# Solar Energy in the Santo Domingo Pueblo

An Interactive Qualifying Project
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science

By
Kyle Fitzgerald
Matthew Houghton
Adam Huber
Yue Li

Date:
5/1/2016

Report Submitted to:

Mr. Joseph Kunkel
Santo Domingo Tribal Housing Authority

Scott Jiusto
David Spanagel

Worcester Polytechnic Institute

## Abstract

The Santo Domingo Pueblo faces growing needs for both housing and economic development. The Santo Domingo Housing Authority asked our group to identify, assess, and make recommendations regarding the potential for solar energy to be implemented in their new housing development, the Domingo Housing Project. Our team researched, analyzed, and presented aesthetic, technical, and financial comparisons of several different photovoltaic systems. The project resulted in a comprehensive report, a list of potential financial sources that could be used to fund different solar energy projects, and an informational video that explores how renewable energy sources might support the goal of energy sovereignty in Native communities.

# Executive Summary

The Santo Domingo Pueblo is a Native American community in New Mexico with great development opportunities. They are currently in the process of creating a new housing development called the Domingo Housing Project. The units in the development will be low-income rental units that will provide housing for community members currently living in the overcrowded village in Santo Domingo (Kunkel, 2016a).

The new units in the Domingo Housing Project are being constructed following the guidelines set by Enterprise Green Communities (Kunkel, 2016a). Under these guidelines the units will be solar ready upon completion. The Santo Domingo Tribal Housing Authority plans to utilize the design of the units and install solar panels. However, planning for the installation of enough solar panels to support 41 families requires research and planning. To support the Housing Authority's solar energy research and development, our group was asked to gather information on different solar options that could be used in the new housing development.

## Methodology and Findings

Our team began the project by visiting the construction site and the village inside Santo Domingo. We found that the new housing site was flat with very few structures nearby. We concluded that the site was optimal for the use of solar panels from the flat landscape, lack of obstacles, and abundance of direct sunlight available at the site. When we visited the village our group was able to discuss the ideas of using solar energy with a few members of the community. Each community member with whom we spoke expressed excitement about the prospective opportunity of using solar energy in Santo Domingo.

Our team analyzed three different configurations for solar photovoltaic systems that could be potentially used in Santo Domingo: residential, commercial, and utility. In a residential solar energy system, individual homeowners acquire ownership of the solar panels being used by the household. A commercial scale solar energy system typically is owned and managed by a single owner, like the Housing Authority, which purchases and maintains the entire network of panels on behalf of the energy needs of a larger area, such as a pueblo community. Solar energy at the utility scale involves the negotiation of a power purchase agreement with a power company, such that the power company utilizes the community's solar panels to generate excess electricity after meeting the community's needs. Utility solar energy systems are typically large and expensive; therefore we did not suggest the use of utility solar to Santo Domingo.

Once we analyzed the solar energy options that are applicable to Santo Domingo, our team utilized the National Renewable Energy Laboratory's (NREL) System Advisor Module (SAM) to create different scenarios for the Housing Authority to explore (National Renewable Energy Laboratory, 2010). Through the SAM program we developed financial and energy output models that would educate and inform the Housing Authority about which solar options could be available for the Domingo Housing Project.

Community support is essential if the use of solar panels in the housing development is to be accepted by Santo Domingo. To help spread awareness on solar energy opportunities, our team also created a short educational film. Within the film we interviewed our sponsor liaison to the Santo Domingo Tribal Housing Authority, Joseph Kunkel, the executive director of the Housing Authority, and the vice-president of Enterprise Green Communities. Through their discussions in the film, these experts discuss energy independence and the opportunities that solar energy present when integrated into a community.

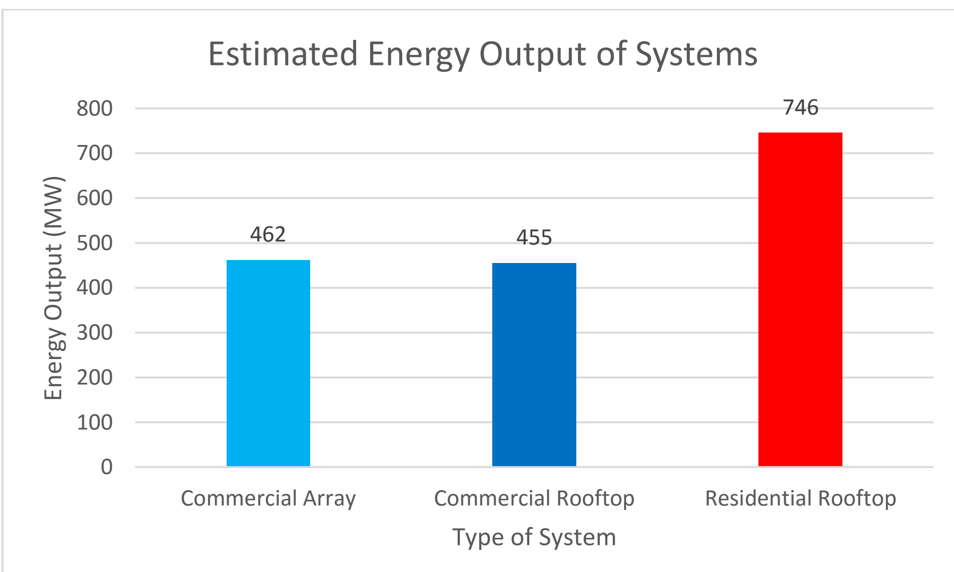
Finally, our project includes potential solar energy funding options available to Santo Domingo. Largely through the use of the Database of State Incentives for Renewables and Efficiency, our team provided a chart of funding that can be applied to a solar energy project (North Carolina Clean Energy Technology Center, n.d.). This chart includes government grants, bonds, and outside investors.

## Results, Recommendations, and Discussion

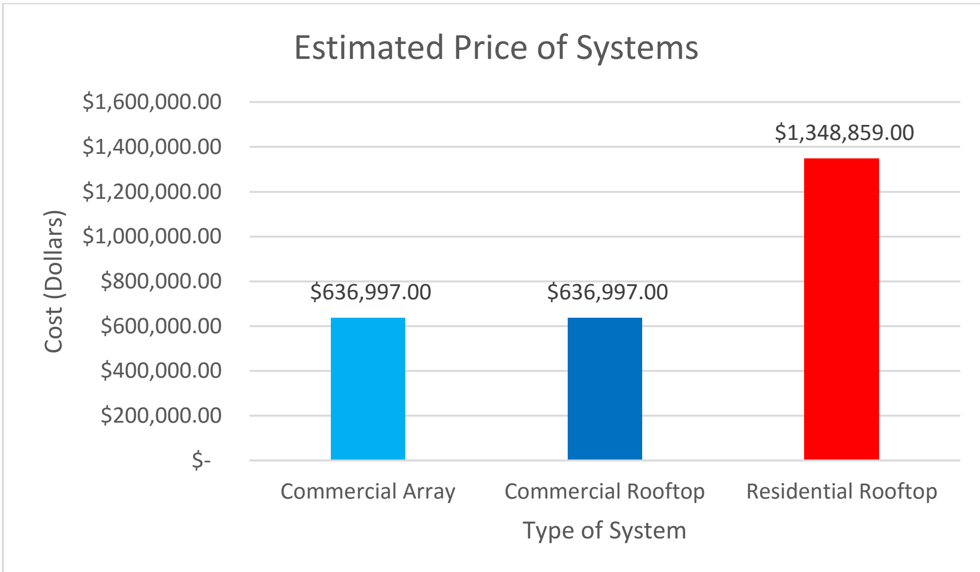
From our research, we analyzed 3 specific solar options that the Santo Domingo Tribal Housing Authority could pursue:

1. A 250 kilowatt Ground-Mounted Commercial Solar Array
2. A 250 kilowatt Rooftop-Mounted Commercial system
3. A 410 kilowatt Rooftop-Mounted Residential system

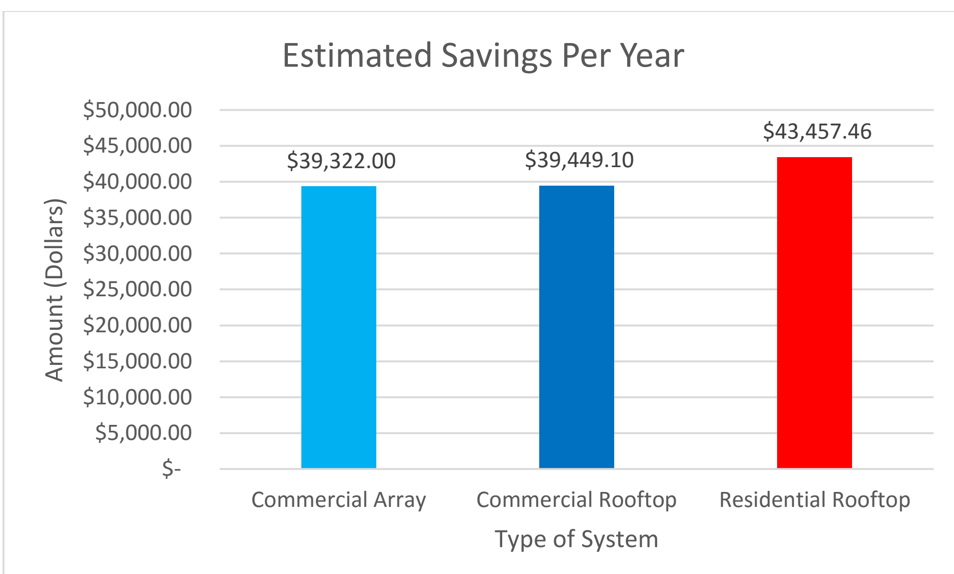
These scenarios were created through the SAM program and designed to provide an excess amount of energy in the community each month. Due to size differences, each system has a different energy output at the end of each year.



The residential rooftop system is the largest, therefore producing the most energy each year. However, the cost of a residential system is significantly higher than the two commercial systems.




Although the residential rooftop option produces the most energy, the system does not generate a large amount of savings. Instead the yearly savings created from the residential scenario and the two commercial scenarios are similar, only varying around $1,000 between the three systems.



The residential option's savings are not significantly higher than those of the two commercial options, and would not be the most cost effective option for Santo Domingo to pursue; instead the commercial options would be far more affordable ways to achieve similar savings.

The Housing Authority must address the idea of system efficiency versus visual appeal. Altering the tilt of the panels on the rooftops of buildings will change the efficiency of the panels. Discovered through the SAM program, a 35 degree tilt will provide the largest energy output through the panels in Santo Domingo. However, community members may not want to have solar panels visible on the new units. If the panels were placed at a 0 degree tilt, they would not be visible, but would have a reduction in energy output, leading to a reduction in total savings. For an array, the 35 degree tilt was the only option considered, as an array will most likely be visible anyways. This issue will need to be addressed in the future when the solar panels are being prepared for installation.

## Conclusion

We suggest that the Housing Authority pursue a ground-mounted commercial array. This system is the most cost effective option, considering the larger energy output and savings each year compared to a commercial rooftop system. However, if the community hesitates at the high visibility of a ground based array of solar panels, then the commercial rooftop system at a 0 degree tilt should be pursued.

When pursuing financial sources for the solar energy project, we suggest prioritizing grants since they do not require a repayment for the funding. If the solar panels can be partially or fully funded through grants, Santo Domingo could begin saving money immediately instead of using the savings gradually to repay the initial cost of the panels.

While our project focused on creating a cost and system analysis report for the community, our team gained insight on Native American life and the implications that locally sourced renewable energy production can have on a community seeking both energy sovereignty and economic development.

## Acknowledgements

We would like to thank the following people for their contribution to the development of this project. Without their help this project would not have been possible.

Joseph Kunkel
Tom Osdoba
The Santo Domingo Tribal Housing Authority
Fabio Carrera
Scott Jiusto
David Spanagel

# Table of Contents

## List of Figures

# 1. Introduction

Native Americans have been living in this region since long before anyone would have dreamed of calling it the Southwest United States. Throughout that time they have adapted their living conditions to suit their needs and comforts. Originally, they built structures in caves and mountainsides to provide shelter from the weather and to function as homes. Afterwards, different Native tribes adapted their living conditions into smaller homes that addressed the issues created by the arid climate that undergoes significant changes in temperature daily. The houses, primarily made of adobe, functioned to stay cool during the day while also insulating the homes at night. Communities were ultimately formed from the collections of the adobe housing. These small villages formed still undergo changes in their housing and use of the natural environment.

The Santo Domingo Pueblo is an example of one of these communities. The pueblo is a relatively small community housing approximately 5,100 members (Santo Domingo Tribal Housing Authority, 2014). The Santo Domingo Tribe's median income is $38,735 (Onboard Informatics, 2016b), which is below the national median income average of $53,657 (DeNavas, 2015, pg. 5) and New Mexico's income average of $44,927 (United States Census Bureau, 2015). However, there has been economic growth in the pueblo since the turn of the century as the median income for the pueblo has increased by 46.95%, which is higher than the state increase of 31.74% and the national increase of 27.36% (USA.com, n.d.). As part of their economic development, recent projects, including the Domingo Housing Project, have been working to improve the homes in the pueblo and develop new housing for the overcrowded living conditions. The new development promises to create 41 new housing units for the pueblo. Once constructed, the housing project will have the opportunity to redefine the standard use of energy in the community through the potential use of solar energy.

Many communities across the Southwest have been using solar energy to significantly lower expenses from outside energy companies. The University of New Mexico Taos Campus recently built a solar photovoltaic array that will allow the campus to produce the entirety of their energy needs (University of New Mexico Taos, n.d.). Through the use of photovoltaic panels and solar hot water panels, the Picuris Pueblo in New Mexico constructed a new fire station that was designed to have zero net energy (U.S. Department of Energy, 2015e). The Santo Domingo Pueblo itself worked with the U.S. Department of Energy to add photovoltaic panels onto the roof of their water pump and treatment facility. As a result of this project, Santo Domingo is expected to save over $20,000 a year from a 75%-85% reduction in power consumption (U.S. Department of Energy, 2015a). Other organizations are making efforts to improve the use of solar energy and other renewable ideas in both existing and new communities. Enterprise Green Communities has created guidelines to support their goal of building affordable green homes (Enterprise Community Partners Inc., 2016). The company focuses on providing affordable housing for low-income areas, and have participated in multiple projects on Native American land.

Although solar energy has been successfully used throughout New Mexico and the Southwestern United States, problems often emerge that hinder the introduction of a renewable energy source into communities like Native American pueblos. The Desert Rock Power Plant attempted to introduce a large solar array onto Navajo land, but that ambitious scheme ended in failure (Paskus, 2010). Among projects that have succeeded, the water pump in Santo Domingo and the fire station in Picuris were small compared the energy consumption needs of a new community like the Domingo housing development. Extensive research about solar energy and funding are essential to ensure the success of a project attempting to introduce solar panels into a new community.

The goal of our project is to help develop solar energy options for the Domingo Housing Project in Santo Domingo. We approach this problem through distinct steps that include analyzing the current construction site, gathering construction details on the progression of the Domingo Housing Project, creating an analysis to find a feasible plan for utilizing solar energy in the area, and producing a video that will explain Native American sustainability throughout history and explain what energy sovereignty could mean for their community. Using a cost analysis report for several solar energy systems, we can convey the different options that Santo Domingo has when deciding on the implementation of solar panels. Our final section of the report includes different sources of funding for solar energy projects. In working with our sponsor Joseph Kunkel and the Santo Domingo Housing Authority, we plan to help them create a foundation for future projects attempting to bring renewable energy sources into Native American Communities.

# 2. Background

The background chapter discusses overcrowding issues in pueblos and then describes the sustainable living techniques used by Native Americans in the Southwest United States. The chapter then covers the recent introduction of solar energy into the area. The background concludes with a description of the history and culture of the Santo Domingo Pueblo. Throughout the chapter multiple examples are given about past projects related to the goals of this project. While information on solar technology and the pueblo assisted the development of the project, past ventures provided our team with important knowledge on the successes and failures of different ideas.

## 2.1 Overcrowding Issues in Pueblos

Population density has been an issue on Native American Reservations for many years. The smaller villages often have overcrowded homes when the community tries to provide enough housing for its members. Overcrowding and other issues involving Native American housing were brought before the Committee on Indian Affairs during the One Hundred Ninth Congress in 2006. As stated by Senator John McCain (Republican- Arizona) in the hearing, "Indeed, the president of the NCAI reported to this committee at our budget hearing in February that in some cases, as many as 25 to 30 people were living in homes with no more than 3 bedrooms." (United States Congress, 2006, pg. 1). Housing close to 10 people in a single bedroom can create hardships on both the host family and those temporarily staying in the households. Former Senator Byron Dorgan (Democrat- North Dakota) stated that 40 percent of on-reservation housing structures are substandard, which is significantly higher than the 6 percent national figure during that time period (United States Congress, 2006, pg. 1). Eventually the combination of substandard housing and overcrowding became prominent enough to reach the United States government.

Through funds made available by the Native American Housing Assistance and Self Determination Act of 1996 (NAHASDA) and the U.S. Department of Housing and Development (HUD), multiple housing projects have been completed to address both the housing and overcrowding issues (United States Congress, 2006, pg. 26). The development of 248 units on the Standing Rock Reservation in North and South Dakota, completed in 2006, created affordable rental housing for members of the reservation (United States Congress, 2006, pg. 11). Between 1970 and 2006, the Muscogee Creek Nation in Oklahoma completed 2,900 homes and 240 low rent apartments while being able to support over 100 employees (United States Congress, 2006, pg. 16).

While NAHASDA and HUD provide funding and assistance for projects to develop, the overall system of federal support and oversight of project expenditures creates obstacles to the development of new housing. In the *Fort Peck Housing Authority vs HUD* case, over $300 million in housing funding was being held from Native American communities until a proper redistribution of funding was made in Fort Peck that accounted for new housing in development (United States Congress, 2006, pages 7-8). The amount owed was only $400,000 but the case held up funding that was set to fund 561 tribes and housing entities (United Sates Congress, 2006, pg. 8). Overcrowding also occurs in the Santo Domingo Pueblo, where there are at times 18 residents in a 900 square foot household (Kunkel, 2016a). However multiple projects are being developed to address this issue, including the Domingo Housing Project and a future housing development inside the pueblo village.

## 2.2 History of Sustainable Living in Pueblos

Sustainable techniques have been used in pueblos for many years before the modern sustainability idea formed. From basic adobe construction to new modern building techniques, different Native Communities are able to construct buildings that work well in the nearby environment. Sustainable design in Native building also includes the use of renewable energy.

### 2.2.1 Adobe Housing

Earth is the most abundant building material, being used for thousands of years. Adobe material is first recorded to be used 8000 to 6000 BC in Russian Turkestan (J. Reveulta-Acosta, 2010, pg. 2212). One such building material is adobe. Adobe is a sun-dried brick mixed with organic materials. Adobe is created with a combination of water, soil, and straw. The straw is very low in concentration in the max, usually around 5-10%. The amount of water is a quarter of the amount of soil (J. Reveulta-Acosta, 2010, pg. 2214). Adobe bricks are made from pouring the mixture into molds (J. Reveulta-Acosta, 2010, pg. 2211). The creation of Adobe has four phases, which are dry, humid, plastic, and liquid. The plastic phase is when the adobe is created and molded. Straw and sand is added to the mixture because as the adobe mixture dries and solidifies large cracks are created. These additives are used to reduce crack sizes (J. Reveulta-Acosta, 2010, pg. 2214).

This material is energy efficient because of its high heat capacity. This allows the adobe material to absorb heat during the day and releases it into the building at night when the temperatures get cooler (J. Reveulta-Acosta, 2010, pg. 2213). Adobe walls are much thicker than walls made of other building material which allows the inside temperature to be more comfortable while using less energy than other materials (J. Reveulta-Acosta, 2010, pg. 2213). An experiment was performed at the Solar Energy Park at the Indian Institute of Technology Delhi in New Delhi to see the savings of an adobe home. Their results were that 370 Gigajoules (GJ) can be saved each year and $CO_2$ released into the atmosphere could be reduced by 101 metric tons per year. They also found that the payback time for the adobe house was 1.54 years (Shukla, 2009).

There are numerous advantageous in building using adobe, however there are some disadvantages. One problem with adobe is the heat capacity property changes with the moisture content of the material. Another problem is the adobe material is subject to damage from weather more than modern building materials. (J. Reveulta-Acosta, 2010, pg. 2213).

### 2.2.2 Other Building Techniques

Navajo FlexCrete is a green style building technique. Theses aerated concrete blocks are made up of fly ash, polypropylene fibers, and aluminum paste. The polypropylene fibers are used for strength, the aluminum paste is used for expansion, and the fly ash is used for the unique qualities given to the materials (The American Institute of Architects, n.d.). The fly ash allows the material to cure at low temperatures and ambient pressure unlike regular concrete that requires energy intensive practices. The properties of this material are beneficial for buildings in a location that is prone to wildfires, high winds, and extreme conditions. The material properties also make good options for firewalls, sound barriers, explosive resistant buildings, or collision sacrifice structure (The American Institute of Architects, n.d.). There are numerous benefits of using this material, which include ease of use, durability, energy efficiency, and sustainability. The FlexCrete material is lightweight and can easily be cut and put into specific shapes for certain conditions. These blocks do not become weaker with the weather cycles when they are protected from moisture and is mold, mildew, and pest resistant. These blocks are good insulators, having an 18-24 R value for an 8 inch block (The American Institute of Architects, n.d.). This material is also energy sustainable because of the lightweight, thermal efficient, low energy intensive properties present.

Straw is the stalk of a grain plant and is high in cellulose, meaning animals cannot eat it. There is not a high demand for straw so builders looking for a new, more natural material started using straw for building. There are two types of straw construction. The first kind is called load bearing. As the names suggests the straw bales are actually holding up all of the weight of the structure (Down to Earth Design, n.d.). The second type of straw bale construction is non-load bearing, when straw bales are added between framing built with another material (Down to Earth Design, n.d.). The straw does not actually hold any of the weight of the structure. The non-load bearing technique is easy to acquire a building permit for and is the most common form of straw construction. Public acceptance is higher because the straw is used more for insulation than actual structural needs.

Another form of construction is Tilt-up Construction (Bob Moore Construction, n.d.). The construction starts by the team making a mold for wooden slabs. These molds for the cement panels contain all the cutouts of the building including windows and doorways. Then a steel grid is added to the mold for reinforcement. Inserts and embeds for lifting are made onto the structure to allow connection to roofing or flooring (Bob Moore Construction, n.d.). Then the area is cleaned and concrete is poured in to the mold to make the panels (Bob Moore Construction, n.d.). Once these panels dry and solidify, the mold is disassembled and the panel is attached to a crane that typically two to three times the size of the largest panel (Bob Moore Construction, n.d.). Braces are attached to the panels and the crane then lifts up the panel to the vertical position where workers help guide the panels into the correct position (Bob Moore Construction, n.d.). This is then repeated with each panel. The workers then caulk the joints and fix any imperfections in the panels. This construction method has many advantages. One advantage is the speed at which a building can be constructed. A crew can lift as many as 30 panels weighing from 50,000 to 125,000 pounds in one day (Bob Moore Construction, n.d.).

Another energy efficient and cost effective building material is structural insulated panels (SIP). An STP is made of two boards on the outside with foam insulation in between (Structural Insulated Panel Association). These are manufactured to fit any size and shape for a building. The advantage of using this material is smaller heating and cooling systems are used in the houses because of its insulation (Structural Insulated Panel Association, n.d.). SIP panels also cost about the same as a wood structured house (Structural Insulated Panel Association, n.d.).

### 2.2.3 Geothermal Heating

Geothermal heating has been a major source of economic savings used by pueblos in the area. The process is shown in Figure 1 (Untitled picture of a geothermal heating process, n.d.). There is ongoing support by federal institutions to increase use of geothermal heating by the pueblos, such as Jemez (Hill, 2004). The Jemez are a neighboring tribe to the Santo Domingo, both which are in Sandoval County. Geothermal energy has traditionally been used as a source of cooking, curing and comfort in the form of heating by southwest tribes (Coskun, 2010). Traditional usage of hot springs as part of local resorts also exists.

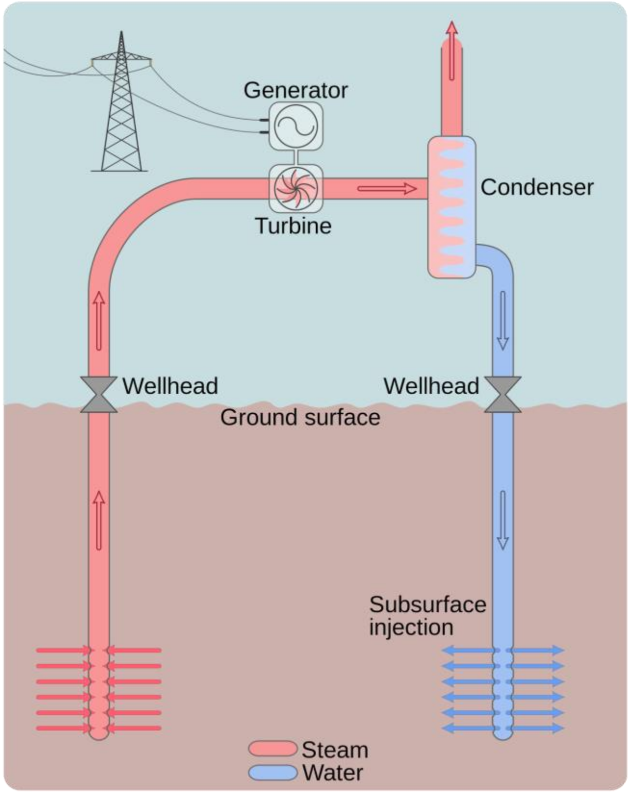



*Figure 1... Geothermal Heating*

In terms of modern usage, aquaculture and greenhouses have seen increased use of geothermal energy. Businesses within New Mexico in aquaculture and greenhouses such as Burgett have saved over $100,000 yearly by using geothermal deposits in place of natural gas (Chiasson, 2011). An estimated 500 jobs have been created by these existing geothermal businesses (Chiasson, 2011). There are still many opportunities to save money through geothermal energy, as many deep springs in Valles Caldera are still untapped (Golf, 2002).

### 2.2.4 Swamp Coolers

Swamp coolers, or evaporative cooling, is a source of economic savings that both pueblos and nearby regions are currently using. In this process warm air passes through water-soaked pads inside the cooler, which creates humidified cool air, as shown in Figure 2 (Evap. cooler illustration, n.d.). This provides an immediate savings in energy costs by being 1/8th the price of traditional air conditioning (Waterline Cooling, 2016). New Mexico's dry climate negates performance issues created by humidity, and the damp air created by swamp coolers helps cope with the arid climate.

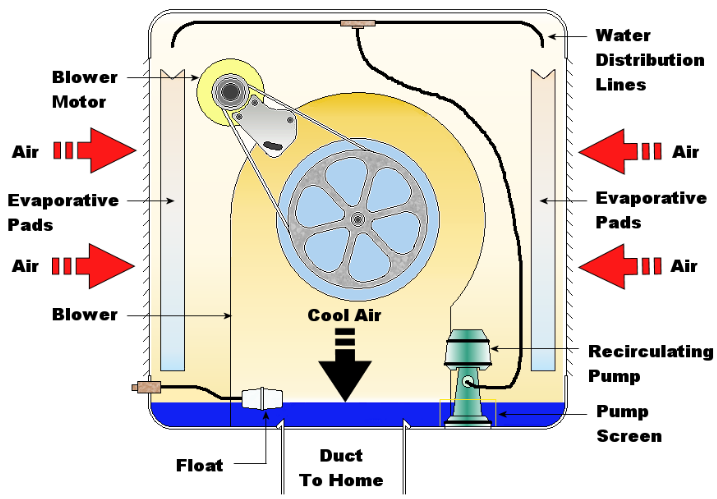



*Figure 2... Swamp Cooler Design*

Although swamp coolers save money and function as effective alternatives to air conditioners, there are multiple negative effects created by evaporative cooling. Studies show swamp-cooling increases the presence of dust mites and mold allergens (Berkeley Lab, n.d.). A study in Colorado homes found the dust mite issues hits its peak in August right when swamp cooling usage is at its pinnacle in those homes (Ellingson, 1995, pg. 475). These issues can be assumed to also affect homes in New Mexico. One solution to these problems is to improve insulation in the homes (Chan, 1999). By improving insulation, houses reduce the need for cooling techniques such as evaporative cooling, which can prevent prolonged sickness.

## 2.3 Solar Technology

Solar Energy is a general term used when referring to the use of the sun's rays to generate power. Four major forms of solar energy commonly used are natural radiation, solar hot water heaters, concentrated solar power systems, and photovoltaic (PV) systems. While they differ in concept and use, each technique can be applied to reduce standard energy consumption from energy companies.

### 2.3.1 Passive Solar Heating

The sun gives off natural radiation, providing heat to the earth. Using this natural heat to warm buildings has been a common practice in home construction for many years. The National Institute of Buildings defines passive solar heating in four main designations: south-facing windows collect solar energy, certain building materials store this energy in "thermal mass," natural convection and radiation are enhanced through design to help distribute this energy throughout the dwelling, and window specifications allow for a higher absorption of solar energy (Fosdick, 2012). Passive solar heating is widely used in many southern United States communities where the sun hits the earth more directly.

The optimization of passive solar energy is a cheap and effective technique for developing “green” homes. When designing for passive solar, a building’s site, climate, and construction materials are chosen to reduce the required energy use needed by the home to properly function (U.S. Department of Energy, n.d. (a)). The southern side of the house should be open to the sun to maximize heating during the summer, and the building is designed with materials specialized to retain heat and provide more natural heating (U.S. Department of Energy, n.d. (a)). Through this process the prospective residents of the home will pay less money for either the gas or electricity required to create heat. Passive solar homes are also designed to have shade available when the sun is at a higher angle during the summer, therefore creating shade only during the summer to prevent the home from overheating (U.S. Department of Energy, n.d. (a)). The placement of objects generating shade (depending on the season) allows for the home to stay cool during the summer while using the sun as a natural heating source in the winter. An example of this energy saving technique is exemplified through the use of a thick masonry wall known as a Trombe wall, which is shown in Figure 3 (U.S. Department of Energy, n.d. (a)).

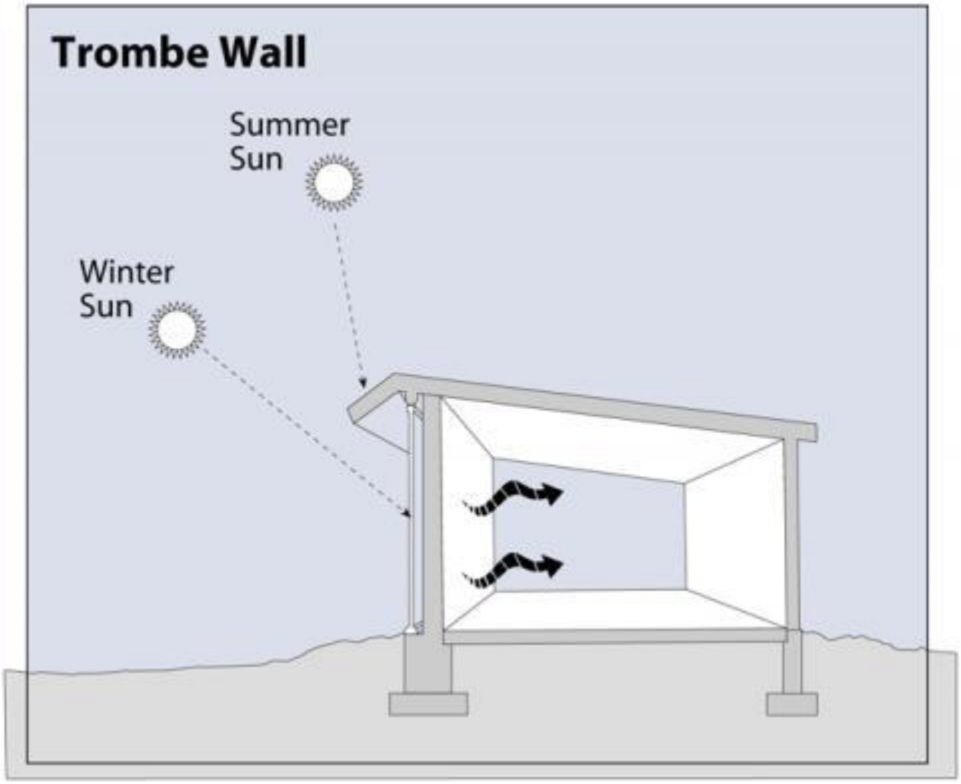



*Figure 3... Example of a Trombe Wall*

Passive solar homes follow certain basic criteria that are used as guidelines, which are provided by the Department of Energy:

- Properly Oriented Windows:
  - Windows should be placed to allow heat to enter the building during colder months while being shaded during warmer months (U.S. Department of Energy, n.d. (a)).
- Thermal Mass:
  - Using different materials like tile and concrete that will remain cool during the summer but heat up during the winter based on the amount of time being exposed to the sun. Other thermal materials like drywall and insulation also act as good thermal masses to help reduce the need of energy in the home (U.S. Department of Energy, n.d. (a)).
- Distribution Mechanisms:
  - Different distribution mechanisms allow for heat to be easily transferred throughout a home. The use of conduction by having objects contacting each other is a viable technique, while using a fluid to transfer heat through convection provides another outlet for heat transfer. Using darker colors in the design of a solar home can improve the amount of heat retained through radiation, and improve passive heating in the house (U.S. Department of Energy, a, n.d. ).

- Control Strategies
    - Different structures like roof overhangs, low emissivity blinds, operable insulating shutters, differential thermostats, and awnings both passively and actively provide energy efficient heating and cooling in the household when needed (U.S. Department of Energy, n.d. (a)).

The use of the natural landscape is another technique used when designing a passive solar home. Creating a design plan for the landscape surrounding the house can provide natural heating and cooling while creating aesthetic appeal. The proper placement of trees shade the house during the summer while obstructing the path of cold winds during the winter that would reduce the natural thermal processes that are providing heat for the building (U.S. Department of Energy, n.d. (b)). While observing the landscape, the general climate of the area depending on the region of the United States must be considered, but the microclimate immediately surrounding the home can heavily influence the design of a passive thermal home (U.S. Department of Energy, n.d. (b)). The shade and wind present immediately surrounding the home can change the materials used and also influence the maximum passive solar heat that can be generated (U.S. Department of Energy, n.d. (b)).

### 2.3.2 Solar Hot Water Heaters

When using solar energy to heat domestically used water, special panels called flat-plate collectors are used to heat a liquid. The interior of each panel contains small tubes that contain water or another liquid. When solar rays contact the collector, the liquid is heated and then transported to the water storage unit for the building, to be used as a heat source later on (Renewable Energy World, n.d. (c)). This process is shown in below in Figure 4 (Untitled picture of a solar hot water heater system, n.d.):

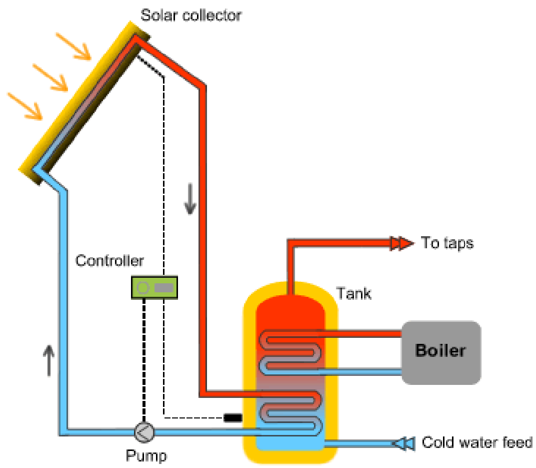



*Figure 4... Layout of a Solar Hot Water Heater*

### 2.3.3 Concentrated Solar Power Systems

A different system that incorporates the process of generating electricity using the sun's rays is a concentrated solar power system. This system uses a set of mirrors to concentrate solar rays, and uses the condensed rays to heat up oil travelling through a tube. The heated oil can then be used to boil water and generate steam through a standard generator (Renewable Energy World, n.d. (b)). This process has the ability to create electricity successfully, but also requires a steam generator and proper equipment to redistribute the power afterwards. Figure 5 is an example of a concentrated solar power system located at Crescent Dunes, Nevada (Crescent Dunes Solar Energy Project as seen from an airliner, 2014). Although using a Concentrated Solar Power System can be effective, Santo Domingo would not have the available resources to support the development and creation of one.

*Figure 5... Concentrated Solar Power System at Crescent Dunes*

### 2.3.4 Solar Photovoltaic Systems

A commonly used type of solar technology is the standard solar photovoltaic (PV) system. The PV cells located on a solar panel directly convert sunlight into energy by activating and separating electrons in the atoms present in the cells. The movement of electrons creates electricity that can be used for general use (Renewable Energy World, n.d. (a)). Figure 6 (Untitled picture of the process of solar PV panels, n.d.) explains the general process of a solar PV system.

Solar PV panels are used across the world providing power for individual homes and entire communities through large solar arrays. The utilization of these panels can reduce the expenses of the owner and reduce dependence on outside companies to provide power while also reducing greenhouse gas emissions.

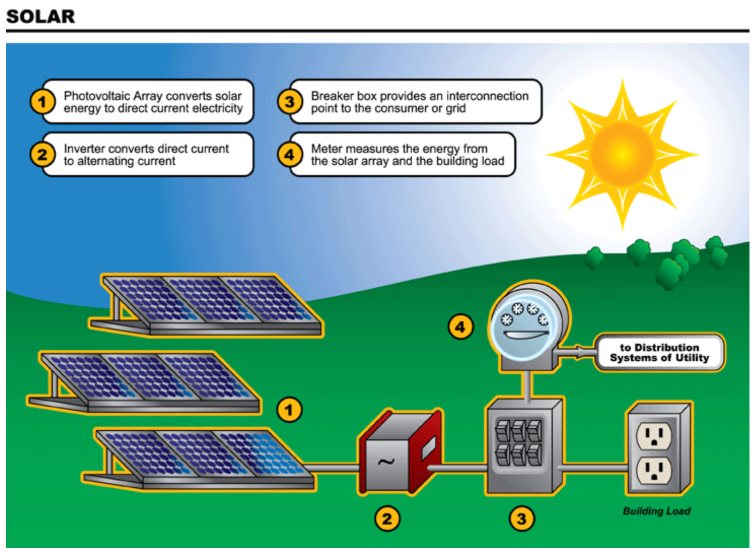



*Figure 6... Process of using Solar PV Panels*

### *2.3.4.1 Types of Solar PV*

There are three different types of system scaling for PV: residential scale, commercial scale, and utility scale. Shown below, The National Renewable Energy Laboratory (NREL) has provided bottom-up modeling for solar PV systems and their pricing trends from Q4 in 2009 to Q1 in 2015. This bottom-up design includes five distinct stages: the Balance of System (BOS) subsystem, the Inverter subsystem, and the Module subsystem for the actual unit, and then includes labor and other miscellaneous costs.

The BOS includes all of the non-module or inverter components of the entire PV system. This may contain the mount, the wiring, the hardware, and the batteries, amongst other components. The inverter changes the DC current—which is converted by the panels from solar radiation—into AC current for distribution throughout the household (Florida Solar Energy Center, 2014b). The module is the actual series of solar cells aligned on the solar panel (Florida Solar Energy Center, 2014a).

Residential: this type of system incorporates panels for use on an individual housing. This type of system would power household appliances and lighting, in general, and a 5.2 kW system was modeled for this pricing trend. NREL's pricing model for residential systems is shown in Figure 7 (Chung, 2015, pg. 12).

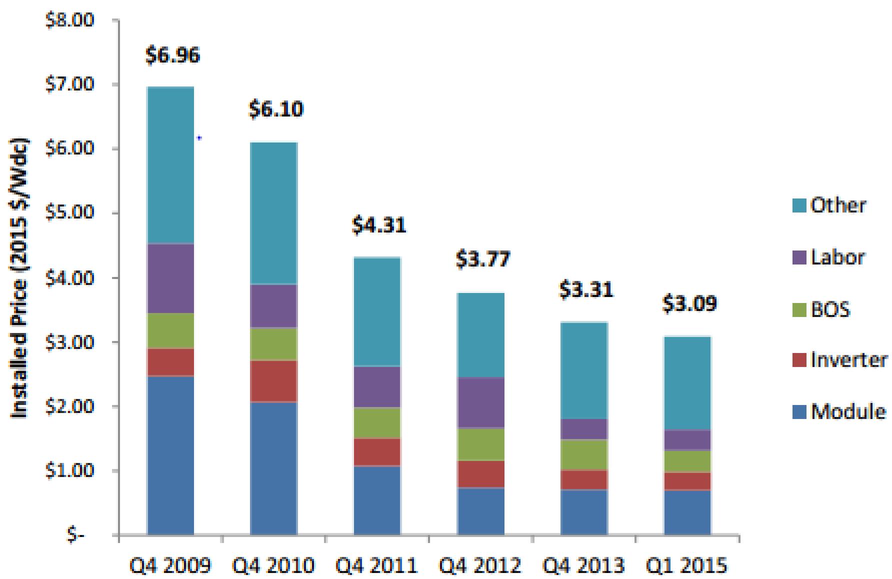



*Figure 7...Residential Solar Costs over Time*

Commercial: this system would incorporate panels for use in an industrial-sized building using commercial-scale utilities. A 200 kW system was modeled for this pricing trend. NREL's pricing model for commercial systems is shown in Figure 8 (Chung, 2015, pg. 24).

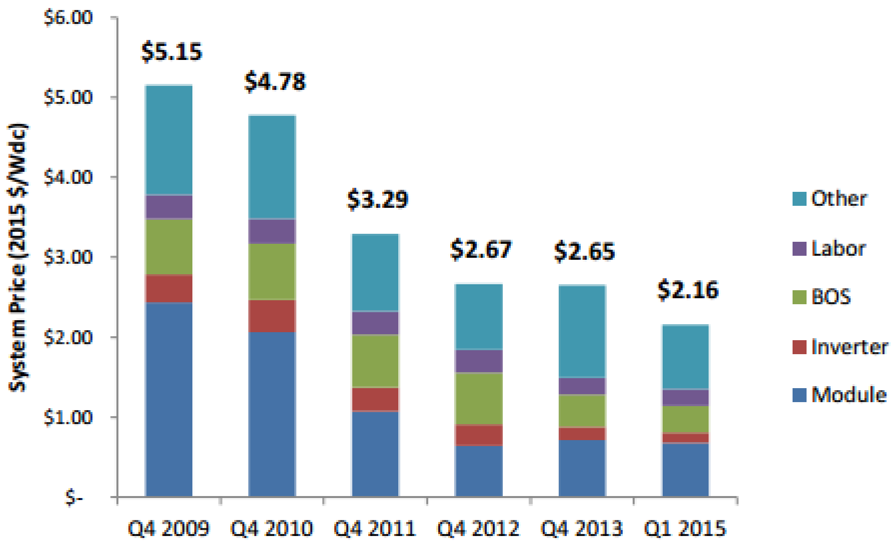



*Figure 8... Commercial Solar Prices over Time*

Utility: a utility scale system differs from residential and commercial-scale systems because utility-scale systems sell electricity to wholesale utility purchasers rather than "end-use consumers" (Solar Energy Industries Association, n.d.). A utility system is also installed on a much larger scale than others, and the system modeled by NREL was 100 MW; the pricing trends are shown in Figure 9 (Chung, 2015, pg. 33).

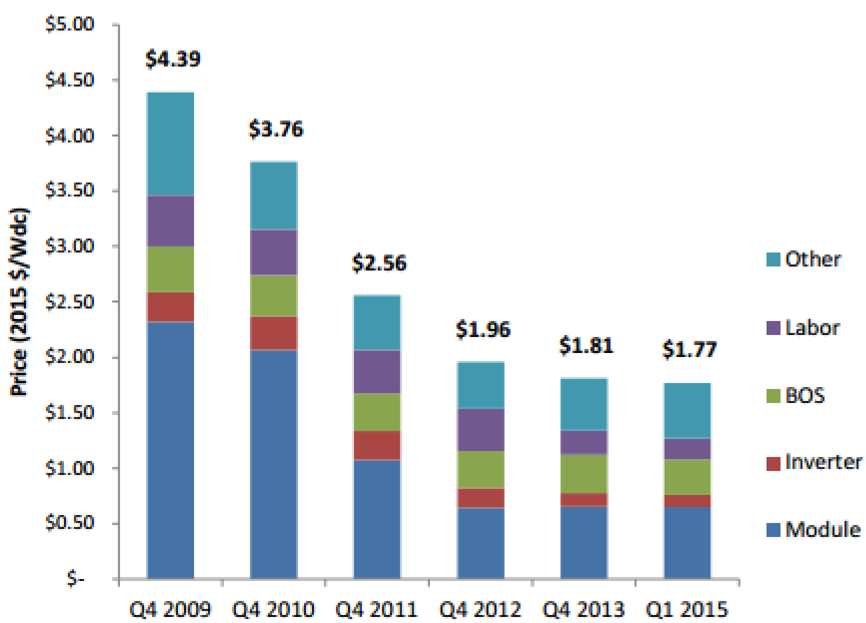



*Figure 9... Utility Solar Costs over Time*

These graphs do not take into account the different types of PV panels: crystalline, thin film, and CPV. In general, these graphs display the expected cost of PV panel installation in 2015, depending upon the total size of the PV system installed (per Watt of DC power). NREL has provided another graph that analyzes the cost/$W_{DC}$ per system and the installation cost trend since 2007. However, the graph accounts only for utility-scale systems. This graph, shown in Figure 10, accounts for pricing differences between crystalline tracking and non-tracking, thin film tracking and non-tracking, CPV systems, and displays a weighted average cost of the given reported (Feldman, 2014, pg. 14).

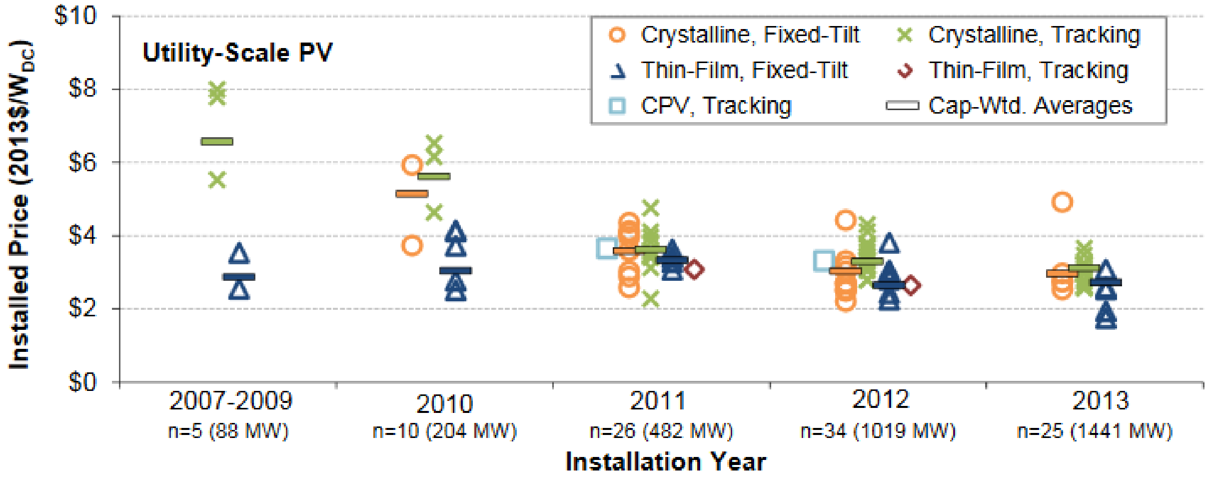



*Figure 10... Comparison of Pricing of Different Solar Designs*

The capacity-weighted averages shown on the graph as the horizontal bars are listed below (Feldman, 2014, pg. 14):

- Crystalline, fixed-tilt: $2.97/$W_{DC}$
- Crystalline, tracking: $3.12/$W_{DC}$
- Thin-film, fixed-tilt: $2.72/$W_{DC}$

NREL separates solar PV systems into three major types of panels that are often used. They are listed below:

- Crystalline: atoms of silicon (this is the most common type of atom used in PV panels) or non-silicon materials bond to form a solid, crystal lattice in a flat-plate design (National Renewable Energy Laboratory, 2014).
- Thin film: amorphous silicon or non-silicon materials (semiconductor materials) form layers just a few micrometers thick (National Renewable Energy Laboratory, 2014).
- Concentrator (CPV) Tracker: a two-axis, flat-plate system that tracks the sun using a concentrated system (National Renewable Energy Laboratory, 2014).

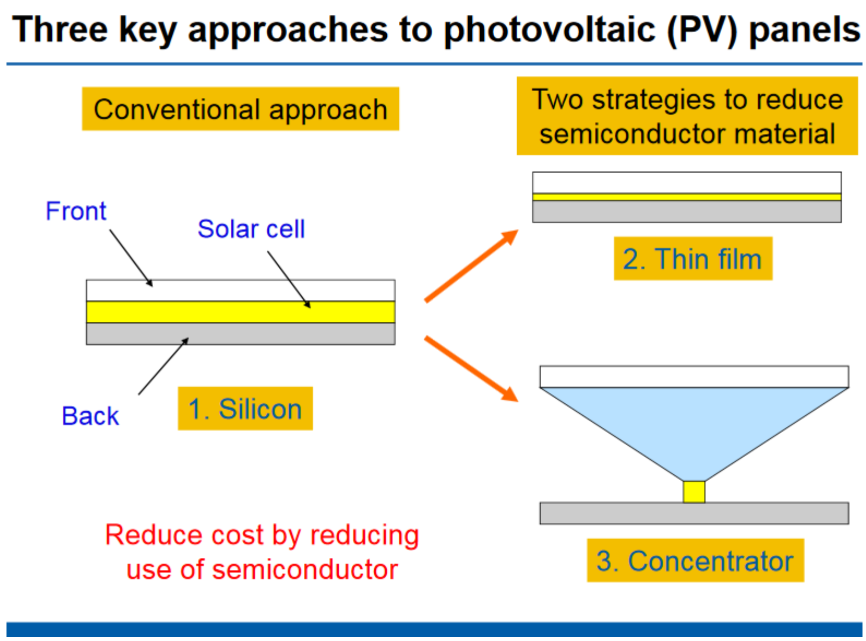



*Figure 11... Different Types of Solar Panels*

A shown in Figure 11, the crystalline system is the left-most diagram of the silicon panels (#1), the thin film system is shown on the top right at #2, and a standard cell from a CPV tracker system is shown on the bottom right (#3) (Kurtz, 2009, pg. 9).

The three subcategories of PV are further separated by tracking and non-tracking. CPV tracker systems are not included, as they are designed to constantly track the sun on a two-axis system, but both thin film and crystalline systems can be designed to be on a fixed-axis, tilted or flat, or on a one or two-axis system to track the sun. While concentrator and thin film reduce the total cost of the system by limiting the use of semiconductor material, the systems themselves may still be impractical due to size and space restrictions.

#### *2.3.4.2 PV in New Mexico*

According to NREL, the area near Santa Fe, New Mexico receives an average of 6.50 to 7.50 kWh/m$^2$/day in direct normal solar radiation, as shown in Figure 12 (Concentrating Solar Resource of the Southwest United States, n.d.):

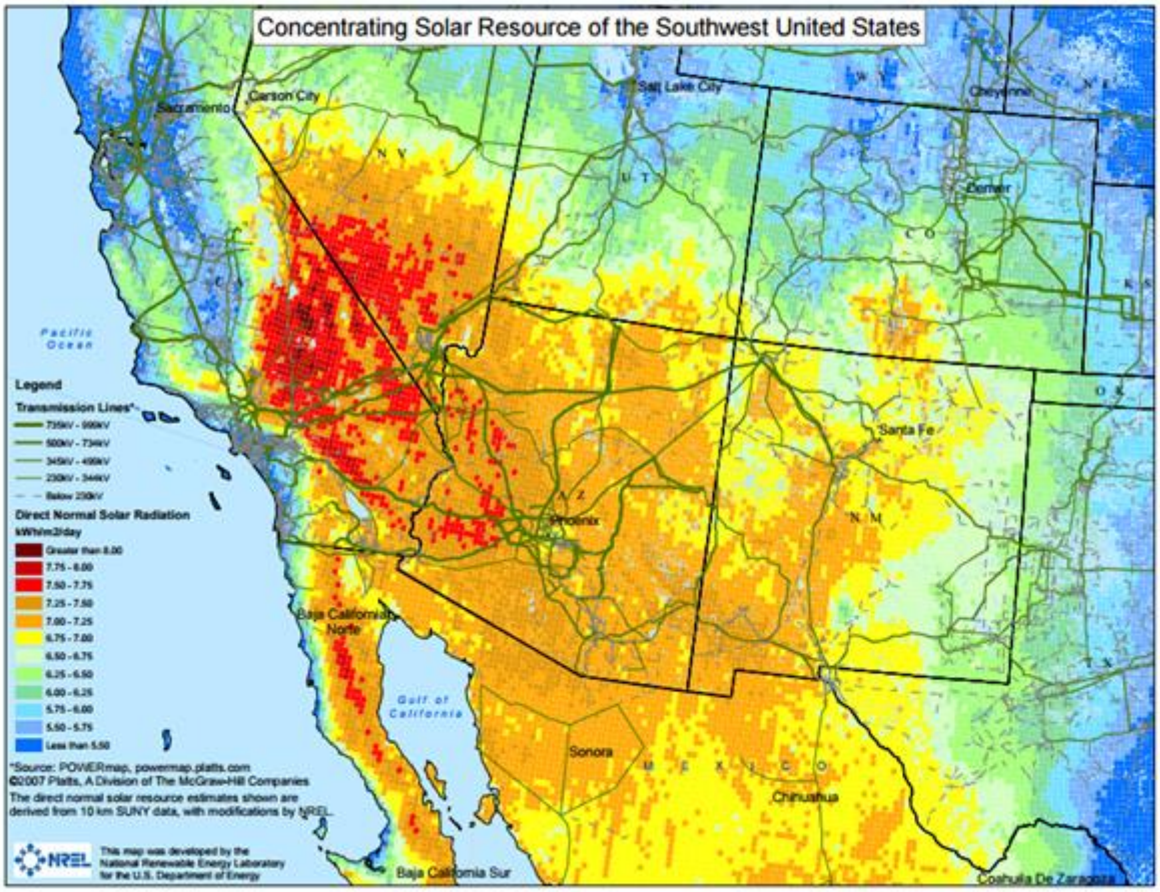



*Figure 12... Direct Normal Solar Radiation in the Southwest United States*

While not as high as some areas further west, Santo Domingo's location in New Mexico is in a prime solar range. Standard solar PV cells return on average 33% of the solar energy they absorb (U.S. Energy Information Administration, 2015), meaning that one panel with an area of one square meter in Santo Domingo may return around 2.33 kWh in one day, or almost 70 kWh per month.

According to the U.S. Energy Information Association, the average American household (complete with full utilities, television, phone, etc.) uses around 911 kWh per month, or around 30 kWh per day (U.S. Energy Information Administration, 2015). With 13 square meter panels, a single dwelling could produce enough solar energy to meet the United States average for energy consumption.

## 2.4 The Santo Domingo Pueblo

The Santo Domingo Pueblo in New Mexico is a Native American Pueblo located 33 miles north of Albuquerque (U.S. Department of Energy, 2015d). The climate throughout the year is arid with a low precipitation rate of 254 mm (10 in.) per year (Climate Data, n.d.), which is significantly less than the national average of 715 mm (28.1 in.) (The World Bank, n.d.). Although there is low rainfall, Santo Domingo still has access to water through the Rio Grande River, as shown in Figure 16. Santo Domingo also averages 277 days of sun per year, versus 66 days of precipitation (City Stats, n.d.). Although the lack of precipitation present in the area potentially creates dry seasons and agricultural issues, the pueblo still manages to have a strong agricultural system that shapes their culture and life (United States National Park Service, n.d).

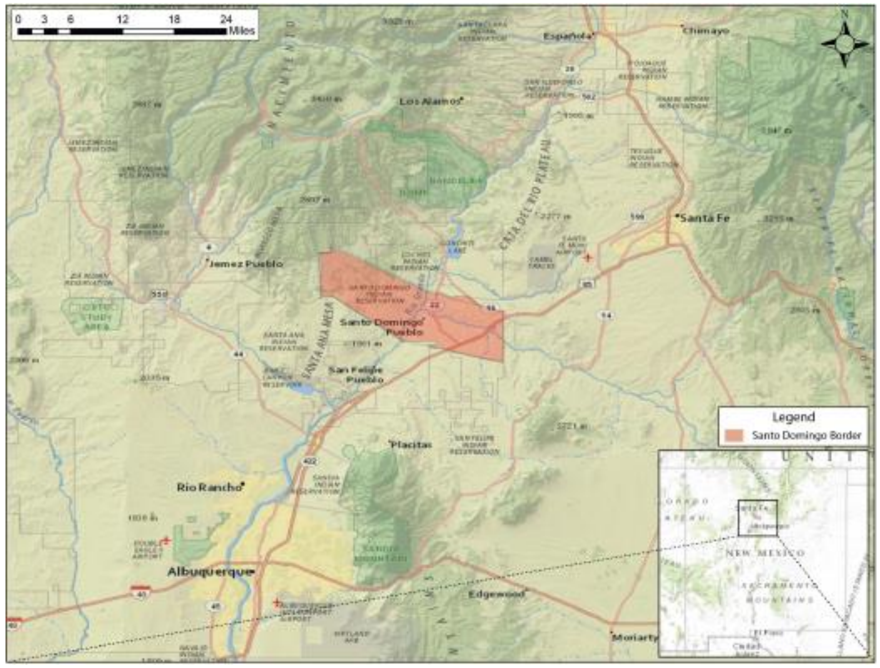



*Figure 13... Santo Domingo and the Surrounding Area*

### 2.4.1 History and Culture

The National Park Service explains that the Santo Domingo Pueblo has undergone multiple changes, including the settling of the Spanish at the end of the 16th century. The pueblo originally welcomed the Spanish as an ally against other tribes, and became a center for the Spanish mission system that was spreading throughout the southwest. Eventually Santo Domingo became a location of violence and revolt as the residents revolted against the Spanish, which ended in Spanish victory. The pueblo has also been rebuilt twice because of major flooding events that occurred in the 1600's and 1886. Although these changes have created struggles and adversity, the residents have held onto their traditions and still practice them today. The pueblo holds their annual feast day on August 4$^{th}$, which is in honor of Saint Dominic, their patron saint. The festival begins with a morning mass, and progresses into different activities like dancing. The Catholic roots, which were created by the Spanish missionaries, are mixed with the traditions of the Native Americans during the Green Corn Dance, which is performed during the feast in front of a statue of Saint Dominic. Another festival occurs in February, where a hunting dance is performed. Both the Hunting Dance and the Green Corn Dance reflect the cultural impact of farming on the community, since both occur during the poles of their agricultural year. Santo Domingo residents also continue to honor their culture through the creation and trading of jewelry and pottery, which are made through traditional crafting techniques (United States National Park Service, n.d.).

### 2.4.2 Demographics and Economics

Santo Domingo currently provides residence to around 5,100 members (Santo Domingo Tribal Housing Authority, 2014). The adobe houses in the pueblo are regarded as low-income housing. Currently Santo Domingo residents subsist below both the local and national averages for median household income. The median income for households in 2013 for Santo Domingo was recorded at $38,735 (Onboard Informatics, 2016b), while New Mexico recorded a median income of $44,927 averaged from 2009 through 2013 (United States Census Bureau, 2015) and the United States held an average of $53,657 in 2014 (DeNavas, 2015, pg. 5). Santo Domingo's low income can also be compared to the nearby Santa Ana pueblo, which had a median income of $45,438 in 2013 (Onboard Informatics, 2016a). Santo Domingo's economic situation has the potential to create barriers to economic development. However steps are being taken to address both the economic and housing issues in the area through the new housing development being built.

#### *2.4.2.1 New Housing Development in Santo Domingo*

The Domingo Housing project is an 8 acre development of new housing being constructed for the Santo Domingo Pueblo (Pavilion Construction, 2015). The general contractor will be Pavilion Construction. This project is expected to be composed of 41units, each of which can support multiple families (Pavilion Construction, 2015).

Pavilion Construction is a relatively new general construction company that was established in 2007 by Derek Mannelin, Brian Gerritz, and Rob Olson (Pavilion Construction, 2012). Their goal was to provide high quality contracting services for a diverse variety of clients. They currently have a broad spectrum of housing projects including low-income housing in New Mexico (Pavilion Construction, 2012).

The land being used for construction in Santo Domingo was previously vacant native land. The land has been assessed to be moisture sensitive, which creates a cause for concern since an increase in moisture can weaken the soil strength and indirectly the housing foundation (Pavilion Construction, 2015). Additionally, soft soil near the surface that individually supports housing may need special site preparation in the form of floor slabs and excavation of the topsoil layer (Pavilion Construction, 2015). This is an example of some difficulties the new housing development has already faced due to modernity of the project.

For a family to gain access to the housing when completed, they have to complete an application. The criteria to apply for the housing is the family must be below area median income (Kunkel, 2016b). When a family is pre-qualified by the housing authority, they will be placed on the waiting list, and once the housing unit is ready, the family will go through a verification process to make sure they still qualify for housing (Kunkel, 2016b). Currently there are 72 families that have been pre-qualified for the Low-Income-Housing-Tax-Credit housing development. (Kunkel, 2016b).

The housing development is contemporary in architecture, reflecting the cultural principles of existing pueblo housing without copying the historic fabric (Kunkel, 2016a). The new housing will be following the criteria of an environmental organization called Enterprise Green Communities.

#### *2.4.3.2 Enterprise Green Communities*

Enterprise Green Communities is branch of the non-profit organization Enterprise Community Partners. This branch is focused on achieving the Green Communities Initiative of Enterprise Community Partners. Housing projects that meet its Green Communities criteria receive funding that they have fundraised from grants, banks, other foundations, and personal donations.

Enterprise Green Communities has specifically collaborated with companies including the Sustainable Native Communities Collaborative and American Indian Supportive Housing Initiative to provide green affordable housing for Native Americans. Since 1997, Enterprise Green Communities has helped provide over $100 million worth of housing and other economic developments for Native American communities. (Enterprise Community Partners Inc., 2016). 50 tribes have benefitted from the over 1800 homes developed by Enterprise Green Communities (Enterprise Community Partners Inc., 2016).

The Thunder Valley Community Development Corporation's (CDC) recent 34-Acre development is one example of a development in progress for low-income families supported by these collaborations. This non-profit organization is run by the Oglala Lakota of South Dakota. One of the forms of independence achieved by Thunder Valley CDC is food sovereignty. Through the use of community gardens, the Lakota have become self-sustaining in terms of agriculture (Thunder Valley Community Development Corporation, n.d.).

Enterprise's actions reflect its ultimate goal to ensure that green, affordable housing exists for all low-income families in the United States (Enterprise Community Partners, Inc. 2016). The company expects communities that follow its housing criteria to make a return on their investments through utility savings over a 10-15 year span. (Bourland 2009). The financial payback comes in 3 forms; simple payback, lifetime utility cost reduction and internal rate of return. All these forms of savings focus on efficiency in the green utilities.

The Domingo housing project is expected to follow the 2015 Enterprise Green Communities Design criteria during construction (Kunkel, 2016a). Its current 2015 criteria involves specific requirements in the following areas: integrative design, location, neighborhood fabric, site improvements, water conservation, energy efficiency, healthy living environment, operation, maintenance and resident engagement (Enterprise Community Partners Inc., 2015).

## 2.5 Funding Green Energy Projects

While solar energy projects are great opportunities for communities, they are impossible to accomplish without the availability of adequate funding. Communities can find funding through government grants and programs, bonds, private investors, and energy payback programs.

### 2.5.1 Government Funding

Currently the United States Government offers specific programs for Native American communities attempting to create solar and other green energy projects:

- Tribal Energy Program
    - The Tribal Energy Program is a program put out by the US Department of Energy Efficiency and Renewable Energy Weatherization and Integration Program. The program seeks to develop renewable energies on tribal lands to enable the tribes to become more independent. This program has given more than 70% of funding for projects to the tribes through grants. The three main approaches of the program are financial opportunities, technical assistance, and education and training. Several tribes in New Mexico have used this program to study how renewable energy could assist their land. There have been 19 projects since 1994 and the most recent being in 2012. (U.S. Department of Energy, 2015b)
- The Office of Indian Energy and Economic Development
    - The Office of Indian Energy and Economic Development (IEED) is an organization that seeks to help Native American tribes become more self-sufficient. This office is made up of three divisions. One of these divisions is called the Division of Capital Investment, which helps the tribes find funding such as loan finances. The Indian Loan Guarantee program has provided 90% of government backed loans for economic development projects. The second division is the Division of Energy and Mineral Development. This helps the tribe acquire a renewable energy source. The last division is the division of Economic Development, which works to create jobs to create a source of income and strengthen the economy of the pueblo through training to make the tribe more skilled. (IEED, 2016)

### 2.5.2 Bonds

A financial option for Native Americans to fund a large-scale energy project is through bonds like the tribal economic development bond. As described by NREL, this bond can be tax exempted and be a beneficial option for the interested party. There is a cap of $2 billion given out each year to tribes. The limitations for receiving this money are the project cannot be in a gaming or housing center and has to be on tribal lands. Another financing option is the clean renewable energy bond. This is beneficial because through a federal tax credit, some of the interest created is paid for. This includes solar and geothermal energy facilities (MacCourt, 2010).

### 2.5.3 Investors

Native American tribes can either find investors or finance a project within the community. NREL describes strategic investors are investors who have some background in the energy field. They play a very active role in the development of the project. There is a high level of risk for these investing companies therefore they will want some ownership in the final project or some other valuable asset in the project. Institutional investors are companies that invest in the project mainly to get tax breaks. They usually are not involved in the project and generally do not care about long-term ownership (MacCourt, 2010).

### 2.5.4 Government and Company Paybacks

Incentives are given to groups that decide to pursue renewable energy by both the government and utility companies. These can take the form of paybacks, which can extend savings to the group using renewable energy source.

#### *2.5.4.1 Government Paybacks*

New Mexico has a program for a personal tax credit for installing a renewable energy source. This is a 10% personal income tax credit with a maximum of $9,000. The program is for residents who buy and install a home solar energy system certified by the New Mexico Energy, Minerals, and Natural Resources Department. (Residential Solar 101, n.d.).

#### *2.5.4.2 Utility Company Paybacks*

In 2007, New Mexico released the renewable portfolio standard requiring 20 percent of energy produced to be generated from renewable sources (Residential Solar 101, n.d.). Energy company paybacks are a technique used by energy companies to attain their required 20 percent renewable energy quota. Examples of companies utilizing energy paybacks are listed below:

- El Paso electric company has a program called the small and medium system renewable energy certificate purchase program. Only energy sources connected to their grid are eligible. They will buy renewable energy credits (REC's) from your system at a price of $0.12 per kilowatt-hour for small-scale systems and $0.155 for medium systems. Payments will be made for a limit of 12 years (Residential Solar 101, n.d.).

- PNM has a program called performance based customer solar PV program. They will pay $0.025/kWh for RECs generated from systems up to 100 kW. For systems from 100 kW to 1 MW the repayment for RECs is $0.02/kWh (North Carolina Clean Energy Technology Center, 2016).

- Xcel Energy has a program called Solar Rewards Program. They will pay $0.20 per kilowatt-hour for REC's. If the system is small (0.5kW to 10kW) customers will get these paybacks for 12 years. If the system is larger (10.1kW to 100kW) customers will receive these paybacks for 10 years (Residential Solar 101, n.d.).

# 3. Methodology

The goal of our project was to help develop solar energy options for the Domingo Housing Project in Santo Domingo. When our group reached Santa Fe, we implemented 7 main objectives:

1. Analyze the Domingo Housing Project construction site and surrounding area.
2. Explore the solar energy goals of the housing development and the community.
3. Research different types of solar options available to Santo Domingo.
4. Utilize NREL's SAM program to develop potential pricing and energy outputs of different solar energy options.
5. Create an energy efficiency and cost analysis proposal to help the community make an informed decision on solar options.
6. Create an educational video to introduce the idea of implementing solar panels into the Domingo Housing Development
7. Research government and other grants that can apply to the project.

## 3.1 Analyze the Domingo Housing Project construction site and surrounding area.

The first major step when our team arrived at the Santo Domingo Pueblo was to visit the construction site. Although we had seen the plans for the construction site, we wanted to see the physical landscape and investigate site details, such as:

- General layout of the site.
- Any nearby structures/trees creating large areas of shade.
- Future building locations.
- Any landscape features preventing future construction.
- Areas open for future solar panel/array use.

Visiting the site provided our team with visual ideas on where solar panels could potentially be used in the area, and helped us determine the feasibility of using solar panels in the area.

## 3.2 Explore the solar energy goals of the housing development and the community.

After visiting the future construction site, we toured the Santo Domingo Pueblo with our sponsor. He provided our group with valuable insight and information on Santo Domingo, such as parts of their culture and the current status of housing inside the village. We then were able to meet with some members of the Housing Authority and a few community leaders. Throughout our discussions we got a strong feeling of excitement about the Domingo Housing Project and the potential introduction of solar panels in the development. Gaining this information during our time in Santo Domingo helped ensure that our project will have some support in the community, and encouraged us to pursue our final feasibility and cost analysis report. Throughout our time in Santa Fe, we also received input from members of the Domingo Housing Authority and our sponsor. Following their direction, we altered and adjusted our cost analysis and video to create a final product that would have the greatest functionality in their office.

### 3.3. Research the different types of solar options available to Santo Domingo.

When looking into different solar options available to Santo Domingo, we focused on the three different types of system scaling for PV: residential scale, commercial scale, and utility scale. These three types of systems provide a variety of options for the pueblo, including:

1. Individually owned panels provided through the residential scale system
2. Commercial scale system being owned by the Housing Authority
3. Utility scale system being provided through PNM.

Our team used our analysis of the construction site and the information provided through the different solar PV systems to consider the different construction techniques for each system. Both residential and commercial scale projects have the opportunity to implement rooftop-mounted solar panels, while utility and commercial allow for the use of an array. Our main goal for this aspect of the project was to compare the compatibility of the system with the community (design, layout, location, etc.) while considering the total cost of the system.

### 3.4. Utilize NREL's SAM program to develop potential pricing and energy outputs of different solar energy options.

NREL's solar PV "PVWatts Calculator" is a useful calculation tool that our team utilized during our analysis. This calculation engine gives a variety of factors for estimating the cost of the project, including the size of the panels, efficiency, weather, and type of panel when finding the total output per year (National Renewable Energy Laboratory, n.d.).

NREL's System Advisor Module (SAM) is the primary calculating tool our team used. In this program you can choose using the PVWatts Calculator to find appropriate solar PV economic models for the Santo Domingo community depending on the panel type and panel company (National Renewable Energy Laboratory, 2010). This software allowed us to analyze the residential, commercial, and utility scenarios being discussed. Using SAM as a foundation, our team created economic models and system efficiency graphics to represent how solar energy would impact the new development. The information generated through SAM allowed our team to prepare cost analysis reports to frame and highlight our findings.

## 3.5. Create an energy efficiency and cost analysis proposal to help the community make an informed decision on solar options.

Once we created different analysis parameters with NREL's SAM program, we discussed the results in a cost analysis report. In the report the efficiency of each system was described while also discussing potential costs of the project and the money being saved by the community. The report included the scenarios analyzed and the information used to generate them.

Each scenario we created followed a general format to provide decision makers and readers with a strong technical background in the use of solar panels. The first page of each report provides graphics and basic information to convey the results of the report, but does not give a surplus of information that could confuse potential readers. The second page provides a basic overview of the project and analysis, while giving more information on the assumptions used in the project. The following pages in each report discus the system analysis and different financial models that may be available to the community.

The small scenario reports were attached into the large cost analysis report, which utilized the information to create comparisons between the different systems. The report also included our recommendations based on the information provided.

The major goal of the report was to provide information in an accessible format while also giving the information needed to replicate the study in the SAM program if the Housing Authority wants to adjust any assumptions or information.

## 3.6. Create an educational video to introduce the idea of implementing solar panels into the Domingo Housing Development.

In addition to the cost analysis plan created through NREL's SAM software, our team created a video to explore the positive and negative social effects that may emerge from a new renewable energy project. The video includes our sponsor, other members of the Housing Authority, and an Enterprise Green Communities Vice President. Our short film was created through the free version of Lightworks (Lightworks, n.d.), and used background music composed by different artists. Our group did all filming, and all pictures in the film were taken during our time in Santa Fe. A general outline of the film is listed in Appendix B.

Throughout the creation of this film our group talked with the community, and received useful information and advice to make the video as successful as possible. To complete the video, our group created a list of questions for the individuals listed above. The questions, listed in Appendix C, were created to best answer the different topics we wanted our video to address.

## 3.7 Research government and other grants that can apply to the project.

Part of our project was to research potential funding for the solar energy project through outside sources. While the Santo Domingo Pueblo funding portions of the project is certainly an option, we found that the government offers a multitude of different grants for different aspects of our project. Not only does the United States host several grant programs for tribal communities, but the state of New Mexico and the Santa Fe locale itself offer some incentives that we proposed for Santo Domingo to look into.

We researched not only government grants, but also bonds, solar rebates, tax credits, and other incentives for the pueblo. The majority of the research done was through careful internet searches for types of funding. Many of the people our team spoke with—both those from organizations like Enterprise Green Communities or just locals in the area—gave us some recommendations for potential funding sources that we investigated. We obtained this information through internet sources, the most useful of which were the Database of State Incentives for Renewables and Efficiency (North Carolina Clean Energy Technology Center, n.d.) and the grants website created by the Department of Health and Human Services (Department of Health and Human Services, n.d.).

# 4. Findings

Through our work in Santa Fe, our group discovered multiple findings that helped formulate our final conclusion. These findings are listed below:

1. The site is suitable for solar development.
2. Community members support the idea of implementing solar energy in the Domingo Housing Project.
3. The use of solar energy is possible in the community.
4. NREL provides different models for solar energy systems.
5. An educational video is an effective way to support the use of solar energy in the community.
6. Multiple different funding sources are available for solar energy projects and Native American communities.

## 4.1 The Construction Site and Surrounding Area

Our team's first objective when we arrived in Santa Fe was to visit the Domingo Housing Project construction site to get a better scope of the development's potential.

### 4.1.1 Location

The housing development will have a road that stems from Indian Service Route 88, connecting the development to New Mexico Route 22, providing the residents easy access by car to the highway and gas station just outside the development. This proximity to two different means of transportation—the highway and the Rail Runner Express—places the Domingo Housing Project in an ideal location for those who need to work outside of the pueblo.


*Figure 14... Santo Domingo Indian Trading Post*

One obstacle to Santo Domingo is the distance from the village to the train station. Currently the village is located nearly two and a half miles away from the train station. To help reduce the distance traveled by community members, plans to create a walking trail are being developed. The trail would connect the village to the trading post and train station, providing easy access for both community members and tourists.

Another plan for Santo Domingo is to reroute traffic so that people must pass by the Santo Domingo Indian Trading Post (seen in Figure 19) and new development to enter the pueblo. This concept will help stimulate interest and promote tourism in the area once the trading post is rehabilitated and re-opened, which is expected to happen by the summer of 2016. The renovated trading post will house art from local craftsmen and craftswomen for sale to travelers, and will also be used as a potential social space for the community when not being used as a galleria (Kunkel, 2016c).

The Domingo Housing Project has the potential to become an important part of Santo Domingo because of the development's close proximity to the trading post, train station, and new walking trail. The potential new direction for traffic will also allow the new housing project to become an important part of the landscape for people traveling through the area.

### 4.1.2 Solar Impact

While our team was initially analyzing the construction site, we looked into the potential impact that the sun has in the area. There were no trees or obstacles that could negatively impact the use of solar panels in the area, and the flat landscape—shown in Figure 20—would create a large potential for solar energy generation.

*Figure 15... Domingo Housing Site*

When considering potential solar energy system options, our team also considered the fact that due to this large open area, a solar array may not be as desirable aesthetically by the community. While there is an abundance of open space allowing the pueblo to fit a large array, the flat landscape provides a high-distance visibility factor, and an array may tarnish the view for those wanting to maintain the natural landscape.

## 4.2 Solar Energy Goals of Santo Domingo

After analyzing the construction site, our team joined our sponsor in Santo Domingo and talked to different members of the community. When we described our project, community members expressed interest in the new idea, indicating that this project could be a success. We did not come across anyone against the idea, although since we only talked to a few locals we cannot assume the excitement is shared throughout the pueblo. Since the new housing units in the Domingo Housing Project will be built solar ready, the introduction of solar panels would be relatively easy if positive support is shown across the community.

## 4.3 Solar Options Available to Santo Domingo

During the first few weeks' preliminary research in Santa Fe, our group focused on finding feasible solar energy options for the community. We focused on the use of solar PV panels and analyzed three different types of distribution: residential, commercial, and utility.

Residential solar is an appropriate option for small scale projects. This system implies that the panels are individually owned. While the potential for individual ownership and operation of the panels increases, the total price would be significantly higher to implement on a community scale and would require more individual work through maintenance and payments by the residents. This option would be cheaper if only looking for the addition of panels on a few units rather than the entire development.

Commercial solar allows the Santo Domingo Housing Authority to maintain ownership of the panels, which works well with their future ownership of the units. This would remove the need for individual responsibility and greatly reduce the total cost of installing the potential panels. The aesthetics of using a commercial solar array may create issues if residents do not want to have solar panels visible. Using a rooftop commercial solar PV system would fix the visual issue, but would generate less energy than an array.

Utility solar allows the community to have a large solar PV system and supply energy back to PNM. Utility systems tend to be the least expensive, but do not allow for full ownership of the panels by the community. Utility systems also are large and may appear aesthetically unappealing for residents in the new housing units. Large utility solar arrays also can be unnecessarily expensive if the size installed is significantly larger than the energy needed by the community.

## 4.4 NREL's SAM Energy Outputs and Potential Pricing

During the energy output and cost analysis process in our project, our team decided to disregard utility solar because of the partial ownership and high probability of unappealing aesthetics. Instead, our team created 4 reports to provide the Housing Authority with resources to make a more informed decision the solar energy options available to them. The reports include the following scenarios:

1. Rooftop-Mounted Residential Solar Report- Single Unit
2. Rooftop-Mounted Residential Solar Report- Community
3. Rooftop-Mounted Commercial Solar Report
4. Ground-Mounted Commercial Solar Array Report

These reports include an introductory section describing the Domingo Housing Project and the need and desire for a renewable energy system to reduce energy costs. A basic design section listing the size, angle, and orientation of the panels is included, as well as basic parameters and information about the analysis our team completed. The report then breaks down the expected cost of installation and upkeep of each system.

## 4.5 The Educational Video

To better help the Santo Domingo Pueblo understand our team's work over the past semester and the implications of solar energy in the Domingo Housing Project, we created an educational video detailing the benefits of solar energy. We hope it will teach the community the positives of solar energy by explaining how solar energy works and how renewable energy has advanced over time.

Our video includes interviews with members of the community, renewable energy specialists from Enterprise Green Communities, and our sponsor and head architect of the Domingo Housing Project, Joseph Kunkel. By including video clips of experts speaking as well as local community members, our video will give the audience the background information they need to understand the importance and advantages solar energy can provide while also showing responses to solar energy in a community like their own.

Our intended immediate audience is Santo Domingo community members, as they are most directly affected by the project. We also made the video to be an example for other rural communities trying to accomplish similar projects. Our hope is that the video will be an example for other project teams when considering solar energy in other communities.

## 4.6 Potential Funding for the Solar Panels

There are a variety of ways that a large-scale renewable energy project can get funded. Our team has researched many different options for funding a project of this scale.

Multiple grants are available that could give the tribe a significant amount of money to pay for the project. The advantages of grants are they can be considered “free money," as the pueblo can apply and receive money with no payback. However, grants can be highly competitive and some of the specifications are very specific. For example, the Weatherization Assistance Program has preferences towards people over 60 years old, families with children, and families with disabilities. This would limit the money the tribe would receive for this grant because only certain members qualify.

Another viable funding option that our team investigated for our project is the use of bonds. Bonds will provide the tribe with money when necessary and can fund projects just as well as grants can, yet unlike grants, bonds are essentially borrowed money that must be repaid eventually.

Investors could also be a beneficial option for financing a renewable energy project. The first step in the process would be to sign a non-binding letter of intent and confidentiality and non-disclosure act. The next step is to create a joint development agreement. This document includes the parties involved, the project description, purpose of agreement, duties of the parties involved, ownership of project assets, terms of agreement, and termination rights (MacCourt, 2010).

Our team also looked at the rebates and financing options that energy companies provide to their customers when installing solar panels. Santo Domingo's current energy provider—PNM—offers rebates each year for reducing energy use from the grid. PNM will also buy renewable energy certificates (REC’s) from customers who use solar panels. If these rebates are utilized, Santo Domingo will continue to receive this money every year that they have the solar panels. The disadvantage of this rebate system is the amount of money the tribe receives is not very high. For example, PNM would pay the tribe $0.02 for every kWh sold back to the grid for a system 100kW to 1MW.

The table in Appendix D displays a variety of financial resources available to fund the photovoltaic solar project. Each of the project's three possible scenarios have some applicable financial incentives listed. In the relevance section, the term “potentially” implies the financial source is less feasible than the other options listed in the chart, meaning the funding option may not be the correct option for this project. This table is not meant to cover all possible financial sources applicable to the project, but rather serve as an outline of potential funding options available for the project and an outlet to research more funding options.

## 5. Cost Analysis Report

The major deliverable we provided to our sponsor Joseph is a cost analysis report that analyzes different solar energy scenarios. The full report is provided in the following section.

# Solar Energy in the Domingo Housing Project

Prepared for the Santo Domingo Housing Authority.

Created By:

Kyle Fitzgerald, WPI Mechanical Engineering Student
Matthew Houghton, WPI Civil Engineering Student
Adam Huber, WPI Mechanical Engineering Student
Jerry Li, WPI Electrical and Computer Engineering Student

## Purpose of Report

The purpose of this analysis is to provide Santo Domingo with the different solar PV options available for their new housing development in Domingo. The following pages contain a comparison of residential and commercial solar options, and provides full cost analysis and system efficiency sections to provide the Santo Domingo Tribal Housing Authority with enough information to make an educated decision.


Figure 1... Domingo Housing Project Sign

This analysis includes 4 smaller reports detailing specific information for 4 different types of solar PV systems: rooftop-mounted residential-single unit, rooftop-mounted residential-community, rooftop-mounted commercial, and ground-mounted commercial array. Each report contains important technical information used to complete the system analysis and cost parameters associated with the project.

## About the Authors

The four authors of this analysis are juniors at Worcester Polytechnic Institute (WPI) Worcester, Massachusetts. The analysis is a section of a full report to complete the Interactive Qualifying Project (IQP) needed for graduation. The information included in this document was created for Joseph Kunkel for utilization by the Santo Domingo Tribal Housing Authority to be implemented in the new Domingo Housing Project.

## Contents

## List of Figures



## List of Tables

## Overview

### SCENARIO ANALYSIS

The 4 major scenarios analyzed were a rooftop-mounted residential system as a single unit and as a community-wide system, a rooftop-mounted commercial system, and a ground-mounted commercial array. Residential rooftop follows Public Service Company of New Mexico's (PNM) Residential 1A electricity rates, while both commercial scenarios utilized PNM's Commercial 2A Small Power Service. A full chart showing the differences in pricing of the scenarios is provided in Appendix B. The scenarios are briefly described below.

Figure 2... Domingo Housing Project Site

#### Residential Rooftop

The residential rooftop scenario utilizes a 410 kilowatt (kW) solar panel system throughout the entire 41 unit development, or 10 kW per household. In a residential solar PV system, each set of panels is typically linked individually to the unit that the panels are in connection with. An example of this scenario on an individual unit is provided in the section labeled Scenario A, while the community residential rooftop scenario is located in the Scenario B section.

#### Commercial Rooftop

The commercial rooftop scenario implements a 250 kW system on the rooftops of the new buildings. In this system each panel would be connected into a network, therefore the new units would be drawing energy from a community source instead of having individual panels for each unit. The commercial rooftop scenario is located in the Scenario C section.

#### Commercial Array

The commercial array scenario has the same technical information as the commercial rooftop scenario, except the panels are ground-mounted in an array instead of being located on the rooftops of the buildings. The energy would still be distributed throughout the community like the commercial rooftop option. The commercial array scenario is located in the Scenario D section.

## FINANCIAL ANALYSIS

Undertaking large solar projects like the scenarios listed above requires funding. When approaching a solar project in the state of New Mexico, it is important to note that the state and federal government both provide incentives up to a certain percentage and sometimes a certain maximum monetary amount, depending on the scenario. These incentives are displayed in Table 1. The New Mexico state incentive provides 10% of the cost or $9,000 maximum. The single unit residential row provides funding details for a single unit in the development, while the community residential row is simply the single unit section multiplied by 41 to represent the 41 units in the development (this is why the state incentives are higher than $9,000).

| Incentives | | | | |
|---|---|---|---|---|
| **System** | **Federal (30%)** | **State (10%)** | **Total System Price (Pre-Incentives)** | **Total System Price (With Incentives)** |
| Single Unit Residential | $9,869.70 | $3,289.90 | $32,899.00 | $19,739.40 |
| Community Residential | $404,657.70 | $134,885.90 | $1,348,859.00 | $809,315.40 |
| Commercial Rooftop | $191,099.25 | $9,000.00 | $636,997.50 | $436,898.25 |
| Commercial Array | $191,099.25 | $9,000.00 | $636,997.50 | $436,898.25 |

**Table 1... Incentives and Costs per Scenario**

Each of the four scenarios our team analyzes can either be fully financed through grants or other options, in which case the cost of the project would be $0 for the pueblo, and the payback period would be eliminated. A situation where the project is fully funded through outside sources is the most desirable for Santo Domingo. However, if complete financing is not possible, our team has also included charts that show the cost and payback period if outside sources provide funding for the entire cost of the project, half of the project, or none of the project .

Table 2 shows the cost and payback period if the project is fully funded by outside sources.

| System | 100% Outside Funding | 100% Payback Period (Years) |
|---|---|---|
| Single Unit Residential | $0.00 | 0 |
| Community Residential | $0.00 | 0 |
| Commercial Rooftop | $0.00 | 0 |
| Commercial Array | $0.00 | 0 |

**Table 2... 100% Outside Funding Scenario**

Table 3 shows the cost and payback period if the project funding is split in half; 50% of the funding comes from the community, and 50% comes from outside funding.

| System | 50% Outside Funding | 50% Payback Period (Years) |
| --- | --- | --- |
| Single Unit Residential | $9,869.50 | 9.31 |
| Community Residential | $404,657.70 | 9.31 |
| Commercial Rooftop | $218,449.13 | 5.54 |
| Commercial Array | $218,449.13 | 5.52 |

Table 3... 50% Outside Funding Scenario

Table 4 shows the cost and payback period if the project is fully funded by the community, with no outside funding.

| System | 0% Outside Funding | 0% Payback Period (Years) |
| --- | --- | --- |
| Single Unit Residential | $19,739.00 | 18.62 |
| Community Residential | $809,315.40 | 18.62 |
| Commercial Rooftop | $436,898.25 | 11.07 |
| Commercial Array | $436,898.25 | 11.03 |

Table 4... 0% Outside Funding Scenario

These may not be the final percentages of outside funding received by the community to finance this project, but they provide a reasonable estimate to show what the payback periods for each of the four evaluated scenarios could be.

## TILT ANALYSIS

Each analyzed scenario has a specified tilt of the panels. Depending on aesthetic appeal, the community may choose a tilt angle that will alter the energy output. While certain tilt angles yield the greatest output, they may not be aesthetically appealing to the community if the panels are clearly visible on the rooftop of a building or in a large array near the development. Both rooftop scenarios utilize a 35 degree tilt, which would be the most energy efficient option, but perhaps not the most aesthetically pleasing. The commercial array scenario was also completed with a 35 degree tilt. Appendix A includes a chart specifying specific financial details and comparing multiple scenarios with different tilts.

## Core Recommendations

Based on the energy output and cost of the different systems, we recommend installing a ground-mounted commercial solar array. This system provides similar savings per year while also costing significantly less than the residential option. The ground-mounted array system described in the commercial array scenario is similar in cost to the commercial rooftop scenario, but allows for more flexibility in tilt, which can maximize the energy output. Depending on the community response to a solar PV system, future residents of the housing development may not want to view solar panels in the area, which would prevent the implementation of an array. This potential dilemma between aesthetics and efficiency will be an important part of the community's decision. If the community does not want solar panels to be visible, then the commercial rooftop system is recommended with a 0 degree tilt. This would allow for the community to use the panels without having them in direct view. The only setback of using this model is that it slightly reduces the potential for maximizing energy output and money return.

We do not recommend a residential system for the community at this point in time. It is much less practical for the pueblo to fund individual systems on each unit rather than tying the community together with one common grid providing power for everyone in the development. Assuming no funding is provided for the installation of solar panels, the payback period for the residential system will be much longer than a commercial system. Although the energy bill each month would be lowered, a new "payback bill" would also affect the community each month. The method of community payback is a decision that will have to be made by Santo Domingo at the time of installation, if no outside funding is available to the pueblo.


**Figure 3... The Domingo Trading Post**

## Scenario Comparison

The three scenarios being analyzed create different opportunities for Santo Domingo. Each option provides different energy outputs and benefits to the community. As seen in Figure 4, the residential scenario provides the largest output of energy, since it is the largest system (410 kW compared to 250 kW). Utilizing this system would allow for the community to maximize their energy output per year.

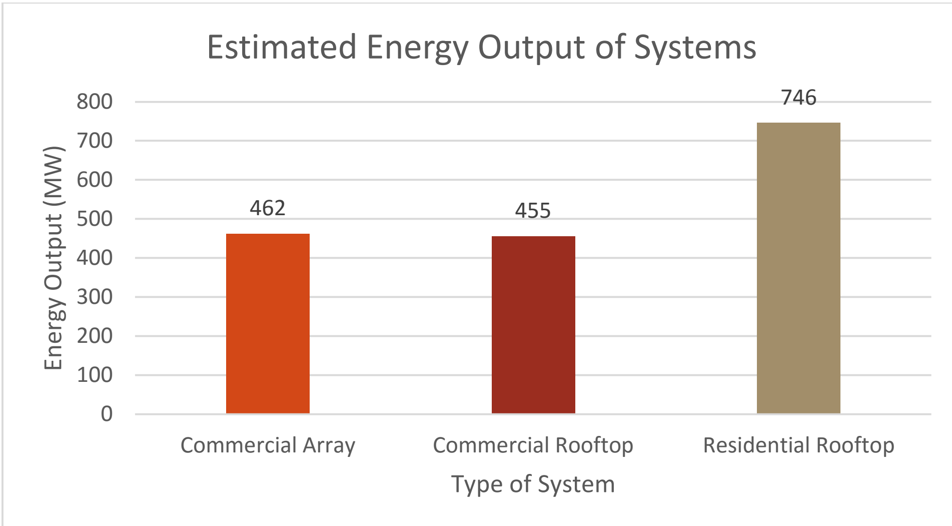



**Figure 4... Estimated Energy Output of Systems**

A major setback in the use of the residential scenario is the total cost compared to both commercial scenarios. Figure 5 demonstrates how the total cost of implementing the residential scenario amounts to approximately double the cost of both commercial options.

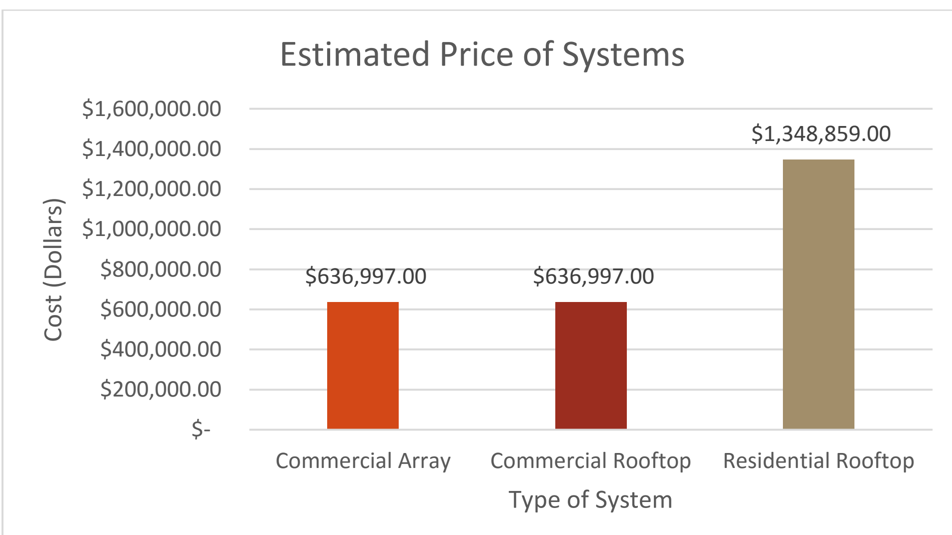



**Figure 5... Estimated Price of Systems**

When comparing cost and efficiency of the three models, residential solar becomes an unreasonable option because the net savings per year are insignificant compared to the differences in system costs between residential and commercial (see Figure 6).

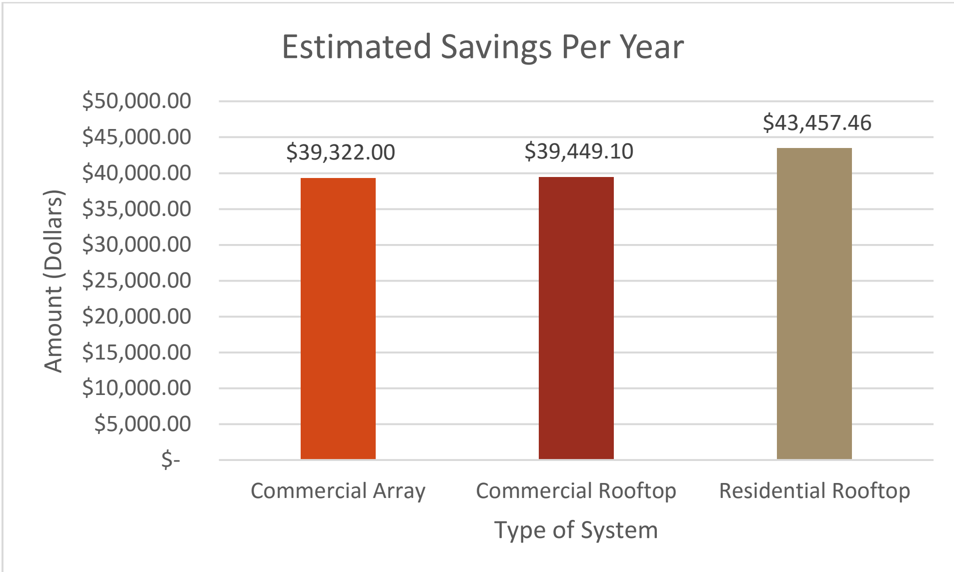



**Figure 6... Estimated Savings per Year**

Commercial systems also have a significantly shorter payback period, averaging a little over 11 years when compared to the 18.6 years it would take to pay off the residential system if all funding is provided locally by the Santo Domingo community (Figure 7).

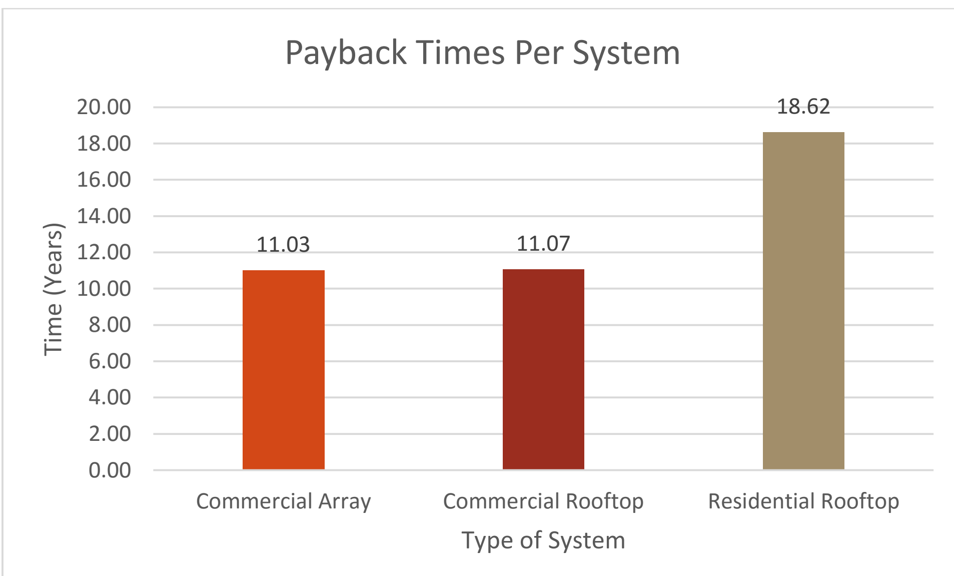



**Figure 7... Payback Period per System**

Based on the financial data, the commercial array system would be the most efficient option for the housing development. Along with the commercial rooftop scenario, the commercial array costs the least amount of money, but has the potential to create more energy because of the increased opportunity for the utilization of tilt angles. It also has a payback time of only 11.03 years without any funding from the government or investors. However, aesthetic considerations could cause the community to not accept a solar array field.

The commercial rooftop system combines the best combination of cost efficiency and aesthetic appeal. This system with a 35-degree tilt produces 7 MW less than the solar array (at the same 35 degree angle) and generates an annual income difference of only about $2,000 in a total of almost $40,000 annual savings. This is not a significant difference in the capabilities of the two systems.

## Technical Details

All of these analyses and numbers are based on specific standards and efficiencies. The energy use per household is based on the Santa Fe average, which is 633 kWh per month. If the new units constructed in the housing development are more energy efficient than the average household in Santa Fe, then the total savings each year would increase if the same system size is used. The size of each system was determined by finding the smallest system that will create a money return through creating excess energy during each month of the year.

## Scenario A: Rooftop-Mounted Residential Solar Report – Single Unit

This analysis was created for the Santo Domingo Housing Authority to provide an estimated overview on the potential for using standard rooftop-mounted solar photovoltaic panels (PV) on one new unit being constructed in the Domingo Housing Project.

Renewable energy can be provided to a single unit in Santo Domingo through a 10 kilowatt (kW) rooftop solar energy system at an approximate cost of $32,899. If the savings created from the system are immediately used to pay for the system, it would take 18.6 years to pay off the system, assuming a no interest loan. This figure includes $5/month to remain connected to the grid in order to obtain electricity at night and during other times when the PV system will not produce electricity, and allows the community to sell excess electricity back to PNM during peak production hours. Currently, Santo Domingo residents pay PNM an average estimated energy bill of $70 per month. Therefore, an average resident would save $65 each month, and while this may not seem like a significant amount of money, residents would be largely protected from future price increases. Once the system is paid for, the residents' electricity bill would be greatly reduced. However, larger savings are available if the community opts for a larger system that can provide energy for the entire new housing development.

### CASE STUDY – GUADALUPE, AZ

As of 2015, according to the Solar Energy Industries Association, an estimated 784,000 American homes and businesses have gone solar (Solar Energy Industries Association, n.d.). In January of 2007, a LEED-certified green home was completed for a single family in Guadalupe, AZ by Arizona State University's Stardust Center. This house incorporated Navajo FlexCrete for passive solar heating and cooling, while also utilizing rooftop solar panels for the electricity needs of the house. The panels are expected to provide 90% of the building's electrical necessities. In the case of Santo Domingo's new housing development, a single unit—much like the Guadalupe House—would be built according to green building standards and could be fitted with panels that also account for a large percentage of the unit's energy needs (Sustainable Native Communities Collaborative, n.d. (b)).

## Scenario Details

**Basic Financing**

**Energy Rates:** PNM's Residential 1A Service-$5.00 base rate

**Incentives:** 30% federal incentive, 10% state incentive.

**Assumptions**

**Size:** 10 kW

**Setup:** Rooftop-Mounted, Azimuth located at 180°, panels are tilted 35°.

**Electricity Load:** 633 kWh per month.

**Inefficiency:** 14.08% system losses, 96% inverter efficiency.

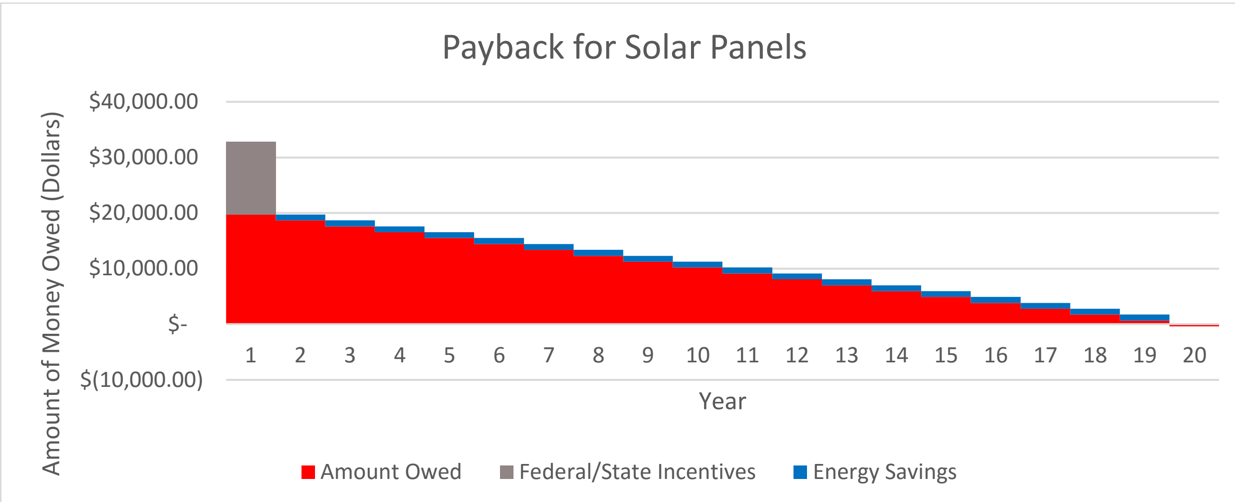
**Lifetime:** .5% AC output degradation rate per year.

**Results**

**Estimated Total Cost:** $32,899.00

**Total Energy Savings:** $1,059.94 per year.

# Rooftop-Mounted Residential Solar-Single Unit Quick Facts




| System Information | | | |
|---|---|---|---|
| **Size** | **Tilt** | **Panel Direction** | **Number of Houses** |
| 10 kW | 35 Degrees | South | 1 Unit |

| Expenses | |
|---|---|
| **Total Cost** | **Total Cost After Incentives** |
| $32,899.00 | $19,739.40 |

| Savings | | | |
|---|---|---|---|
| **Incentives** | **Federal** | **State** | **Energy Savings Per Year** |
| **Amount** | $5,921.82 | $1,973.94 | $1,059.94 |

## BASIC DESIGN CRITERIA

Using a 10 kW system will ensure that there is a surplus of energy produced each month that can be sold back to PNM (Figure 9). The tilt of the panels for this analysis is 35°, and the panel azimuth is located at 180°, or directly south. These panels are assumed to be installed as fixed roof-mounted panels on the new buildings.

## ANALYSIS INFORMATION

The analysis for residential solar PV uses the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM) program using their PVWatts analysis to estimate the total cost and efficiency of installing 10 kilowatt energy systems on a new unit in the housing development. The weather information used in the solar analysis for this report is the 2014 Santo Domingo Pueblo weather records, which is also provided in SAM.

## BASIC PARAMETERS FOR ANALYSIS

Multiple assumptions were used during the analysis. An assumed 14.1% energy loss and a 96% inverter efficiency is used to account for imperfect energy conversion in the solar panels. A 0.5% degradation of AC output in the panels per year is assumed for the lifetime of the panels. The basic solar PV system assumptions used for the analysis are provided in Table 5. This table is shown as a full page and includes notes for the single unit scenario to provide clarity.

| | Residential Rooftop- 35° | NOTES |
|---|---|---|
| System Specifications | A residential-scale system installed on the rooftops of the housing units with a fixed 35° tilt. Electricity costs and savings are for whole development. | Brief explanation of each scenario |
| System Size | 10 kW | How many watts produced at a standard irradiance level of 1,000 w/m2 at 77° F |
| Price (per Watt)- Solar Cells | $0.70 | Cost of the module (solar cells) based on system size |
| Price (per Watt)- Inverter | $0.33 | Cost of the inverter based on system size |
| Price (per Watt)- Balance of System (B.O.S.) | $0.82 | Cost of the B.O.S. based on system size |
| Price (per Watt)- Installation Labor | $0.30 | Cost of installation labor based on system size |
| Price (per Watt)- Installer Margin and Overhead | $0.95 | Cost of installer margin and overhead based on system size |
| Price (per Watt)- Permitting and Environmental Studies | $0.10 | Cost to gain permitting and environmental licensing based on system size |
| **Estimated Total (per Watt)** | **$3.20** | Total price per watt, based on system size |
| Sales Tax Basis | 58% | Assumed tax values from NREL's SAM |
| Sales Tax Rate | 5% | Assumed tax values from NREL's SAM |
| **Total Cost per Capacity (per Watt)** | **$3.29** | Total price per watt after sales taxes are considered |
| **Total Cost of System** | **$32,899.00** | Total price of the system for one of the 41 units |
| Federal Incentives (30%) | $9,869.70 | 30% of the total cost |
| State Incentives (10%) | $3,289.90 | 10% of the total cost ($9,00 maximum) |
| **Total Cost of System (With All Incentives)** | **$13,159.60** | Final total cost of system for all 41 units, after state and federal incentives |
| Maintenance (per kW-yr) | $20.00 | Estimated cost of maintaining system for each kW produced over a year |
| Annual Electricity Costs (Without System) | $854.87 | Average power costs for the community without the solar energy system per year |
| Annual Electricity Costs (With System) | $(205.07) | Average power costs for the community with the solar energy system per year |
| **Annual Savings (With System)** | **$1,059.94** | How much money is saved per year for all 41 units |
| **Payback Period in Years** | **18.62** | The amount of time it takes for the system to be paid off (total cost/savings) |

**Table 5...Design Criteria for Analysis- Community Res.**

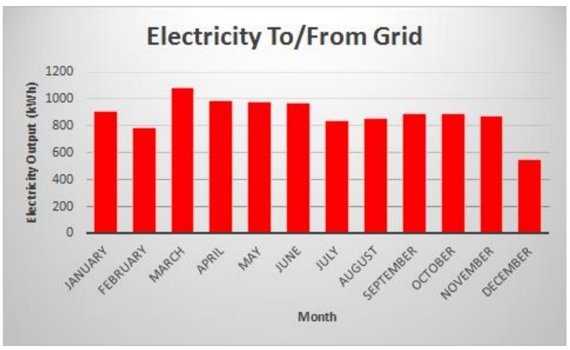
## BASIC FINANCIAL INFORMATION

In the analysis PNM's residential 1A service is used to determine the electricity rates for the new unit—these rates determine what the members of that unit will pay for electricity. For a solar energy system up to 10 kW in size, PNM will pay $0.025 for every kWh of energy produced by the solar panels, which will return money to the community throughout the year. PNM's current monthly electricity charges for 1A are shown in Table 6:

| Fee | Monthly Rate (Sept.-May) | Monthly Rate (June-Aug.) |
|---|---|---|
| Base Fee | $5.00/Bill | $5.00/Bill |
| First 450 kWh | $0.091/kWh | $0.091/kWh |
| Next 450 kWh | $0.119/kWh | $0.137/kWh |
| Any Additional kWh | $0.128/kWh | $0.158/kWh |

Table 6... PNM Monthly Electricity Fees- Single Unit Res.

## SYSTEM ANALYSIS



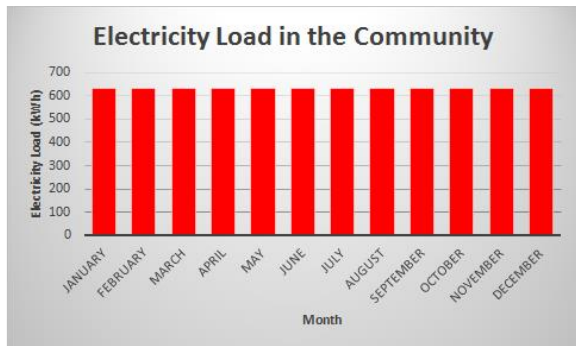




Figure 8... Electricity Generation and Load- Single Unit Res

NREL's SAM program provides an in-depth analysis of the energy production available in Santo Domingo and calculates the projected energy creation from the entire system throughout the year (Figure 8). The assumed electricity load for Santo Domingo is based on Santa Fe's average monthly energy consumption of 633 kWh (Figure 8). Based on the assumed electricity load and the weather data, a graph representing the electricity being bought and sold from PNM can be created to model the energy usage in the community (Figure 9). As shown in the chart, the solar panels located on the unit would be selling energy back to PNM every month of the year.

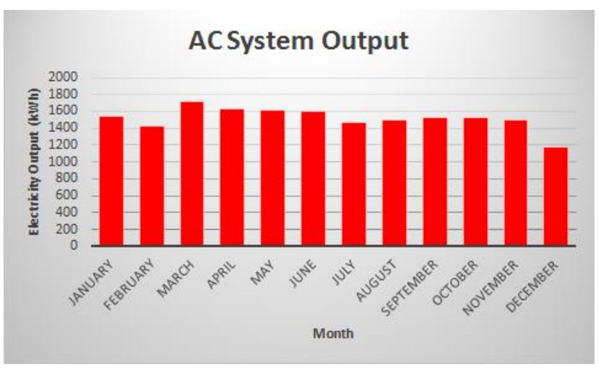



Figure 9... Electricity Bought From and Sold to PNM- Single Unit Res.

| Month | Without System | With System | Savings |
|---|---|---|---|
| January | $70.38 | $5.00 | $65.38 |
| February | $70.38 | $5.00 | $65.38 |
| March | $70.38 | $5.00 | $65.38 |
| April | $70.38 | $5.00 | $65.38 |
| May | $70.38 | $5.00 | $65.38 |
| June | $73.82 | $5.00 | $68.82 |
| July | $73.82 | $5.00 | $68.82 |
| August | $73.82 | $5.00 | $68.82 |
| September | $70.38 | $5.00 | $65.38 |
| October | $70.38 | $5.00 | $65.38 |
| November | $70.38 | $5.00 | $65.38 |
| December | $70.38 | $(260.07) | $330.45 |
| Annual Total | $854.87 | $(205.07) | $1,059.94 |

**Table 7... Monthly Electricity Costs and Savings- Single Unit Res.**

Over a year, the estimated savings per household is $1,059.94 per unit, with rollover credits each month creating a payback in December (Table 7). The final analysis with this PV system causes the residents in the unit to be paid $205.07 each year for using the system. If the system is not used, the annual cost for electricity throughout the year would amount to $854.87. Each month the resident would only pay PNM's base fee for electricity to PNM. The base monthly electricity load rate will vary from each unit based on the energy saving techniques used by the residents and will include the overall home efficiency and construction materials. These factors will lead to adjustments in the savings and energy costs per month. Over a 25 year period the panels would become less efficient and create a reduction in savings per year. Eventually the panels would need to be replaced which would cause a need for labor, funding, and maintenance.

The numbers in the table that are in parentheses () are negative numbers, while all those outside parentheses are positive.

## COST ANALYSIS CALCULATIONS

Net Capital Cost= $32,899

$$Community\ Cost = Capital\ Cost - Federal\ Incentives - State\ Incentives$$
$$Community\ Cost = \$32{,}899 - (\$32{,}899 * .30) - [(\$32{,}899 * .10)\ if\ ans < 9{,}000]$$
$$Community\ Cost = \$19{,}739.40$$

$$Cost\ for\ Entire\ Project: \$19{,}739.40$$

Total money needed from grants: $19,739.40

With half the money provided through grants:

$$\frac{\$19{,}730.40}{2} = \$9{,}865.20$$

Money needed from grants: $9,865.20

Money needed from community: $9,865.20

$$Payback\ period\ with\ using\ the\ \$1{,}059.94\ per\ year\ in\ total\ savings.$$
$$\frac{\$9{,}865.20}{\$1{,}059.94} = 9.31\ years$$

With no money provided through grants:

Money needed from community: $19,739.40

$$Payback\ period\ with\ using\ the\ \$1{,}059.94\ per\ year\ in\ total\ savings.$$
$$\frac{\$19{,}739.40}{\$1{,}059.94} = 18.62\ years$$

# System Advisor Model Report

| | | |
|---|---|---|
| Photovoltaic System | 10 DC kW Nameplate | -, - |
| Residential | $3.29/W Installed Cost | 35.53 N, -106.38 E GMT -7 |

## Performance Model

| PV System Specifications | |
|---|---|
| System nameplate size | 10 kW |
| Module type | 0 |
| DC to AC ratio | 1.1 |
| Rated inverter size | 9.1 kW |
| Inverter efficiency | 96 % |
| Array type | fixed roof mount |
| Array tilt | 35 degrees |
| Array azimuth | 180 degrees |
| Ground coverage ratio | N/A |
| Total system losses | 14.1 % |
| Shading | no |

| Performance Adjustments | |
|---|---|
| Availability/Curtailment | none |
| Degradation | 0.5 %/yr |
| Hourly or custom losses | none |

| Results | Solar Radiation | AC Energy |
|---|---|---|
| | (kWh/m2/day) | (kWh) |
| Jan | 6,109.23 | 1,539 |
| Feb | 6,388.97 | 1,419 |
| Mar | 7,175.82 | 1,715 |
| Apr | 7,117.57 | 1,623 |
| May | 7,050.06 | 1,607 |
| Jun | 7,583.69 | 1,604 |
| Jul | 6,752.34 | 1,466 |
| Aug | 6,810.5 | 1,491 |
| Sep | 7,089.98 | 1,521 |
| Oct | 6,604.34 | 1,525 |
| Nov | 6,327.78 | 1,501 |
| Dec | 4,683.81 | 1,183 |
| Year | 6,641.18 | 18,198 |

## Financial Model

| Project Costs | |
|---|---|
| Total installed cost | $32,899 |
| Salvage value | $0 |

| Analysis Parameters | |
|---|---|
| Project life | 25 years |
| Inflation rate | 2.5% |
| Real discount rate | 5.5% |

| Project Debt Parameters (Standard Loan) | |
|---|---|
| Debt fraction | 0% |
| Amount | $0 |
| Term | 25 years |
| Rate | 0% |

| Tax and Insurance Rates | (% of installed cost) |
|---|---|
| Federal income tax | 0%/year |
| State income tax | 0%/year |
| Sales tax | 5% |
| Insurance | 0.5%/year |
| Property tax (% of assess. val.) | 2%/year |

| Incentives | |
|---|---|
| Federal ITC | 30% |
| State ITC | 10%, $9,000 max |

**Electricity Demand and Rate Summary**

Annual peak demand 2.2 kW
Annual total demand 7,595 kWh
Public Service Co of NM
1A (Residential Service)
Fixed charge: $5/month
Net metering
Tiered TOU energy rates: 2 periods, 3 tiers

| Results | |
|---|---|
| Nominal LCOE | 17.6 cents/kWh |
| Net present value | $-18,800 |
| Payback period | > 25 years |

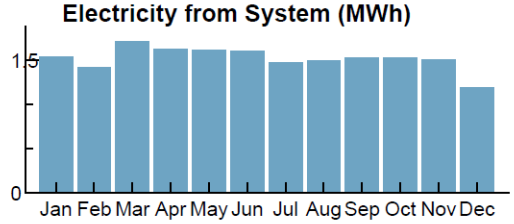
Residential | PVWatts System Model

System Advisor Model Standard Report generated by SAM 2016.3.14 on Thu Apr 28 15:38:12 2016 1 / 3

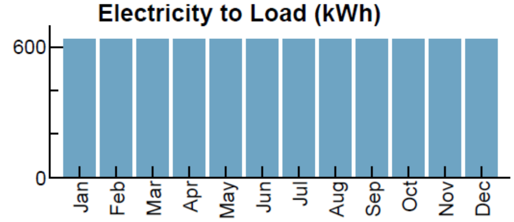
# System Advisor Model Report, Page 2

| | | |
|---|---|---|
| Photovoltaic System | 10 DC kW Nameplate | -, - |
| Residential | $3.29/W Installed Cost | 35.53 N, -106.38 E GMT -7 |

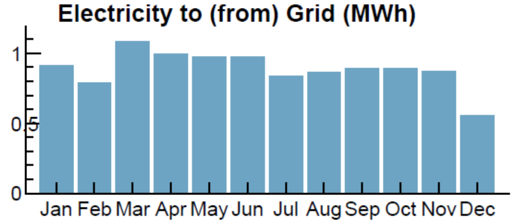
**Electricity from System (MWh)**




**Electricity to Load (kWh)**




**Electricity to (from) Grid (MWh)**




No Net Metering Credits

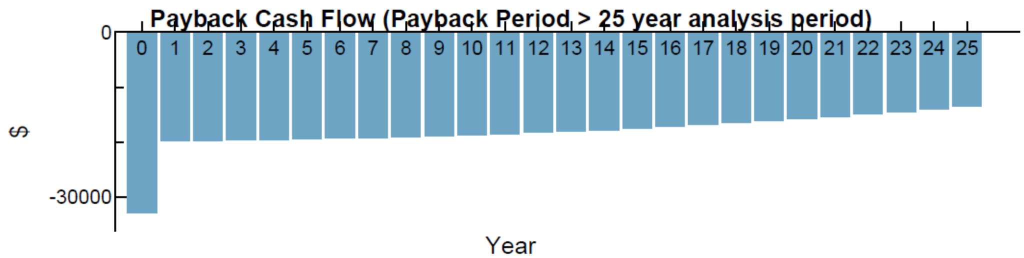
**Monthly Electricity Purchases and Savings (Year 1 $)**

| Month | Without System | With System | Savings |
|---|---|---|---|
| Jan | 70 | 5 | 65 |
| Feb | 70 | 5 | 65 |
| Mar | 70 | 5 | 65 |
| Apr | 70 | 5 | 65 |
| May | 70 | 5 | 65 |
| Jun | 73 | 5 | 68 |
| Jul | 73 | 5 | 68 |
| Aug | 73 | 5 | 68 |
| Sep | 70 | 5 | 65 |
| Oct | 70 | 5 | 65 |
| Nov | 70 | 5 | 65 |
| Dec | 70 | -260 | 330 |
| Annual | 854 | -205 | 1,059 |

**NPV Approximation using Annuities**

| Annuities, Capital Recovery Factor (CRF) = 0.0948 | | |
|---|---|---|
| Investment | $-3,100 | Sum: |
| Expenses | $-1,100 | $-1,700 |
| Savings | $1,100 | NPV = Sum / CRF: |
| Energy value | $1,200 | $-18,000 |

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 8.1375%




System Advisor Model Standard Report generated by SAM 2016.3.14 on Thu Apr 28 15:38:12 2016 2 / 3

## Scenario B: Rooftop-Mounted Residential Solar Report – Community

This analysis was created for the Santo Domingo Housing Authority to provide an estimated overview on the potential for using standard rooftop-mounted solar photovoltaic panels (PV) on the new units being constructed in the Domingo Housing Project.

Providing renewable energy for these units in Santo Domingo would be a relatively inexpensive option that would provide savings for the residents throughout the year and a payback in December. Currently, Santo Domingo residents pay PNM an estimated energy bill of $70 per month, when they could be paying just $5 per month for their energy bill after the community pays for solar energy system. While solar panels are being paid for, community members would pay their normal energy bill, but the cost would decrease greatly once the system is paid off. The total cost of installing a 10 kilowatt (kW) system on the roof of each unit in the Domingo Housing Project would total approximately $1,348,859.00. Over the course of each year the community would save an estimated $43,457.46 on their electricity bill, and the development would receive $8,407.91 in December as rollover credits from the unit's sale of energy back to the energy company. With a 410 kW system, the residents of each unit would only be required to pay the base $5 price for energy from Santo Domingo's energy provider, the Public Service Company of New Mexico (PNM).

### CASE STUDY – WAIMANAIO, HI

As of 2015, according to the Solar Energy Industries Association, an estimated 784,000 American homes and businesses have gone solar (Solar Energy Industries Association, n.d.). In the spring of 2011, 45 units of affordable housing were built in Waimanaio, HI for homeownership. The homes have 2.5 kW solar PV panels for electricity, solar hot water panels for heating, and incorporate passive solar building practices. Due to these new home's aesthetic design and energy efficiency, the demand for them was so high that every home was sold on the first day of sale. The Domingo Housing Project similarly aims to incorporate solar technology throughout the development as well as a visually pleasing community design. If residential rooftop panels are chosen like in the Kumuhau Subdivision project, the new development could be a huge success for Santo Domingo (Sustainable Native Communities Collaborative, n.d. (a)).

## Scenario Details

**Basic Financing**

**Energy Rates:** PNM's Residential 1A Service-$5.00 base rate

**Incentives:** 30% federal incentive, 10% state incentive.

**Assumptions**

**Size:** 410 kW

**Setup:** Rooftop-Mounted, Azimuth located at 180°, panels are tilted 35°.

**Electricity Load:** 633 kWh per month.

**Inefficiency:** 14.08% system losses, 96% inverter efficiency.

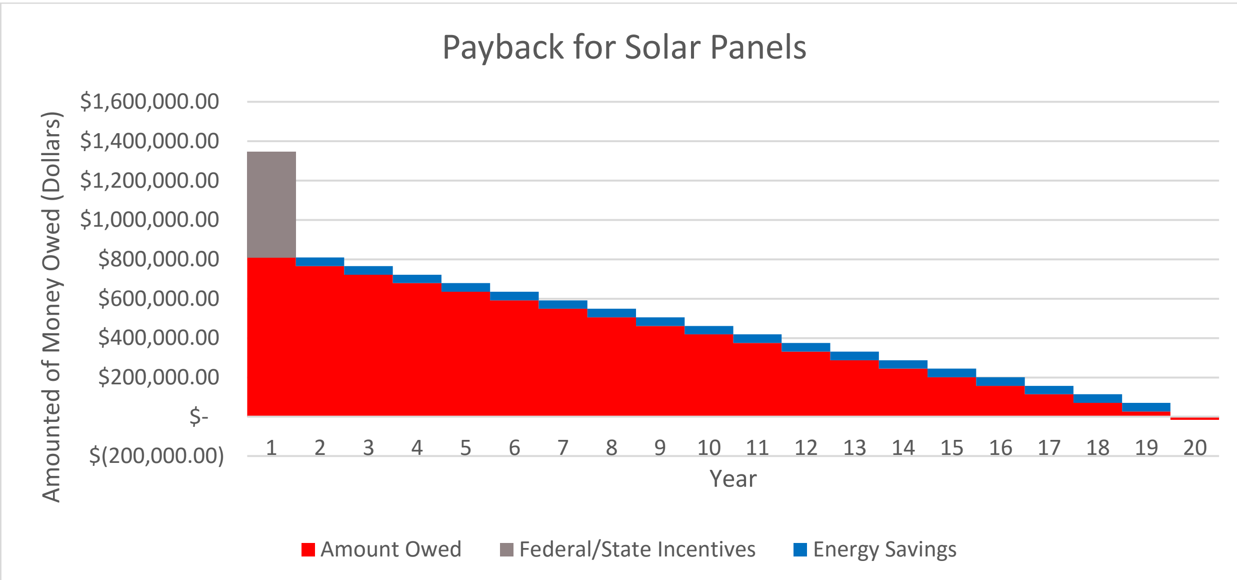
**Lifetime:** 0.5% AC output degradation rate per year.

**Results**

**Estimated Total Cost:** $1,348,859

**Total Energy Savings:** $43,457.46 per year.

# Rooftop-Mounted Residential Solar- Community Scale Quick Facts




| System Information | | | |
|---|---|---|---|
| **Size** | **Tilt** | **Panel Direction** | **Number of Houses** |
| 10 kW | 35 Degrees | South | 41 Units |

| Expenses | |
|---|---|
| **Total Cost** | **Total Cost After Incentives** |
| $1,348,859.00 | $809,315.40 |

| Savings | | | |
|---|---|---|---|
| **Incentives** | **Federal** | **State** | **Energy Savings Per Year** |
| **Amount** | $404,657.70 | $134,885.90 | $43,457.46 |

## BASIC DESIGN CRITERIA

Using a 410 kW system will ensure that there is a surplus of energy produced each month that can be sold back to PNM (Figure 11). The tilt of the panels for this analysis is 35°, and the panel azimuth is located at 180°, or directly south. These panels are assumed to be installed as fixed roof-mounted panels on the new buildings.

## ANALYSIS INFORMATION

The analysis for residential solar PV uses the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM) program using their PVWatts analysis to estimate the total cost and efficiency of installing a 410 kilowatt energy system on the new units in the housing development. The weather information used in the solar analysis for this report is the 2014 Santo Domingo Pueblo weather records, which is also provided in SAM.

## BASIC PARAMETERS FOR ANALYSIS

Multiple assumptions were used during the analysis. An assumed 14.1% energy loss and a 96% inverter efficiency is used to account for imperfect energy conversion in the solar panels. A 0.5% degradation of AC output in the panels per year is assumed for the lifetime of the panels. The basic solar PV system assumptions used for the analysis are provided in Table 8.

| | | Residential Rooftop- 35° |
|---|---|---|
| System Specifications | | A residential-scale system installed on the rooftops of the housing units with a fixed 35° tilt. Electricity costs and savings are for whole development. |
| System Size | | 410 kW |
| Price (per Watt)- Solar Cells | $ | 0.70 |
| Price (per Watt)- Inverter | $ | 0.33 |
| Price (per Watt)- Balance of System (B.O.S.) | $ | 0.82 |
| Price (per Watt)- Installation Labor | $ | 0.30 |
| Price (per Watt)- Installer Margin and Overhead | $ | 0.95 |
| Price (per Watt)- Permitting and Environmental Studies | $ | 0.10 |
| **Estimated Total (per Watt)** | **$** | **3.20** |
| Sales Tax Basis | | 58% |
| Sales Tax Rate | | 5% |
| **Total Cost per Capacity (per Watt)** | **$** | **3.29** |
| **Total Cost of System (per Unit)** | **$** | **32,899.00** |
| **Total Cost of System (Pre-Incentives)** | **$** | **1,348,859.00** |
| Federal Incentives (30%) | $ | 404,657.70 |
| State Incentives (10% OR $9,000 max) | $ | 134,885.90 |
| **Total Cost of System (With All Incentives)** | **$** | **809,315.40** |
| Maintenance (per kW-yr) | $ | 20.00 |
| Annual Electricity Costs (Without System) | $ | 35,049.55 |
| Annual Electricity Costs (With System) | $ | (8,407.91) |
| Annual Savings (With System) | $ | 43,457.46 |
| **Payback Period in Years (Total cost/Savings)** | | **18.62** |

**Table 8...Design Criteria for Analysis- Community Res.**

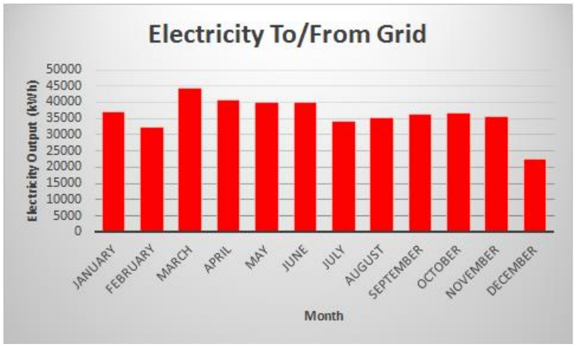
## BASIC FINANCIAL INFORMATION

In the analysis PNM's residential 1A service is used to determine the electricity rates for the new unit—these rates determine what the members of that unit will pay for electricity. For a solar energy system up to 10 kW in size, PNM will pay $0.025 for every kWh of energy produced by the solar panels, which will return money to the community throughout the year. PNM's current monthly electricity rates for 1A are shown in Table 9:

| Fee | Monthly Rate (Sept.-May) | Monthly Rate (June-Aug.) |
|---|---|---|
| Base Fee | $5.00/Bill | $5.00/Bill |
| First 450 kWh | $0.091/kWh | $0.091/kWh |
| Next 450 kWh | $0.119/kWh | $0.137/kWh |
| Any Additional kWh | $0.128/kWh | $0.158/kWh |

**Table 9... PNM Monthly Electricity Fees- Community Res.**

## SYSTEM ANALYSIS



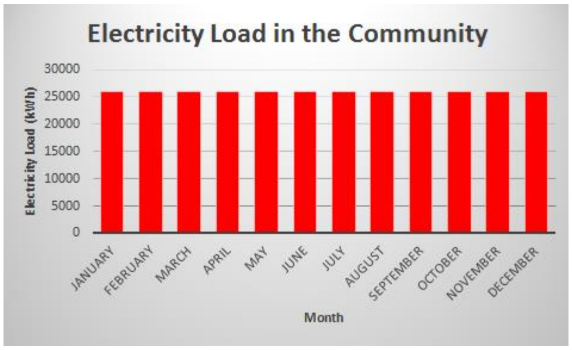




**Figure 10... Electricity Generation and Load- Community Res.**

NREL's SAM program provides an in-depth analysis of the energy production available in Santo Domingo and calculates the projected energy creation from the entire system throughout the year (Figure 10). The assumed electricity load for Santo Domingo is based on Santa Fe's average monthly energy consumption of 633 kWh (Figure 10). Based on the assumed electricity load and the weather data, a graph representing the electricity being bought and sold from PNM can be created to model the energy usage in the community (Figure 11). As shown in the chart, the solar panels located on the unit would be selling energy back to PNM every month of the year.

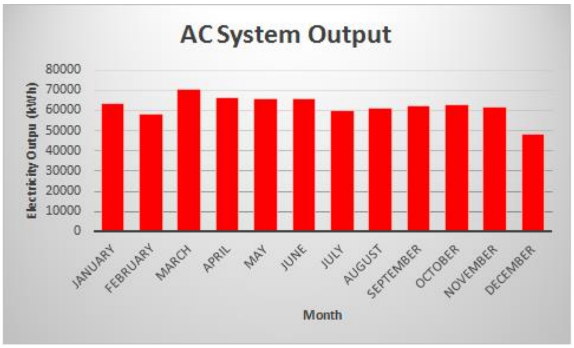



**Figure 11... Electricity Bought From and Sold to PNM-Community Res.**

| Month | Without System | With System | Savings |
|---|---|---|---|
| January | $70.38 | $5.00 | $65.38 |
| February | $70.38 | $5.00 | $65.38 |
| March | $70.38 | $5.00 | $65.38 |
| April | $70.38 | $5.00 | $65.38 |
| May | $70.38 | $5.00 | $65.38 |
| June | $73.82 | $5.00 | $68.82 |
| July | $73.82 | $5.00 | $68.82 |
| August | $73.82 | $5.00 | $68.82 |
| September | $70.38 | $5.00 | $65.38 |
| October | $70.38 | $5.00 | $65.38 |
| November | $70.38 | $5.00 | $65.38 |
| December | $70.38 | $(260.07) | $330.45 |
| Annual Total | $854.87 | $(205.07) | $1,059.94 |
| Total Across Community | $35,049.55 | $(8,407.91) | $43,457.46 |

**Table 10... Monthly Electricity Costs and Savings- Community Res.**

Over a year, the estimated savings for the entire community is $43,457.46, with rollover credits each month creating a payback in December (Table 10). The final analysis with this PV system causes the residents in the units to be paid a total of $8,407.91 each year for using the system. If the system is not used, the annual cost for electricity throughout the year would amount to $35,049.55. Each month the resident would only pay PNM's base fee for electricity to PNM. The base monthly electricity load rate will vary from each unit based on the energy saving techniques used by the residents and will include the overall home efficiency and construction materials. These factors will lead to adjustments in the savings and energy costs per month. Over a 25 year period the panels would become less efficient and create a reduction in savings per year. Eventually the panels would need to be replaced which would cause a need for labor, funding, and maintenance.

The numbers in the table that are in parentheses () are negative numbers, while all those outside parentheses are positive.

## COST ANALYSIS CALCULATIONS

Net Capital Cost= $32,899*41 units= $1,348,859.00

$$Community\ Cost = Capital\ Cost - Federal\ Incentives - State\ Incentives$$

$$Community\ Cost = \$1{,}348{,}859 - 41 * (\$32{,}899 * .30) - 41 * [(\$32{,}899 * .10)\ if\ ans < 9{,}000]$$

$$Community\ Cost = \$1{,}348{,}859 - \$404{,}657.70 - \$134{,}885.90$$

$$Cost\ for\ Entire\ Project: \$809{,}315.40$$

Total money needed from grants: $809,315.40

With half the money provided through grants:

$$\frac{\$809{,}315.40}{2} = \$404{,}657.70$$

Money needed from grants: $404,657.70

Money needed from community: $404,657.70

$Payback\ period\ with\ using\ the\ \$43{,}457.46\ (\$1{,}059.94\ per\ unit)\ per\ year\ in\ total\ savings.$

$$\frac{\$404{,}657.70}{\$43{,}457.46} = 9.31\ years$$

With no money provided through grants:

Money needed from community: $809,315.40

$Payback\ period\ with\ using\ the\ \$43{,}457.46\ (\$1{,}059.94\ per\ unit)\ per\ year\ in\ total\ savings.$

$$\frac{\$809{,}315.40}{\$43{,}457.46} = 18.62\ years$$

# System Advisor Model Report

Photovoltaic System | 10 DC kW Nameplate | -, -
Residential | $3.29/W Installed Cost | 35.53 N, -106.38 E GMT -7

## Performance Model

| PV System Specifications | |
|---|---|
| System nameplate size | 10 kW |
| Module type | 0 |
| DC to AC ratio | 1.1 |
| Rated inverter size | 9.1 kW |
| Inverter efficiency | 96 % |
| Array type | fixed roof mount |
| Array tilt | 35 degrees |
| Array azimuth | 180 degrees |
| Ground coverage ratio | N/A |
| Total system losses | 14.1 % |
| Shading | no |

| Performance Adjustments | |
|---|---|
| Availability/Curtailment | none |
| Degradation | 0.5 %/yr |
| Hourly or custom losses | none |

| Results | Solar Radiation | AC Energy |
|---|---|---|
| | (kWh/m2/day) | (kWh) |
| Jan | 6,109.23 | 1,539 |
| Feb | 6,388.97 | 1,419 |
| Mar | 7,175.82 | 1,715 |
| Apr | 7,117.57 | 1,623 |
| May | 7,050.06 | 1,607 |
| Jun | 7,583.69 | 1,604 |
| Jul | 6,752.34 | 1,466 |
| Aug | 6,810.5 | 1,491 |
| Sep | 7,089.98 | 1,521 |
| Oct | 6,604.34 | 1,525 |
| Nov | 6,327.78 | 1,501 |
| Dec | 4,683.81 | 1,183 |
| Year | 6,641.18 | 18,198 |

## Financial Model

| Project Costs | |
|---|---|
| Total installed cost | $32,899 |
| Salvage value | $0 |

| Analysis Parameters | |
|---|---|
| Project life | 25 years |
| Inflation rate | 2.5% |
| Real discount rate | 5.5% |

| Project Debt Parameters (Standard Loan) | |
|---|---|
| Debt fraction | 0% |
| Amount | $0 |
| Term | 25 years |
| Rate | 0% |

| Tax and Insurance Rates | (% of installed cost) |
|---|---|
| Federal income tax | 0%/year |
| State income tax | 0%/year |
| Sales tax | 5% |
| Insurance | 0.5%/year |
| Property tax (% of assess. val.) | 2%/year |

| Incentives | |
|---|---|
| Federal ITC | 30% |
| State ITC | 10%, $9,000 max |

**Electricity Demand and Rate Summary**

Annual peak demand 2.2 kW
Annual total demand 7,595 kWh
Public Service Co of NM
1A (Residential Service)
Fixed charge: $5/month
Net metering
Tiered TOU energy rates: 2 periods, 3 tiers

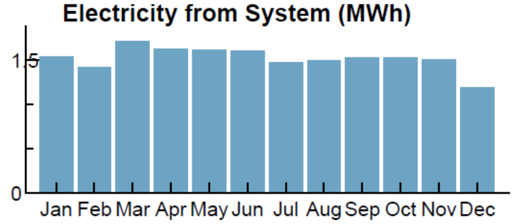
| Results | |
|---|---|
| Nominal LCOE | 17.6 cents/kWh |
| Net present value | $-18,800 |
| Payback period | > 25 years |

Residential | PVWatts System Model
System Advisor Model Standard Report generated by SAM 2016.3.14 on Thu Apr 28 15:38:12 2016 1 / 3

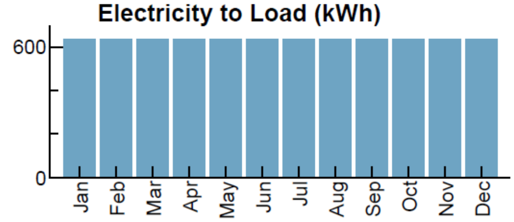
# System Advisor Model Report, Page 2

| | | |
|---|---|---|
| Photovoltaic System | 10 DC kW Nameplate | -, - |
| Residential | $3.29/W Installed Cost | 35.53 N, -106.38 E GMT -7 |

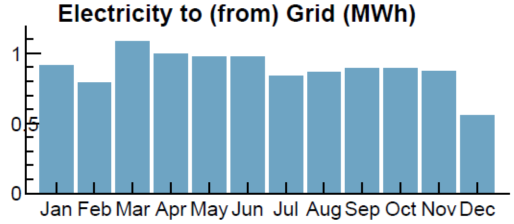
**Electricity from System (MWh)**




**Electricity to Load (kWh)**




**Electricity to (from) Grid (MWh)**




No Net Metering Credits

**Monthly Electricity Purchases and Savings (Year 1 $)**

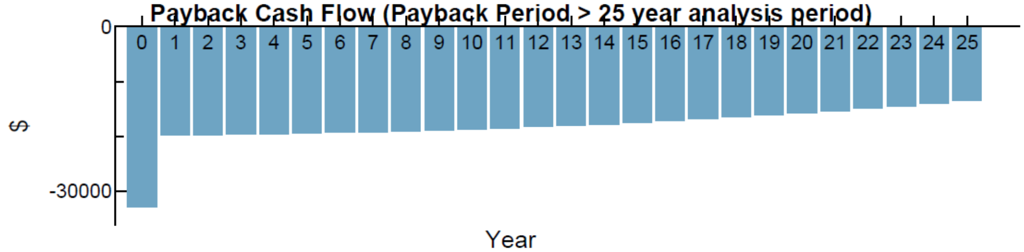
| Month | Without System | With System | Savings |
|---|---|---|---|
| Jan | 70 | 5 | 65 |
| Feb | 70 | 5 | 65 |
| Mar | 70 | 5 | 65 |
| Apr | 70 | 5 | 65 |
| May | 70 | 5 | 65 |
| Jun | 73 | 5 | 68 |
| Jul | 73 | 5 | 68 |
| Aug | 73 | 5 | 68 |
| Sep | 70 | 5 | 65 |
| Oct | 70 | 5 | 65 |
| Nov | 70 | 5 | 65 |
| Dec | 70 | -260 | 330 |
| Annual | 854 | -205 | 1,059 |

**NPV Approximation using Annuities**

| Annuities, Capital Recovery Factor (CRF) = 0.0948 | | |
|---|---|---|
| Investment | $-3,100 | Sum: |
| Expenses | $-1,100 | $-1,700 |
| Savings | $1,100 | NPV = Sum / CRF: |
| Energy value | $1,200 | $-18,000 |

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 8.1375%

**Payback Cash Flow (Payback Period > 25 year analysis period)**




System Advisor Model Standard Report generated by SAM 2016.3.14 on Thu Apr 28 15:38:12 2016 2 / 3

## Scenario C: Rooftop-Mounted Commercial Solar Report

This analysis was created for the Santo Domingo Housing Authority to provide an estimated overview on the potential for using standard rooftop-mounted solar photovoltaic panels (PV) on the new units being constructed in the Domingo Housing Project on a commercial scale.

Providing renewable energy for a single unit in Santo Domingo would be a relatively inexpensive option that would provide savings for the residents throughout the year and a payback in December. Currently, Santo Domingo residents pay PNM an estimated energy bill of $70 per month, when they could be paying just $5 per month for their energy bill after the community pays for solar energy system. While solar panels are being paid for, community members would pay their normal energy bill, but the cost would decrease greatly once the system is paid off. The total cost of installing a 250 kilowatt (kW) system on the rooftops of all units in the Domingo Housing Project would be approximately $636,998. Over the course of each year the community would collectively save an estimated $39,449.10 on their electricity bills, and the community would receive $2,862.25 in December as rollover credits from the community's sale of energy back to the energy company. With a 250 kW system, the residents in the community would only be required to pay the base $8.46 price for energy from Santo Domingo's energy provider, the Public Service Company of New Mexico (PNM).

### CASE STUDY – PICURIS, NM

As of 2015, according to the Solar Energy Industries Association, an estimated 784,000 American homes and businesses have gone solar (Solar Energy Industries Association, n.d.). 50 miles north of Santa Fe, Kit Carson Electric completed a solar project in October of 2015 for the Picuris Pueblo. The installation included solar hot water heating panels and PV panels on the top of the community's 2,640-square-foot fire station. This pueblo is much smaller than Santo Domingo in population and land area – 300 people and around 320 acres compared to Domingo's 3,000 and 2 square miles – but are a good representation of how beneficial a commercial rooftop system could be, as the building was designed to be a net zero energy structure U.S. Department of Energy, 2015).

## Scenario Details

### Basic Financing

**Energy Rates:** PNM's Commercial 2A Small Power Service-$8.46 base rate

**Incentives:** 30% federal incentive, 10% state incentive with a $9,000 maximum value.

### Assumptions

**Size:** 250 kW total

**Setup:** Rooftop-Mounted, Azimuth located at 180°, panels are tilted 35°.

**Electricity Load:** 633 kWh per month for each unit. 26 MWh per month in total.

**Inefficiency:** 14.08% system losses, 96% inverter efficiency.

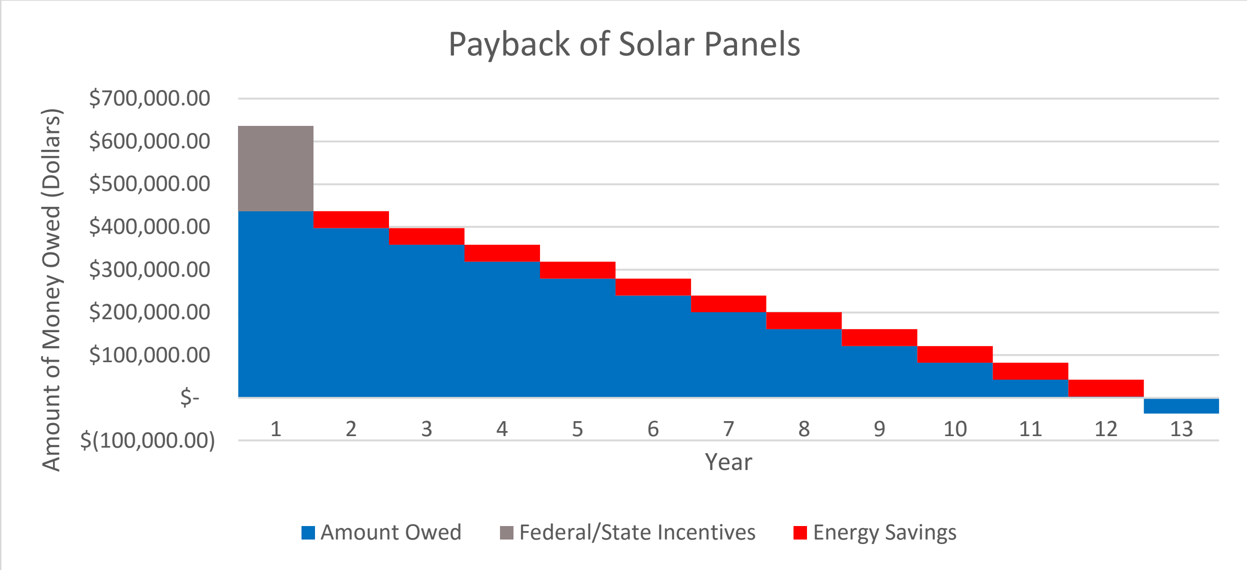
**Lifetime:** 0.5% AC output degradation rate per year.

### Results

**Estimated Total Cost:** $15,536.52 per unit, $636,997.50 in total.

**Total Energy Savings:** $39,449.10 in total per year.

# Rooftop-Mounted Commercial Solar Array Quick Facts




| System Information | | | |
|---|---|---|---|
| **Size** | **Tilt** | **Panel Direction** | **Number of Houses** |
| 250 kW | 35 Degrees | South | 41 Units |

| Expenses | |
|---|---|
| **Total Cost** | **Total Cost After Incentives** |
| $636,997.50 | $436,898.25 |

| Savings | | | |
|---|---|---|---|
| **Incentives** | **Federal** | **State** | **Energy Savings Per Year** |
| **Amount** | $191,099.25 | $9,000 | $39,449.10 |

## BASIC DESIGN CRITERIA

Using a 250 kW system will ensure that there is a surplus of energy produced each month that can be sold back to PNM (Figure 13). The tilt of the panels for this analysis is 35°, and the panel azimuth is located at 180°, or directly south. These panels are assumed to be installed as fixed roof-mounted panels on the new buildings.

## ANALYSIS INFORMATION

The analysis for residential solar PV uses the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM) program using their PVWatts analysis to estimate the total cost and efficiency of installing a 250 kilowatt energy system on the new units in the housing development. The weather information used in the solar analysis for this report is the 2014 Santo Domingo Pueblo weather records, which is also provided in SAM.

## BASIC PARAMETERS FOR ANALYSIS

Multiple assumptions were used during the analysis. An assumed 14.1% energy loss and a 96% inverter efficiency is used to account for imperfect energy conversion in the solar panels. A 0.5% degradation of AC output in the panels per year is assumed for the lifetime of the panels. The basic solar PV system assumptions used for the analysis are provided in Table 11.

| | | Commercial Rooftop- 35° |
|---|---|---|
| System Specifications | | A commercial-scale system installed on the rooftops of the housing units with a fixed 35° tilt. Electricity costs and savings are for whole development. |
| System Size | | 250 kW |
| Price (per Watt)- Solar Cells | $ | 0.71 |
| Price (per Watt)- Inverter | $ | 0.21 |
| Price (per Watt)- Balance of System (B.O.S.) | $ | 0.57 |
| Price (per Watt)- Installation Labor | $ | 0.15 |
| Price (per Watt)- Installer Margin and Overhead | $ | 0.75 |
| Price (per Watt)- Permitting and Environmental Studies | $ | 0.06 |
| **Estimated Total (per Watt)** | **$** | **2.45** |
| Sales Tax Basis | | 82% |
| Sales Tax Rate | | 5% |
| **Total Cost per Capacity (per Watt)** | **$** | **2.55** |
| **Total Cost of System (per Unit)** | **$** | **15,536.52** |
| **Total Cost of System (Pre-Incentives)** | **$** | **636,997.50** |
| Federal Incentives (30%) | $ | 191,099.25 |
| State Incentives (10% OR $9,000 max) | $ | 9,000.00 |
| **Total Cost of System (With All Incentives)** | **$** | **436,898.25** |
| Maintenance (per kW-yr) | $ | 20.00 |
| Annual Electricity Costs (Without System) | $ | 36,679.91 |
| Annual Electricity Costs (With System) | $ | (2,769.19) |
| Annual Savings (With System) | $ | 39,449.10 |
| **Payback Period in Years (Total cost/Savings)** | | **11.07** |

**Table 11...Design Criteria for Analysis- Comm. Rooftop**

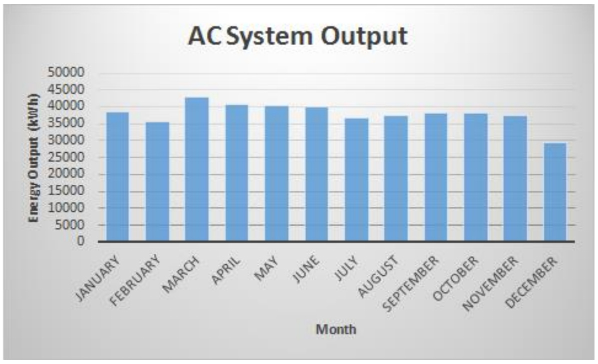
## BASIC FINANCIAL INFORMATION

In the analysis PNM's commercial 2A service is used to determine the electricity rates for the new unit—these rates determine what the members of that unit will pay for electricity. For a solar energy system from 100 kW to 1 MW in size, PNM will pay $0.02 for every kWh of energy produced by the solar panels, which will return money to the community throughout the year. PNM's current monthly electricity rates for 2A are shown in Table 12:

| Fee | Monthly Rate (Sept.-May) | Monthly Rate (June-Aug.) |
|---|---|---|
| Base Fee | $8.46/Bill | $8.46/Bill |
| Pricing for all kWh | $0.11/kWh | $0.13/kWh |

**Table 12... PNM Monthly Electricity Fees- Comm. Rooftop**

## SYSTEM ANALYSIS



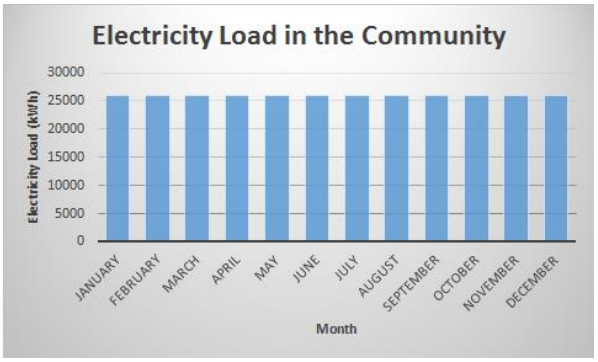




**Figure 12... Electricity Generation and Load- Comm. Rooftop**

NREL's SAM program provides an in-depth analysis of the energy production available in Santo Domingo and calculates the projected energy creation from the entire system throughout the year (Figure 12). The assumed electricity load for Santo Domingo is based on Santa Fe's average monthly energy consumption of 25,953 kWh (Figure 12). Based on the assumed electricity load and the weather data, a graph representing the electricity being bought and sold from PNM can be created to model the energy usage in the community (Figure 13). As shown in the chart, the solar panels located on the units would be selling energy back to PNM every month of the year.

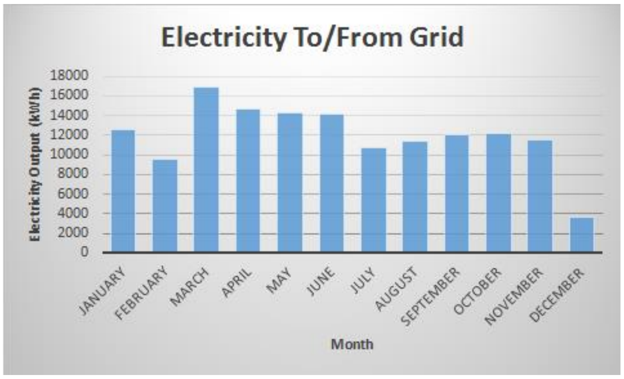



**Figure 13... Electricity Bought From and Sold to PNM- Comm. Rooftop**

| Month | Without System | With System | Savings |
|---|---|---|---|
| January | $2,920.06 | $8.46 | $2,911.60 |
| February | $2,920.06 | $8.46 | $2,911.60 |
| March | $2,920.06 | $8.46 | $2,911.60 |
| April | $2,920.06 | $8.46 | $2,911.60 |
| May | $2,920.06 | $8.46 | $2,911.60 |
| June | $3,466.46 | $8.46 | $3,458.00 |
| July | $3,466.46 | $8.46 | $3,458.00 |
| August | $3,466.46 | $8.46 | $3,458.00 |
| September | $2,920.06 | $8.46 | $2,911.60 |
| October | $2,920.05 | $8.46 | $2,911.59 |
| November | $2,920.06 | $8.46 | $2,911.60 |
| December | $2,920.06 | $(2,862.25) | $5,782.31 |
| Annual Total | $36,679.91 | $(2,769.19) | $39,449.10 |

**Table 13... Monthly Electricity Costs and Savings- Comm. Rooftop**

Over a year, the estimated savings in total is $39,449.10, with rollover credits each month creating a payback in December (Table 13). The final analysis with this PV system causes the community to be paid $2,769.19 each year for using the system. If the system is not used, the annual cost for electricity throughout the year would amount to $36,679.91. Each month the resident would only pay PNM's base fee for electricity to PNM. The base monthly electricity load rate will vary from each unit based on the energy saving techniques used by the residents and will include the overall home efficiency and construction materials. These factors will lead to adjustments in the savings and energy costs per month. Over a 25 year period the panels would become less efficient and create a reduction in savings per year. Eventually the panels would need to be replaced which would cause a need for labor, funding, and maintenance.

The numbers in the table that are in parentheses () are negative numbers, while all those outside parentheses are positive.

## COST ANALYSIS CALCULATIONS

Net Capital Cost= $636,998

$$Community\ Cost = Capital\ Cost - Federal\ Incentives - State\ Incentives$$

$$Community\ Cost = \$636{,}997.50 - (\$636{,}997.50 * .30) - [(\$636{,}997.50 * .10)\ if\ ans < 9{,}000]$$

$$Community\ Cost = \$636{,}997.50 - \$191{,}099.25 - \$9{,}000$$

$$Community\ Cost = \$436{,}898.25$$

$$Cost\ for\ Entire\ Project = \$436{,}898.25$$

Total money needed from grants: $436,898.25

With half the money provided through grants:

$$\frac{\$436{,}898.25}{2} = \$218{,}449.13$$

Money needed from grants: $218,449.13

Money needed from community: $218,449.13

$$Payback\ period\ with\ using\ the\ \$39{,}449.10\ per\ year\ in\ total\ savings.$$

$$\frac{\$218{,}449.13}{\$39{,}449.10} = 5.53\ years$$

With no money provided through grants:

Money needed from community: $436,898.25

$$Payback\ period\ with\ using\ the\ \$39{,}449.10\ per\ year\ in\ total\ savings.$$

$$\frac{\$436{,}898.25}{\$39{,}449.10} = 11.07\ years$$

# System Advisor Model Report

Photovoltaic System
Commercial

250 DC kW Nameplate
$2.55/W Installed Cost

-, -
35.53 N, -106.38 E GMT -7

## Performance Model

| PV System Specifications | |
|---|---|
| System nameplate size | 250 kW |
| Module type | 0 |
| DC to AC ratio | 1.1 |
| Rated inverter size | 227.3 kW |
| Inverter efficiency | 96 % |
| Array type | fixed roof mount |
| Array tilt | 35 degrees |
| Array azimuth | 180 degrees |
| Ground coverage ratio | N/A |
| Total system losses | 14.1 % |
| Shading | no |

| Performance Adjustments | |
|---|---|
| Availability/Curtailment | none |
| Degradation | 0.5 %/yr |
| Hourly or custom losses | none |

| Results | Solar Radiation | AC Energy |
|---|---|---|
| | (kWh/m2/day) | (kWh) |
| Jan | 6,109.23 | 38,496 |
| Feb | 6,388.97 | 35,495 |
| Mar | 7,175.82 | 42,891 |
| Apr | 7,117.57 | 40,575 |
| May | 7,050.06 | 40,178 |
| Jun | 7,583.69 | 40,119 |
| Jul | 6,752.34 | 36,665 |
| Aug | 6,810.5 | 37,291 |
| Sep | 7,089.98 | 38,027 |
| Oct | 6,604.34 | 38,127 |
| Nov | 6,327.78 | 37,525 |
| Dec | 4,683.81 | 29,577 |
| Year | 6,641.18 | 454,971 |

## Financial Model

| Project Costs | |
|---|---|
| Total installed cost | $636,997 |
| Salvage value | $0 |

| Analysis Parameters | |
|---|---|
| Project life | 25 years |
| Inflation rate | 2.5% |
| Real discount rate | 5.5% |

| Project Debt Parameters | |
|---|---|
| Debt fraction | 0% |
| Amount | $0 |
| Term | 25 years |
| Rate | 0% |

| Tax and Insurance Rates | (% of installed cost) |
|---|---|
| Federal income tax | 0%/year |
| State income tax | 0%/year |
| Sales tax | 5% |
| Insurance | 0.5%/year |
| Property tax (% of assess. val.) | 2%/year |

| Incentives | |
|---|---|
| Federal ITC | 30% |
| State ITC | 10%, $9,000 max |
| Federal Depreciation | None |
| State Depreciation | None |

**Electricity Demand and Rate Summary**

Annual peak demand 83.4 kW
Annual total demand 311,436 kWh
Public Service Co of NM
2A (Small Power Service)
Fixed charge: $8.46/month
Net metering
Tiered TOU energy rates: 2 periods, 1 tier

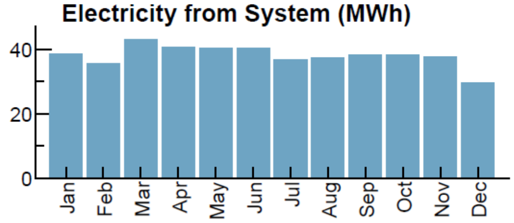
| Results | |
|---|---|
| Nominal LCOE | 15 cents/kWh |
| Net present value | $-182,500 |
| Payback period | 17.3 years |

Commercial | PVWatts System Model
System Advisor Model Standard Report generated by SAM 2016.3.14 on Thu Apr 28 15:38:44 2016 1 / 3

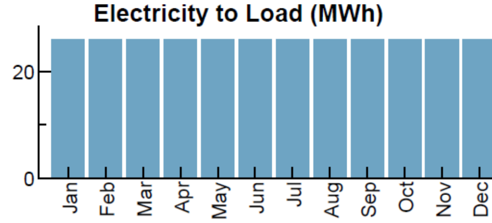
## System Advisor Model Report, Page 2

| | | |
|---|---|---|
| Photovoltaic System | 250 DC kW Nameplate | -, - |
| Commercial | $2.55/W Installed Cost | 35.53 N, -106.38 E GMT -7 |

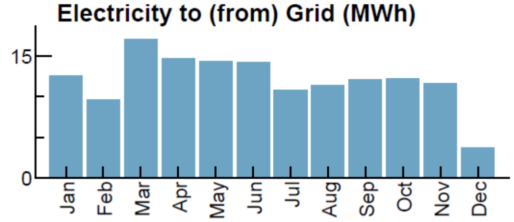
**Electricity from System (MWh)**




**Electricity to Load (MWh)**




**Electricity to (from) Grid (MWh)**




No Net Metering Credits

**Monthly Electricity Purchases and Savings (Year 1 $)**

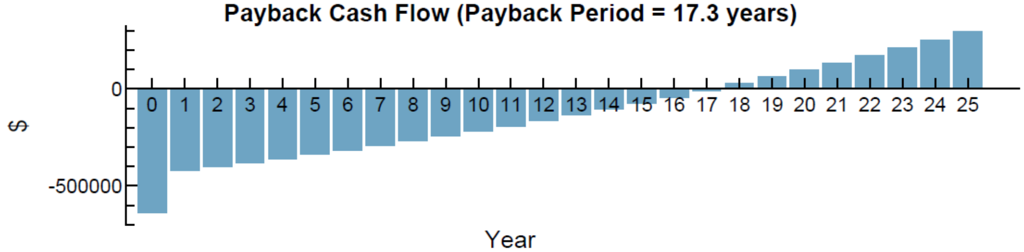
| Month | Without System | With System | Savings |
|---|---|---|---|
| Jan | 2,920 | 8 | 2,911 |
| Feb | 2,920 | 8 | 2,911 |
| Mar | 2,920 | 8 | 2,911 |
| Apr | 2,920 | 8 | 2,911 |
| May | 2,920 | 8 | 2,911 |
| Jun | 3,466 | 8 | 3,458 |
| Jul | 3,466 | 8 | 3,458 |
| Aug | 3,466 | 8 | 3,458 |
| Sep | 2,920 | 8 | 2,911 |
| Oct | 2,920 | 8 | 2,911 |
| Nov | 2,920 | 8 | 2,911 |
| Dec | 2,920 | -2,862 | 5,782 |
| Annual | 36,679 | -2,769 | 39,449 |

**NPV Approximation using Annuities**

| Annuities, Capital Recovery Factor (CRF) = 0.0948 | | |
|---|---|---|
| Investment | $-60,300 | Sum: |
| Expenses | $-22,800 | $-17,300 |
| Savings | $17,500 | NPV = Sum / CRF: |
| Energy value | $48,400 | $-182,000 |

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 8.1375%

**Payback Cash Flow (Payback Period = 17.3 years)**




System Advisor Model Standard Report generated by SAM 2016.3.14 on Thu Apr 28 15:38:44 2016 2 / 3

## Scenario D: Ground-Mounted Commercial Solar Array Report

This analysis was created for the Santo Domingo Housing Authority to provide an estimated overview on the potential for using solar photovoltaic panels (PV) in a ground-mounted fixed open rack array within the Domingo Housing Project development on a commercial scale.

Providing renewable energy for a single unit in Santo Domingo would be a relatively inexpensive option that would provide savings for the residents throughout the year and a payback in December. Currently, Santo Domingo residents pay PNM an estimated energy bill of $70 per month, when they could be paying just $5 per month for their energy bill after the community pays for solar energy system. While solar panels are being paid for, community members would pay their normal energy bill, but the cost would decrease greatly once the system is paid off. The total cost of installing a 250 kilowatt (kW) system as a ground-mounted array in the Domingo Housing Project would be approximately $636,998. Over the course of each year the community would collectively save an estimated $39,595 on their electricity bills, and the community would receive $3,008 in December as rollover credits from the community's sale of energy back to the energy company. With a 250 kW system, the residents in the community would only be required to pay the base $8.46 price for energy from Santo Domingo's energy provider, the Public Service Company of New Mexico (PNM).

### CASE STUDY – UNM TAOS

As of 2015, according to the Solar Energy Industries Association, an estimated 784,000 American homes and businesses have gone solar (Solar Energy Industries Association, n.d.). Solar projects are being successfully implemented across the United States to benefit community or larger-scale entities that invest in the use of solar panels. The Klauer Campus of the University of New Mexico-Taos (UNM-Taos) installed a 500 kW, three and a half acre solar array consisting of 2,700 panels. An array of this size provides the campus with 100% of its electricity needs. Implementing an array in the Domingo Housing Project would be a very cost efficient way to ensure that the electricity needs of the community are met without installing panels on individual houses, which may be a concern (University of New Mexico Taos, n.d.).

## Scenario Details

**Basic Financing**

**Energy Rates:** PNM's Commercial 2A Small Power Service-$8.46 base rate

**Incentives:** 30% federal incentive, 10% state incentive with a $9,000 maximum value.

**Assumptions**

**Size:** 250 kW total

**Setup:** Fixed ground-mounted, Azimuth located at 180º, panels are tilted 35º.

**Electricity Load:** 633 kWh per month for each unit. 26 MWh per month in total.

**Inefficiency:** 14.08% system losses, 96% inverter efficiency.

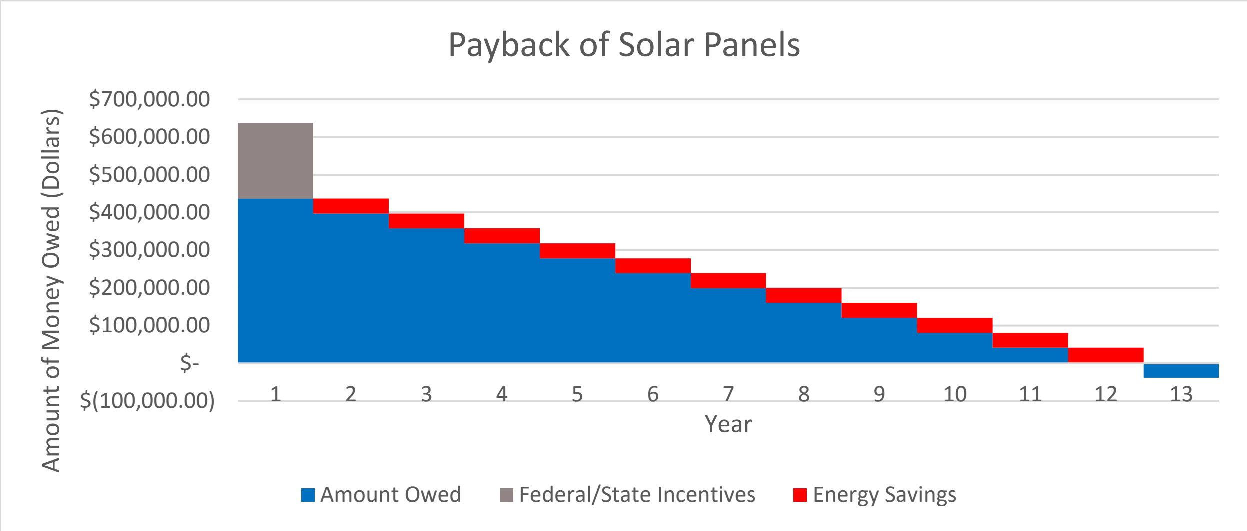
**Lifetime:** 0.5% AC output degradation rate per year.

**Results**

**Estimated Total Cost:** $15,536.52 per unit, $636,997.50 in total.

**Total Energy Savings:** $39,595.14 in total per year.

# Ground-Mounted Commercial Solar Array Quick Facts




| System Information | | | |
|---|---|---|---|
| **Size** | **Tilt** | Panel Direction | **Number of Houses** |
| 250 kW | 35 Degrees | South | 41 Units |

| Expenses | |
|---|---|
| **Total Cost** | **Total Cost After Incentives** |
| $636,997.50 | $436,898.25 |

| Savings | | | |
|---|---|---|---|
| **Incentives** | **Federal** | **State** | **Energy Savings Per Year** |
| **Amount** | $191,099.25 | $9,000 | $39,595.14 |

## BASIC DESIGN CRITERIA

Using a 250 kW system will ensure that there is a surplus of energy produced each month for repurchasing by the energy company (Figure 15). The tilt of the panels for this analysis is 35°, and the panel azimuth is located at 180°, or directly south. These panels are assumed to be installed as fixed ground-mounted panels in an array.

## ANALYSIS INFORMATION

The analysis for residential solar PV uses the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM) program using their PVWatts analysis to estimate the total cost and efficiency of installing a 250 kilowatt energy system as an array in the housing development. The weather information used in the solar analysis for this report is the 2014 Santo Domingo Pueblo weather records, which is also provided in SAM.

## BASIC PARAMETERS FOR ANALYSIS

Multiple assumptions were used during the analysis. An assumed 14.1% energy loss and a 96% inverter efficiency is used to account for imperfect energy conversion in the solar panels. A 0.5% degradation of AC output in the panels per year is assumed for the lifetime of the panels, which would eventually cause the panels to have a need for replacement. The basic solar PV system assumptions used for the analysis are provided in Table 14.

| | Commercial Array- 35° | |
|---|---|---|
| System Specifications | A commercial-scale system installed as a ground-mounted array with a fixed 35° tilt. Electricity costs and savings are for whole development. | |
| System Size | | 250 kW |
| Price (per Watt)- Solar Cells | $ | 0.71 |
| Price (per Watt)- Inverter | $ | 0.21 |
| Price (per Watt)- Balance of System (B.O.S.) | $ | 0.57 |
| Price (per Watt)- Installation Labor | $ | 0.15 |
| Price (per Watt)- Installer Margin and Overhead | $ | 0.75 |
| Price (per Watt)- Permitting and Environmental Studies | $ | 0.06 |
| **Estimated Total (per Watt)** | **$** | **2.45** |
| Sales Tax Basis | | 82% |
| Sales Tax Rate | | 5% |
| **Total Cost per Capacity (per Watt)** | **$** | **2.55** |
| **Total Cost of System (per Unit)** | **$** | **15,536.52** |
| **Total Cost of System (Pre-Incentives)** | **$** | **636,997.50** |
| Federal Incentives (30%) | $ | 191,099.25 |
| State Incentives (10% OR $9,000 max) | $ | 9,000.00 |
| **Total Cost of System (With All Incentives)** | **$** | **436,898.25** |
| Maintenance (per kW-yr) | $ | 20.00 |
| Annual Electricity Costs (Without System) | $ | 36,679.91 |
| Annual Electricity Costs (With System) | $ | (2,915.23) |
| Annual Savings (With System) | $ | 39,595.14 |
| **Payback Period in Years (Total cost/Savings)** | | **11.03** |

**Table 14...Design Criteria for Analysis- Comm. Array**

## BASIC FINANCIAL INFORMATION

In the analysis PNM's commercial 2A service is used to determine the electricity rates for the new unit—these rates determine what the members of that unit will pay for electricity. For a solar energy system from 100 kW to 1 MW in size, PNM will pay $0.02 for every kWh of energy produced by the solar panels, which will return money to the community throughout the year. PNM's current monthly electricity rates for 2A are shown in Table 15:

| Fee | Monthly Rate (Sept.-May) | Monthly Rate (June-Aug.) |
|---|---|---|
| Base Fee | $8.46/Bill | $8.46/Bill |
| Pricing for all kWh | $0.11/kWh | $0.13/kWh |

**Table 15... PNM Monthly Electricity Fees- Comm. Array**

## SYSTEM ANALYSIS

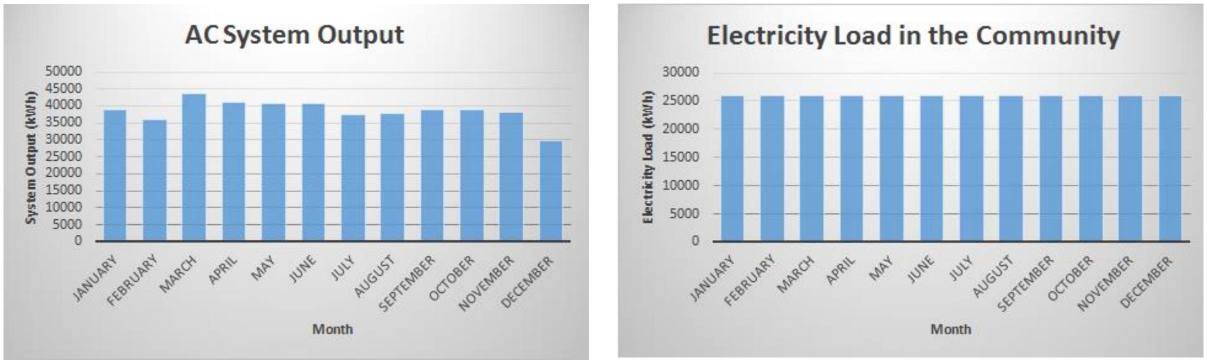



**Figure 14... Electricity Generation and Load- Comm. Array**

NREL's SAM program provides an in-depth analysis of the energy production available in Santo Domingo and calculates the projected energy creation from the entire system throughout the year (Figure 14). The assumed electricity load for Santo Domingo is based on Santa Fe's average monthly energy consumption of 25,953 kWh (Figure 14). Based on the assumed electricity load and the weather data, a graph representing the electricity being bought and sold from PNM can be created to model the energy usage in the community (Figure 15). As shown in the chart, the solar panels located on the units would be selling energy back to PNM every month of the year.

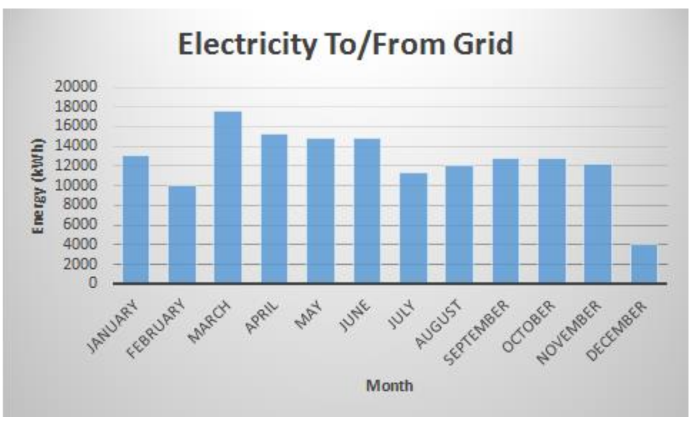



**Figure 15... Electricity Bought From and Sold to PNM- Comm. Array**

| Month | Without System | With System | Savings |
|---|---|---|---|
| January | $2,920.06 | $8.46 | $2,911.60 |
| February | $2,920.06 | $8.46 | $2,911.60 |
| March | $2,920.06 | $8.46 | $2,911.60 |
| April | $2,920.06 | $8.46 | $2,911.60 |
| May | $2,920.06 | $8.46 | $2,911.60 |
| June | $3,466.46 | $8.46 | $3,458.00 |
| July | $3,466.46 | $8.46 | $3,458.00 |
| August | $3,466.46 | $8.46 | $3,458.00 |
| September | $2,920.06 | $8.46 | $2,911.60 |
| October | $2,920.05 | $8.46 | $2,911.59 |
| November | $2,920.06 | $8.46 | $2,911.60 |
| December | $2,920.06 | $(3,008.29) | $5,928.35 |
| Annual Total | $36,679.91 | $(2,915.23) | $39,595.14 |

**Table 16... Monthly Electricity Costs and Savings- Comm. Array**

Over a year, the estimated savings in total is $39,595.14, with rollover credits each month creating a payback in December (Table 16). The final analysis with this PV system causes the community to be paid $2,915.23 each year for using the system. If the system is not used, the annual cost for electricity throughout the year would amount to $36,679.91. Each month the resident would only pay PNM's base fee for electricity to PNM. The base monthly electricity load rate will vary from each unit based on the energy saving techniques used by the residents and will include the overall home efficiency and construction materials. These factors will lead to adjustments in the savings and energy costs per month. Over a 25 year period the panels would become less efficient and create a reduction in savings per year. Eventually the panels would need to be replaced which would cause a need for labor, funding, and maintenance.

The numbers in the table that are in parentheses () are negative numbers, while all those outside parentheses are positive.

## COST ANALYSIS CALCULATIONS

Net Capital Cost= $636,998

$$Community\ Cost = Capital\ Cost - Federal\ Incentives - State\ Incentives$$

$$Community\ Cost = \$636{,}997.50 - (\$636{,}997.50 * .30) - [(\$636{,}997.50 * .10)\ if\ ans < 9{,}000]$$

$$Community\ Cost = \$636{,}997.50 - \$191{,}099.25 - \$9{,}000$$

$$Community\ Cost = \$436{,}898.25$$

$$Cost\ for\ Entire\ Project = \$436{,}898.25$$

Total money needed from grants: $436,898.25

With half the money provided through grants:

$$\frac{\$436{,}898.25}{2} = \$218{,}449.13$$

Money needed from grants: $218,449.13

Money needed from community: $218,449.13

$$Payback\ period\ with\ using\ the\ \$39{,}595.14\ per\ year\ in\ total\ savings.$$

$$\frac{\$218{,}449.13}{\$39{,}595.14} = 5.52\ years$$

With no money provided through grants:

Money needed from community: $436,898.25

$$Payback\ period\ with\ using\ the\ \$39{,}595.14\ per\ year\ in\ total\ savings.$$

$$\frac{\$436{,}898.60}{\$39{,}595.14} = 11.03\ years$$

# System Advisor Model Report

| | | |
|---|---|---|
| Photovoltaic System | 250 DC kW Nameplate | -, - |
| Commercial | $2.55/W Installed Cost | 35.53 N, -106.38 E GMT -7 |

## Performance Model

| PV System Specifications | |
|---|---|
| System nameplate size | 250 kW |
| Module type | 0 |
| DC to AC ratio | 1.1 |
| Rated inverter size | 227.3 kW |
| Inverter efficiency | 96 % |
| Array type | fixed open rack |
| Array tilt | 35 degrees |
| Array azimuth | 180 degrees |
| Ground coverage ratio | N/A |
| Total system losses | 14.1 % |
| Shading | no |

| Performance Adjustments | |
|---|---|
| Availability/Curtailment | none |
| Degradation | 0.5 %/yr |
| Hourly or custom losses | none |

| Results | Solar Radiation | AC Energy |
|---|---|---|
| | (kWh/m2/day) | (kWh) |
| Jan | 6,109.23 | 39,027 |
| Feb | 6,388.97 | 35,990 |
| Mar | 7,175.82 | 43,571 |
| Apr | 7,117.57 | 41,199 |
| May | 7,050.06 | 40,810 |
| Jun | 7,583.69 | 40,779 |
| Jul | 6,752.34 | 37,334 |
| Aug | 6,810.5 | 37,972 |
| Sep | 7,089.98 | 38,745 |
| Oct | 6,604.34 | 38,779 |
| Nov | 6,327.78 | 38,092 |
| Dec | 4,683.81 | 29,969 |
| Year | 6,641.18 | 462,273 |

## Financial Model

| Project Costs | |
|---|---|
| Total installed cost | $636,997 |
| Salvage value | $0 |

| Analysis Parameters | |
|---|---|
| Project life | 25 years |
| Inflation rate | 2.5% |
| Real discount rate | 5.5% |

| Project Debt Parameters | |
|---|---|
| Debt fraction | 0% |
| Amount | $0 |
| Term | 25 years |
| Rate | 0% |

| Tax and Insurance Rates | (% of installed cost) |
|---|---|
| Federal income tax | 0%/year |
| State income tax | 0%/year |
| Sales tax | 5% |
| Insurance | 0.5%/year |
| Property tax (% of assess. val.) | 2%/year |

| Incentives | |
|---|---|
| Federal ITC | 30% |
| State ITC | 10%, $9,000 max |
| Federal Depreciation | None |
| State Depreciation | None |

**Electricity Demand and Rate Summary**

Annual peak demand 83.4 kW
Annual total demand 311,436 kWh
Public Service Co of NM
2A (Small Power Service)
Fixed charge: $8.46/month
Net metering
Tiered TOU energy rates: 2 periods, 1 tier

| Results | |
|---|---|
| Nominal LCOE | 14.8 cents/kWh |
| Net present value | $-180,700 |
| Payback period | 17.2 years |

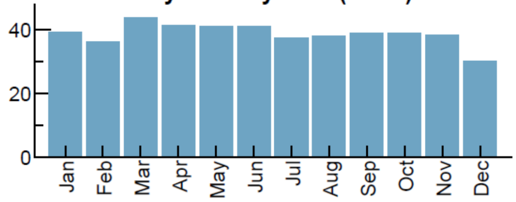
Commercial | PVWatts System Model

System Advisor Model Standard Report generated by SAM 2016.3.14 on Wed Apr 20 11:37:27 2016 1 / 3

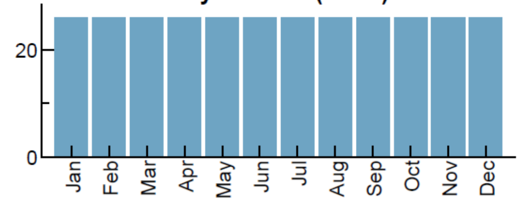
# System Advisor Model Report, Page 2

| | | |
|---|---|---|
| Photovoltaic System | 250 DC kW Nameplate | -, - |
| Commercial | $2.55/W Installed Cost | 35.53 N, -106.38 E GMT -7 |

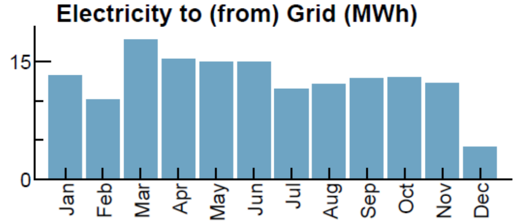
**Electricity from System (MWh)**




**Electricity to Load (MWh)**




**Electricity to (from) Grid (MWh)**




No Net Metering Credits

**Monthly Electricity Purchases and Savings (Year 1 $)**

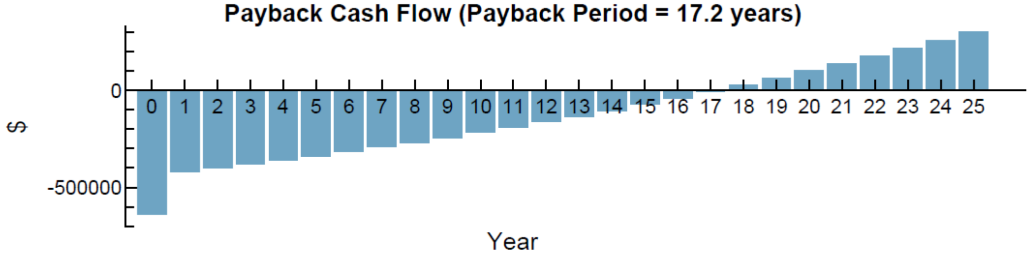
| Month | Without System | With System | Savings |
|---|---|---|---|
| Jan | 2,920 | 8 | 2,911 |
| Feb | 2,920 | 8 | 2,911 |
| Mar | 2,920 | 8 | 2,911 |
| Apr | 2,920 | 8 | 2,911 |
| May | 2,920 | 8 | 2,911 |
| Jun | 3,466 | 8 | 3,458 |
| Jul | 3,466 | 8 | 3,458 |
| Aug | 3,466 | 8 | 3,458 |
| Sep | 2,920 | 8 | 2,911 |
| Oct | 2,920 | 8 | 2,911 |
| Nov | 2,920 | 8 | 2,911 |
| Dec | 2,920 | -3,008 | 5,928 |
| Annual | 36,679 | -2,915 | 39,595 |

**NPV Approximation using Annuities**

| Annuities, Capital Recovery Factor (CRF) = 0.0948 | | |
|---|---|---|
| Investment | $-60,300 | Sum: |
| Expenses | $-22,800 | $-17,100 |
| Savings | $17,500 | NPV = Sum / CRF: |
| Energy value | $48,500 | $-180,000 |

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 8.1375%

**Payback Cash Flow (Payback Period = 17.2 years)**




System Advisor Model Standard Report generated by SAM 2016.3.14 on Wed Apr 20 11:37:27 2016 2 / 3

# SOURCES

**Programs**

Program used for analysis: National Renewable Energy Laboratory's System Advisory Module (SAM) https://sam.nrel.gov/.

All Charts and Graphs generated from NREL's SAM Analysis.

PNM Residential Energy Costs determined from Residential 1A form: https://www.pnm.com/documents/396023/396197/schedule_1_a.pdf/d9cfda9e-61a1-4008-ba3c-4152c9dbe7f1.

PNM Commercial Energy Costs determined from Commercial 2A Small Power Service form:

https://www.pnm.com/documents/396023/396197/schedule_2_a.pdf/1704b220-5119-4f54-8d7a-43a7bff0139f.

All efficiencies and system prices were determined from the default information provided through NREL's SAM PVWatts Analysis.

**Case Studies**

Solar Energy Industries Association. (n.d.). *Solar Market Insight Fact Sheet*. Retrieved April 28, 2016, from http://www.seia.org/sites/default/files/Q2 2015 SMI Fact Sheet.pdf

Sustainable Native Communities Collaborative. (n.d. (a)). *Department of Hawaiian Home Lands-Kumuhau Subdivision*. Retrieved April 28, 2016, from http://sustainablenativecommunities.org/wp-content/uploads/2013/07/130611_02_CS-HUD-Kumuhau-Subdivision.pdf

Sustainable Native Communities Collaborative. (n.d. (b)). *Pascua-Yaqui Guadalupe House*. Retrieved April 28, 2016, from http://sustainablenativecommunities.org/wp-content/uploads/2013/07/130611_12_CS-HUD-Guadalupe-House.pdf

University of New Mexico Taos. (n.d.). UNM Taos Solar Array. Retrieved April 29, 2016, from http://taos.unm.edu/about-unm-taos/solar-array.html

U.S. Department of Energy. (2015, December 1). Solar Projects on the Rise for New Mexico's Picuris and Zia Pueblos. Retrieved April 29, 2016, from http://www.energy.gov/indianenergy/articles/solar-projects-rise-new-mexico-s-picuris-and-zia-pueblos

## Appendix A: Tilt Angles

| Scale | Type | Size | Tilt (degrees) | Annual Solar Panel Energy Output (kWh) |
|---|---|---|---|---|
| Residential | Rooftop Mounted | 10 kW | 0 | 15373.6 |
| Residential | Rooftop Mounted | 10 kW | 15 | 17262.1 |
| Residential | Rooftop Mounted | 10 kW | 25 | 17960.2 |
| **Residential** | **Rooftop Mounted** | **10 kW** | **35** | **18198.9** |
| Residential | Rooftop Mounted | 10 kW | 45 | 17983.5 |
| Residential | Rooftop Mounted | 10 kW | 55 | 17332.3 |
| Residential | Rooftop Mounted | 10 kW | 65 | 16249.1 |
| Residential | Rooftop Mounted | 10 kW | 75 | 14746.5 |
| Residential | Rooftop Mounted | 10 kW | 85 | 12884.7 |

| Scale | Type | Size | Tilt (degrees) | Annual Solar Panel Energy Output (kWh) |
|---|---|---|---|---|
| Residential | Rooftop Mounted | 410 kW | 0 | 630317.6 |
| Residential | Rooftop Mounted | 410 kW | 15 | 707746.1 |
| Residential | Rooftop Mounted | 410 kW | 25 | 736368.2 |
| **Residential** | **Rooftop Mounted** | **410 kW** | **35** | **746154.9** |
| Residential | Rooftop Mounted | 410 kW | 45 | 737323.5 |
| Residential | Rooftop Mounted | 410 kW | 55 | 710624.3 |
| Residential | Rooftop Mounted | 410 kW | 65 | 666213.1 |
| Residential | Rooftop Mounted | 410 kW | 75 | 604606.5 |
| Residential | Rooftop Mounted | 410 kW | 85 | 528272.7 |

| Scale | Type | Size | Tilt (degrees) | Annual Solar Panel Energy Output (kWh) |
|---|---|---|---|---|
| Commercial | Rooftop Mounted | 250 kW | 0 | 384,339 |
| Commercial | Rooftop Mounted | 250 kW | 15 | 431,553 |
| Commercial | Rooftop Mounted | 250 kW | 25 | 449,005 |
| **Commercial** | **Rooftop Mounted** | **250 kW** | **35** | **454,971** |
| Commercial | Rooftop Mounted | 250 kW | 45 | 449,587 |
| Commercial | Rooftop Mounted | 250 kW | 55 | 433,307 |
| Commercial | Rooftop Mounted | 250 kW | 65 | 406,229 |
| Commercial | Rooftop Mounted | 250 kW | 75 | 368,663 |
| Commercial | Rooftop Mounted | 250 kW | 85 | 322,118 |

| Scale | Type | Size | Tilt (degrees) | Annual Solar Panel Energy Output (kWh) |
|---|---|---|---|---|
| Commercial | Solar Array | 250 kW | 0 | 389,726 |
| Commercial | Solar Array | 250 kW | 15 | 438,182 |
| Commercial | Solar Array | 250 kW | 25 | 456,142 |
| **Commercial** | **Solar Array** | **250 kW** | **35** | **462,273** |
| Commercial | Solar Array | 250 kW | 45 | 456,717 |
| Commercial | Solar Array | 250 kW | 55 | 439,918 |
| Commercial | Solar Array | 250 kW | 65 | 412,084 |
| Commercial | Solar Array | 250 kW | 75 | 373,592 |
| Commercial | Solar Array | 250 kW | 85 | 325,968 |

# Appendix B: Pricing Comparison Table

**Pricing Comparison Chart**

| | Commercial Array- 35° | Commercial Rooftop- 0° | Commercial Rooftop- 35° | Residential Rooftop- 0° | Residential Rooftop- 35° | NOTES |
|---|---|---|---|---|---|---|
| System Specifications | A commercial-scale system installed as a ground-mounted array with a fixed 35° tilt. Electricity costs and savings are for whole development. | A commercial-scale system installed on the rooftops of the housing units with a fixed 0° tilt. Electricity costs and savings are for whole development. | A commercial-scale system installed on the rooftops of the housing units with a fixed 35° tilt. Electricity costs and savings are for whole development. | A residential-scale system installed on the rooftops of the housing units with a fixed 0° tilt. Electricity costs and savings are for whole development. | A residential-scale system installed on the rooftops of the housing units with a fixed 35° tilt. Electricity costs and savings are for whole development. | Brief explanation of each scenario |
| System Size | 250 kW | 250 kW | 250 kW | 410 kW | 410 kW | How many watts produced at a standard irradiance level of 1,000 w/m2 at 77° F |
| Price (per Watt)- Solar Cells | $ 0.71 | $ 0.71 | $ 0.71 | $ 0.70 | $ 0.70 | Cost of the module (solar cells) based on system size |
| Price (per Watt)- Inverter | $ 0.21 | $ 0.21 | $ 0.21 | $ 0.33 | $ 0.33 | Cost of the inverter based on system size |
| Price (per Watt)- Balance of System (B.O.S.) | $ 0.57 | $ 0.57 | $ 0.57 | $ 0.82 | $ 0.82 | Cost of the B.O.S. based on system size |
| Price (per Watt)- Installation Labor | $ 0.15 | $ 0.15 | $ 0.15 | $ 0.30 | $ 0.30 | Cost of installation labor based on system size |
| Price (per Watt)- Installer Margin and Overhead | $ 0.75 | $ 0.75 | $ 0.75 | $ 0.95 | $ 0.95 | Cost of installer margin and overhead based on system size |
| Price (per Watt)- Permitting and Environmental Studies | $ 0.06 | $ 0.06 | $ 0.06 | $ 0.10 | $ 0.10 | Cost to gain permitting and environmental licensing based on system size |
| **Estimated Total (per Watt)** | **$ 2.45** | **$ 2.45** | **$ 2.45** | **$ 3.20** | **$ 3.20** | Total price per watt, based on system size |
| Sales Tax Basis | 82% | 82% | 82% | 58% | 58% | Assumed tax values from NREL's System Advisor Module |
| Sales Tax Rate | 5% | 5% | 5% | 5% | 5% | Assumed tax values from NREL's System Advisor Module |
| **Total Cost per Capacity (per Watt)** | **$ 2.55** | **$ 2.55** | **$ 2.55** | **$ 3.29** | **$ 3.29** | Total price per watt after sales taxes are accounted for |
| **Total Cost of System (per Unit)** | **$ 15,536.52** | **$ 15,536.52** | **$ 15,536.52** | **$ 32,899.00** | **$ 32,899.00** | Total price of the system for one of the 41 units |
| **Total Cost of System (Pre-Incentives)** | **$ 636,997.50** | **$ 636,997.50** | **$ 636,997.50** | **$ 1,348,859.00** | **$ 1,348,859.00** | Total price of the system for all 41 units, before state and federal incentives |
| Federal Incentives (30%) | $ 191,099.25 | $ 191,099.25 | $ 191,099.25 | $ 404,657.70 | $ 404,657.70 | The cost eliminated from the total due to the 30% federal incentives |
| State Incentives (10% OR $9,000 max) | $ 9,000.00 | $ 9,000.00 | $ 9,000.00 | $ 134,885.90 | $ 134,885.90 | The cost eliminated from the total due to the 10% state incentives |
| **Total Cost of System (With All Incentives)** | **$ 436,898.25** | **$ 436,898.25** | **$ 436,898.25** | **$ 809,315.40** | **$ 809,315.40** | Final total cost of system for all 41 units, after state and federal incentives |
| Maintenance (per kW-yr) | $ 20.00 | $ 20.00 | $ 20.00 | $ 20.00 | $ 20.00 | Estimated cost of maintaining system for each kW produced over a year |
| Annual Electricity Costs (Without System) | $ 36,679.91 | $ 36,679.91 | $ 36,679.91 | $ 35,049.55 | $ 35,049.55 | Average power costs for the community without the solar energy system per year |
| Annual Electricity Costs (With System) | $ (2,915.23) | $ 735.24 | $ (2,769.19) | $ (5,512.00) | $ (8,407.91) | Average power costs for the community with the solar energy system per year |
| **Annual Savings (With System)** | **$ 39,595.14** | **$ 37,415.15** | **$ 39,449.10** | **$ 40,561.55** | **$ 43,457.46** | How much money is saved per year for all 41 units |
| **Payback Period in Years (Total cost/Savings)** | **11.03** | **11.68** | **11.07** | **19.95** | **18.62** | The amount of time it takes for the system to be paid off |

# 6. Conclusions and Recommendations

The main deliverables for our project include an eight minute long educational video, a cost analysis report detailing 4 different solar energy options, a comprehensive price comparison chart for the different solar energy options we analyzed, a funding table showing what options are available from grants, bonds, and other sources, and finally a working spreadsheet that can be used to estimate pricing for different scenarios. Our team also created a website showing the stages of our work in Santa Fe from the early work beginning in the first of the 14 weeks to the project completion.

## 6.1 Final Recommendations and Outcomes

During our time working with Santo Domingo, we have developed several recommendations and potential outcomes that our project may have on the community. They are listed below:

Recommendations

1. Install a ground-mounted commercial array
2. Pursue funding for the project through grants

Potential Outcomes

1. Provide a renewable energy source for the pueblo
2. Promote energy sovereignty
3. Spur economic development
4. Become a solar model community

### 6.1.1 Install a Ground-Mounted Commercial Array

Our final recommendation for the community is to install a ground-mounted 250 kW commercial-scale solar PV array, where the panels have a 35° tilt. This recommendation does not account for the aesthetic appeal of the solar panels. The commercial array provides the shortest payback period and the best cost-to-savings ratio. This is the best-case scenario if no funding is available.

If the Santo Domingo community is against having solar panels visible in the new development, then the best option to pursue is the rooftop-mounted commercial system with a slightly decreased tilt, to more easily hide the system on a rooftop. This scenario is a significantly more cost-effective option than installing a rooftop-mounted residential system.

When comparing the panels on rooftops to those in a ground-mounted array, the following notes should be considered:

- The payback period for rooftop panels compared to an array is longer

- If the roof needs to be redone, rehabilitation will be more time consuming and costly, as the panels have to be removed then reinstalled
- As the community grows in size, expanding a ground-mounted array will be simpler than retrofitting and designing buildings for rooftop solar.

Along with the pricing differences in cost of system versus savings, these points are also important to consider when making the final decision for what solar energy system to use in the Domingo Housing Project. These conditions are why our team has recommended a commercial ground-mounted array for the Santo Domingo Pueblo.

### 6.1.2 Pursue Funding for the Project through Grants

As the cheapest option, the commercial solar array that we recommend will still cost nearly $437,000 after all incentives are applied. It would be very beneficial for Santo Domingo to look into funding this project through grants or other means of outside support. If the solar panels were paid for by means other than community money, the $437,000 that would have gone into the solar project can be put towards other projects that the community wishes to focus on. In addition, the cash flow for this project would immediately be positive, as there will have been no initial investment for the community, meaning the pueblo can immediately start looking into funding other projects.

### 6.1.3 Provide a Renewable Energy Source for the Pueblo

The introduction of solar panels will provide a renewable and sustainable energy source for the community. Not only does this meet the development's electricity needs, but does so in a way that is good for the environment.

### 6.1.4 Promote Energy Sovereignty

Santo Domingo is a sovereign nation, and as such should have their own sovereign energy system. A positive outcome of solar panels in the Domingo Housing Project is that it allows the community to possess their own energy production system. Rather than being tied to contracts with power companies, the pueblo will have control of the system and be able to enter into a power-purchase agreement that works in their favor.

### 6.1.5 Spur Economic Development

The Domingo Housing Project is a project that aims to help the pueblo promote economic progress. The low-income rental project will provide affordable housing and access to public transportation to members of the community, and is located between Santa Fe and Albuquerque—two of New Mexico's largest urban centers. The development is a short walk from the Kewa stop of the Rail Runner Express train, located next to the Santo Domingo Indian Trading Post.

Already in an economically beneficial location, the installation of solar panels within the Domingo Housing Project could help this development become a strong economic community for the pueblo. Not only does the development lie close to what will be two of Santo Domingo's means of monetary input (the gas station and the trading post), but it will be cheaper to live in this development as less money will be paid for electricity.

#### 6.1.6 Become a Solar Model Community

An area like the Domingo Housing Project with solar panels installed could very well serve as a model for other communities attempting to go green. The location will feature an environmentally sensitive yet still contemporary building style, and be able to provide its residents with their own power. As the development continues to grow and modify to enhance its role as a green community, the hope is that other places will look at the Domingo Housing Project as a solar model to develop their own green communities.

Santo Domingo should not be viewed only by American Indian groups as a solar model, but the hope is that it will be viewed by any community trying to install solar panels. By the time the project is complete, the Domingo Housing Project can be a solar model community.

## 6.2 Deliverables for Future Work in Santo Domingo

Due to the fact that our team cannot help implement our recommendations (construction will have started after our departure), this section explains how our deliverables can help the Santo Domingo Pueblo execute the most ideal solar energy system for the Domingo Housing Project. Our deliverables also aim to help other communities execute similar solar energy projects.

### 6.2.1 Educational Video

This video was created to explain to the Santo Domingo community what the project hopes to achieve and demonstrate how solar energy can help their community. The storyboard and progression of the video is also set in a way so that other communities trying to achieve similar solar energy goals can watch this film and gauge the reactions of the Santo Domingo community to solar energy. If another community is hesitant to install a solar energy system, our video will hopefully ease some of the reluctance by showing how beneficial solar can be to promote energy sovereignty in a community.

### 6.2.2 Cost Analysis Report

This report breaks down each of our team's three modeled solar energy systems: residential rooftop, commercial rooftop, and commercial array. Each report goes into technical detail about the design aspects of each system, the size, expected power output and savings for the community, and also includes a pricing breakdown for the total cost of the system.

In an attempt to ease any confusion about the technicality of our reports, a basic overview of each system and our recommendation is included in the introductory section of our report. In addition, we included a report detailing a residential rooftop system for a single unit within the community, so Santo Domingo can more easily understand what the implications of the project are for a single unit.

At the beginning of each individual report, graphics are included that explain the basic details of each system through charts and graphs. These graphics display cost breakdowns, payback periods, and other basic information about each system. The reports also contain an overview section that covers what the Domingo Housing Project is, the current conditions of electricity consumption for the pueblo, and briefly explains what can be saved by implementing solar panels in the development.

These reports are for the Santo Domingo Tribal Housing Authority and the members of the pueblo to use in the future when deciding what type of solar energy system would be best for the housing project. The graphics and basic information are to help explain the project in the simplest way possible so anyone reading the reports with limited knowledge of solar power can understand the goals of such a project.

### 6.2.3 Price Comparison Chart

We have created a spreadsheet that details the costs of 5 different solar energy systems: Residential Rooftop with tilts of 0° and 35°, Commercial Rooftop with tilts of 0° and 35°, and a Commercial Array with a tilt of 35°. These five systems are detailed because they provide the optimal aesthetic tilt (0°) and the optimal solar absorption tilt (35°) for residential and commercial rooftop systems, and the optimal array tilt (35°) for the commercial array.

This chart will compare each aspect of the system pricing in an easy to read, side-by-side manner. Rather than having to go back through each of the individual solar energy reports to search for the cost breakdowns of each system, this price comparison chart will act as a quick guide for important information.

### 6.2.4 Funding Table

The funding table is an easy to read table that details grants, bonds, incentives, and other funding from the government and private investors. By separating the table into easy to read sections that are alphabetized within each major segment—grants, bonds, etc.—we hope that this will also be another useful tool in the future for community decision makers, as they can reference this chart and see which funding options are readily available to the community. While the table helps give Santo Domingo an idea of what funding is available, the financial decisions must be made by the community when deciding which funding options to pursue.

### 6.2.5 Excel Sheet for Calculating Potential Solar Costs

If the Santo Domingo Pueblo decides not to follow our team's recommendations for a commercial solar array, we have created a working chart for them to use that will adjust the pricing of a different sized system. The user will be able to enter the size of the system, the amount of funding they receive, and federal/state incentives that apply to the project. The spreadsheet will calculate the final price needed from the community and if there is any excess money available. The goal of the spreadsheet is to provide a quick calculation option for the Housing Authority to help provide more information in the decision process.

## Bibliography


Acker, T. L., Auberle, W. M., Duque, E. P. N., Jeffery, W. D., LaRoche, D. R., Masayesva, V., & Smith, D. H. (2003). Implications of the Regional Haze Rule on Renewable and Wind Energy Development on Native American Lands in the West. *Wind Energy*, *6*(4), 347-354.

Alazraque-Cherni, J. (2008). Renewable energy for rural sustainability in developing countries. *Bulletin of Science, Technology & Society*, *28*(2), 105-114.

AmbiWeb. (2012). Climate: Santo Domingo Pueblo. Retrieved April 25, 2016, from http://en.climate-data.org/location/125630/

Balo, F. (2015). Feasibility study of "green" insulation materials including tall oil: Environmental, economical and thermal properties. *Energy and Buildings*, *86*, 161-175.

Berkeley Lab. (n.d.). Health Risks of Dust Mite Allergens. Retrieved February 28, 2016, from https://iaqscience.lbl.gov/dampness-risks-mites

Bob Moore Construction. (n.d.). What is Tilt-up Construction? How Are Tilt-up Concrete Buildings Constructed? Retrieved April 22, 2016, from http://www.tiltup.com/commercial-construction-articles/concrete-panel-building/

Bourland, Dana. "Incremental cost, measurable savings: Enterprise green communities' criteria." Columbia: Enterprise Community Partners, Inc. (2009).

Brown, S. V., Nderitu, D. G., Preckel, P. V., Gotham, D. J., & Allen, B. W. (2011). Renewable Power Opportunities for Rural Communities. Retrieved March 6, 2016, from http://www.usda.gov/oce/reports/energy/RenewablePowerOpportunities-Final.pdf

Chan, D., Romero, R., Bojorquez, G., & Luna, A. (1999). *Thermal evaluation of strategies for an adequate housing in arid zones and their impact on energy saving*.

Chiasson, A. (2011). The Economic, Environmental, and Social Benefits of Geothermal Use in Oregon. *GHC Bulletin (Geo-Heat Center*.

City Stats. (n.d.). Santo Domingo Pueblo (New Mexico). Retrieved February 27, 2016, from http://city-stats.org/nm/santo-domingo-pueblo/climate/santo-domingo-pueblo-climate-data

Consolidated Solar Technologies. (n.d.). Commercial Projects Gallery. Retrieved February 27, 2016, from http://www.gocstsolar.com/commercial-projects-gallery/

[Concentrating Solar Resource of the Southwest United States]. Retrieved from http://www.nrel.gov/csp/pdfs/csp_sw.pdf

Coskun, C., Oktay, Z., & Dincer, I. (2010). Investigation of some renewable energy and exergy parameters for two geothermal district heating systems. *International Journal of Exergy, 8*(1), 1-15.

[Crescent Dunes Solar Energy Project as seen from an airliner], (December 2014). Retrieved from https://en.wikipedia.org/wiki/Crescent_Dunes_Solar_Energy_Project#/media/File:Crescent_Dunes_Solar_December_2014.JPG

DeNavas-Walt, C., & Proctor, B. D. (2015, September). Income and Poverty in the United States: 2014. Retrieved February 7, 2016, from https://www.census.gov/content/dam/Census/library/publications/2015/demo/p60-252.pdf

Department of Health and Human Services. (n.d.). Search Grants. Retrieved April 21, 2016, from http://www.grants.gov/web/grants/search-grants.html

[Desert Rock Resistance]. Retrieved from https://www.indybay.org/uploads//admin_uploads/2010/03/10/desert-rock-resistance.jpg

DeVito, D., & Desmond, M. (n.d.). Homes in Santa Fe, New Mexico. Retrieved February 07, 2016, from http://homesinsantafenm.com/

Down to Earth Design. (n.d.). Overview of Strawbale Construction. Retrieved April 22, 2016, from http://www.buildnaturally.com/EDucate/Articles/Strawbale.htm

Earthship Biotecture. (n.d.). Earthship Biotecture. Retrieved February 27, 2016, from http://earthship.com/

Edelstein, M. R., & Kleese, D. A. (1995). Cultural relativity of impact assessment: Native Hawaiian opposition to geothermal energy development. *Society & Natural Resources, 8*(1), 19-31.

Ellingson, A. R., LeDoux, R. A., Vedanthan, P., & Weber, R. W. (1995). The prevalence of Dermatophagoides mite allergen in Colorado homes utilizing central evaporative coolers. *The Journal of Allergy and Clinical Immunology, 96*(4), 473-479. http://dx.doi.org/10.1016/S0091-6749(95)70289-X

Energy Concepts. (2014). Energy Concepts History & Vision. Retrieved February 27, 2016, from http://eccsolar.com/energy-concepts-history-vision/

Enterprise Community Partners, Inc. (2015). 2015 Enterprise Green Communities Criteria. Retrieved April 25, 2016, from http://www.enterprisecommunity.com/servlet/servlet.FileDownload?file=00P1400000jTtDLEA0

Enterprise Community Partners, Inc. (2016). Enterprise Green Communities. Retrieved April 25, 2016, from http://www.enterprisecommunity.com/solutions-and-innovation/enterprise-green-communities

[Evap. Cooler Illustration]. Retrieved from https://commons.wikimedia.org/wiki/File:Evap_cooler_illustration.png

Florida Solar Energy Center. (2014a). Cells, Modules, and Arrays. Retrieved April 30, 2016, from http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/cells_modules_arrays.htm

Florida Solar Energy Center. (2014b). Types of PV Systems. Retrieved April 30, 2016, from http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/types_of_pv.htm

Fosdick, J., & Holmes, T. C. (2012, August 24). Passive Solar Heating. Retrieved February 27, 2016, from http://www.wbdg.org/resources/psheating.php

Geiger, J., Lisell, L., & Mosey, G. (2013). *Feasibility Study of Economics and Performance of Solar Photovoltaics at the Santo Domingo Pueblo in Sandoval County, New Mexico* (Tech. No. 6A10-58844). Retrieved March 23, 2016, from http://www.nrel.gov/docs/fy13osti/58844.pdf

Global Energy Network Institute. (2015, July 23). Research. Retrieved February 28, 2016, from http://www.geni.org/globalenergy/research/#tribalrenewables

Green Home Building. (n.d.). Adobe. Retrieved February 27, 2016, from http://www.greenhomebuilding.com/adobe.htm

Goff, F. (2002). Geothermal potential of Valles Caldera, New Mexico. *Geo-Heat Center, Quarterly Bulletin, 23*(4), 7-12.

Healthy House Institute. (2011, February 28). Polyurethane and Polyisocyanurate. Retrieved February 27, 2016, from http://www.healthyhouseinstitute.com/hhip-505-Polyurethane-and-polyisocyanurate

Hill, R. (2004). GeoPowering the West. *Geothermal Resources Council Bulletin, 33*(2), 63-66.

Holladay, M. (2014, May 23). Earthship Hype and Earthship Reality. Retrieved February 27, 2016, from http://www.greenbuildingadvisor.com/blogs/dept/musings/earthship-hype-and-earthship-reality

Hughes, T. (2016). Solar industry growing, with some setbacks. Retrieved January 24, 2016, from http://www.usatoday.com/story/tech/news/2016/01/13/solar-industry-growing-some-setbacks/78699966/

Johansson, T. B., & Burnham, L. (1993). Renewable energy: Sources for fuels and electricity. Washington, D.C.: Island Press.

Kunkel, J. (2016a, February 5). 1st Santo Domingo General Information Interview [Telephone interview].

Kunkel, J. (2016b, February 26). 2nd Santo Domingo General Information Interview [Telephone interview].

Kunkel, J. (2016c, April 12). *The Domingo Housing Development*. Speech presented at The Presentation of the Santo Domingo Pueblo to Enterprise Green Communities in Santo Domingo Pueblo.

Lakota Solar Enterprises. (n.d.). Our Work. Retrieved February 27, 2016, from http://www.lakotasolarenterprises.com/

Lightworks. (n.d.). The Professional Editor for Everyone. Retrieved April 21, 2016, from https://www.lwks.com/

Lisell, L., Tetreault, T., & Watson, A. (2009). Solar Ready Buildings Planning Guide (Tech. No. 7A2-46078). Retrieved February 28, 2016, from http://www.nrel.gov/docs/fy10osti/46078.pdf

MacCourt, D. (2010, June). Renewable Energy Development in Indian Country: A Handbook for Tribes [PDF file]. Available from http://www.nrel.gov/docs/fy10osti/48078.pdf

Meisen, P., & Erberich, T. (n.d.). Renewable Energy on Tribal Lands (Tech.). Retrieved February 28, 2016, from Global Energy Network Institute website: http://www.geni.org/globalenergy/research/renewable-energy-on-tribal-lands/Renewable-Energy-on-Tribal-Lands.pdf

National Aeronautics and Space Administration (NASA). (2013, October 18). Solar Arrays. Retrieved February 27, 2016, from https://www.nasa.gov/mission_pages/station/structure/elements/solar_arrays.html#.VqQmMCorKUk

National Geographic. (n.d. (a)). Geothermal Energy. Retrieved February 27, 2016, from http://environment.nationalgeographic.com/environment/global-warming/geothermal-profile/

National Geographic. (n.d. (b)). Solar Energy. Retrieved February 27, 2016, from http://environment.nationalgeographic.com/environment/global-warming/solar-power-profile/

National Renewable Energy Laboratory. (n.d.). PVWatts Calculator. Retrieved April 28, 2016, from http://pvwatts.nrel.gov/

National Renewable Energy Laboratory. (2010, April 05). System Advisor Model (SAM). Retrieved April 27, 2016, from https://sam.nrel.gov/

National Renewable Energy Laboratory. (2014, July 25). Solar Photovoltaic Technology Basics. Retrieved April 04, 2016, from http://www.nrel.gov/learning/re_photovoltaics.html

North Carolina Clean Energy Technology Center. (n.d.). Programs. Retrieved April 21, 2016, from http://programs.dsireusa.org/system/program?zipcode=87052

North Carolina Clean Energy Technology Center. (2016, March 29). PNM - Performance-Based Solar PV Program. Retrieved April 28, 2016, from http://programs.dsireusa.org/system/program/detail/1277

Obafemi, A. O., & Kurt, S. (2016). Environmental impacts of adobe as a building material: The north Cyprus traditional building case. Case Studies in Construction Materials, 4, 32-41.

Office of Indian Energy and Economic Development (IEED). (2016, January 31). Retrieved January 28, 2016, from http://www.bia.gov/WhoWeAre/AS-IA/IEED/index.htm

Oktay, Z., & Dincer, I. (2008). Energetic, Exergetic and Environmental Assessments of the Edremit Geothermal District Heating System. *ASHRAE transactions*, *114*(1).

Onboard Informatics. (2016a). Santa Ana Pueblo, New Mexico. Retrieved April 25, 2016, from http://www.city-data.com/city/Santa-Ana-Pueblo-New-Mexico.html

Onboard Informatics. (2016b). Santo Domingo Pueblo, New Mexico. Retrieved April 25, 2016, from http://www.city-data.com/city/Santo-Domingo-Pueblo-New-Mexico.html

Osceola Energy. (n.d.). About Osceola Energy. Retrieved February 27, 2016, from http://osceolaenergy.com/about-osceolaenergy/

Paradise Power Company. (n.d.). UNM Solar Array Project. Retrieved February 27, 2016, from http://www.ppcsolar.com/unm-solar-array-project/

Paskus, L. (2010, August 16). The life and death of Desert Rock. Retrieved February 14, 2016, from http://www.hcn.org/articles/the-life-and-death-of-desert-rock

Pavilion Construction. (2012). The Pavilion Story. Retrieved April 28, 2016, from http://www.pavilionconstruction.com/our-firm/

Pavilion Construction. (2015, November 2). Domingo Housing Project - Santo Domingo, NM. Retrieved April 28, 2016, from http://www.pavilionconstruction.com/open-for-bid/domingo-housing-project/

Pino, P., & Lakshman, J. (2013, July 26). Pueblo of Zia - 2012 Project. Retrieved January 31, 2016, from http://apps1.eere.energy.gov/tribalenergy/projects_detail.cfm/project_id=208

Pierce, L. (2016, September 16). Funding Opportunity Announcement Webinar [Webinar]. Retrieved from http://apps1.eere.energy.gov/tribalenergy/pdfs/foa-webinar-ppt.pdf

Portland Sustainability Institute. (2011, December). The EcoDistricts Toolkit: Assessment. Retrieved February 28, 2016, from http://ecodistricts.org/wp-content/uploads/2013/03/4_Toolkit_EcoDistrict_Assessment_v_1.12.pdf

Positive Energy Solar. (n.d. (a)). About Us. Retrieved February 27, 2016, from https://www.positiveenergysolar.com/about-us/

Positive Energy Solar. (n.d. (b)). New Mexico Rail Runner Express and the Mid-region Council of Governments. Retrieved February 27, 2016, from https://www.positiveenergysolar.com/projects/new-mexico-rail-runner-express-and-the-mid-region-council-of-governments/

Renewable Energy World. (n.d. (a)). Photovoltaic Systems. Retrieved February 27, 2016, from http://www.renewableenergyworld.com/solar-energy/tech/solarpv.html

Renewable Energy World. (n.d. (b)). Solar Electricity. Retrieved February 27, 2016, from http://www.renewableenergyworld.com/solar-energy/tech/solarconcentrating.html

Renewable Energy World. (n.d. (c)). Solar Hot Water. Retrieved February 27, 2016, from http://www.renewableenergyworld.com/solar-energy/tech/solarhotwater.html

Residential Solar 101. (n.d.). New Mexico Solar Rebates, Incentives and Tax Credits. Retrieved March 06, 2016, from http://www.residentialsolar101.org/new-mexico-solar-rebates-incentives-and-tax-credits/

Reveulta-Acosta, J., Garcia-Diaz, A., Soto-Zarazua, G., & Rico-Garcia, E. (2010). Adobe as a Sustainable Material: A Thermal Performance. *Journal of Applied Sciences, 10*(19), 2211-2216. doi:10.3923/jas.2010.2211.2216

Santo Domingo Tribal Housing Authority. (2014). *Request for Qualifications for Master Planning & Architectural Services*. Retrieved April 26, 2016, from http://www.firstnations.org/sites/documents/Santo Domingo 140122_NewDevelopment_RFQ-RFP.pdf

Sathaye, J., Lucon, O., Rahman, A., Christensen, J., Denton, F., Fujino, J., & Shmakin, A. (2011). Renewable energy in the context of sustainable development. *Renewable Energy Sources and Climate Change Mitigation*.

Shukla, A., Tiwari, G., & Sodha, M. (2009). Embodied Energy Analysis of Adobe House [Abstract]. *Renewable Energy*, *34*(3), 755-761. doi:10.1016/j.renene.2008.04.002

Solar Electricity Handbook 2015 Edition. (n.d.). Solar Irradiance Calculator. Retrieved February 23, 2016, from http://solarelectricityhandbook.com/solar-irradiance.html

Solar Energy Industries Association. (n.d.). Solar Industry Facts and Figures. Retrieved February 27, 2016, from http://www.seia.org/research-resources/solar-industry-data

Structural Insulated Panel Association. (n.d.). What Are SIPs? Retrieved April 22, 2016, from http://www.sips.org/about/what-are-sips

The American Institute of Architects. (n.d.). *Navajo FlexCrete FRAC Masonry Blocks* (Rep. No. ESR-2866). Retrieved April 22, 2016, from http://navajoflexcrete.com/overview.pdf

The World Bank. (n.d.). Average precipitation in depth (mm per year). Retrieved February 27, 2016, from http://data.worldbank.org/indicator/AG.LND.PRCP.MM

Thunder Valley Community Development Corporation. (n.d.). Food Sovereignty & Community Gardens. Retrieved February 28, 2016, from http://www.thundervalley.org/programs/food-sovereignty-community-gardens/

USA.com. (n.d.). Santo Domingo Pueblo, NM. Retrieved March 04, 2016, from http://www.usa.com/santo-domingo-pueblo-nm.htm

U.S. Climate Data. (n.d.). Climate Santa Fe- New Mexico. Retrieved February 27, 2016, from http://www.usclimatedata.com/climate/santa-fe/new-mexico/united-states/usnm0292

U.S. Department of Energy. (n.d. (a)). Passive Solar Home Design. Retrieved March 22, 2016, from http://energy.gov/energysaver/passive-solar-home-design

U.S. Department of Energy. (n.d. (b)). Landscaping for Energy-Efficient Homes. Retrieved March 22, 2016, from http://energy.gov/energysaver/landscaping-energy-efficient-homes

U.S. Department of Energy. (2013). Pueblo of Zia Renewable Energy Development Feasibility Study (Tech.). Retrieved February 28, 2016, from http://apps1.eere.energy.gov/tribalenergy/pdfs/zia_pueblo_final_report_ee0005628.pdf

U.S. Department of Energy. (2015a, March 18). Energy Department Selects 11 Tribal Communities to Deploy Energy Efficiency and Renewable Energy Technologies. Retrieved February 27, 2016, from http://energy.gov/articles/energy-department-selects-11-tribal-communities-deploy-energy-efficiency-and-renewable

U.S. Department of Energy. (2015b, April 1). About the Tribal Energy Program. Retrieved February 27, 2016, from http://apps1.eere.energy.gov/tribalenergy/about.cfm

U.S. Department of Energy. (2015c, April 6). Projects in New Mexico. Retrieved February 14, 2016, from http://apps1.eere.energy.gov/tribalenergy/projects_state.cfm/state=NM

U.S. Department of Energy. (2015d, May). Community Water Pump and Treatment Facility PV Solar Power Project. Retrieved February 28, 2016, from http://apps1.eere.energy.gov/tribalenergy/pdfs/2015-review/34_sherri_bozic.pdf

U.S. Department of Energy. (2015e, December 1). Solar Projects on the Rise for New Mexico's Picuris and Zia Pueblos. Retrieved February 28, 2016, from http://www.energy.gov/indianenergy/articles/solar-projects-rise-new-mexico-s-picuris-and-zia-pueblos

U.S. Department of Housing and Urban Development. (n.d.). Grants. Retrieved February 27, 2016, from http://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/grants

U.S. Energy Information Administration. (2015, October 21). How much electricity does an American home use? Retrieved February 14, 2016, from https://www.eia.gov/tools/faqs/faq.cfm?id=97

U.S. Environmental Protection Agency. (2016, February 26). Learn More About RE-Powering. Retrieved March 28, 2016, from https://www.epa.gov/re-powering/learn-more-about-re-powering#what_is

United States Census Bureau. (n.d.). American FactFinder. Retrieved February 27, 2016, from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

United States Census Bureau. (2015, December 1). New Mexico QuickFacts. Retrieved February 27, 2016, from http://quickfacts.census.gov/qfd/states/35000.html

United States. Congress. Senate. Committee on Indian Affairs (1993- ). (2006). *Native American Indian housing programs : Hearing before the committee on Indian affairs, United States Senate, one hundred ninth congress, second session, on oversight hearing to review the Native American Indian housing programs, June 28, 2006, Washington, DC*. United States:

United States National Park Service. (n.d.). Pueblo of Santo Domingo (Kewa Pueblo). Retrieved February 27, 2016, from http://www.nps.gov/nr/travel/route66/pueblo_of_santo_domingo_kewa_pueblo.html

University of New Mexico Taos. (n.d.). UNM Taos Solar Array. Retrieved February 14, 2016, from http://taos.unm.edu/about-unm-taos/solar-array.html

[Untitled picture of a geothermal heating process]. Retrieved from https://upload.wikimedia.org/wikipedia/commons/thumb/e/e4/Diagram_VaporDominatedGeothermal_inturperated_version.svg/2000px-Diagram_VaporDominatedGeothermal_inturperated_version.svg.png

[Untitled picture of a solar hot water heater system]. Retrieved from http://www.heat-efficient.co.uk/images/shwsystem.gif

[Untitled picture of the process of solar PV panels]. Retrieved from http://gilmourbiology.wikispaces.com/file/view/SolarDiagram_Lg.gif/96329670/729x529/SolarDiagram_Lg.gif

Washington State Department of Transportation. (2013). *The EcoDistricts Framework: Building Blocks of Sustainable Cities* (Rep.). Retrieved May 1, 2016, from http://www.wsdot.wa.gov/NR/rdonlyres/6F915B3C-4206-437A-8798-C595D5729901/0/EcoDistrictsFrameworkMay2013.pdf

Water Use and Conservation Bureau. (n.d.) A waterwise guide to evaporative coolers [Brochure]. Santa Fe, NM: New Mexico Office of the State Engineer.

Waterline Open Space Cooling. (n.d.). Comparison with other Cooling Alternatives. Retrieved February 27, 2016, from http://waterlinecooling.com/13Comparison-with-other.html

Wilson, A. (2009, August 1). Avoid Polystyrene Insulation. Retrieved February 27, 2016, from http://www2.buildinggreen.com/blogs/avoid-polystyrene-insulation

Wilson, Q. (n.d.). Green Home Building: Mass and insulation with adobe. Retrieved February 07, 2016, from http://www.greenhomebuilding.com/QandA/adobe/mass.htm

## Appendix A: Solar Companies

Potential energy companies in the area offering solar power:

a) PPC Solar- This company has done major solar array projects, including making the UNM-Taos Campus the first community college in the nation to be 100% powered by solar energy. (http://www.ppcsolar.com/unm-solar-array-project/)
b) Energy Concepts- This Company is Christian-based and offers solar panels for both grid-tied and off-grid solar power. (http://eccsolar.com/energy-concepts-history-vision/)
c) Zia Sun's Green Construction Co. - Zia Sun supplies solar panels and installation options for interested parties, but would mostly focus on the option of having solar panels attached to buildings. (http://www.ziasuns.com/)
d) Consolidated Solar Technologies- With an office in Santa Fe, this company is nearby and have a history with creating solar arrays. (http://www.gocstsolar.com/commercial-projects-gallery/)
e) Osceola Energy- Based in Albuquerque, Osceola Energy has a wide variety of panels that could potentially give Santo Domingo different options based on preference. (http://osceolaenergy.com/solar-package-details/)
f) DKD Electric- DKD Electric is a company that has worked with the Pueblo of Santa Ana and done electrical work on the Santa Ana Star Casino. (http://dkdelectric.com/index.php?page=about-us)
g) Positive Energy Solar- Positive Energy is the final company in the area and have done work with power systems at railways, which could be utilized at the train station nearby. (https://www.positiveenergysolar.com/projects/new-mexico-rail-runner-express-and-the-mid-region-council-of-governments/)

## Appendix B: Outline of Film

The following is a general outline that the video we created follows:

1. Introduction
    a. Discussion of Native American Housing.
    b. Introduction to Adobe Housing.
    c. The Santo Domingo Pueblo is discussed.
2. The Domingo Housing Project
    a. Joseph introduces the Domingo Housing Project in Santo Domingo.
    b. Greta continues the housing development discussion.
    c. Discussion on the benefits of the Domingo Housing Development
    d. Great describes the new housing development that will be developed in the future.
3. Enterprise Green Communities
    a. Tom introduces Enterprise Green Communities
    b. Narrator states that the Domingo Housing Development will use Enterprise Green Communities' guidelines to install solar panels
    c. Tom talks about renewable energy in different areas.
4. Renewable Energy and Solar Power
    a. Joseph discusses possible obstacles to renewable energy.
    b. Greta talks about solar energy in different Native Communities and the lack of communication present between the communities in regards to solar energy
    c. Introduction to WPI students working in Santo Domingo to help research solar energy.
5. Energy Sovereignty
    a. Tom discusses the benefits that solar energy can bring into a community.
    b. Greta discusses the want for solar panels in the community
    c. Joseph introduces the idea of Energy Sovereignty
6. Conclusion
    a. Joseph discusses the goal to have the Domingo Housing Project become an inspiration for other Native American communities.

## Appendix C: Interview Questions

Joseph (Sponsor)

- What is the Domingo Housing Project?
- What impact do you see this housing development having on the community?
- Are solar panels a feasible option for the new housing development?
- What would energy sovereignty mean for this community?
- How do you picture these new developments and solar projects serving as a model for Indian country?
- What do you envision as the biggest obstacles for renewable energy projects in Native communities in the future?
- What does energy sovereignty mean to you?

Greta (Executive Director of Housing Authority)

- How do you see the housing project affecting the community?
- What has been the most successful project by the housing authority?
- How do you feel about the possibility of mounting solar panels on the rooftops of the new houses?
- Would you be open to the possibility of a solar array in the area near the Domingo Housing Development?
- What does energy sovereignty mean to you?

Tom (Enterprise Green Communities Vice President)

- What is Enterprise Green Communities and what does your company do?
- How does Enterprise Green communities try and use renewable energy in new developments?
- How does Enterprise Green Communities try and use energy sovereignty as an outlet for economic development?

## Appendix D: Table of Potential Financial Sources

The following sources in the chart below were found on the Database of State Incentives for Renewables and Efficiency (North Carolina Clean Energy Technology Center, n.d.) and the grants website created by the Department of Health and Human Services (Department of Health and Human Services, n.d.).

| Type/Name | Description | Eligibility | Relevance |
|---|---|---|---|
| **Grants** | | | |
| AmeriCorps Indian Tribes Grants | Corporation for National & Community Service provides funding for the investment in national service resources | Investment must be related to one of the following topics:<br>-Disaster Services<br>-Economic Opportunity<br>-Education<br>-Healthy Futures, positively impacting behavioral health outcomes and/or increasing the capacity of tribal communities to offer behavioral health prevention and support services<br>-Veterans and Military Families | Can be applied regardless of project scale |
| Awesome Foundation Micrograats | The Santa Fe chapter offers $1000 grants for projects that will enhance and improve Santa Fe | -Projects must help Santa Fe or immediate surrounding communities<br>-Project can be completed in a reasonable time frame | Can be applied regardless of scale as long as project is well organized |
| Bank of America grants (Bank of America Charitable Foundation) | Community grants and sponsorships are offered by Bank of America to help nonprofit organizations | Requests for proposals(RPPs) must be in one of the 3 following areas:<br>-Workforce development and education<br>-Community development<br>-Basic Needs | Can be applied for if project is residential or commercial scale |
| Conservation Innovation Grants | Competitive grants that stimulate the development and adoption of innovative approaches and technologies for conservation on agricultural lands | -Non-Federal governmental or nongovernmental organizations, American Indian Tribes, or individuals<br>-EQIP eligible | Can be applied for if project is residential or commercial scale |

| | | | |
|---|---|---|---|
| High Energy Cost Grants | USDA funding the improvement of energy generation, transmission, and distribution facilities in rural communities | Communities that have average home energy costs at least 275% above the national average. | Can be applied for if project is residential scale |
| Indian Community Development Block Grant | Part of Native American Housing Assistance and Self Determination Act of 1996, A formula grant that provides a range of affordable housing activities on Indian reservations and Indian areas | Be able submit to HUD an Indian Housing Plan (IHP) for it | Can be applied regardless of scale |
| Low-Income Home Energy Assistance Program (LIHEAP) | Federally funded assistance related to home energy bills, energy crises and weatherization/energy related home repairs | Must have issues relating to :<br>-Home energy bills<br>-Energy crises<br>-Weatherization and energy-related minor home repairs | Can potentially be applied to residential scale project |
| NIH Small Research Grant Program (Parent R03) | Financial Support for small research projects that can be carried out in a short period of time with limited resources | Must be one of the following:<br>-pilot and feasibility studies<br>-secondary analysis of existing data<br>-small, self-contained research projects<br>-development of research methodology<br>-development of new research technology | Can be applied regardless of scale as long as project is well organized |
| Conservation Innovation Grants | Competitive grants that stimulate the development and adoption of innovative approaches and technologies for conservation on agricultural lands | -Non-Federal governmental or nongovernmental organizations, American Indian Tribes, or individuals<br>-EQIP eligible | Can be applied for if project is residential or commercial scale |

| | | | |
|---|---|---|---|
| NIH Small Research Grant Program (Parent R03) | Financial Support for small research projects that can be carried out in a short period of time with limited resources | Must be one of the following:<br>-pilot and feasibility studies<br>-secondary analysis of existing data<br>-small, self-contained research projects<br>-development of research methodology<br>-development of new research technology | Can be applied regardless of scale as long as project is well organized |
| NOI: Cities Leading through Energy Analysis and Planning/EERE Funding Opportunity Exchange | A variety of funding relating to sustainable energy usage in cities | Varies by program | Can be applied regardless of scale |
| REAP grant (Rural Energy for America Program ) | Part of Farm Bill, grants and guaranteed loans to help purchase renewable energy systems | - Must be either an Agricultural Producer or Small rural businesses<br>- Rural defined as population of under 50,000 | Can be applied for if project is residential or commercial scale |
| USDA – Repowering Assistance Bio Refinery Program | USDA pays bio refineries to replace fossil fuels with renewable biomass | Eligible technologies may include, but are not limited to, anaerobic digesters, processed steam, biomass boilers, or combined heat and power technologies (CHP). | Can potentially be applied to commercial or utilities scale project |
| Weatherization Assistance Program (WAP) | Gives grants to states, territories, and some Indian tribes to improve the energy efficiency of the homes of low-income families | -State income requirements<br><br>-Preferences:<br>• People over 60 years of age<br>• Families with one or more members with a disability<br>• Families with children (in most states). | Can potentially be applied to residential scale project |

| | | | |
|---|---|---|---|
| **Bonds** | | | |
| Clean Energy Revenue Bond Program | Part of Energy Efficiency and Renewable Energy Bonding Act, program aims to help state agencies, universities, and public school districts cut utility bills and reduce energy use | All state agencies, universities and public school districts that occupy and maintain buildings owned by the state or school district are eligible to participate in the program | Can be applied for if project is utility scale |
| New Clean Renewable Energy Bonds | Part of Energy Improvement and Extension Act of 2008, $800 million allocated to finance renewable energy projects | Fill out application, Requirements are fairly vague | Very flexible, can be applied regardless of scale |
| **Rebates** | | | |
| New Mexico Gas | Residential energy efficiency programs to save money and energy by New Mexico Gas users | New Mexico Gas Company Residential Customer | Can be a financial source regardless of project scale |
| PMN | PNM offers money back for purchasing, installing or recycling of a qualified item and using less electricity every month | -Using under a certain threshold of electricity from PNM each month<br>-Possessing the qualified items | Can be a financial source regardless of project scale |
| **Tax Credits** | | | |
| Renewable Energy Production Tax Credit | Income tax credit based on amount of renewable energy produced | In city of Santa Fe<br>-Only for the first 1-400,000 megawatts of electricity generated per decade | Can be a financial source regardless of project scale |
| Solar Market Development Tax Credit | Federal tax credit that reimburses up to 30 % of the cost of a solar PV or solar thermal system | In city of Santa Fe | Can be a financial source regardless of project scale |

| | | | |
|---|---|---|---|
| Sustainable Building Tax Credit | Income tax credits for building energy efficient sustainable commercial, institutional and residential buildings. | In city of Santa Fe<br>-Commercial and institutional buildings must be 50% more energy efficient than standard building code. | Can be applied for if project is residential or commercial scale |
| **Other Incentives** | | | |
| Advanced Energy Gross Receipts Tax Deduction | Revenue generated by the sale and installation of a "qualified generating facility" may be deducted from gross receipts before the gross receipts tax is calculated | Follow the following process:<br>-Obtain a certificate of eligibility from the Department of Environment<br>-Present the certificate of eligibility to the Taxation and Revenue Department to obtain a nontaxable transaction certificate<br>-Give the nontaxable transaction certificate to the seller of the equipment | Can potentially be applied to commercial or utilities scale project |
| PNM Performance Based Incentive | PNM will purchase RECs from customers who install photovoltaic (PV) and solar thermal electric systems | Rates of payback vary based on electricity system | Can be a financial source regardless of project scale |
| Property Tax Exemption for Residential Solar Systems | Residential solar energy systems are usually able to be exempted from property tax assessments in New Mexico | Must be an "installation that is used to provide space heat, hot water, or electricity to the property and is: (1) an installation that uses solar panels that are not also windows; (2) a dark-colored water tank exposed to sunlight; or (3) a non-vented trombe wall." | Can be applied for if project is residential scale |