy development.

	Total	
Information used to make decision	**Count**	**Percent**
Land Use	39	24%
Water Use	38	24%
GHG emissions	26	16%
Cultural impacts	14	9%
Preference for RE	13	8%
Electricity bill	10	6%
Using the tool	7	4%
Opposition to FF	5	3%
Employment & economic benefit	4	2%
Preference for FF	3	2%
Health impacts from pollution	1	1%
Opposition to RE	1	1%

4.5. Discussion – Study 1

4.5.1. How does including culturally relevant information influence preferences with respect to energy development?

On balance, individuals strongly preferred renewables be developed on the Nation over fossil fuels and they also wanted this type of energy to power their homes. However, after learning about the potential impacts (environmental, economic, cultural) of fossil fuel *and*

renewable development, preference for renewables for future energy development on the Navajo Nation increased and preference for renewables as a source of home electricity decreased. It possible that participants may not have considered the magnitude of environmental impacts of large scale fossil fuel development which could in part explain the increase in positive views of renewables for future energy development. Conversely it possible that participants had not considered the increased cost of electricity from renewable resources and thus may in part explain the decrease in positive views about electricity from renewable resources.

Interestingly, we found that cultural information appeared to have no influence on decision making. However, it seems as if the environmental information may have served as a proxy for assessing the cultural impacts of development. Thus, specific cultural impact information may have simply confirmed what many participants had concluded when making a decision. However further testing would be needed to validate this finding for example by comparing the difference that environmental and cultural information has on these preferences in isolation. Participants reported that they relied primarily on the environmental impact information to inform their decision. As one participant explained, "My political, ethical, social, and moral attitudes and beliefs towards fossil fuels (which I believe are detrimental to the planet) and renewable energy sources (which I believe to be imperative for our people's survival)." People saw development as resulting in economic benefit (perhaps having do to with direct personal experience) but apparently no strong feelings about whether it results in environmental and cultural impacts (perhaps indicating little knowledge of what they might be).

In this study we provided a decision aid that provided point estimates of potential outcomes of environmental impact. In many instances decisions on energy resource management often require consideration of uncertainty in the potential outcomes. For example, the

environmental impacts of energy development have high levels of uncertainty as types of technologies, existing environmental conditions, or other aspects of construction and operation can vary. The presence of uncertainty information could lead individuals to pursue more certain outcomes and also more carefully consider the decision at hand (Tversky & Kahneman, 1989, 1979). Therefore, in study 2 we replicated study 1 with the addition of uncertainty information in the environmental outcomes.

4.6. Study 2 – Tool outcomes with uncertainty information

4.6.1. Methods

4.6.1.1. Experimental procedures

Participants followed the same experimental procedures as Study 1 except they were shown uncertainty information (see Figures 8-11). To aid in understanding this uncertainty information, participants were provided with additional tutorial to aid in interpretation of the information. For example, Figure 8 shows the tutorial for interpreting the range of uncertainty. These studies provided ranges and sources of uncertainties of the various environmental and cultural impacts however, participants were not provided with detailed information about the sensitivity, how they could be reduced, nor the potential uncertainties around the environmental impacts. We provide a summary of the Cronbach's alpha values for the mean indices for study 1 and 2 (Table 10)

Table 10: Cronbach's alphas for study 1 and 2

Variable	**Study 1**	**Study 2**
(a1) Baseline preference for source of electricity	0.85	0.71
(a2) Post tool preference for source of electricity	0.85	0.65
(b) Tool views and learning	0.87	0.83
(c) Views about environmental & cultural impacts	0.69	0.65

(d) Views on economic impacts	-	-
(e) Preference for scale of energy project	-	-
(f) Views of the Navajo Nation Government,	0.84	0.78
(g) Views of Non-Navajo companies	0.87	0.76
(h) Climate change views	0.84	0.67

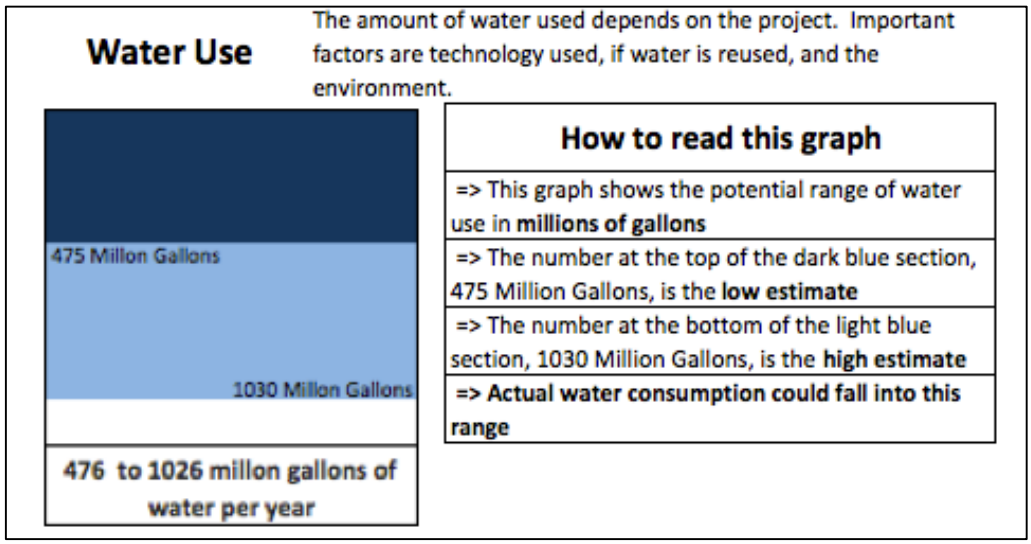


Figure 8: Tutorial provided to assist in interpretation of uncertainty.

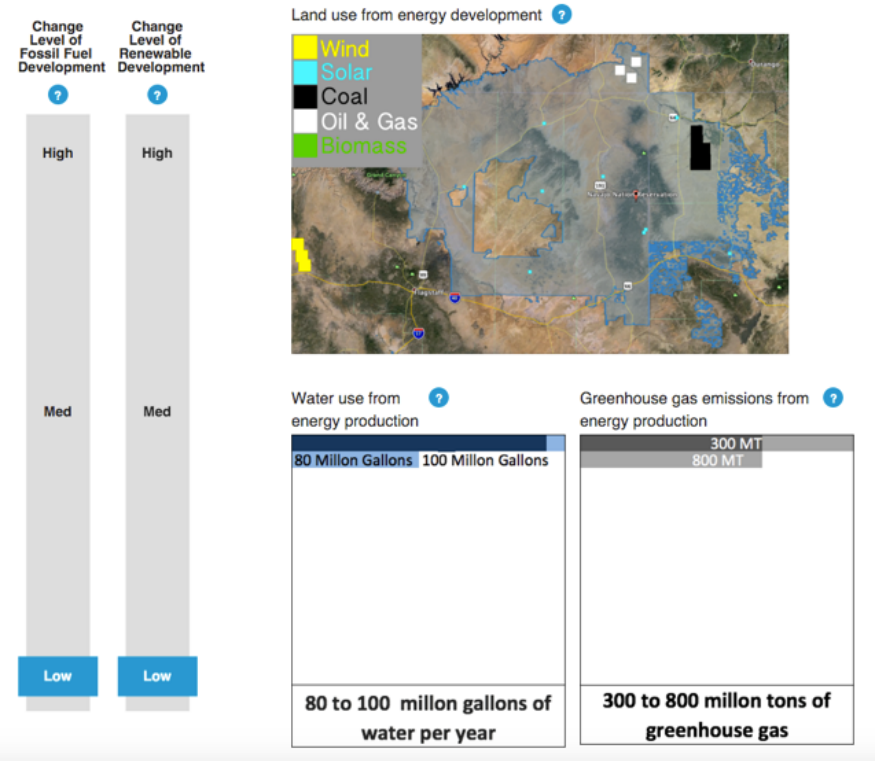


Figure 9: Example screenshot of the Environmental decision aid

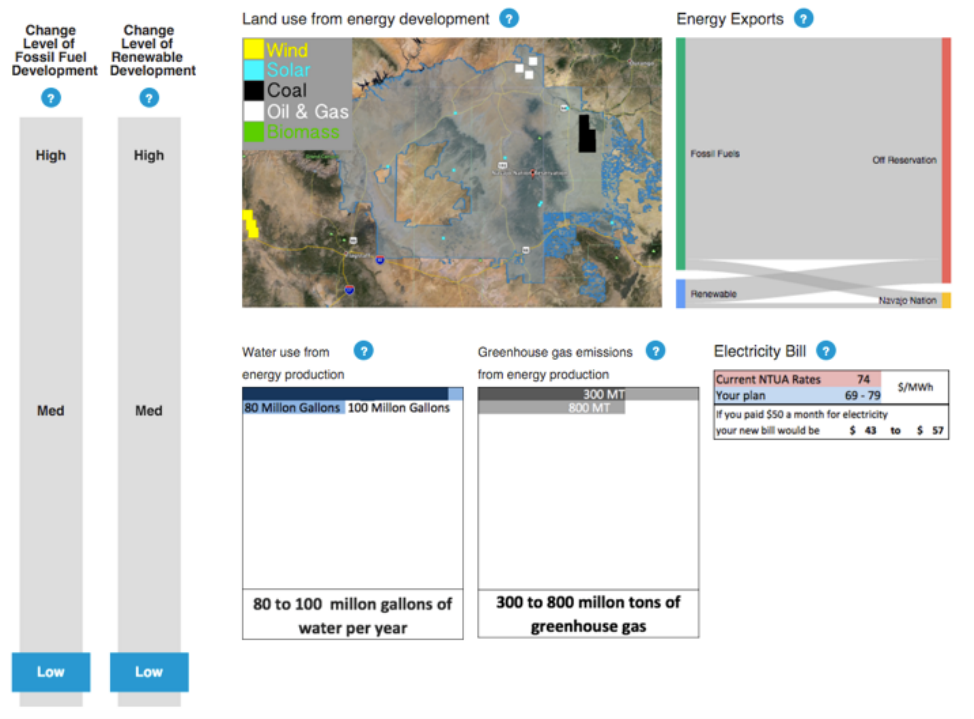


Figure 10: Example screenshot of the Environmental and Economic decision aid

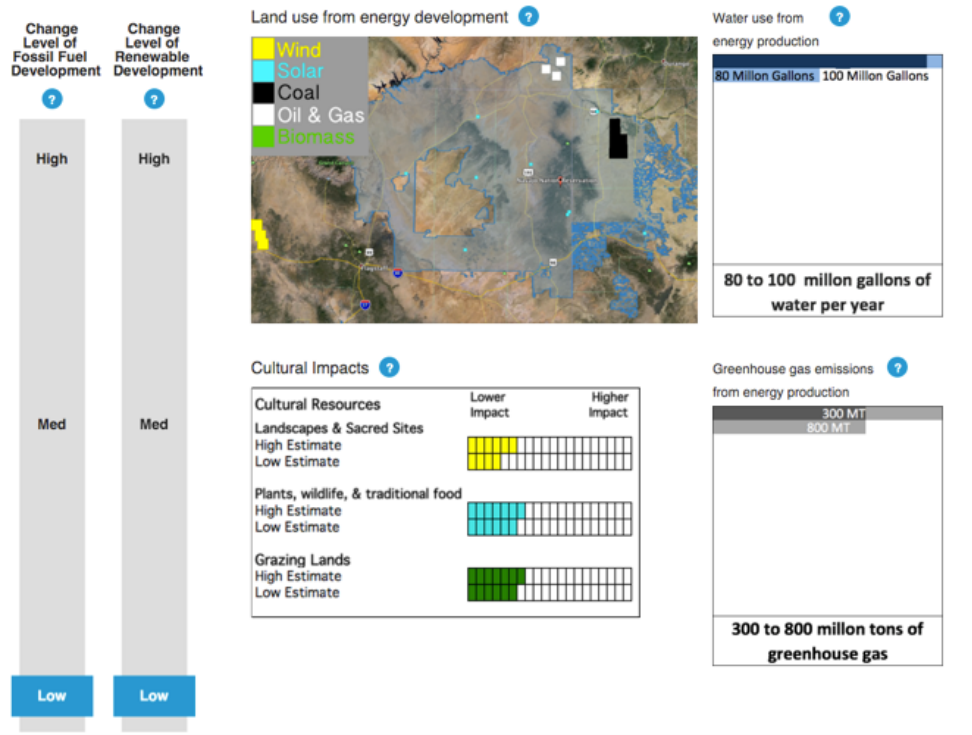


Figure 11: Example screenshot of the Environmental and Cultural decision aid

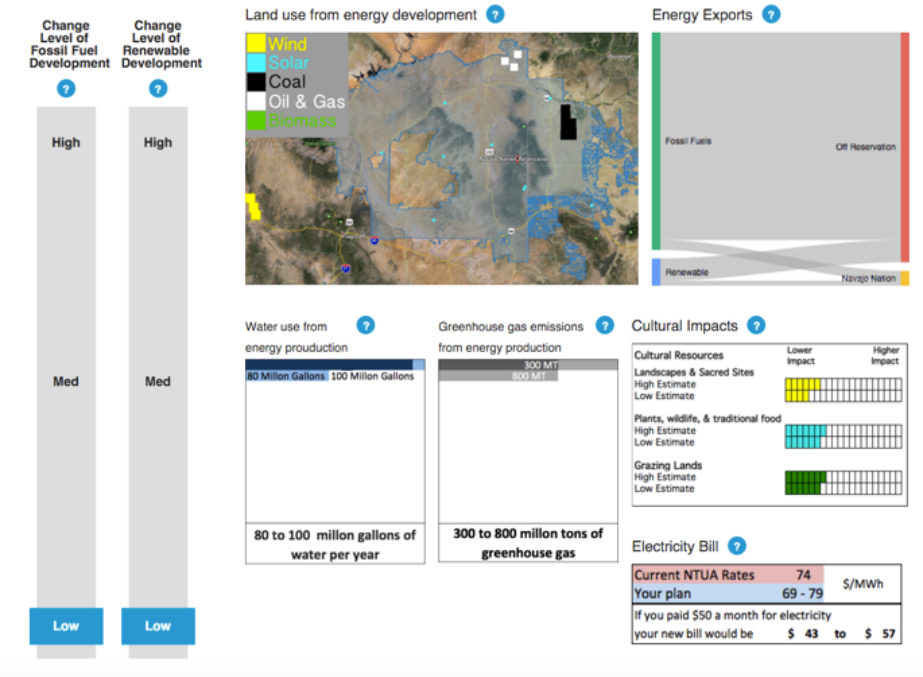


Figure 12: Example screenshot of the Environmental, Cultural & Economic decision aid

4.7. Recruitment and Participants

4.7.1. Recruitment

Similar to study one we recruited participants through snowball sampling and online recruitment through social media websites that target a Navajo demographic, using the same sites as those used for Study 1. We conducted snowball sampling through 12 individuals that we interviewed in a previous study and an additional 4 contacts on the Navajo Nation – all individuals were not contacted for study one (Necefer, et al., 2015). We then asked these individuals to help us recruit people they know to participate that had not participated in Study 1. As before, the experiment was conducted online with no compensation, and taking participants approximately 20 minutes to complete.

4.7.2. Participants

As shown in Table 6, a total of 44 individuals were recruited with a median age of 37 years old (range of 23 to 61 years old). Most participants also self-reported gender as female (77.3 %), followed by 22.7% as male. Participants reported their highest level of education as 4-year college (17 people – 38.6%), master's degree (8 people – 18.2%), some college (8 people – 18.2%), 2-year college (5 people – 11.4%), Doctoral degree (4 people – 9.1%), High School / GED (1 person – 2.3%), and professional degree (JD or MD) (1 person – 2.3%). For current residence, 17 people (38.6%) participants reported currently living on the Navajo Nation while 27 people (61.4%) reported living off the reservation (Table 11). In addition, participants reported being affiliated with a total of 26 chapters - out of a 110 on the Navajo Nation. The chapters with the most respondents included: St. Michaels/Ft. Defiance (7), Black Mesa (2), Many Farms (2), Crownpoint (2), Olajito (2), and To'naness'dizi (2).

Participants self reported their employment as Healthcare / Social Services (8 people – 18.1%); Management (6 people – 13.6%); Engineering and environmental services (5 people – 11.4%); Higher education (4 people - 9%); Education (3 people – 6.8%); other professions (3 people – 6.8%); Student (2 people – 4.5%); Unemployed (2 people – 4.5%) Government (1 person – 2.3%); Hospitality (1 person – 2.3%).

Individuals reported their household income as the following: Below $20,000 (6 people – 14%); $20,000 - $29,999 (5 people – 11.6%); $30,000 - $39,999 (4 people – 9.3%); $40,000 - $49,999 (11 people – 25.6%); $50,000 - $59,999 (5 people – 11.6%); $60,000 - $69,999 (0 people – 0%); $70,000 - $79,999 (2 people – 4.7%); $80,000 - $89,999 (4 people – 9.3%); above $90,000 (6 people – 14.0%) (Table 11).

Individuals reported participating in the following cultural activities Navajo medicine (23 people – 52.3%); Farming (18 people – 40.9%); Herb gathering (17 people – 38.6%); Ranching

(15 people – 34.1%); Native American Church (10 people – 40 %); Other artisan (11 people – 25%); and Weaving (4 people – 9%).

Table 11: Demographics of Navajo Nation vs. Study 1 & 2

Age	**Median**	**Range**			
Navajo Nation[1]	28	N/A			
Study 1	30	18-65			
Study 2	36.5	23 - 61			
Gender	**Female**	**Male**	**Transgender**		
Navajo Nation[1]	51%	49%	N/A		
Study 1	62%	37%	2%		
Study 2	77%	23%	0%		
Education	**Less Than HS**	**HS**	**AA / Some College**	**BS**	**Grad. / Prof.**
Navajo Nation[1]	20%	47%	22%	8%	3%
Study 1	2%	20%	17%	31%	30%
Study 2	0%	2%	30%	39%	30%
Income	**Median**				
Navajo Nation1[1]	$22,392				
Study 1	$45,000				
Study 2	$45,000				

[1](NNDED, 2009)

4.8. Results – Study 2

4.8.1. Data analytic plan

We conducted the same tests as we did for Study 1.

4.8.2. Randomization Check

A one-way analysis of variance (ANOVA) found no for pre-tool preferences for the source of electricity by aid (M=5.66, SD=1.40, $F(3,73)$=.14, p=.94) and the type of energy development on the Navajo Nation by aid (M=5.79, SD=1.20, $F(3,72)$=.30, p=.84).

4.8.3. Initial Analysis

A series of one-sample t-tests were conducted as an initial exploration of preferences across all conditions. As shown in Table 7, participants preferred renewables over fossil fuels, that preference strengthened after engaging with the decision aid (a2) than before (a1). Participants demonstrated that they learned about energy after using the tool (b), and they expressed the belief that energy development would yield economic benefits (d). As found in previous literature (Necefer, et al., 2015), participants expressed negative views of both the Navajo government (f) and non-Navajo companies.

Table 12: One-sample t-tests of all variables (midpoint=4 unless otherwise specified)

Variable (Response Scale)	**Mean (SD)**	**t (df)**
(a1) Pre-tool preference for source of energy (1 FF - 7 RE)	5.71 (1.21)	12.85 (81)**
(a2) Post-tool preference for source of energy (1 FF - 7 RE)	6.03 (1.57)	16.66 (44)**
(b) Tool views and learning (1-7)	4.76 (1.13)	4.45(43)**
(c) Views on environmental and cultural impacts (1-7)	3.92 (1.48)	-.36 (43)
(d) Views on economic benefit (1-7)	5.27 (1.63)	5.17 (43)**
(e) Preference for scale of energy projects (1 Sm., 2 Med., 3 Lrg.)[a,b]	2.03 (.77)	.21(39)
(f) Views on the Navajo Nation government (1-7)	2.42 (1.23)	-8.65 (43)**
(g) Views on Non-Navajo companies (1-7)	2.72 (1.28)	-6.62 (43)**
(h) Climate change views (1 Definitely True – 4 Definitely false)[c]	1.40 (.63)	-11.70 (43)**

Note: Variables presented in order of assessment
**p<.0001
[a] Midpoint 2
[b] We did not find significant difference between participants who correctly identified the scale of projects vs. those that did not F(1,39)=1.21, *p=.28*
[c] Midpoint 2.5

4.8.4. How does the inclusion of uncertainty influence preferences with respect to energy development?

We found no interaction between preferences for energy development (pre vs. post) or tool (Environment vs. Environment + Economic vs. Environment + Cultural vs. Environment + Economic + Cultural) when uncertainty information is included ($F(3,40)=0.63$, $p=.60$). However, we did find a main effect for preferences where people expressed stronger preferences for

renewable development after using the tool than before (Pre: *M*=5.79, *SD*=1.20 vs. Post: *M*=5.98, *SD* =1.00).

We also found no interaction between preferences for the source of electricity and tool when uncertainty information is included ($F(3,40)=.92$, $p=.44$). As before, however, participants had stronger preferences for renewables as a source of electricity after using a tool than before (Pre: *M*=5.66, *SD*=1.40 vs. Post: *M*=6.09, *SD*=.88).

Table 8 shows choices made by individuals about the level of renewable and fossil fuel development on the Navajo Nation. We found a significant difference between the choices made between the tool types ($\chi^2(4, N=42)=13.02$, p=.01). Comparatively, individuals reporting preferring high levels of renewable energy development and slightly lower levels of fossil fuel development. Table 14 shows the information that individuals reporting using to make selections in the decision tool. Individuals reported using information about land use, water use, and the projected electricity bill displayed in tools 2 and 4 (Figure 10 and Figure 12).

Table 13: Energy development preferences made by individuals by tool type

Tool 1 - Environmental with uncertainty

Renew. Energy \ Fossil Fuel	None	Low	Med	High
None	0	0	0	0
Low	0	0	1	0
Med	0	0	2	0
High	0	6	2	0

Tool 2 - Environmental & economic with uncertainty

Renew. Energy \ Fossil Fuel	None	Low	Med	High
None	0	0	0	0
Low	0	0	0	1
Med	0	0	2	0
High	0	5	2	1

Tool 3 - Environmental & culture with uncertainty

Renew. Energy \ Fossil Fuel	None	Low	Med	High
None	0	0	0	0
Low	0	0	0	0
Med	0	0	2	0
High	0	7	3	0

Tool 4 - Environmental, economic, and culture with uncertainty

Renew. Energy \ Fossil Fuel	None	Low	Med	High
None	0	0	0	0
Low	0	0	1	0
Med	0	1	0	1
High	0	7	0	2

Table 14: Information used to make a decision about energy development preferences

	Total	
Information used to make decision	**Count**	**Percent**

Land Use	16	36%
Water Use	7	16%
Electricity bill	4	9%
Preference for RE	3	7%
Using the tool	3	7%
Preference for FF	3	7%
Health impacts from pollution	2	5%
GHG emissions	2	5%
Opposition to FF	2	5%
Employment & economic benefit	2	5%
Cultural impacts	0	0%
Opposition to RE	0	0%

4.9. Discussion – Study 2

Including uncertainty information did not seem to change to the direction of relationships observed in Study 1. People still strongly preferred renewables, were ambivalent about potential environmental and cultural impacts that could occur as a result of energy development, and were skeptical of intentions of the Navajo Nation government and Non-Navajo companies and their ability to make decisions consistent with the Navajo people. As was found in Study 1, the inclusion of cultural impact information did not seem to make a difference.

However, including uncertainty information seemed to strengthen positions with participants expressing stronger preferences for renewables. This increase in preference for renewable energy after using the tool may reflect our natural preference for certain outcomes (Tversky & Kahneman, 1989, 1979). For example, the renewable scenarios shown in the tools had significantly smaller uncertainty ranges in environmental impacts as compared to the fossil fuel scenarios and thus people expressed stronger preferences for them. We also found that people who saw uncertainty information held doubts that energy development would result in economic benefit to the Navajo people compared to those who did not receive uncertainty information. Again, this could be a reflection of a desire for certainty and aversion to risk

(Tversky & Kahneman, 1989) as economic benefits are less certain given the potential range of environmental impacts that could occur. In addition, the inclusion of the uncertain values may cause individuals to interpret environmental impacts as costs that come at the expense of the economic benefit that may result from energy development.

4.10. Conclusions

In this paper we explored how a decision aid for energy resource development influenced individuals' beliefs and preferences for energy, its development and its associated impacts. On balance we found a strong preference for renewable development, which became even stronger after including uncertainty information. Although people did not seem moved by culturally specific information, this may have to do with the fact that people were basing their decisions on environmental impacts. Previous research has identified the connection between environmental impacts and those on cultural resources in the mental models of Navajo stakeholders and concerns about future development (Necefer, et al., 2015; Schloepfle, et al., 1984). As a result, individuals using this decision tool may interpret environmental impacts as being synonymous with impacts on cultural resources. By and large, people held positive views about energy development resulting in economic benefits for the Navajo people, however these views were moderated with the provision of uncertainty information. This moderation in views could have resulted from individuals being less certain in the projected outcomes with the inclusion of uncertainty information.

The decision support tool used within these studies allows for stakeholders to explore alternative energy development pathways, their associated tradeoffs, and uncertainties. However, there is no generally accepted approach to communicating uncertainty within a decision support tool framework (Refsgaard, et al., 2007). This study provides a basis for which to communicate

social-cultural impacts, specifically those that are connected to environmental changes. While we didn't find that including uncertainty changed preferences, they apparently strengthened them. Frewer et al. (2002) found that failure to include and communicate uncertainty information by institutional actors in decision making about risk management has been shown increase distrust in the process and its outcomes. Thus, providing culturally relevant information in addition to uncertainty could provide an effective means for engaging with the public on complex topics such as energy development, however more should be done to investigate how including uncertainty may deepen trust within this context.

While these studies provide key insights into the influence of a decision aid on decision making, there are a number of limitations: first we did not conduct in person sampling on the Navajo Nation and thus were not able to assess views of individuals who may not have access to the internet; second the small number of participants in Study 2 limited the conclusions that could be drawn; lastly the we focus specifically on one unique cultural context. As a result, the sampling may not be fully representative of income distributions, educational attainment, and individuals who may still rely on traditional economies for their livelihoods (Table 11). A significant portion of the Navajo population, not fully represented in both of these studies, relies on traditional and informal economies based on cultural resources. It is possible that more representative sampling could increase concern and weighting of cultural impacts within the tools. In addition, this prevented participation who still speak Navajo as a primary language. The focus on one cultural context also limits the larger generalizability of these results. Future research should consider exploring cultural framings in other societies and contexts. For example, future study should consider the ways in which worldview orientations of individuals

and societies on their position within the environment influences their preferences and beliefs about energy use and development.

A sustainable future requires both technological advancement and a deeper understanding of people's attitudes and behaviors with respect to energy. We found that providing culturally relevant information did not seem to influence preferences but including uncertainty may deepen existing ones. Careful consideration of these cultural factors in the process of planning and development of energy projects can ensure a sustainable energy future for generations to come.

5. Summary and Conclusions

This dissertation documents the development and testing of a decision aid that incorporates cultural values on the environment with a specific focus on the Navajo Nation. Each of the chapters provides a unique contribution toward the development of a decision aid for the Navajo Nation. In their compilation these chapters provide both a useful decision tool that incorporates socio-cultural values and also measurement of public opinion about energy development on the Navajo Nation. More broadly this research provides an interdisciplinary perspective on addressing energy development by integrating both the technical and non-technical aspects of these decisions. This final chapter explores the contribution that this dissertation has provided to the development of decision aids, larger implications for the Navajo Nation and other Native Nations, and opportunities for further research.

5.1. Decision aids incorporating social factors

The decision aid developed in this research contributes to a growing body of work on decision aids and multi-criteria assessment for decisions on electricity and energy resources (Trutnevyte, et al. 2011, 2012; Trutnevyte, 2013; Mayer, et al., 2014; Wang, et al., 2009). Additionally, the decision aid developed in this dissertation also contributes to research on incorporating social factors into decision aids and multi-criteria assessment frameworks focusing on energy (Miller, et al., 2015; Ribeiro, et al., 2011). The research in this dissertation provides an alternative to economic valuation based on willingness-to-pay or related monetization methods by connecting impacts on Navajo cultural resources to environmental impacts that affect them, thereby creating an ordinal index to reflect the relative magnitude of cultural loss. This contribution provides a method of incorporating culturally specific impacts which could ensure that these decision tools engage and provide information to a broader range of stakeholders and

concerns (Fernald, 2012; Wong-Parodi, et al., 2014). Engaging a wider range of stakeholder and concerns can engender trust and understanding around energy development decisions potentially increasing chances of their success (Lynam, et al., 2007; Ramirez, 1999). In addition, providing uncertainty information on these specific impacts and their sources could also further engender trust (Frewer, et al., 2002)."

5.2. Public Participation in Energy and Environmental Decision Making

This dissertation contributes to the research area of environmental decision making specifically by strengthening methods and tools to connect environmental impacts to those on a society from energy development. While not a direct overlap with this dissertation, traditional ecological knowledge (TEK) has been studied to improve scientific research, methods of assessing environmental quality, and the management of natural resources (Huntington, et al., 2004; Gilchrist, et al., 2005; Danielson, et al., 2009; Roux, et al., 2006). There has been minimal research on incorporating TEK or other cultural knowledge into the management of energy resources (Necefer, et al., 2015). This dissertation provides a starting point for incorporating these areas of knowledge through structure public engagement through the use of a decision tool.

5.3. Implications for the Navajo Nation and other Native Nations

This dissertation provides useful information and feedback about the views of the Navajo public on energy issues to the Navajo Nation government and stakeholders concerned with energy issues on the reservation. Reflected in these results is the significant challenge that faces decision makers; despite nearly three decades since the last study engaging the Navajo public on energy issues we found similar results, suggesting that there is significant frustration about energy development and the decision makers behind them (Turner-Ruffing, 1978; Schoepfle, et al., 1983; Necefer, et al., 2015). Most importantly, this research demonstrated cultural values still

play a significant role in the views of the Navajo public in assessing the risks and opportunities from future energy development. Furthermore, this research provides an opportunity to explore paths for energy development that could better coincide with the wishes of the Navajo public.

While a number of the concerns about environmental impacts from land transformation of energy development could be answered by information about remediation, an unresolved issue for a sizeable number of individuals was the change in the cultural relationship with the land. These individuals expressed a worldview that saw all land as sacred, regardless of its economic or lack of specific spiritual significance. Protecting a subsection of more 'sacred' land while allowing for development to occur nearby is a particularly contentious proposition. In addition, a number of these individuals expressed the idea that removing fossil fuels from the ground fundamentally and irreversibly changes the nature of the environment in ways that are not fully understood. This in part motivated participants to actively oppose certain types of development. One participant, in reference to coal mining, said 'Leave it alone, don't mess with it, it has a purpose there (in the ground)'. Land transformation associated with renewable energy resources such as wind and solar generally have a lighter footprint on the surrounding environment compared to coal. These types of development may garner more support if they are framed as having a minimal and relatively reversible impact on the environment.

Community scale renewable energy development has significant potential for support on the Navajo Nation as it could minimize environmental impacts, such as land transformation, and allow for electricity generated on the Navajo Nation to be used by communities on the reservation. Focusing efforts upon these scales of projects first could address concerns expressed by citizens about environmental impacts and also a desire for the Navajo Nation to be self-sufficient. Additionally, these scale of projects could also address changing settlement patterns

on the Navajo Nation that are shifting away from dispersed homes located far off the grid to more clustered and concentrated housing that is currently being developed (NHA, 2009). However, it will be critically important that the Navajo public be provided with information about the impacts of energy development as well as their associated uncertainties and their sources from these projects. Pursuing this scale of projects while paying close attention to these considerations could be a fruitful path for future energy development.

This dissertation provides a starting point for the development of participatory practices on the Navajo Nation that engender trust, increase the perceived legitimacy, and improve the quality of the decision making process on energy resource management. The extensive history of energy resource development by non-Navajo companies and the Navajo Nation Government has left many Navajo citizens distrustful of both these companies and the Navajo Nation Government (McPherson, 2003; Wilkins, 2013). Despite these challenges there are ample opportunities for the institutions on the Navajo Nation to pursue participatory, trust-building activities around decision making that encourage Navajo citizens to participate in a meaningful way. The significant decisions that the Navajo Nation will need to make in the coming decades on energy resources will require levels of trust that do not currently exist. Entities such as the Navajo Tribal Utility Authority, Tribal Colleges, and the Navajo Transitional Energy Corporation, for example, could lead efforts to engage citizens in public participation in decision making around energy resource management. It will be critical that these entities clearly the communicate the purpose of why they are soliciting public input and the extent which public input will be considered within the process (Stern & Dietz, 2008). Failure to do so can lead to ambiguity, misunderstandings, and potentially a loss in trust (Stern & Dietz, 2008).

This research also has a number of important implications for other indigenous communities. The framework of decision making that this dissertation provides, using community engagement to develop a decision aid, could provide an option for tribes to engage in difficult decisions on energy resources while ensuring that their communities and cultural values are systematically considered in the process. Previous research has demonstrated that community engagement and explicit consideration for cultural values of a community leads to decision making processes and outcomes that are better suited to indigenous communities (Lane, 2003; Jojola, 2000; Korsgaard, et al., 1995). Furthering this research and efforts of community engagement could ensure that American Indian and Alaskan Native communities are further empowered to create successful energy resource management plans that are consistent with their cultural values.

5.4. Guidance for conducting research in indigenous communities

The number of indigenous researchers working within their own and other indigenous communities are increasing with each passing year. This presents an opportunity for research that is both beneficial to their community and also has greater awareness of the culture and context in which they are working. Key takeaways for both indigenous and non-indigenous researchers are the importance of familiarizing or re-familiarizing oneself with a culture and context prior to conducting research. If possible, spending time in a community, not for the purpose of research is a significant step. The researcher will be more adept to cultural factors, cues, and other aspects that otherwise would be missed. Overall this speaks to the importance of developing a mindset that can lead to approaches that "respects and protects the rights, interests, and sensitivities of the communities and people being studied" (Smith, 1999, pg. 119).

Lisa Tuhiwai Smith in her book 'Decolonizing Methodologies' describes research ethics within the context of Maori communities in New Zealand which extends beyond normal consent and confidentiality developed by the researcher, Ngahuia Te Awekotuku (Smith, 1999). The framework of these research ethics are based on codes of conduct of the New Zealand Association of Social Anthropologists and also the American Anthropological Association's guidelines yet are framed within culturally specific Maori ideas (Smith, 1999; Te Awekotuku, N. & Maori, M., 1991). The basic guidelines, while framed in the context of Maori, have significant overlap and applicability to the personal behavior of researchers in other indigenous communities.

1. *Aroha ki te tangata (a respect for people).*
2. *Kanohi kitea (the seen face, that is present yourself to people face to face) .*
3. *Titiro, whakarongo ... korero (look, listen, ... then speak).*
4. *Manaaki ki te tangata (share and host people, be generous).*
5. *Kia tupato (be cautious).*
6. *Kaua e takahia te mana o te tangata (do not trample over the mana*[1] *of people).*
7. *Kaua e mahaki (don't flaunt your knowledge).*

From: Smith, 1999; Te Awekotuku, N. & Maori, M., 1991

Broadly these guidelines are based upon respect of relationships and humanity – that everything and everyone in the universe has a place and they must be kept in balance and harmony (Smith, 1999). This environment of respect is built upon the personal conduct of the researcher and in many respects these guidelines are analogous to those that are used to determine if someone has 'good' qualities as a person in the Navajo worldview. Adapting this framework of principles to other indigenous communities can ensure that researchers conduct

[1] The Maori word, *Mana*, can take a number of meanings and has a number of different aspects that cannot be explained in a simple definition. Broadly it has been used to describe the "prestige, authority, control, power, influence, status, spiritual power, charisma of a person - *mana* is a supernatural force in a person, place or object" (Sachdev, 1989). In this context this speaks to the role of the researcher respecting the role and place in the universe that a person and community has. For example, respecting the social structures, norms, and not imposing one's presence or worldview onto others. In short this in this environment the researcher should treating these cultural and social norms as one's own.

research that is both beneficial and not imposing upon communities and individuals. These principles can also ensure that researchers create comfortable environments that allow for free expression of thought and ideas by participants that minimize cues and other influencing factors that could sway results.

5.5. Further research

This dissertation highlights the need to assess and quantify the connections between energy, the environment, and the resulting impact on cultural resources of indigenous people. There were significant challenges modeling impacts on cultural resources from the environmental outcomes of energy development, and future research could explore the nature of these relationships. While the connections between these outcomes and impacts on cultural resources presented in this dissertation are unique to the Navajo Nation, the methods used to explore them can be used as a guide when considering studies of other communities (Thomas & Truini, 2000; Brown & Eychaner, 1998; Redsteer, et al. 2012; Cozetto, et al. 2013; Lynn, et al., 2013; Vogesser, et al., 2013). A critical challenge of conducting this research is ensuring that this knowledge and subsequent research is used for the benefit of a community in order to make informed decision about their resources (Morgan & Cole-Hawthorne, 2016; Webster, 2015).

Further research can explore the role which decision aids containing culturally relevant information influence decision making and preferences within a group and community contexts. Many indigenous communities share collective identities and thus individual decision making may not accurately represent the influences which inform decision making in these contexts (Hossain, Skurky, Joe, and Hunt, 2011; Erazo, 2010; Turner-Ruffing, 1979, Triandis, 2001). Decision aids have been helpful in facilitating group decision making around pre-feasibility rankings of renewable resources (Nigim, et al., 2004). This research could be furthered by

exploring how such tools can be used within facilitated conversations and strategic energy planning sessions within indigenous communities building upon existing research on group decision making and frameworks based on indigenous practices (Dockry, et al., 2016).

5.6. Concluding comments

This dissertation provides a starting point for incorporating decision aids on energy resources into decision making and public engagement within indigenous communities in the United States. This research however is limited in scope to one particular community and consequently should be seen only as a partial guide to engaging other communities in these decision making processes. Special consideration must be paid to the uniqueness in cultures and histories with energy development of each American Indian & Alaskan Native group when applying these lessons. Solutions to energy and environmental issues within these communities are complex and will require the expertise and knowledge which technically oriented perspectives cannot provide alone (Lane, 2003; Jojola, 2000).

The success of future energy development on tribal lands requires the symbiosis of technical, economic, and social influences; focusing singularly on any of these factors in isolation could miss significant opportunities to identify pathways for success. The development of planning and decisions tools specific to each tribe can assist in building the technical capacities of these nations. Incorporating social and cultural factors into these tools can enable tribal policy makers and citizens to make well-informed choices consistent with their cultural values. More broadly these tools can enable tribes to illuminate paths for energy resource development that provide for economic development, energy self-sufficiency, and most importantly the preservation of cultural traditions.

References

[1] Aberle, D., Cernea, M., & Guggenheim S. (1993). *The Navajo-Hopi land dispute and Navajo relocation*. Westview Press

[2] Acker, T. L., Williams, S. K., Duque, E. P. N., Brummels, G., & Buechler, J. (2007). Wind resource assessment in the state of Arizona: Inventory, capacity factor, and cost. *Renewable Energy*, *32*(9), 1453–1466. doi:10.1016/j.renene.2006.06.002

[3] Ackerman, F., Jackson, S., & Fields, S. (2014). *Sustainable Development for the Navajo Nation*

[4] Apache, D. & MacCourt, D. (2014, March 25). Tribal Renewable Energy: To'Hajiilee Navajo Case Study. 2014 Department of Energy Tribal Energy Program Review. Lecture conducted from Department of Energy Tribal Energy Program, Golden, CO.

[5] Begay-Campbell, S. (2005, August). Native American Sustainable Energy Systems–Navajo Solar Electric Case Study. In *Arizona Governor's Tribal Energy Meeting, Arizona*.

[6] Berkes, F. (1999). Sacred ecology: Traditional ecological knowledge and resource management. Philadelphia, PA: Taylor and Francis

[7] Biernacki, P, & Waldorf, D. (1981) Snowball sampling: Problems and techniques of chain referral sampling. *Sociological methods & research* 10.2 141-163.

[8] Blaacker, D., Woods, J., & Oliver, C. (2012). How Big is Big Coal? Public Perceptions of the Coal Industry's Economic Impact in West Virginia. *Organization & Environment*

[9] Braddock III, C. H., Edwards, K. A., Hasenberg, N. M., Laidley, T. L., & Levinson, W. (1999). Informed decision making in outpatient practice: time to get back to basics. *Jama*, *282*(24), 2313-2320.

[10] Brown, J. G., & Eychaner, J. H. (1988). *Simulation of five ground-water withdrawal projections for the Black Mesa area, Navajo and Hopi Indian Reservations, Arizona* (No. 88-4000). US Geological Survey Brugge, D., & Goble, R. (2002). The history of uranium mining and the Navajo people. *American Journal of Public Health*, *92*(9), 1410-1419

[11] Brugge, D., & Goble, R. (2002). The history of uranium mining and the Navajo people. *American Journal of Public Health*, *92*(9), 1410-1419.

[12] Brugge, D., & Missaghian, M. (2006). Protecting the Navajo People through tribal regulation of research. *Science and Engineering Ethics*, *12*(3), 491–507. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16909153

[13] Brummels, G., Acker, T., & Williams, S. (2006). Navajo Wind Energy Development Exclusions: An analysis of Suitable Wind Energy Development on the Navajo Nation. *The Twenty-Sixth ESRI International User Conference*.

[14] Brundtland, G. H. (1987). Our Common Future, World Commission on Environment and Development (WCED).

[15] Burkhardt, J. J., Heath, G., & Cohen, E. (2012). Life cycle greenhouse gas emissions of trough and tower concentrating solar power electricity generation. *Journal of Industrial Ecology*, *16*(s1), S93-S109.

[16] Burnham, A., Han, J., Clark, C. E., Wang, M., Dunn, J. B., & Palou-Rivera, I. (2011). Life-cycle greenhouse gas emissions of shale gas, natural gas, coal, and petroleum. *Environmental science & technology*, *46*(2), 619-627.

[17] Burpo, R. (2012). *Tohajiilee Economic Development, Inc.(TEDI) Feasibility Study for Utility-Scale Solar* (No. DE-EE0002521). Tohajiilee Economic Development, Inc.

[18] Campbell, G. R. (1987). Northern Cheyenne Ethnicity, Religion, and Coal Energy Development. *The Plains Anthropologist*, 378-388.

[19] Clay, R. F. (2014). Tribe at a crossroads: the Navajo Nation purchases a coal mine. *Environmental health perspectives*, *122*(4), A104.

[20] Cornell, S. E., & Kalt, J. P. (1992). *Reloading the dice: Improving the chances for economic development on American Indian reservations* (Vol. 59). Malcolm Wiener Center for Social Policy, John F. Kennedy School of Government, Harvard University.

[21] Cortner, H. J., & Shannon, M. A. (1993). Embedding public participation in its political context. *Journal of forestry (USA)*.

[22] Cozzetto, K., Chief, K., Dittmer, K., Brubaker, M., Gough, R., Souza, K., ... & Chavan, P. (2013). Climate change impacts on the water resources of American Indians and Alaska Natives in the US. *Climatic change*, *120*(3), 569-584.

[23] Danielsen, F., Burgess, N. D., Balmford, A., Donald, P. F., Funder, M., Jones, J. P., ... & Child, B. (2009). Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology*, *23*(1), 31-42.

[24] Dawson, S. E., & Madsen, G. E. (2011). Psychosocial and health impacts of uranium mining and milling on Navajo lands. *Health physics*, *101*(5), 618-625.

[25] Department of Energy – Office of Utility Technologies; Energy Efficiency and Renewable Energy (1997). Renewable Energy Technology Characterizations. *Topical Report TR-109496, Energy Efficiency and Renewable Energy (EERE), US Department of Energy< http://www. nrel gov/docs/gen/fy98/24496. pdf*.

[26] Department of Energy (2016, January 14). Navajo Tribal Utility Authority Moves Forward with First Utility-Scale Solar Plant. Retrieved April 26, 2016, from

http://www.energy.gov/indianenergy/articles/navajo-tribal-utility-authority-moves-forward-first-utility-scale-solar-plant

[27] Department of Interior. (2015). ONRR Statistical Information Page. Retrieved July 3, 2015, from http://statistics.onrr.gov/ReportTool.aspx

[28] Dietz, T. (2013). Bringing values and deliberation to science communication.*Proceedings of the National Academy of Sciences*, *110*(Supplement 3), 14081-14087.

[29] Dietz, T., & Stern, P. C. (Eds.). (2008). *Public participation in environmental assessment and decision making*. National Academies Press.

[30] Dockry, M. J., Hall, K., Van Lopik, W., & Caldwell, C. M. (2016). Sustainable development education, practice, and research: an indigenous model of sustainable development at the College of Menominee Nation, Keshena, WI, USA. *Sustainability Science*, *11*(1), 127-138.

[31] DOE 1983 Energy Technology Characterizations

[32] DOE-TEP. (2013, July 23). Navajo Hopi Land Commission Office (NHLCO): Navajo Hopi Land Commission Office (NHLCO) - 2012 Project. Retrieved June 18, 2015, from http://apps1.eere.energy.gov/tribalenergy/projects_detail.cfm/project_id=207

[33] DOE-TEP. (2013, July 23). Navajo Hopi Land Commission Office (NHLCO): Navajo Hopi Land Commission Office (NHLCO) - 2012 Project. Retrieved June 18, 2015, fromhttp://apps1.eere.energy.gov/tribalenergy/projects_detail.cfm/project_id=207

[34] Donahue, J. (1997). *Water, culture, and power: local struggles in a global context*. Island Press

[35] Douglas, M., & Wildavsky, A. (1983). *Risk and culture: An essay on the selection of technological and environmental dangers*. University of California Press.

[36] Douglas, M., & Wildavsky, A. (1983). *Risk and culture: An essay on the selection of technological and environmental dangers*. Univ of California Press.

[37] Douglas, M., & Wildavsky, A. B. (1983). *Risk and culture: An essay on the selection of technological and environmental dangers*. University of California Press.

[38] Downs, J. S., Murray, P. J., de Bruin, W. B., Penrose, J., Palmgren, C., & Fischhoff, B. (2004). Interactive video behavioral intervention to reduce adolescent females' STD risk: A randomized controlled trial. *Social science & medicine*, *59*(8), 1561-1572.

[39] Duffy, D., & Stubben, J. (1998) An assessment of native American economic development: Putting culture and sovereignty back in the models. *Studies in Comparative International Development*, *32*(4), 52–78. doi:10.1007/BF02712505

[40] Eichstaedt, P. H. (1994). *If you poison us: Uranium and Native Americans*. Santa Fe, NM: Red Crane Books.

[41] Ellis, M. G. (1988). Navajo economic behavior. *Journal of Behavioral Economics*, *17*(2), 119–131. doi:10.1016/0090-5720(88)90003-4

[42] Energy Information Administration. (2014). Residential Energy Consumption Survey (RECS).

[43] Energy Information Administration. 2000. *Energy consumption and renewable energy development potential on Indian lands*. Washington, DC: U.S. Department of Energy.

[44] EPA – Environmental Protection Agency (2014) EPA cuts emissions at Navajo Generating Station, protecting public health, preserving tribal jobs and improving visibility at the Grand Canyon, http://yosemite.epa.gov/opa/admpress.nsf/2dd7f669225439b78525735900400c31/e26806c557e820e485257d2300664dfa!OpenDocument

[45] EPA – Environmental Protection Agency (2015). Four Corners Power Plant Clean Air Act Settlement. Enforcement. http://www2.epa.gov/enforcement/four-corners-power-plant-clean-air-act-settlement Accessed: September 15, 2015

[46] Erazo, J. (2010). Constructing indigenous subjectivities: economic collectivism and identity in the Ecuadorian Amazon. *Development and Change*, *41*(6), 1017-1039.

[47] Ericsson, KA, Simon, HA (1980) Verbal reports as data. *Psych Rev*, 87(3):215-251.

[48] Farella, J. R. (1984). *The main stalk: A synthesis of Navajo philosophy*. University of Arizona Press.

[49] Fernald, A., Tidwell, V., Rivera, J., Rodríguez, S., Guldan, S., Steele, C., & Cibils, A. (2012). Modeling sustainability of water, environment, livelihood, and culture in traditional irrigation communities and their linked watersheds. *Sustainability*, *4*(11), 2998-3022.

[50] Fischhoff, B. (2010). Judgment and decision making. Wiley Interdisciplinary Reviews: Cognitive Science, 1(5), 724-735.

[51] Fischhoff, B. (2013). The sciences of science communication. *Proceedings of the National Academy of Sciences*, *110*(Supplement 3), 14033-14039.

[52] Fischhoff, B., Bostrom, A., & Quadrel, M. J. (2011). 8.9 Risk perception and communication. *Cardiovascular diseases*, *3*, 49.

[53] Frewer, L. J., Miles, S., Brennan, M., Kuznesof, S., Ness, M., & Ritson, C. (2002). Public preferences for informed choice under conditions of risk uncertainty. *Public understanding of science*, *11*(4), 363-372.

[54] Fthenakis, V., & Kim, H. C. (2009). Land use and electricity generation: A life-cycle analysis. *Renewable and Sustainable Energy Reviews*, *13*(6), 1465-1474.

[55] Gedicks, A. 1994. *The New Resource Wars: Native and Environmental Struggles Against Multinational Corporations*. (Vol. 210). Black Rose Books Ltd.

[56] Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, *36*(3), 399-417.

[57] Gil, A., Shafer, D., & Elmer, J. (2012, July). US Department of Energy Office of Legacy Management's Tribal Interactions–12513. WM Symposia, 1628 E. Southern Avenue, Suite 9-332, Tempe, AZ 85282 (United States).

[58] Gilchrist, G., Mallory, M., & Merkel, F. (2005). Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society*, *10*(1), 20.

[59] Greenberg, M. R. (2014). Energy policy and research: The under appreciation of trust. *Energy Research & Social Science*, *1*, 152-160.

[60] Greenberg, M. R. (2014). Energy policy and research: the underappreciation of trust. *Energy Research & Social Science*, *1*, 152-160.

[61] Haggett, C. (2011). 'Planning and Persuasion': Public Engagement in Renewable Energy Decision-Making. *Renewable energy and the public: From NIMBY to participation*, 15-27.

[62] Harmsworth, G. R., Young, R. G., Walker, D., Clapcott, J. E., & James, T. (2011). Linkages between cultural and scientific indicators of river and stream health. *New Zealand Journal of Marine and Freshwater Research*, *45*(3), 423-436.

[63] Häubl, G., & Trifts, V. (2000). Consumer decision making in online shopping environments: The effects of interactive decision aids. *Marketing science*, *19*(1), 4-21.

[64] Heinrich, M., Ankli, A., Frei, B., Weimann, C., & Sticher, O. (1998). Medicinal plants in Mexico: Healers' consensus and cultural importance. *Social Science & Medicine*, *47*(11), 1859-1871.

[65] Henderson, Al 1979 "*The Aneth community: Oil crisis in Navajoland*" Indian Historian 12 (winter) 33-36

[66] Hibbard, M., Lane, M. B., & Rasmussen, K. (2008). The Split Personality of Planning: Indigenous Peoples and Planning for Land and Resource Management. *Journal of Planning Literature*, *23*(2), 136–151. doi:10.1177/0885412208322922

[67] Hossain, Z., Skurky, T., Joe, J., & Hunt, T. (2011). The sense of collectivism and individualism among husbands and wives in traditional and bi-cultural Navajo families on the Navajo Reservation. *Journal of Comparative Family Studies*, 543-562.

[68] Huntington, H. P. (1998). Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. *Arctic*, 237-242.

[69] Huntington, H., Callaghan, T., Fox, S., & Krupnik, I. (2004). Matching traditional and scientific observations to detect environmental change: a discussion on Arctic terrestrial ecosystems. *Ambio*, 18-23.

[70] Huntington, H., Callaghan, T., Fox, S., & Krupnik, I. (2004). Matching traditional and scientific observations to detect environmental change: a discussion on Arctic terrestrial ecosystems. *Ambio*, 18-23.

[71] Hurlbut, D. J., Haase, S., Brinkman, G., Funk, K., Gelman, R., Lantz, E., … Engineering, H. D. R. (2012). Navajo Generating Station and Air Visibility Regulations: Alternatives and Impacts. *Clean Air*, (January).

[72] Jefferson, M. (2014). Closing the gap between energy research and modeling, the social sciences, and modern realities. *Energy Research & Social Science*,*4*, 42-52.

[73] Jett, S. C. (1992). An introduction to Navajo sacred places. *Journal of Cultural Geography*, *13*(1), 29-39.

[74] Johnson, B. B., & Slovic, P. (1995). Presenting uncertainty in health risk assessment: Initial studies of its effects on risk perception and trust. *Risk analysis*, *15*(4), 485-494.

[75] Johnson, B. B., & Slovic, P. (1998). Lay views on uncertainty in environmental health risk assessment. *Journal of Risk Research*, *1*(4), 261-279.

[76] Jojola, T. (2000). Indigenous planning and community development. *Traditional Dwellings and Settlement Review*, *12*(1).

[77] Jollands N., & Harmsworth, G. (2007) Participation of indigenous groups in sustainable development monitoring.: Rationale and examples from New Zealand. *Ecological Economics,* 62(3), 716-726

[78] Kahan, D. M., Braman, D., Gastil, J., Slovic, P., & Mertz, C. K. (2007). Culture and identity-protective cognition: Explaining the white-male effect in risk perception. *Journal of Empirical Legal Studies*, *4*(3), 465-505.

[79] Kahneman, D. (2011). *Thinking, fast and slow*. Macmillan.

[80] Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the econometric society*, 263-291.

[81] Keirstead, J. (2006). Evaluating the applicability of integrated domestic energy consumption frameworks in the UK. *Energy policy*, *34*(17), 3065-3077.

[82] Kelley, K., and H. Francis. 1993. Places important to Navajo people. *American Indian Quarterly* 17 (2):151–69. doi:10.2307/1185525

[83] Kingston, R., Carver, S., Evans, A., & Turton, I. (2000). Web-based public participation geographical information systems: an aid to local environmental decision-making. *Computers, environment and urban systems*, *24*(2), 109-125.

[84] Kline, R. R. (2002). Resisting development, reinventing modernity: Rural electrification in the United States before World War II. *Environmental Values*,*11*(3), 327-344.

[85] Korsgaard, M. A., Schweiger, D. M., & Sapienza, H. J. (1995). Building commitment, attachment, and trust in strategic decision-making teams: The role of procedural justice. *Academy of Management journal*, *38*(1), 60-84.

[86] Laduke, W. (1994). Traditional Ecological Knowledge and Environmental Futures. *Colorado Journal of International Environmental Law and Policy*, *5*(127), 127–148.

[87] LaDuke, W. (1998). All Our Relations. Native Struggles for Land and Life. Cambridge MA: South End Press.

[88] Landy, M. (1993). 2. Public Policy and Citizenship. *Public policy for democracy*, 19.

[89] Lane, M. B. (2003). Participation, decentralization, and civil society indigenous rights and democracy in environmental planning. *Journal of planning education and research*, *22*(4), 360-373.

[90] LeBeau, T. A. (2001). Reclaiming Reservation Infrastructure: Regulatory and Economic Opportunities for Tribal Development. *Stanford Law & Policy Review.*, *12*, 237.

[91] Lutzenhiser, L. (1992). A cultural model of household energy consumption. *Energy*, *17*(1), 47-60.

[92] Lynam, T., De Jong, W., Sheil, D., Kusumanto, T., & Evans, K. (2007). A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. *Ecology and society*, *12*(1), 5.

[93] Lynn, K., Daigle, J., Hoffman, J., Lake, F., Michelle, N., Ranco, D., ... & Williams, P. (2013). The impacts of climate change on tribal traditional foods. *Climatic Change*, *120*(3), 545-556.

[94] Macknick et al. (2011), A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies. NREL: Golden, CO

[95] Manfren, M., Caputo, P., & Costa, G. (2011). Paradigm shift in urban energy systems through distributed generation: Methods and models. *Applied Energy*,*88*(4), 1032-1048

[96] McPherson, R. S. (1992). Sacred land, sacred view: Navajo perceptions of the Four Corners Region (No. 19). Charles Redd Center for Western Studies.

[97] McPherson, R. S. (2003). *Navajo land, Navajo culture: The Utah experience in the twentieth century*. University of Oklahoma Press.

[98] McPherson, R., & Wolff, A. (1997). The Utah Navajo and the Poverty , Politics , and Petroleum : Aneth Oil Field. *American Indian Quarterly*, *21*(3), 451–470.

[99] Miller, C. A., Richter, J., & O'Leary, J. (2015). Socio-energy systems design: a policy framework for energy transitions. *Energy Research & Social Science*,*6*, 29-40.

[100] Morgan, E., & Cole-Hawthorne, R. (2016). Applying a shared understanding between Aboriginal and Western knowledge to challenge unsustainable neo-liberal planning policy and practices. *Australian Planner*, 1-9.

[101] Morgan, M. G., Fischhoff, B., Bostrom, A., & Atman, C. J. (2001). *Risk communication: A mental models approach*. Cambridge University Press.

[102] Murray, E., Davis, H., Tai, S. S., Coulter, A., Gray, A., & Haines, A. (2001). Randomised controlled trial of an interactive multimedia decision aid on benign prostatic hypertrophy in primary care. *Bmj*, *323*(7311), 493.

[103] National Renewable Energy Laboratory (NREL) (2011. Solar-Augment Potential of U.S. Fossil-Fired Power Plants. Accessed March 2014 at: http://www.nrel.gov/docs/fy11osti/50597.pdf

[104] Navajo Hopi Land Commission. (2014). Feasibility Study for 4,000 MW of Renewable Power at the Paragon-Bisti Ranch. In *DOE TEP Review*. Golden, CO.

[105] Necefer, L., Wong-Parodi, G., Small, M. (2016) Integrating technical, economic and cultural impacts in a decision support tool for energy resource management in the Navajo Nation. *Energy Policy (in review)*

[106] Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fischer, J., & Hutchings, J. A. (1999). Fisheries assessment: what can be learned from interviewing resource users?. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(10), 1949-1963.

[107] New Mexico EMNRD - New Mexico Energy, Minerals, and Natural Resources Department (2005). Renewable Energy Resources—Hydropower. Retrieved July 23, 2015, from http://www.emnrd.state.nm.us/MAIN/documents/SER1_electricity.pdf

[108] Nigim, K., Munier, N., & Green, J. (2004). Pre-feasibility MCDM tools to aid communities in prioritizing local viable renewable energy sources. *Renewable energy*, *29*(11), 1775-1791.

[109] NNDED -The Navajo Nation Department of Economic Development. (2009). *2009-2010 Comprehensive Economic Development Strategy The Navajo Nation*. *Navajo Nation Business Council*.

[110] Noppers, E. H., Keizer, K., Bolderdijk, J. W., & Steg, L. (2014). The adoption of sustainable innovations: driven by symbolic and environmental motives.*Global Environmental Change*, *25*, 52-62.

[111] Nuttall, M. (1998). *Protecting the Arctic: Indigenous peoples and cultural survival* (Vol. 3). Taylor & Francis

[112] O'Connor, Annette M., et al. "Decision aids for people facing health treatment or screening decisions." *The Cochrane Library* (2009).

[113] Office of Surface Mining Reclamation and Enforcement (OSMRE) (2014). *Four Corners Power Plant and Navajo Mine Energy Project - Draft Environmental Impact Statement*. Washington, DC.

[114] Office of Surface Mining Reclamation and Enforcement (OSMRE) (2014). *Four Corners Power Plant and Navajo Mine Energy Project - Draft Environmental Impact Statement*. Washington, DC.

[115] Ohnemus, K. R., & Biers, D. W. (1993, October). Retrospective versus concurrent thinking-out-loud in usability testing. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 37, No. 17, pp. 1127-1131). SAGE Publications.

[116] Pasqualetti, M. J. (2011). Social barriers to renewable energy landscapes*.*Geographical Review*, *101*(2), 201-223.

[117] Pasqualetti, M. J.; Jones, T; Necefer, L.; Scott, C.; Columbi, B. (2016) A paradox of plenty: Renewable energy on Navajo Nation Lands. *Society & Natural Resources*. 22

[118] Pemberton Jr, R. (1985). I Saw That It Was Holy: The Black Hills and the Concept of Sacred Land. *Law & Ineq.*, *3*, 287.

[119] Piña, V. Y., and W. W. Covington. 1993. Conservation biology, restoration ecology, and a Navajo view of nature. General Technical Report RM-247, USDA Forest Service. http://library.eri.nau.edu/gsdl/collect/erilibra/import/YazzieEtAl_1993_SustainableEcolo

gical.pdf (accessed January 20, 2016).

[120] Powell, D. E., & Curley, A. (2008). K'e, Hozhó, and non-governmental politics on the Navajo Nation: Ontologies of difference manifest in Environmental Activism. *Anthropological Quarterly*, *81*, 17-58.

[121] Powell, D. E., & Long, D. J. (2010). Landscapes of power: Renewable energy activism in Diné Bikéyah. *Indians & energy: Exploitation and opportunity in the American Southwest*, 231-262.

[122] Ramirez, R. (1999). Participatory learning and communication approaches for managing pluralism: Implications for sustainable forestry, agriculture and rural development.

[123] Redsteer MH, Kelley KB, Francis H, Block D (2010) Disaster risk assessment case study: recent drought on the Navajo nation, southwestern United States. UN Global Assessment Report 2011. http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Redsteer_Kelley_Francis_&_Block_2010.pdf. Accessed 14 Nov 2012

[124] Refsgaard, J. C., van der Sluijs, J. P., Højberg, A. L., & Vanrolleghem, P. A. (2007). Uncertainty in the environmental modelling process–a framework and guidance. *Environmental modelling & software*, *22*(11), 1543-1556.

[125] Reno, P. (1981). *Mother Earth, Father Sky, and economic development: Navajo resources and their use* (No. 3). University of New Mexico Press.

[126] Ribeiro, F., Ferreira, P., & Araújo, M. (2011). The inclusion of social aspects in power planning. *Renewable and Sustainable Energy Reviews*, *15*(9), 4361-4369.

[127] Roux, D. J., Rogers, K. H., Biggs, H., Ashton, P. J., & Sergeant, A. (2006). Bridging the science-management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing.

[128] Royster, J. (2009). Practical Sovereignty, Political Sovereignty, and the Indian Tribal Energy Development and Self-Determination Act.

[129] Ruffing, L. (1976). Navajo Economic Development Subject to Cultural Constraints. *Economic Development and Cultural Change*, *24*(3), 611–621.

[130] Ruffing, L. T. (1979a). 'Strategy for asserting Indian control over mineral development'. *Economic Development in American Indian Reservations, Native American Studies, University of New Mexico, Development Series*, (1).

[131] Ruffing, Lorraine (1979b) Navajo Economic Development: A Dual Perspective. American Indian Economic Development edited by Sam Stanley.

[132] Sachdev, P. S. (1989). Mana, tapu, noa: Maori cultural constructs with medical and psycho-social relevance. *Psychological medicine*, *19*(04), 959-969.

[133] Sacred Power. (2014). SP Hybrid. Retrieved June 18, 2015, from http://sacredpower.com/s/SP-Hybrid-Spec-FINAL-2014.pdf

[134] Schoepfle, M., Burton, M., & Begishe, K. (1984). Navajo attitudes toward development and change: A unified ethnographic and survey approach to an understanding of their future. *American Anthropologist*, *86*(4), 885-904.

[135] Scholz, R. (2007). Assessment of land use impacts on the natural environment. Part 1: an analytical framework for pure land occupation and land use change (8 pp). *The International Journal of Life Cycle Assessment*, *12*(1), 16-23.

[136] Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental politics*, *16*(4), 584-603.

[137] Shirley, J. 2005. *Desert rock energy project will help Navajo Nation regain its economic independence*. The Navajo Nation, Office of the President. http://www.navajo-nsn.gov/images/pdf%20releases/George%20Hardeen/march07/Desert%20Rock%20Energy%20Project%20Will%20Help%20Navajo%20Nation%20Regain%20Its%20Economic%20Independence_March.pdf (accessed January 20, 2016).

[138] Shirley, J. 2009. *Navajo President Joe Shirley, Jr. places Desert Rock project into international perspective during State of Nation address*. The Navajo Nation, Office of the President and Vice President. http://www.navajonsn.gov/News%20Releases/George%20Hardeen/Apr09/090422pres_Navajo%20president%20puts%20Desert%20Rock%20into%20international%20perspective.pdf (accessed January 20, 2016).

[139] Shove, E. (2003). Converging conventions of comfort, cleanliness and convenience. *Journal of Consumer Policy*, *26*(4), 395-418.

[140] Siegrist, M., Earle, T. C., & Gutscher, H. (2010). *Trust in risk management: Uncertainty and scepticism in the public mind*. Earthscan.

[141] Siegrist, M., Earle, T. C., & Gutscher, H. (2010). *Trust in risk management: Uncertainty and scepticism in the public mind*. Earthscan.

[142] Slovic, P. (1987). Perception of risk. *Science*, *236*(4799), 280-285.

[143] Smith, L. T. (1999). *Decolonizing methodologies: Research and indigenous peoples*. Zed books.

[144] Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research & Social Science*, *1*, 1-29.

[145] Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research & Social Science*, *1*, 1-29.

[146] Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., & Thorsnes, P. (2010). Energy cultures: A framework for understanding energy behaviours. *Energy policy*, *38*(10), 6120-6129.

[147] Stevenson, M. (1998). *Traditional Knowledge in Environmental Management?: From Commodity to Process*. Edmonton: Sustainable Forest Management Network.

[148] Stevenson, M. G. (1996). Indigenous Knowledge in Environmental Assessment. *Arctic*, *49*(3), 278–291.

[149] Stoffle, R. W., & Evans, M. J. (1988). American Indians and nuclear waste storage: the debate at Yucca Mountain, Nevada. *Policy Studies Journal*, *16*(4), 751-767.

[150] Tarasi, D., Alexander, C., Gregory, B., Chan, N., & Vilsack, D. (2011). Electricity : Illuminating and Solving the Navajo Energy Crisis. *Colorado Journal of International Environmental Law and Policy*, *22*(2).

[151] Te Awekotuku, N. & Maori, M. (1991), He Ttkanga Wbakaaro. Research Ethics in the Maori Community), Manatu Maori, Wellington.

[152] The Navajo Nation Department of Economic Development (NNDED) (2009). *2009-2010 Comprehensive Economic Development Strategy The Navajo Nation*. *Navajo Nation Business Council*.

[153] Thomas, B. E., & Truini, M. (2000). Ground-Water, Surface-Water, and Water-Chemistry Data, Black Mesa Area, Northeastern Arizona-1999. DEPARTMENT OF THE INTERIOR WASHINGTON DC.

[154] Thorpe, N. L. (2000). *Contributions of Inuit ecological knowledge to understanding the impacts of climate change on the Bathurst caribou herd in the Kitikmeot region, Nunavut*. Simon Fraser University.

[155] Tidwell, V. C., Passell, H. D., Conrad, S. H., & Thomas, R. P. (2004). System dynamics modeling for community-based water planning: Application to the Middle Rio Grande. *Aquatic Sciences*, *66*(4), 357-372.

[156] Topcu, Y. I., & Ulengin, F. (2004). Energy for the future: An integrated decision aid for the case of Turkey. *Energy*, *29*(1), 137-154.

[157] Trentmann, F. (2009). Disruption is normal: blackouts, breakdowns and the elasticity of everyday life. *Time, consumption and everyday life: practice, materiality and culture*, 67-84.

[158] Triandis, H. C. (1995). *Individualism & collectivism*. Westview press.

[159] Triandis, H. C. (2001). Individualism-collectivism and personality. *Journal of personality*, *69*(6), 907-924.

[160] Trutnevyte, E. (2013). EXPANSE methodology for evaluating the economic potential of renewable energy from an energy mix perspective. *Applied Energy*, *111*, 593-601.

[161] Trutnevyte, E., Stauffacher, M., & Scholz, R. W. (2011). Supporting energy initiatives in small communities by linking visions with energy scenarios and multi-criteria assessment. *Energy Policy*, *39*(12), 7884-7895.

[162] Tsosie, R. (2012). *Climate Change, Sustainability, and Globalization: Charting the Future of Indigenous Environmental Self-Determination.*

[163] Tsosie, R. 2009. Climate change, sustainability, and globalization: Charting the future of indigenous environmental self-determination. *Environmental & Energy Law & Policy Journal* 4 (2):188–255.

[164] US EPA (2014, March 1).2012 Update – Renewable Energy on Mine Sites. Retrieved June 18, 2015, from http://www.epa.gov/aml/revital/amlrenew0312.pdf

[165] Vinje, D. L (1985) Cultural values and economic development on reservations. American Indian Policy in the Twentieth Century, Edited by Vine Deloria Jr 155-75. Norma University of Oklahoma Press.

[166] Voggesser, G., Lynn, K., Daigle, J., Lake, F. K., & Ranco, D. (2013). Cultural impacts to tribes from climate change influences on forests. *Climatic Change*,*120*(3), 615-626.

[167] Wang, J. J., Jing, Y. Y., Zhang, C. F., & Zhao, J. H. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and Sustainable Energy Reviews*, *13*(9), 2263-2278.

[168] Webster, R. M. (2016). This land can sustain us: cooperative land use planning on the Oneida Reservation. *Planning Theory & Practice*, *17*(1), 9-34.

[169] Weiss K., Hamann M., & Marsh H. (2013) Bridging Knowledges: Understanding and Applying Indigenous and Western Scientific Knowledge for Marine Wildlife Management, Society & Natural Resources: An International Journal, 26:3, 285-302, DOI: 10.1080/08941920.2012.690065

[170] Whitaker, M., Heath, G. A., O'Donoughue, P., & Vorum, M. (2012). Life Cycle Greenhouse Gas Emissions of Coal-Fired Electricity Generation. *Journal of Industrial Ecology*, *16*(s1), S53-S72.

[171] Wilkins, D. E. (2013). *The Navajo political experience*. Rowman & Littlefield.

[172] Williams, B. A., & Matheny, A. R. (1995). Democracy, dialogue, and environmental disputes: The contested languages of environmental dispute.

[173] Wilson, C., & Dowlatabadi, H. (2007). Models of decision making and residential energy use. *Annu. Rev. Environ. Resour.*, *32*, 169-203.

[174] Woods, S. (2013). The Navajo Nation: Preparing the Future's Energy Resources for Tomorrow. In *11th Annual CO2 EOR Carbon Management Workshop*.

[175] Yazzie, D. (2005) Master Land Use Plan – Shiprock Chapter, New Mexico. Shiprock Chapter

[176] Yazzie, R., Benally, M., Curley, A., Alex, N., Singer, J., & Crotty, A. (2008). Navajo Nation Constitutional Feasbility and Government Reform Project. *Diné Policy Institute*, 1–71.

[177] Yurth, C. 2011. LEEDing by example: NTUA goes green with new Chinle facility. http://navajotimes. com/news/2011/0711/072311green.php#.VThoL61Viko (accessed April 19, 2015).

Appendix 1: Interview protocol for chapter 2

Perceptions of energy projects on the Navajo Nation

June 15th, 2012

Note to interviewer

Interview should be cut off after 1.5 hours.

Preparation

[Phone interview]

Before we start the interview, I would like to ask you to move into a quiet room where you will not be interrupted. If it is possible to turn off call waiting, please do so.

[In person interview]

Make sure participant is comfortable and willing to begin the interview

Introduction

Shi ei Len Necefer yinishe. Tachii'nii nishli, Bilagaana Bashichiin, Naakai Dine'e dashichei, doo Bilagaana dashinali. Tseili dee naasha.

(My name is Len Necefer, I am from Tsaile, Arizona. I represent the Tachiinii and Naakai Dine'e Clans.)

I am a Graduate Student at Carnegie Mellon University in Pittsburgh, PA.

Today we are going to talk about your views about energy on the Navajo Nation. I will be talking to other people on the Nation about their views too. I am doing this so that I can make a tool to help people make better decisions about energy on the Nation.

Your participation in this study is voluntary. We will replace your name with a code number to protect your identity. What you tell me today will be confidential.

I will give you $25 for participating in this interview.

This interview should not take more than 1.5 hours. You will be asked questions more than once, to ensure that I know what you are saying. Tell me if you feel uncomfortable answering any of the questions. We will skip it and move to the next one.

Please feel free to contact me at lnecefer@andrew.cmu.edu or call me at (785) 764-0873 for more information.

I want to make sure that I get what your are saying "right." So, I would like to audio-record our conversation. Is that okay with you?

Do you have any questions before we begin?

Do you have any questions before we start?

I will start recording our conversation now, is that okay with you?

Basic Prompts

Can you tell me about what you know about Diné (Navajo) teachings on this?

Anything else?

Can you tell me more?

Can you explain why?

Some prompts are mentioned in the protocol, and only have to be asked if the interviewee seems to have a hard time finding an answer

Get definitions for probability terms, if they are mentioned. Ask

What do you mean by…?

What is…?

Can you tell me more about…?

Part I: Elicitation of values and issue importance

First, I would like to learn more about you and your community.

Are you originally from [xx]?

If yes, describe for me the place in this area that you like the best. Why?

If no, tell me how you came to live in this place.

Please tell me what you value the most about being a member of [xx].

Tell me more about "xx." Anything else?

Please tell me what you think other people in [xx] value the most.

Tell me more about "xx." Anything else?

Now, I'd like to talk about issues that might be important to you and other people in your community. Here are some issues that might be important....

Pull out "topics flashcards" and lay out on the table; randomize the order by shuffling each time you show the cards: (a) water, (b) jobs, (c) environment, (d) energy, (e) cultural continuity [The Navajo culture will continue to exist], political sovereignty [The Navajo Nation will govern itself], and (f) other.

Please read each one carefully and think about which one is the most important to you as a member of [xx]. If there is anything that is missing, what is it? [If an important issue is missing, tell the interviewee to think of the "other" card as that issue. If there is more than one issue missing, write it down on extra flash cards]

Please pick the out the issue that is most important and place it here [indicate on the table where you'd like that card to be].

How would you define this issue?

Why is this one the most important? Anything else?

Now, I would like you take the rest of the cards and put them in the order of importance to you as a member of [xx]. That is, if [xx] is #1, then what would be #2 [point to the space below the card that they selected as #1. If some of the issues are tied in importance to you that is okay; just put the cards side-by-side.

I see that [xx] is last. How would you define this issue?

Why is this one the least important? Anything else?

Write down the order of the cards on a notebook. Gather the cards and put them away (out of sight).

Part II: Beliefs about Navajo economy and power generation projects

First I'm going to ask you about how you use energy just to get an idea of how you see using energy everyday.

Tell me about how you use electricity?

Can you tell me where you think this comes from?

Can you tell me about how you use fuels like propane, gasoline, or diesel?

Can you tell me where you think this comes from?

Now, I'd like to learn more about your thoughts about energy on the Navajo Nation as a whole. And not just about [xx]. Specifically I'd like your views on energy projects. By energy projects I mean things such as coal mining, coal power generation, oil and gas drilling, renewable energy projects

Employment/Unemployment

Tell me energy projects on the Navajo Nation. Anything else?

If the interviewee bring up jobs, ask: Tell me more about jobs. Anything else?

If the interviewee doesn't bring up jobs, ask: Tell me about jobs and energy projects. Anything else?

Think about past energy projects that you can remember. Do you think that they have brought more (or less) jobs to the reservation? Why?

Revenue from energy projects

Today, the Navajo Nation receives about half of its operating budget from money collected from

Coal, Oil, and Natural Gas operations.

Please tell me what you think about this. Why? Anything else?

Part III: Beliefs about the Environment

Now, I'd like to learn more about your thoughts about some possible impacts from having energy projects on the reservation.

Pull out the "impacts cards." Select the one about land use and put it on the table in from of the participant.

a. Land Use For Energy Projects

Some projects that involve mining or power generation require land to be set aside for their usage.

Tell me what you think about this. Why?

Tell me what you think about having land set aside and used only for energy projects.

Anything else?

What if the land is used for energy projects that involve coal or natural gas?

What if the land is used for energy projects that involve wind or solar?

Some energy projects such as [xx] require that the land be repaired after the project is over. This can include covering mines with dirt and planting native plants. The purpose of doing this is to make the land go back to its original state. Or even a better one after the project is over.

Tell me what you think about this. Why?

How do you think the land could be used after this repair happens? Why?

Where should the waste from projects be put? Why?

I'd like for you to think about the Diné teachings about how people should relate to the land.

Please describe how people should relate to the land. Anything else?

Do you believe people follow these teachings today?

Can the land be changed while respecting Diné Teachings?

In the permitting process for some mining or power generation groups involved must consider the locations of sacred areas such as burial grounds or other sites.

Tell me what you think about this. Why?

Take away the card about land use, and now select the card about pollution and emissions. Put this card down on the table.

b. Pollution and Emissions: Soil, Water, Air

For energy projects like xx, pollution from runoff can get into the soil, air or water. For example, this pollution can come from the chemicals used or minerals produced during coal mining.

Tell me what you think about this pollution. Why?

What are the possible health impacts from this pollution? Anything else?

Take away the card about pollution and emissions, and now select the card about water usage. Put this card down on the table.

c. Water Usage

Water is used for some energy projects. This water is used for cooling power plants or transformation of solid fuels to liquid or gases.

Tell me about what you think about using water for energy projects. Why?

Pull out the cards about land use and pollution and emissions and put them on the table next to the card about water usage.

We've had a really good discussion about some effects of energy projects on the Nation. I would like for you to think back on our conversation about jobs and energy projects.

Tell me if you think the possible effects from energy projects can be balanced against the possible benefits (e.g. jobs). Why? Anything else?

Part IV: Beliefs about trust of information and management

I am interested in learning how people think about information coming from groups that help develop energy projects on the Navajo Nation

Pull out the "Information and Management" Select the one about land use and put it on the table in from of the participant.

a. Navajo Nation Government

The Navajo Nation government in Window Rock, such as the President and Vice-President and the Council have the final say on energy projects on the Navajo Nation.

Can you tell me about what you think about the Navajo Nation Gov't?

Can you tell me about information you have received from the NN Gov't about these energy projects?

Can you tell me where you have received information about health effects of mining, energy technology, or related topics?

Do you believe that the Navajo nation government take Diné teaching into consideration into the development of energy projects?

b. State and Federal Government

Now we are going to talk about other governments such as state governments like New Mexico, Arizona, and Utah. WE will also talk about the Federal Government in Washington, D.C. We want to talk about their role in energy projects on the Navajo Nation.

The Federal Government includes the BIA, EPA, DOE, [create list] Can you tell me what you think about the Federal Government?

Can you tell me about information you have received from these groups about these energy projects?

c. Non- Governmental Organization

So let's talk about Non-Governmental Organizations (NGOs) that have an interest in Navajo Energy Projects. These include groups such as Dine CARE (Citizens Against Ruining our Environment), Black Mesa Water Coalition, Eastern Navajo Diné Against Uranium Mining ENDAUM.

Have you ever worked for or been contacted by NGOs working on the Navajo Nation? If so which ones?

Can you tell me where you have received information about health effects of mining,

energy technology, or related topics?

Do you believe that these NGOs take Diné teaching into consideration?

d. Outside companies

Outside companies such as, BHP Billiton, Arizona Power Services, Resolute Oil and Gas, Exxon Mobil, and Peabody Western Coal Company.

Can you tell me about what you think about these outside companies?

Can you tell me about information you have received from these groups about these energy projects?

Part V: Beliefs about the Desert Rock Power Generation Project

Are you familiar with any plants on the Navajo Nation that were not built, such as Desert Rock?

For a part of our project we want to understand people's views on the failed Desert Rock Power Plant near Newcomb, NM. This will allow us to understand views on energy projects on the Navajo Nation.

Can you tell me why, you think, the Desert Rock plant was not built?

Should this plant have been built?

Were you or your family affected by Desert Rock?

Do you believe the Navajo Nation should consider another project like it?

Part V: Personal Information

What is your gender

What is your age?

In which chapter do you live? _____

What is currently the highest level of education you have completed?

Land Use Personal Information

Do you or your family currently have a summer camp/home and a winter camp/home?

Do you or your family have a farm?

Do you or your family have livestock?

Do you or your family practice Navajo medicine?

Energy Resource Connection

Have you or your family worked in?

Uranium mining/milling

Coal mining/Coal Power Generation

Oil Production

Supporting roles for any of these industries

Non-governmental organizations

Navajo Nation Government

Medicine Man (NAC/Navajo)

Indian Health Service

Appendix 2: Flashcard definitions, master list of codes & interrater reliability calculation for chapter 2

Table 15: The seven topics of concern with definitions shown to participants on flashcards for the interviews.

Topic		Provided Definition
Cultural Continuity	CUL	The Navajo culture will continue to exist and be important in the future.
Energy	NRG	Energy plays a role in everyday life from burning gasoline to drive a car to being able to turn on a light in a home.
Environment	ENV	The environment includes the air, water, soil, and how people and animals interact with it.
Jobs	EMP	Employment on the reservation can come from many sources. Energy projects can provide these jobs.
Political Sovereignty	SOV	The Navajo Nation will govern itself free of outside influence.
Water	H2O	This includes water from the ground, streams, rain, and other sources.
Other	ETC	Any topic that is important to you that is not included in the cards

Definitions for topics developed after pre-testing the protocol with seven Navajo volunteers

Table 16: Master List of Codes

Category and Codes	Notes on application
Health, Environment, + Water	
Drought & water scarcity	Specific mention of drought, lack of precipitation
Climate & environmental change	People referring to how the land has become drier, the environment changing in a specific way due to human activity, or climate change.
Resource depletion	Mentions of natural resources being depleted by human activity
Navajo Culture + Cultural Resources	
1 - Values	
Navajo culture & cultural resources	When asked what they valued: these included agriculture, livestock, medicinal practices, ceremonies, sacred sites
Protection of environment & water	Specific mention of the importance of protecting the environment or water resources
Concern for future generations	Concern or the importance of maintaining the environment for future generations.
Rural character	This was describing people enjoying the scenery, the remoteness, lack of people, quiet
Education	Specific mention of education as being important
Sovereignty & political sovereignty	Specific mention of tribal sovereignty as being important
2 - Dine Teachings	
Hózhó - K'é	This is when specific mentions or allusions to these concepts
Human Concerns, Wants, and Needs	
1 - Access to running water & electricity	
No running water	Specific mention of no running water or "hauling" water
No electricity	Specific mention of not having access to electricity
2 - Employment	
Energy Projects	These were specific mentions of employment coming from coal, petroleum, or renewable sources
Employment - Navajo	These were specific mentions of employment coming from agriculture, livestock, and medicinal practices,
Energy Resource Development	
1 - Energy Resources	
Non-renewable resources	Mentions of wind, solar, or geothermal

Renewable resources	Mentions of coal, oil, natural gas, or uranium
2 - Energy Resource Impacts	
Concern for health & environment	People mentioning damage to the environment/impacts on health
Land & water use	People mentioning that land & water use from energy projects as a concern
Pollution - Inevitable	Mentions of pollution being uncontrollable

Calculation of Inter-rater reliability

We evaluated coding reliability by assessing how each coder (1) divided responses into codable response data segments (Table 16), and (2) assigned a category and code to each segment (Table 17). Each coder identified the same relative amount of data segments, as shown in Table 17.

Table 17: Inter-coder consistency in identifying data segments (1).

Data segments that were codable	**Count**	**Percent**
Unique to each researchers	128	14.5%
Identified by both researchers	755	86.5%
Total	883	100%

For task (2), assigning a category and code, both coders identically coded 73% of data segments and coded 27% differently. We identified the following differences (Table 18): (1) Coding participant's concerns for environmental effects: in these instances each coder used one of three different codes to describe the concern for environmental impacts: *Concern for health & environment, Concern for land and water use, Values – Protection environment + water,* or *Climate and Environmental Change*; (2) Next we found that a single coder correctly identified specific mentions of Renewable Energy and Non-renewable resources whereas the other did not. Similarly we found the same identification errors in specific mentions of (3) cultural resource and Navajo concepts, (4) participant views on the decisions and values of the Navajo Nation

government and non-Navajo companies, (5) revenue and sovereignty, (6) corruption, lack of trust and transparency, and (7) no running water or no electricity.

Table 18: Of the 27% of data segments that were coded differently, we identified these areas of difference.

Identified Difference	**% Coded differently**
(1) Identification of Concern for environmental effects	40.0%
(2) Specific mention of renewable or non-renewable resources	17.4%
(3) Cultural Resources and Navajo Concepts	17.0%
(4) Values/decisions of stakeholder groups	11.1%
(5) Revenue + Sovereignty/Political Sovereignty	6.4%
(6) Corruption-Trust-Transparency	4.7%
(7) No running water or No electricity	3.4%

Appendix 3: Environmental impact values and calculation of cultural impact index for chapter 3

Table 19: Land transformation values for sources of electricity from Fthenakis and Kim, 2009

	Land Transformation (m^2/GWh)		
	Low Estimate	Median	High Estimate
Concentrated Solar	160	336	550
Solar Photovoltaic	164	330	552
Wind Turbines	1030	2040	2780
Coal IGCC w/ CCS [1]	31	160	783
Natural Gas[2]	100	200	354
Biomass	101	114	193
NTUA Electricity	86	192	440

[1]Total land transformation for Coal Power Generation considers both mining and solid waste disposal

[2]Total land transformation for Natural gas generation includes production, transport, and the power plant's construction

Table 20: Lifecycle water withdrawal and consumption for electricity generating sources from Macknick, et al., 2011

	Consumption (Gal / MWh)		
	Low Est.	Median	High Est.
Concentrated Solar	725	906	1109
Solar PV	0	1	5
Wind Turbines	0	0	1
Coal IGCC w/ CCS	522	549	608
Coal Supercritical	445	493	594
Natural Gas	130	205	300
Biomass	235	235	235
NTUA electricity	392	435	535

Table 21: Greenhouse gas emissions per unit of electricity for generating technologies used within the tool. Values are provided in pounds of CO_2 equivalent greenhouse gas emissions per megawatt-hour from Burkhardy, et al., 2012 and Whitaker, et al. 2012.

	Emissions Rate (lbs CO_2e / MWh)		
	Low Estimate	Median	High Estimate
Concentrated Solar	165	220	220
Solar PV	1	2	4
Wind Turbines	20	70	156
Advanced Coal	1980	2150	4715
Natural Gas	750	1030	1650
Biomass	740	900	1100
NTUA Electricity[1]	1730	1930	4101

[1]The calculated the greenhouse gas emission factor for NTUA electricity purchases were based upon the averaged emission factors of the each of the sources (US EPA eGrid; Wisser, 2007). Currently NTUA purchases 63 MW from Tucson Electric Power (2,003 lb/MWh CO_2e), 62 MW from WAPA – Desert Southwest region (515.85 lb/MWh CO_2e), and the remaining 5 MW is sourced from nearby electric cooperatives that were assume to have same emissions factor as Tucson Electric Power (2,003 lb/MWh CO2e).

Table 22: Capacity factors and electricity prices for electricity generating sources from the 2015 EIA Annual Energy Outlook.

Generation Technology	Capacity Factors	Electricity Prices (2030)
Wind	0.35	56
Solar PV Residential	0.22	120
Utility Solar PV	0.22	120
Solar Thermal	0.31	139
Biomass	0.83	700
Coal	0.85	53
Natural Gas	0.87	53
Grid Storage	0.9	265
NTUA Electricity	1	74

Calculation of cultural impact index

We calculate impacts on (1) Landscapes and Sacred Sites based upon the amount of land transformation. Next (3) Grazing Lands by proportionally scaling them to the largest and smallest land transformation and greenhouse gas emissions within each of the scenarios. Impacts on (2) Plants, wildlife, and traditional foods & medicine are proportional to an equal weighting of water consumption, land transformation, and greenhouse gas emissions. We calculated the index for these impacts by dividing total land use of each scenario by the total land use for the scenario that transformed the most land – in this instance the High Fossil Fuel and High Renewable energy scenario. We calculated this index by dividing each of the of the environmental impact categories by the scenario with the largest impact of each category in this instance this was also the “High” Fossil Fuel and “High” Renewable energy scenario.

Plants, Wildlife, and Traditional Foods

$$Impact\ Index = x$$

Grazing Lands

$$\boldsymbol{Im}pact\ Index = \frac{\frac{(Land)_{Level\ RE,Level\ FF}}{(Max\ Land\ Use)_{\square igh\ RE,High\ FF}} + \frac{(Water)_{Level\ RE,Level\ FF}}{(Max\ Water\ Use)_{High\ RE,High\ FF}} + \frac{(GHG)_{Level\ RE,Level\ FF}}{(Max\ GHG)_{High\ RE,High\ FF}}}{3}$$

Sacred Sites & Landscapes

$$I\square pact\ Index = \frac{(Land)_{Level\ RE,Level\ FF}}{(Max\ Land\ Use)_{High\ RE,High\ FF}}$$

Appendix 4: Survey protocol for online tool for chapter 4

SCREEN 1

1. Tell us your thoughts about energy on the Navajo Nation. (1 to 2 sentences).

   (Open-Ended)

SCREEN 2

We will now ask you about electricity used in your home.

2. I think the electricity we use in our home should come from.

   (1=Only Fossil Fuels (Coal & Natural Gas), 2, 3, 4=50/50 Mix Renewable & Fossil Fuels, 5, 6, 7= Only Renewable Energy (Wind, Solar))

Energy has been developed on the Navajo Nation. Please rate your agreement with the following statements.

3. Energy resource management on the Navajo Nation should focus on.

   (1=Only Fossil Fuels (Coal & Natural Gas), 2 More FF, 3 Slightly more FF, 4=50/50 Mix Renewable & Fossil Fuels, 5 Slightly more RE, 6 More RE, 7= Only Renewable Energy (Wind & Solar))

SCREEN 3

On the next page is a tool. We want you to choose the sources of energy for the Navajo Nation.

The tool will show you the outcomes of your choices. Adjust the tool until you are happy.

SCREEN 3a (Control: Outcomes)

Insert photo

SCREEN 3b (Outcome + Electricity Bill)

Insert photo

SCREEN 3c (Outcome + Cultural Values)

Insert photo

SCREEN 3d (Outcome + Cultural Values + Electricity bills)

Insert photo

SCREEN 4

We will now ask your about your views on the tool.

4. The tool is easy to use.

   (1=Strongly disagree, 2= Disagree, 3=Slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=Strongly Agree)

5. The tool is easy to understand.

   (1=Strongly disagree, 2= Disagree, 3=Slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=Strongly Agree)

6. The tool made me more interested in energy.

   (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

7. I learned how sources of energy could change my electricity bill.

   (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

8. I learned about how energy could impact Navajo culture.

   (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

9. I learned about how energy could impact the environment.

   (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

SCREEN 5

Energy development can result in good or bad things. Please rate your agreement with the statements below.

10. Energy development is bad for the environment.

    (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

11. Environmental impacts from energy last a long time.

    (1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree, 5=slightly disagree, 6=disagree, 7=strongly disagree)

12. Energy development means economic benefit for the Navajo people.

    (1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree, 5=slightly disagree, 6=disagree, 7=strongly disagree)

13. Navajo culture is threatened by energy development.

    (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

14. If things continue on their present course, we will soon experience a major ecological catastrophe.

    (1=strongly disagree, 2= Disagree, 3=slightly disagree, 4=Agree nor disagree 5= Slightly agree, 6= Agree, 7=strongly Agree)

SCREEN 5a (If Q13 < 4)

15. Please tell us how Navajo culture is threatened by energy development. (1 to 2 sentences).

    (Open-ended)

SCREEN 6

We will now ask you about electricity used in your home.

16. I think the electricity we use in our home should come from.

    (1=Only Fossil Fuels (Coal & Natural Gas), 2, 3, 4=50/50 Mix Renewable & Fossil Fuels, 5, 6, 7= Only Renewable Energy (Wind & Solar))

Energy has been developed on the Navajo Nation. Please rate your agreement with the following statements.

17. Energy resource management on the Navajo Nation should focus on.

    (1=Only Fossil Fuels (Coal & Natural Gas), 2 More FF, 3 Slightly more FF, 4=50/50 Mix Renewable & Fossil Fuels, 5 Slightly more RE, 6 More RE, 7= Only Renewable Energy (Wind & Solar))

SCREEN 7

Energy projects can be of different sizes. Some project cans be small enough to fit on a roof. Other projects can be large enough to cover thousands of acres. We will now ask you questions about what size energy projects on the Navajo Nation.

18. Question that test's people's knowledge about sizes.
    a. Do we ask direct questions about sizes (e.g. acres)?

Have four maps and show sizes of different acres –

Comparison of different sizes

Then ask which they prefer

SCREEN 8

We will now ask you questions about your views about the Navajo government.

19. The Navajo government makes good choices about energy. **(1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree 5=slightly disagree, 6=disagree, 7=strongly disagree)**
20. The Navajo government provides good information on energy.

(1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree 5=slightly disagree, 6=disagree, 7=strongly disagree)

21. The Navajo Nation government uses Diné teachings to make choices about energy.

    (1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree 5=slightly disagree, 6=disagree, 7=strongly disagree)

SCREEN 8a (answers >=3 for Q21)

22. Please tell us why the Navajo government does not make good choices on energy. (1 to 2 sentences).

    (Open-ended)

SCREEN 8b (answers <=4 for Q21)

23. Please tell us why the Navajo government makes good choices on energy. (1 to 2 sentences).

    (Open-ended)

SCREEN 9

We will now ask you questions about your views about= non-Navajo companies.

24. Non-Navajo companies make good choices about energy.

(1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree 5=slightly disagree, 6=disagree, 7=strongly disagree)

25. Non-Navajo companies provide good information on energy.

    (1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree 5=slightly disagree, 6=disagree, 7=strongly disagree)

26. The non-Navajo companies uses Diné teachings to make choices about energy.

    (1=strongly agree, 2=agree, 3=slightly agree, 4=Agree nor disagree 5=slightly disagree, 6=disagree, 7=strongly disagree)

SCREEN 9a (answers >=3 for Q25)

27. Tell us why non-Navajo companies do not make good choices on energy. (1 to 2 sentences). **(Open-ended)**

SCREEN 9b (answers <=4 for Q25)

28. Tell us why non-Navajo companies make good choices on energy. (1 to 2 sentences).

    (Open-ended)

SCREEN 10

We will now ask you questions about you.

29. What is your age?

    (Pull down list)

30. What is your gender?

    (Pull down list - Male, Female, Naadleeh Female, Naadleeh Male)

31. What is your highest education level?

    (Pull down list)

32. What is your current employment?

    (Pull down list)

33. What is your household income?

    (Pull down list)

34. What chapter do you belong?

    (Pull down list)

35. Do you currently live on the Navajo Nation (Y/N)

    (Check boxes)

36. Do you participate in any of the following?

    (Check boxes)

Navajo Medicine.	(Y/N)
Herb gathering.	(Y/N)
Grazing.	(Y/N)
Farming.	(Y/N)
NAC.	(Y/N)
Weaving.	(Y/N)

Artisan. (Y/N)

The next two questions are about your beliefs on climate change. Please tell us if you believe the statements is **definitely true**, **probably true**, **probably false**, or **definitely false** – or if you **don't know**.

37. Recently you may have noticed that global warming has been getting some attention in the news. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result.
    (**Definitely true**, **probably true**, **probably false**, **definitely false**, **don't know**)

38. Global warming is primarily caused by human activities.
    (**Definitely true**, **probably true**, **probably false**, **definitely false**, **don't know**)

39. Please use the space below if you have any more thoughts on energy and the Navajo Nation.
    (open-ended)

Appendix 5: Information provided within tools about environmental, economic, and cultural impacts

Land Transformation: Land can be changed and used only for the energy project for many years. Sometimes these projects leave long lasting changes to the land that they cover. For example, land could be flattened, plants and animals would be moved, and the way water flows into underground sources could be changed. These land changes can be fixed after the project is done through remediation

Water Consumption: Water is used in electricity generation to either cool or clean a power plant or move fossil fuels. Water will be taken from rivers and underground aquifers for these projects. The water will be used and not returned to its source. Large water uses can deplete underground aquifers and draw down rivers. Large water use can lower water levels and make wells difficult to use.

Greenhouse Gas Emissions: Greenhouse gases are things like carbon dioxide, methane, nitrous oxide, and ozone. These emissions result from burning fossil fuels to generate electricity or to create the materials used in energy projects. Greenhouse gasses contribute to climate change (also known as global warming). Climate change will have significant impacts on the environment.

Energy Exports: Some of the electricity and fuels generated will be used on the Navajo Nation. The other portion of the electricity will be sold off the reservation to power other communities in the southwest. These include larger cities such as Albuquerque, Las Vegas, Tucson, Phoenix, and Los Angeles to name a few.

Utility Bill: Electricity generated from different sources can have different prices. NTUA buys most of their power from hydropower, coal and natural gas power plants.

Cultural Impacts: Large land transformations could impact sacred sites, medicinal plants and animals, places for offerings, and sacred sites. Large water use can impact medicinal plants and landscapes. Rising temperatures from climate change can make it difficult for medicinal plants to grow. Effects of climate change can also increase droughts. These impacts can be long lasting affecting future generations.