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Adapting Renewable Energy Systems for a Changing Climate in Remote Tribal Communities – Navajo Nation, Arizona

Nikki Tulley
University of New Mexico
Anthony Martino, Manager (Org. 06124) Sandra Begay-Campbell, Technical Advisor
Sandia National Laboratories[1]
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Abstract

The intent of this research paper is to help bring awareness that changing climates, such as desert drought conditions, may require renewable energy technology to be adapted. More specifically this paper addresses the relationships between lack of precipitation, drought, desertification, temperature fluctuations, lightning, photovoltaic systems, and soil resistivity. With extreme/severe drought on the Navajo Nation in Arizona, the climate conditions have created high soil resistivity that inhibits the effectiveness of a residential off-grid photovoltaic grounding system. In order to install a grounding rod, the dry soil needs water; thus, requiring the implementation of a greywater system to be used to moisten the soil.

Introduction

"Climate change is about my future and the future of my entire generation and those to follow."
-Nelson Kanuk

In the comfort of numerous U.S. cities, the realism of climate change has not reached many people and remains more of a debated philosophical topic. Looking to Alaska, native people like Nelson Kanuk (age seventeen from Kipnuk), face the truth that the world is changing. Nelson stated, "Each year due to increasing global temperatures, late winters, and melting permafrost erosion has become a problem[2]." The erosion is removing land on which the Yup'ik people have lived for generations.

Increasing awareness of greenhouse gases and climate change on a global scale has established great interest in creating power from resources other than fossil fuels to mitigate the

[1] Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
[2] Coastal Peoples Address Climate Change, First Stewards Symposium, Washington, D.C., July 18, 2012.

increase of global temperatures. Renewable energy sources such as solar, wind, hydropower, biomass, geothermal are some of the leading resources for creating energy without fossil fuels. Tribal renewable energy development in Indian Country is not primarily for addressing climate change, but also to bring electricity to tribal people and create energy independence through green power. Green power, being defined here as renewable energy used to generate electricity, is less harmful to the environment than fossil fuels, which create greenhouse gases.

The U.S. Department of Energy's Office of Indian Energy (IE) promotes opportunities of producing and distributing energy in Indian Country. The "sister" DOE program, Tribal Energy Program (TEP) promotes tribal energy sufficiency, and fosters economic development and employment on tribal lands through the use of renewable energy and energy efficiency technologies[3]. In May 2010, the Sandia National Laboratories' Lab News featured an interview of Sandra Begay-Campbell regarding the solar energy projects on the Navajo Nation. She summed up the goals of her work with the Navajo Nation as follows, "The goal is to provide Navajo (Native American) people a choice: whether they want electricity from renewables or a line extension. I never want it to be that they never had the opportunity to have electricity[4]."

For numerous Native Americans the chance to have electricity has not been possible due to the remote locations of where they have established their homesteads for many generations. The developing renewable energy projects in Indian Country has allowed for electricity to reach families in the remote areas of Native American communities. Along side federal programs establishing renewable energy in Indian Country, various non-profit organizations have also begun bringing forth projects. The long-term success will be in developing a renewable energy system that will endure the harsh conditions where these systems are fielded.

On the Navajo Nation, one source of renewable energy that has been primarily developed is solar energy. To date, residential stand-alone photovoltaic (PV) systems are being established more so than commercial photovoltaic systems. Residential stand-alone photovoltaic systems on the Navajo Nation are established at the homesteads of tribal members often, living in far off remote communities. The importance of creating a renewable energy system that will last and hold up to climatic changes in the environment is significant. This paper focuses on the development of photovoltaic systems located within the Western Agency of the Navajo Nation located in the state of Arizona.

Many communities throughout the world are experiencing climatic changes including Arizona. The most prevalent climatic change in northern Arizona is diminished precipitation and drought. The intent of this research paper is to help bring awareness that changing climates, such

[3] *Website: U.S. Department of Energy: Energy Efficiency & Renewable Energy, Tribal Energy Program page http://apps1.eere.energy.gov/tribalenergy/about.cfm, Accessed July 19, 2012.*
[4] *Sandia Lab News, Tribal power Sandia supplies options for electricity, Vol. 62, No. 9, May 21, 2010.*

as desert drought conditions, may require renewable energy technology to be adapted. More specifically this paper addresses the relationships between lack of precipitation, drought, lightning, photovoltaic systems, and soil resistivity. With the extreme/severe drought on the Navajo Nation, the climate conditions have created high soil resistivity that inhibits the effectiveness of the photovoltaic grounding system. In order to install a grounding rod, the dry soil needs moisture; thus, requiring the implementation of a greywater system to be used to water the soil to install the grounding rod.

Climate Change

Climate change has been disputed for both the good and the bad, for being real and unreal, having an extremist environmental approach and the contrary; whatever the outlooks maybe, it is not a philosophy. Climate change is indeed a scientific fact; nevertheless, people may dispute the exact magnitude of change. Greenhouse gases are the most talked about reasons for climate change because the gases trap heat in the atmosphere inhibiting natural flow of heat leaving and entering Earth[5]. Of the greenhouse gases, the most widely discussed is carbon dioxide (CO_2).

CO_2 enters the atmosphere largely as a result of the burning of fossil fuels. Figure 1 shows that over the last 650,000 years CO_2 has been going through cycles of increasing and decreasing in parts per million (ppm) in ice cores taken from Antarctica. However, since the 1950s CO_2 has been on the rise higher than it has ever been recorded in the last 650,000 years.

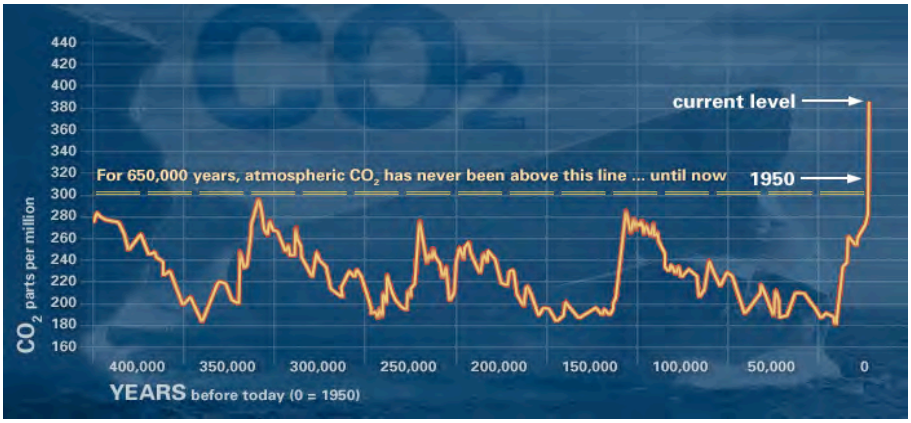

Figure 1. A graph showing the cycles of Carbon Dioxide as recorded in ice core samples taken from Antarctica dating back to 650,000 years ago.[6]

[5] Website: United States Environmental Protection Agency, Greenhouse Gas Emissions page http://epa.gov/climatechange/ghgemissions/gases.html, Accessed July 20, 2012.
[6] Website: National Aeronautics and Space Administration, Global Climate Change page http://climate.nasa.gov/evidence/, Accessed July 20, 2012.

As a result of increasing greenhouse gases over for several decades, global temperatures and precipitation have also changed. Increasing global temperatures have been recorded worldwide. Using three datasets, a global temperature anomaly was created to show the temperature increases (Figure 2). An anomaly uses a reference value or the averages from a long period of time to create a mean that can show how far temperatures depart from that mean to give us an estimated scale of change. To create this anomaly (Figure 2) the Global Historical Climate Network-Monthly (GHCN-M), Extended Reconstructed Sea Surface Temperature (ERSST), and the International Comprehensive Ocean-Atmosphere Data Sets (ICOADS) were used.

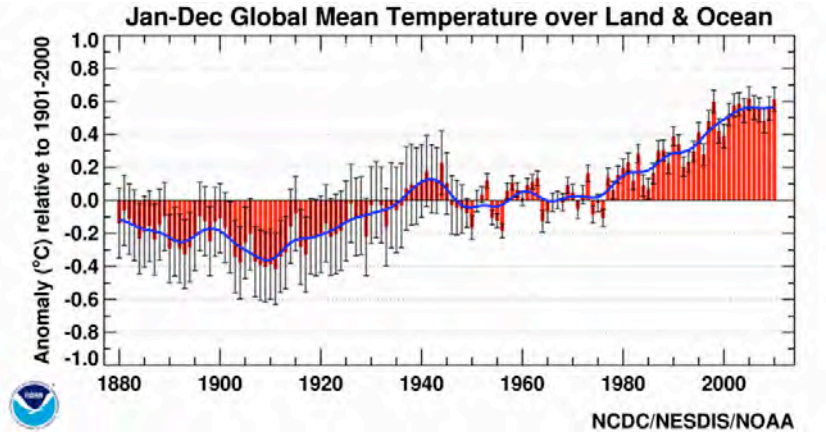

Figure 2. Global temperature anomaly created for the years 1880-2010 showing the variations of decreasing and increasing global mean temperatures over the land and ocean[7].

Along the side of temperature changes, there has been an observed change in the annual precipitation shown with data collected from the U.S. Global Change Research Program as shown in Figure 3. Although Figure 3 shows that the U.S. has had an increase of precipitation by 5% over the past fifty years, (1958-2008) there is an increase for the entire country. It is important to note that this paper focuses on the influences of climate change in the northern part of Arizona. Figure 3 shows that Arizona as a state has had a decrease in precipitation ranging from 0 to -40% change in the annual lack of precipitation over the past fifty years.

[7]Website: NOAA Satellite and Information Service, Global Surface Temperature Anomalies page http://www.ncdc.noaa.gov/cmb-faq/anomalies.php, Accessed July 20, 2012.

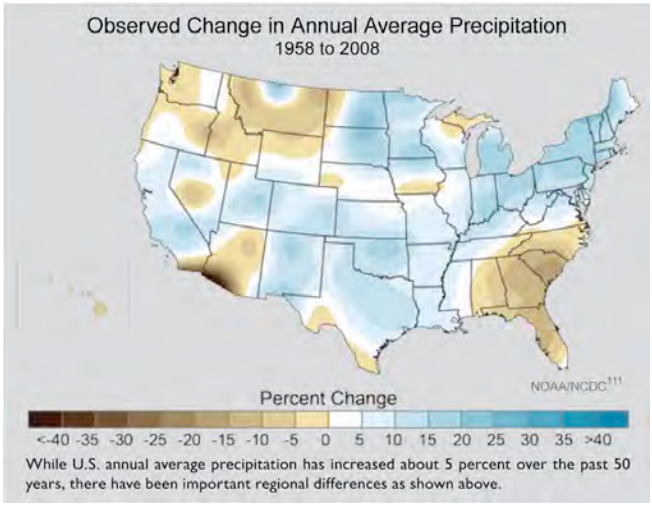

Figure 3. Observed annual change in average precipitation recorded over fifty years 1958-2008 presented in a percentage change[8].

As a result of changing temperatures and precipitation, the occurrence of drought is greater. In the state of Arizona there is a history of long and short-term droughts (Figure 4). Even with the monsoons that come to Arizona, drought conditions continue to stay steady. Most often the ground is extremely dry that when it rains and the water glides over the land causing flash floods, which are seldom completely absorbed into the soil.

[8]Website: United States Global Change Research Program, Water Resources page http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/climate-change-impacts-by-sector/water-resources, Accessed July 20, 2012.

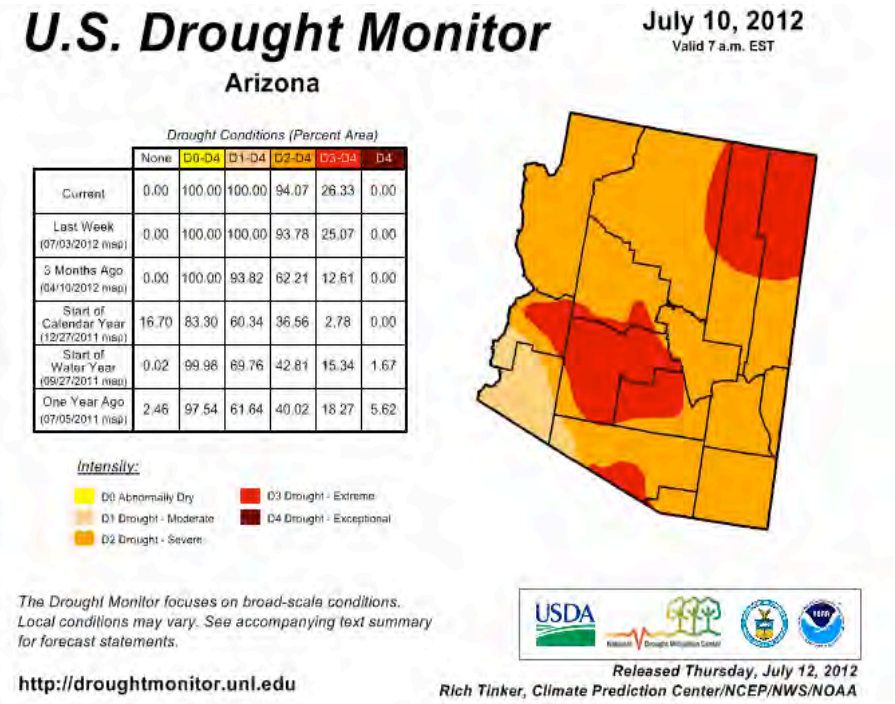

Figure 4. Indications that the current drought intensity in Arizona ranges from moderate to extreme[9].

In the previous paragraphs of this paper climate change was discussed on a global, national, and more specifically, a state perspective. As stated before with a changing global climate, renewable energy as a clean energy solution is highly discussed. For Indian Country renewable energy is a chance to produce clean energy, and it is also an opportunity for many tribal members to have electricity for the first time. However, it is important to adapt renewable energy power resources to the environment in which they are established, especially with changing climates.

[9] Website: U.S. Drought Monitor, Arizona Region Drought Monitor page http://droughtmonitor.unl.edu/DM_west.htm, Accessed July 10, 2012.

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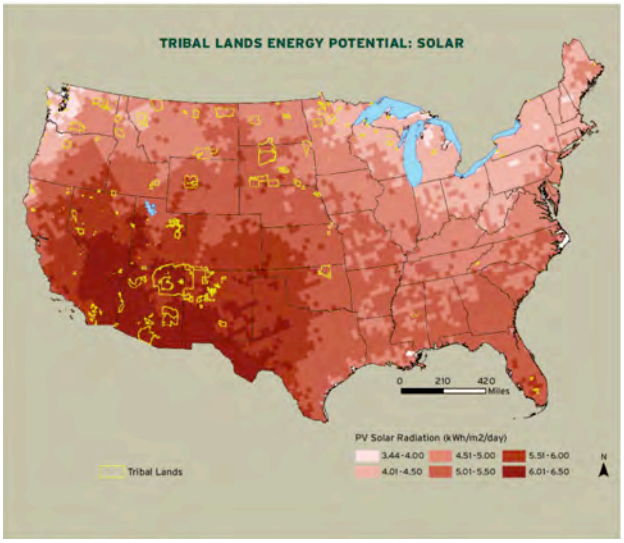
Renewable Energy in Indian Country

Renewable energy refers to the mechanism in which fossil fuels are not used, but rather by using natural resources such as solar, wind, geothermal, biomass, and water. Using renewable energy is a clean energy solution to mitigating greenhouse gas reduction goals. Possibilities of renewable energy in Indian Country holds potential, due to the large land masses that tribal communities own and manage totaling up to over 95 million acres nationwide[10]. In 2010, the National Renewable Energy Laboratory came up with a statistic that Indian Country comprises of 5% of the land area making up the U.S. and contains an estimated 10% of all energy resources in the U.S[11].

Consideration of renewable energy in Indian Country is more than reducing greenhouse gases. Renewable energy for tribal communities offers power to remote locations, economic development, opportunities to set an example for other tribal nations, and ultimately, this type of development can provide a sense of energy independence.

For varying tribal nations, there are opportunities to develop the different types of renewable energy mentioned previously. In the southwest region of the United States, the predominant sources of renewable energy are solar and wind.



[10] National Wildlife Federation. (2010). *The New Energy Future in Indian Country: Confronting Climate Change, Creating Jobs, and Conserving Nature*. Boulder, Colorado: Rocky Mountain Regional Center, NWF.

[11] MacCourt, D.C. (2010). *Renewable Energy Development in Indian Country: A Handbook for Tribes*. Golden Colorado: MacCourt, D.C.

Figure 5. Map of the U.S. showing the potential of solar energy based on PV solar radiation. The map also shows the potential solar energy of each tribal reservation.[12]

Solar energy simply stated is the ability to capture solar radiation in the form of radiant light and heat coming in from the sun. The specific sites this paper focuses on, within the Navajo Nation, captures solar radiation through the use of photovoltaics. Photovoltaics (PV) create electrical power by using solar radiation converting it into direct current electricity, through the use of solar modules composed of solar cells. In this research paper, the Navajo Tribal Utility Authority (NTUA) procured the PV systems shown. On the Navajo Nation, it is estimated that 18,000 residents live without electricity[13]. Of the 18,000, much of that population is living in remote areas. As a tribal utility authority, NTUA is placed with expectations of providing energy opportunities to all people living on the Navajo Nation. In accomplishing the goal of meeting the energy demand, renewable energy is a part of the energy solution. NTUA has a renewable energy program whose goals are to promote the use of renewable energy, be an example for other native communities, and increase and stress the importance of energy efficiency[14].

[12] National Wildlife Federation. (2010). *The New Energy Future in Indian Country: Confronting Climate Change, Creating Jobs, and Conserving Nature*. Boulder, Colorado: Rocky Mountain Regional Center, NWF.

[13] Johnson, E. (2012, June 7). Personal Interview.

[14] Terry, D. (2012, June). *Navajo Tribal Utility Authority: Utilities for the Navajo Nation.* Presentation for Sandia National Laboratories Internship Program, Chinle, AZ.

Figure 6. A 1,080 w PV array and 400 w wind turbine set up by Navajo Tribal Utility Authority (NTUA) on the Navajo Nation. Photo taken by Dr. Stanley Atcitty.

The majority of PV systems established on the Navajo Nation are residential stand-alone units (Figure 6). Residential stand-alone PV systems are not connected to the electrical grid (Figure 7). The advantages of residential stand-alone PV systems are that NTUA is able to provide electricity to those families living completely off the electrical grid on the Navajo Nation. Energy generation from a stand-alone system is highly dependent on properly working components of the entire system. If something should happen to one component of the system electricity will not be produced. As a provider of renewable energy to remote areas, NTUA is placed with these demands on the Navajo Nation. There are numerous factors in the arid climate found on the Navajo Nation that can impact the PV systems and these climates that are further impacted by the changing climate.

Figure 7. Navajo hogan home located on the Navajo Nation connected to a renewable hybrid energy system. Photo taken by Chelsea Chee.

Climate Influences on PV Systems

There are numerous scientific studies providing strong evidence that global climates are changing in response to increasing emissions of greenhouse gases[15]. In the southwest of the United States, the primary concerns of climate change are changes in precipitation patterns and increasing recorded temperatures which both lead to longer droughts. Drought is the primary

[15] Ganey, J.L. & Vojta, S.C. (2011). Tree mortality in drought-stressed mixed-conifer and ponderosa pine forests, Arizona, USA. *Journal of Forest Ecology and Management,* 261, 162-168.

indication of climate change found on the Navajo Nation and is defined as a period of time with an unusually low precipitation that has the potential of causing damage to endemic vegetation, ecosystems, and freshwater supplies. The most severe drought in Arizona history was from 1896-1904, however in recent years the second most severe drought was recorded from 1996-2004[16]. Extreme/severe drought on the Navajo Nation has increased erosion, formation of sand dunes, dust storms, soil resistivity, and dry lightning storms. Figure 8 shows the arid environment found at the field sites of the PV systems presented in this research paper.

Figure 8. The severe drought conditions in a historic arid land have increased dust storms and sand dune formation. The above photos were taken in the Monument Valley, Utah area.

Examples of PV systems with notable concerns of climate affects on the Navajo Nation's desert-like regions are presented in Figures 9 and 10. As shown in Figure 9, the outdoor installed inverters and batteries are located in boxes. Although there are filters to keep the sand and dust out, the batteries and inverters are subjected to the uncontrollable high winds, dust storms, and extreme temperature fluctuations. The dust and sand found in the boxes can cause damage if it enters the sealed components of the inverter. Through normal service and maintenance, this problem of sand and dust entering the boxes can be solved. However, normal service and maintenance is difficult to accomplish due to the large area NTUA serves, the remote locations of the PV systems, and frequent dust storms. Figure 10 shows the effects of erosion on a PV system's foundation, it has been exposed.

[16] Goodrich, G.B. & Ellis, A.W. (2006). Climatological Drought in Arizona: An Analysis of Indicators for Guiding the Governor's Drought Task Force. *Journal of The Professional Geographer,* 58 (4), 460 469.

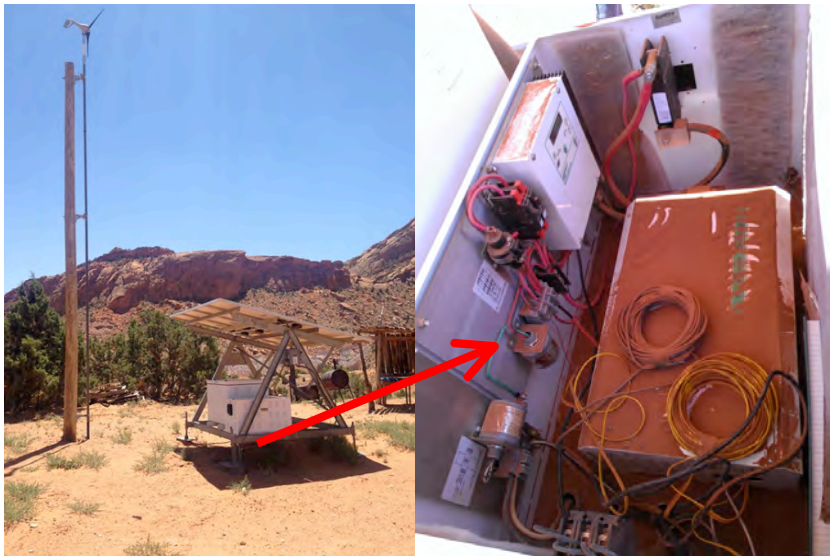


Figure 9. A PV system established by NTUA on the Navajo Nation that shows the effects of climate change brought on by the drought with sand entering the inverter and battery box.

Figure 10. The high winds during an extended drought period have eroded the land surrounding the foundation of a PV system. Photo taken by Dr. Stanley Atcitty.

Of the climatic influences that PV systems face during extreme/severe drought in a desert-like environment, the greatest threat is posed by lightning. Damage caused to a PV system by lightning strikes can cause expensive system component replacements and more importantly can cause harm to human lives[17]. Although lighting protection provided by

[17] Cetin, E., Yilanci, H.K., Ozturk, G., Uckan, M., Hekim, M., Colak, S. & Icli, S. (2001). Lightning Protection for Buildings Energized by Renewable Energy Sources. *Journal of Electronics and Electrical Engineering,* 6 (112), 7-10.

grounding systems are not 100% effective, they do provide safeguards to electrical equipment and are designed to protect people from electrical shock. Drought causes the grounding systems to be less effective due to the increase of high soil resistivity.

Grounding Systems

High soil resistivity does not allow electricity to flow easily in a grounding system. Therefore, the grounding system cannot effectively provide a path for the electrical connection to the ground to direct the current of an electrical surge away from the home and PV system in the occurrence of a lightning strike. Worldwide 4 million lightning flashes have been recorded during the period of one day and it is anticipated that worldwide lightning activity will increase with global warming[18]. In accordance with the National Electrical Code found within the United States and the oversight plan with contractors, NTUA has established a grounding system near all PV units. Each grounding system includes a 1/2 inch copper rod that is driven to a depth of 8 feet[19]. An example of a grounding rod established at the PV units is shown in Figure 13. The lightning safety measures are very site specific.

Figure 13. Grounding rod that has been exposed more than two feet above ground due to the extended drought in Arizona causing increased durst storms and erosion. Photo taken by Dr. Stanley Atcitty.

Two main factors important to having effective grounding systems are soil ionization and inductive behavior both of which have to do with the soil in which the grounding rod is placed.

[18] Dwyer, J.R. & Rassoul, H.K. (2009). Lightning Physics and The Study of Climate Change and Sustainability. In G.L. Nelson & I. Hronszky (Eds.), American Institute of Physics. Paper presented at the Sustainability 2009: The Next Horizon, Melbourne, Florida, 3-4 March (26-31). Melville, NY: AIP; Price, C. (2009). Will a drier climate result in more lightning? *Journal of Atmospheric Research*, 91, 479-484.

[19] Terry, D. (2012, July 19). Email interview.

The efficiency of a grounding system and level of lightning protection is determined by how the discharge currents under electrical surge conditions from lightning are directed into the Earth[20].

Due to the drought conditions and other climatic changes related to lack of precipitation, the grounding systems are not as effective as would be found with lower soil resistivity. The compromise that soil resistivity acting as an inhibitor of the effectiveness of a residential off-grid photovoltaic grounding system is noted by incidents in which during a lightning strike the electrical surge was great enough to travel from the PV system and entered the home. It is important to note that the specific lightning incident mentioned in this research paper did not occur with NTUA's PV units, but occurred with another organization's PV units fielded on the Navajo Nation. To address the issue of drought conditions and other related climatic changes influences on PV grounding systems, the idea of implementing a greywater system is a suggested solution.

Greywater Systems

In remote areas of the Navajo Nation, at such locations of where the PV systems are found, human safety is crucial when considering electrical components. Often times, these remote communities are found with rugged roads, limited means of transportation, and far removed from hospitals. With extreme/severe drought on the Navajo Nation in Arizona creating high soil resistivity and inhibiting the effectiveness of a residential off-grid photovoltaic grounding system, further measures must be taken to ensure consumer safety.

[20] Grcev, L. (2011). Lightning Surge Efficiency of Grounding Grids. *Journal of Electronics and Electrical Engineering,* 26 (3), 1692-1699.

Figure 14. An elderly women siphoning water from a large barrel to a small bucket is a common sight to see on the Navajo Nation for thousands of tribal members who continue to haul water to sustain their homes. Photo taken from Black Falls Safe Drinking Water Project, Forgotten People.

The suggested measure of ensuring a more effective grounding system is to establish a greywater system to build up the conductivity of soil surrounding the grounding rod. Greywater is defined as untreated household wastewater that has not come into contact with sewage[21]. In the state of Arizona a permit is not required for a greywater system, if the flow is less than 400 gallons per day[22]. On the Navajo Nation, unique implementations of greywater systems would have to be established because thousands of Navajo families live without running water. For houses with running water, a simple gravity-based greywater system with no pump or any other approved off-the-shelf system commercially available could be implemented to direct water from the home to the land surrounding the grounding rod.

However, if the house does not have running water, a more educational approach in addressing the use of greywater would be implemented. Taking greywater from the home to the grounding rod area requires much dedication because it requires actual physical labor of moving greywater from the home to the grounding rod area to establish the conductivity needed for an effective grounding system. Until further development of a system used for greywater collection

[21] Allen, L., Christian-Smith, J., and Palaniappan, M. (2010). *Overview of Greywater Reuse: The Potential of Greywater Systems to Aid Sustainable Water Management*. Oakland, California: Pacific Institute

[22] Tier 1 Arizona Gray Water Law, Article 7. Direct Reuse of Reclaimed Water 7 A.A.R. 758, effective January 16, 2011 (Supp. 01-1).

in a home with no running water can be created, the importance of lightning protection safety will have to be stressed.

Conclusions

When establishing a new form of living to a people, consumer safety takes high priority. For many of the residents receiving electricity by way of PV systems on the Navajo Nation, it is the first time that they have had electric power in their homes. An effective grounding system is one crucial part of establishing a long lasting PV unit. Also, a part of establishing a long lasting PV unit is taking into account the other factors that inhibit a grounding system produced by extended drought (i.e. dust storms and erosion).

Due to the limited time of the summer internship, preliminary research was the primary goal in bringing awareness to the issue of effective lightning protection safety. Future work on this topic will continue to focus on the original hypothesis: in order to establish an effective grounding system, the dry soil needs water, thus, requiring the implementation of a greywater system to be used to water the soil. This hypothesis is based on the idea that the extreme/severe drought on the Navajo Nation in Arizona has created high soil resistivity that inhibits the effectiveness of a residential off-grid photovoltaic grounding system.

It is important to note that some greywater systems have been established in conjunction with PV units in one location created by entities other than NTUA. However, studies of the impacts of greywater systems on grounding systems are not fully known on the Navajo Nation. For this reason, the hypothesis stated previously was established. Future tasks desired to be conducted in reference to this hypothesis is as follows:

- Establish a process to monitor ohm readings for several months at different locations
- Establish study sites at different areas with varying geology
- Monitor PV unit lightning incidents
- Create a PV grounding system as a control that uses a greywater system to help with soil resistivity
- Develop a group of tribal members with PV units mixed with those who have running and no running water to participate in implementing greywater systems

In presenting this preliminary research, it is desired that more awareness is provided to the fact that influences of climate change increase the measures of work needed to establish safe and long lasting PV units specific to the site in which they are placed. Further actions in adapting renewable energy systems for a changing climate in remote tribal communities are done to ensure the utmost safety to the equipment and human lives.

Reflections

"The Mother Earth provides us with food, provides us with air, provides us with water. We, the people, are going to have to put our thoughts together, to save our planet here. We've only got one water, one air, one Mother Earth. Let's take care of her and she will take care of us."

–Corbin Harney, Western Shoshone spiritual leader and peace activist[23]

The above quote was taken from a book that I received from Winona LaDuke while at a Tribal Energy Program workshop in Milwaukee, WI. LaDuke is an internationally known Indigenous woman who advocates for protecting Mother Earth, which is among many other issues which Indigenous Peoples face. Mother Earth refers to the Earth on which we live. The idea that the title Mother Earth creates is that the Earth is a living entity that has offered life to all who walk and breathe, and as any other living entity she can be damaged. As a Native American person living off the reservation for a number of years, this connection and teaching of being tied to the Earth began to compete with the western education I was receiving at my university. I did not forget the teachings that had been taught to me while living on the Navajo Nation, however being away at school so many other ideas and new teachings had become a part of my life.

Being a part of the Indian Energy Program internship has allowed me to rekindle my connection of wanting to help tribal people. Through the visits to tribal lands and talks with people living and working with tribal nations concerning renewable energy, I have seen the ways in which others are incorporating Indigenous thought and western thought together to benefit the tribal nation. Seeing these examples have brought much insight as to how I can continue my studies at the university and understanding that I am unique in the manner that I can apply traditional and western knowledge to solutions I am seeking. This summer I was taught once again that only when I remember where I come from I am able to know where I am going.

In reflecting on this internship I would like to acknowledge and express gratitude to those who contributed greatly to a positive and successful experience as an intern. First and foremost, I would like to thank Sandra Begay-Campbell, my mentor, for the great example she has been to me in helping me gain an extensive knowledge about the Indian Energy Program amongst other topics. Secondly, I would like to thank Dr. Stanley Atcitty for the insight he has shared with me regarding the research topic I have worked with this summer. I would also like to thank Lesley Kabotie, NTUA, Department of Energy's Indian Energy Office, Sandia National Laboratories, and all other people I have met and learned from this summer.

[23] LaDuke, W. (2011). *The Militarization of Indian Country*. Honor the Earth: Minneapolis, MN.