Investments in Energy Efficiency and Solar Photovoltaic Systems for the Tohono O'Odham Nation: An Economic Feasibility Study

by

Gnianso A. Dakouo

A Thesis Submitted to the Faculty of the

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

In the Graduate College

The University of Arizona

Year 2015

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona.

SIGNED: Gnianso A. Dakouo

APPROVAL BY THESIS DIRECTOR

This Thesis has been approved on the dates shown below

Professors Name Date

ACKNOWLEDGEMENTS

I would never have been able to finish my thesis without the guidance of my committee members, help from friends, and support from my family and wife.

I would like to express my deepest gratitude to my advisor, Prof. George Frisvold, for his excellent guidance, caring, patience, providing me with an excellent atmosphere for doing research, patiently correcting.

I would like to thank Prof. Trent Teegerstrom and Prof. Russ Tronstad for accepting to be part of my thesis committee. I would also like to thank Ardeth M Barnhart for allowing me the opportunity to work on the Tohono O'odham Land use plan.

I would like to thank the whole AREC department for their continuous support and also for allowing me the opportunity to begin with my higher education without formerly being accepted into the program as a Bachelor student. I also would like to thank my cohort for their help and guidance throughout the program.

I would also like to thank God, my parents, my older brother, and my three younger brothers. They were always supporting me and encouraging me with their best wishes.

Finally, I would like to thank my wife, Khadidjatou Koumare. She was always there cheering me up and stood by me through the good times and bad.

TABLE OF CONTENTS

LIST OF FIGURES

Figure 12: Result of the simulation with Net Metering, Vertical Tracking and a price of reduction of $1.50/watt for the Police Department.

Figure 13: Result of the simulation with Net Metering, Vertical Tracking and a price of reduction of $1.50/watt for the San Xavier Recreational Center.

LIST OF TABLES

ABSTRACT

Objectives: This study analyzes the costs and benefits to the Tohono O'odham Nation of alternatives to lessen their reliance on external supplies of electricity (grid dependency). Two options are considered: (a) investments to improve the energy efficiency for existing public buildings and (b) investments in distributed solar photovoltaic systems. Analysis considers the effects of interest rates, net metering options and the potential of solar tracking technologies on relative costs and benefits of alternative investments.

Methods: Estimates of investment options for energy efficiency were obtained from a detailed energy study (ASHRAE Level II) of 28 tribal facilities of >200,00 square feet conducted by 7th Gen Energy Solutions. Distributed solar photovoltaic options were assessed using the HOMER micro power optimization software developed by the National Renewable Energy Laboratory (NREL). Data on tribal facilities and local energy market parameters were used to evaluate the economic feasibility of alternative designs for grid-connected power systems for a variety of applications. Comparisons were made between (a) investments in improved building energy efficiency, (b) investments in new photovoltaic systems and (c) joint investments in both improved energy efficiency and photovoltaic.

Results: The HOMER analysis suggests that the optimal solution in alleviating grid dependency is to just retrofit the tribal buildings for improved energy efficiency. Given the current electricity pricing and taxation policies in place, this provided a higher payoff than either investment in PV systems alone or combining improved building energy efficiency measures with PV systems. A combination of lower price per watt for solar photovoltaic and an increase in current electricity price per kWh would make the investment more viable.

CHAPTER ONE: INTRODUCTION

In 2010, collaboration between the University of Arizona and the Tohono O'odham nation was set up to develop a land use plan. This collaboration will be the first in its kind for the Nation since it will help identify and give the Nation a planning document that addresses specific district needs and differences according to Assistant Professor Iris Patten (University of Arizona) the principal investigator for the project. The goal of this project would be to address housing, economic development, transportation, recreation, open space, water, energy, safety, land use, cost of development, public service and facilities, growth area, environmental planning and conservation.

This paper will look at achieving the energy goal of this project. The objective of this research was to evaluate the costs of alleviating the Grid dependency for 28 Tohono O'Odham public buildings. To achieve this goal, the energy modeling software chosen for this study was: HOMER (2012). HOMER, software developed by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy, has been frequently used in such feasibility analyses due to its flexibility in adding different components to work together. HOMER is a micro-power optimization model that simplifies the task of evaluating power system designs in a variety of applications. HOMER does both optimization and sensitivity analysis. It makes easier to evaluate many possible system configurations of the large number of technology options and the variation in technology costs and availability of energy resource.

CHAPTER TWO: LITERATURE REVIEW

Energy efficiency measures decrease the energy required in production of the same quantity of commodities that is goods and services or boost the production while maintaining the energy utilization steady. There are various energy efficiency measures that will be elaborated later in this study. These measures provide benefits that can be classified as direct or indirect which improve on the output level. According to IEA (IEA, 2012), the indirect benefits consists of minimal maintenance costs, high motivation levels, secure working environment.

Energy efficiency measures costs are commonly given in terms of additional costs as opposed to conservative technology costs. In most circumstances, the energy cost to the end customer is not regulated while this cost should not have a big difference with the cost of supply. If the two prices do not match then there is indiscretion since they mainly consider the fuel and electricity costs without including the development and environmental costs which are critical.

According to European Council for Energy Efficient Economy (ECEEE 2013), the energy efficiency non-price or indirect measures should be put in place to harmonize the function of prices. The most important objective of this type of measure is to generate the essential setting to pace up the growth and the use of market proficient gear, through encompassing the following practices; “Information for and communication with final consumers; Risk sharing with producers and distributors; R&D and dissemination of expertise in the field of energy efficiency; Deployment of specific financing mechanisms; Regulation of appliances and equipment, or for consumers’, this is according to the

Institute for European Environmental Policy (IEEP) in the UK.

The commonly techniques put in place to reduce the energy cost are; construction retrofits, power plants, combined heat, lighting and energy decrease technologies. An effective promotion and execution of creating energy efficiency standards improves the energy reliability of new buildings, consequently the equipment efficiency standards helps in reduction of energy utilization and release of the greenhouse.

Research shows that having information programs which provide precise and reliable content on energy consumption and energy efficiency controls is very handy in producers and consumers decision making processes. These programs may include; Forecasts of prospect energy costs, relative information to smoothen the progress of expertise on product selection and definite reference for producers' and clients' venture choices or conduct changes.

According to the study done by the Energy and Climate Change Department in the UK 2012, there are various benefits of energy efficiency measures: Economic Growth, Reduction of Green House and Reduction of Energy cost. Reduction in the domestic /household energy costs which results from the deployment of the efficiency measures will channel the income to other different use in the economy, and at the same time the organization will be able to minimize the operation costs and realize an increase their production.

A Building Research Establishment Modeling in the UK highlighted another benefit as Domestic and business users' savings. This means that improvement of the efficiency measures will lead to offering a reasonable pact to the consumers and therefore they are able to save the extra coin. There some other benefits that are inherent of the cost savings realized by applying the energy efficiency measures so of which may include improvement of the people's wellbeing. Most people will now be able to keep track of their health status since they got some disposable income to spend.

Another critical benefit is emission reduction, (The 2011 Carbon Plan, UK), sets out the energy efficiency measure to eradicate the greenhouse gas secretion to avoid global warming. Also by utilizing the energy efficiency measures there is a reduction in energy usage hence a continued safe energy system and by doing so there will be a little disclosure to global energy market cost increase and impulsiveness. This factor will enable the consumers to participate in the global export market and compete effectively by offering products that utilize little energy.

The most commonly costs experienced in such a procedure is the additional costs to the normal operation and expenditure costs on policies and programs. Energy efficiency measures may entail major aggravated costs for people undertaking the investment, which leads to a rise in the investment costs. Energy efficiency development may not be given a priority by the company since it was not among the planned for events. One of the factors that make the investment costs to remain high is lack of means to impel market growth hence being stuck with the embryonic markets. Misaligned monetary incentives may be considered as another cost related hindering factor.

Various studies suggests that the development of energy efficiency measures is cost-effective in the long run but the accomplishment cost is the barrier to implementation since most organizations or private investments cannot afford the costs required to implement the energy efficiency measures and therefore they source out for financiers. For Example in the UK, The Green Investment Bank (GBK) together with Societe

Generale Equipment Finance (SGEF) combined their forces to fund energy efficiency measures projects. This support plays a major role in helping the companies proceed with the development of the projects without having to worry about upfront cash.

According to the post evaluations done by the UK Institution Click Green, strongly suggested the benefits prevail over the costs of energy efficiency measures taking considerations both from the recipients and investors offering funds for the pertinent measures and policies.

CHAPTER THREE: METHODS AND DATA

Description of Buildings

The 7th Gen report [7th Gen E.S, 2011: 1] originally considered the effects of installing efficiency measures in 28 buildings. Information on building structures comes from that report. Of the 28 buildings, 24 are located in Sells, one is at the San Xavier Reservation south of Tucson, one is in Hickiwan, and the remaining two are located in Pisinimo and Meneger's Dam, Arizona. The buildings range in size from 994 square feet to 25,000 square feet and serve a variety of uses from office spaces to recreational centers.

The buildings are constructed with different framing materials. Wooden frame and stucco are the most common framing materials, followed by concrete block walls with R11 and R19 insulation, wooden frame with wood siding, wooden frame walls, and brick walls. The lighting fixtures found in most buildings are T-12 fluorescent fixtures with magnetic ballasts. There are also some T-8 fluorescent fixtures with electronic ballasts and a few incandescent fixtures.

The 28 buildings were divided into four categories based on their hours of operation.

1. *Buildings operating 8:00-8:30 a.m. to 5-5:30 p.m. Monday-Friday.* Twenty-one of the buildings, all located in Sells, fall in this category. All are single-story buildings, with the oldest built in 1930 and the newest in 1998. They are mostly offices and support spaces. They may also include meeting rooms, kitchens, clinics, exam rooms and break-room (e.g. the Family Assistance Building).
2. *Buildings operating (24 hours per day, seven days per week).* The Police Department

in Sells is the only building in this category. It is a two-story building, built in 1982. The building is continuously occupied, housing male and female inmates. The interior is comprised of offices, support spaces, a large kitchen, a dining hall, dormitories, individual cells, conference rooms, a control room, laundry facilities, and day rooms.

3. *Buidldings operating Monday through Friday 8 a.m. to 9 p.m., Saturday 11 a.m. to 7 p.m., and Sunday noon to 8 p.m.* Five recreational centers are in this category. Their interiors include offices, support spaces, a multi-use room, a kitchen, a game room, a lounge, a weight room, a computer room, a commons, a snack bar, a basketball court, a stage with changing rooms, and an aerobics room.
4. *Buildings operating Monday-Friday, from 7 a.m. to 8 p.m*. The Department of Education building in Sells is the only building in this category. It is a single story building with offices, support spaces, a break room, and a server room.

In sum, there are 21 buildings in category 1, one building in category 2, five buildings in category 3, and one building in category 4. Rather than conduct analysis for all 28 buildings, the Family Assistance Building was selected to be representative of 21 of the category 1 buildings and the San Xavier Recreation Center was chosen to be representative of all five of the recreation centers (category 4).

Energy Efficiency Measures

All the buildings surveyed in the 7th Gen report (7th Gen E.S, 2011: 63-68) qualified for at least one type of energy efficiency upgrade. The measures included lighting retrofits, lighting controls, window retrofits, airside economizers, programmable thermostats, evaporator controls, HVAC equipment replacement, heat exchanger treatment, thermostat relocation, general repairs, and increased cooling capacity.

For our analysis, we only evaluated measures with a payback period of less than five years. These measures included lighting retrofits, programmable thermostats, economizers, and occupancy sensors. Retrofitting lighting from T12 to T8 saves electricity since T12 uses more wattage than T8. Programmable thermostats allow for the automatic setting and control of the cooling system based on the occupancy of the building. Economizers save energy by drawing cool air from the outside when the ambient temperature and humidity is lower than temperature and humidity in the building. They are found on most cooling systems that have a capacity of 7.5 tons or more. Occupancy sensors monitor and control the use of lights based on the people are in rooms or hallways, automatically turning off lighting in unoccupied areas.

None of these types of measures had a payback period of less than five years for the Police Department, so it was assumed that such measures would not be installed there. Tables 1, 2 and 3 below show the annual electricity savings, implementation costs and payback periods for the other buildings to be evaluated. The 7th Gen report report gives a wide range of areas where energy savings could be achieved. For instance, none of the HVAC units have economizers installed, even though the units are pre-wired to operate them. The report also estimates the capital cost required to install different efficiency measures, the expected savings in kilowatt hours (kWh), and the payback time in years for the amount invested.

Efficiency Measures	Annual Electrical Savings (KWh)	Implementation Costs	Pay-Back In Years
Lighting Retrofit	11,641	$3,258	2.6
Programmable Thermostat	3,589	$629	1.6
Economizer	9,079	$1,680	1.7
Total	24,309	$5,567	

Table 1: Efficiency measures with a payback less than 5 years for the Family Assistance Building

Efficiency Measures	Annual Electrical Savings (KWh)	Implementation Costs	Pay-Back In Years
Occupancy Sensors	6,338	$840	1.2
Programmable Thermostat	5,426	$1,250	2.1
Economizer	92,495	$16,800	2.3
Total	104,259	$18,890	

Table 2: represents the efficiency measures with payback less than 5 years for the Recreational Center at San Xavier Reservation

Efficiency Measures	Annual Electrical Savings (KWh)	Implementation Costs	Pay-Back In Years
Lighting Retrofit	25,448	$5,527	2

Table 3: represents the efficiency measures with payback less than 5 years for the Education Department

A choice of settings in Homer allows the user to run simulations, This assumes the user has data on how much electricity would be saved in case the building is retrofitted with energy efficiency measures. This data when inputted into Homer, allows a simulation to be run simultaneously with the original data set. This allows a side-by-side comparison of PV installation with and without the efficiency measures. These efficiency measures, when properly chosen, can save significant amounts of electricity and compensate for their initial cost of installation.

Estimating Building Electricity Loads

According to 7th Gen energy study report (7th Gen E.S, 2011: 35-36), the estimated total electrical annual load of the 28 buildings is 2,902,111 kWh. This estimate is based on the monthly electricity usages of the months for which data were available. Most of the buildings in the study have nine months of monthly data, which spans from October 2010 to July 2011. Some have 10 months of data, but others only eight. There are 18 buildings with nine months of data from October 2010 to June 2011. Another building has nine months of data from October 2010 to June 11, with February 2011 data missing. Six buildings have eight months of monthly load data from October 2010 to May 2011. The last three buildings have ten months of data available from Oct 2010 to July 2011.

One of the information inputs required to conduct an analysis in Homer is a daily energy load profile, which in turn depends on the hourly load throughout the day. This daily energy profile can differ for buildings depending on whether it is a weekday or weekend. Hourly loads are greater for operating hours than for non-operating hours. During operating hours, buildings are occupied and use more energy for air conditioning, computers, lights, and so on. Energy loads are much lower during non-operating hours. According to the EIA (EIA, 2003), space conditioning and lighting together account for 70% of all energy consumed in a typical office building, with an additional 20% of energy consumption used to power office equipment. The remaining energy is consumed by: water heating, cooking, and refrigeration systems, as well as other miscellaneous uses.

For buildings that did not operate 24 hours per day, it was assumed that 90% of a building's electricity use occurred during operating hours, with the remaining 10% occurring during non-operating hours. A better way to have allocated electricity across the day would probably to have assumed that loads during non-operating hours were 10% to 20% of peak loads (EIA, 2009). However, given that we are examining a Grid connected system with net metering potential the difference in the estimates would not be significant.

The Family Assistance Building has an estimated annual electricity load of 46,168 KWh. This is an average of 3,584 KWh per four-week (28-day) period, with 3,225.6 KWh (90%) used during operating hours and 358.4 KWh (10%) used during non-operating hours. Over the 28 days, there are 180 working hours (9 hours / work day x 5 work days / week x 4 weeks =180 hours). The hourly load during operating hours is 3,584 KWh / 180h = 17.92 kW. There are 492 non-operating hours over the 28 days, 300 weekday hours and 192 weekend hours [((15*5=75)*4=300) + ((24*2=48)*4=192)]. The hourly load during non-operating hours is 358.4 KWh / 494 h = 0.73 kW.

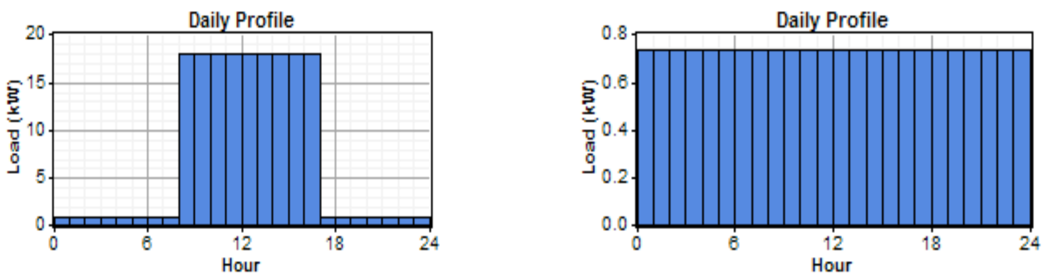

Fig.1: Assumed Hourly Daily Load Profile for the weekdays on the left and weekend on the right for the Family Assistance Building. Note: the graphs are not on the same scale.

The Department of Education Building has an estimated annual electrical load of 124,075kWh. It operates (is occupied) 13 hours on weekdays and does not operate on weekends. Following the same procedure as above, it is assumed that the Education Building's hourly load is 33.4 kW during operating hours and 2.43 kW during non-operating hours.

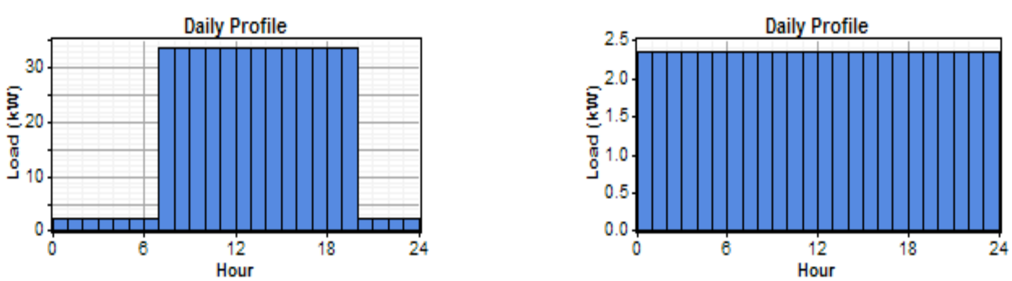

Fig. 2: Assumed Hourly Daily Load Profile for the weekdays on the left and weekend on the right for the Dept. of Education. Note: the graphs are not on the same scale.

The Police Department has an annual estimated electrical load of 451,668 kWh. It is in operation 24 hours per day every day, which averages to 1,237.45 kWh per day. To get the hourly estimated electrical load, the total daily load of 1,237.45 was divided by 24 hours, which gives an estimated hourly load of 51.6 kW.

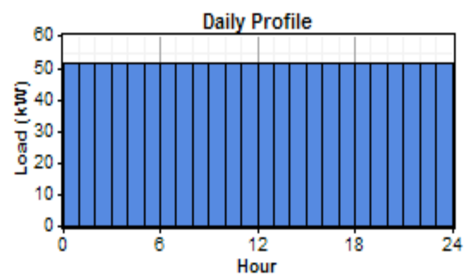

Fig.3: Assumed Hourly Daily Load Profile for the weekdays and weekends for the Police Department. Note: no distinction is made between weekend and weekday use because the building is in continuous operation.

The recreational center at San Xavier reservation has an annual estimated electrical load of 387,137 kWh. It is in operation 13 hours per day on weekdays and 8 hours per day on weekends. Following the same procedure as above, it is assumed that the hourly load is 83.64 kW during operation and 8.65 kW during hours of non-operation.

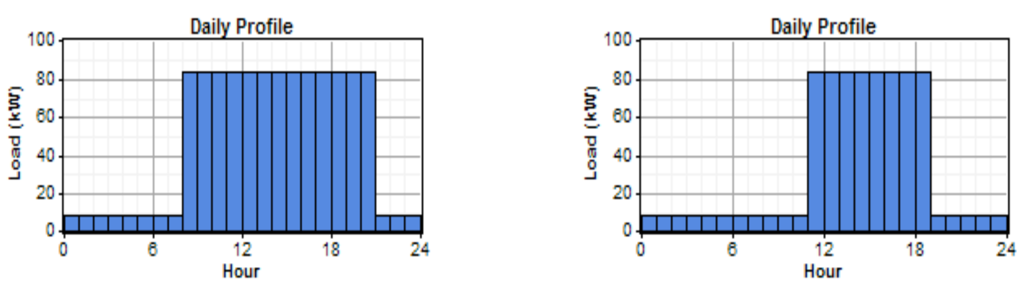

Fig. 4: Assumed Hourly Daily Load Profile for the weekdays on the left and weekend on the right for the San Xavier Rec. Center. Note: the graphs are not on the same scale.

Utility Rates in the Tohono O'odham Nation

The Tohono O'odham Nation meets its electricity needs through its own electrical company, the Tohono O'odham Utility Authority. The Tohono O'odham Utility Authority provides electricity to all the facilities in the study area (7th Gen E.S, 2011: 33). Given the information found on the electricity bills for each of the twenty-eight buildings, it was determined that the Tohono O'odham Utility Authority charged a fixed rate of $0.1085 per kWh.

The Efficiency Inputs

Efficiency inputs are measured by the combination of three things working simultaneously: an efficiency multiplier, capital cost and device lifetime. The efficiency multiplier is the factor by which this primary load would be multiplied if the efficiency package were implemented. The formula to determine the efficiency multiplier is expressed in percentage, as follows: 1- (total annual electrical savings in kWh / total estimated annual electrical usage). Capital cost is the amount of money required to implement the efficiency package. The lifetime is the number of years over which the capital cost is annualized. In this study, the lifetime is expected to be 12 years, the lifespan of economizers.

Solar Photovoltaic

The capital cost was specified to be $5.00 / watt before rebates. This price includes the price of the system plus installation cost and hardware needed for the installation. Replacement and O&M costs were considered to be zero because solar PV systems require minimal maintenance and the life expectancy chosen for this study is 30 years. A derating factor of 90% was chosen that accounts for elements such as temperature, dust and dirt that can negatively affect the performance of the module by causing losses of energy. A slope of 31 degrees was assumed because the solar PVs are not expected to be laid flat on the rooftop. The ground reflectance for rooftop with coating is expected to be 20%.

Inverter/Converter

Electricity generated from the solar photovoltaic system comes out as a direct current (DC), which needs to be converted to alternative current (AC) for usage. Homer allows the user to add inverters with the cost per watt, efficiency and lifespan to the solar system. An inverter transforms the electricity generated by the solar photovoltaic from a DC current to an AC current. The average price per watt for inverter is $.71 per watt (Solarbuzz, 2010). According to NREL (HOMER, 2012), the addition of an inverter is just like any other component in the functioning of the incorporation of an inverter/converter to invert the electricity generated by the solar photovoltaic from a DC current into an AC current. The inverter and the rectifier efficiencies were assumed to be 96% and 85% for all the sizes considered. A price of $0.71/w was considered with a lifespan of 15 years.

Economic Analysis

In the economic analysis segment, Homer allows users to enter two economic components critical for any business decisions: discount rate and project lifespan. For the analysis discount rates of 0% and 6% were chosen. The lifespan chosen for the study is similar to the corresponding lifespan for solar photovoltaic, estimated to be between 25 to 30 years. Based on that knowledge, a lifespan of 25 years was chosen for the duration of the loan. It is assumed that system investments are funded via loans that are paid back over the life of the project. A higher discount rate lowers the present value of future payments.

Solar Resource

Two estimates of solar resources were obtained for this study, one for Sells and the second for the San Xavier Reservation (nearest data from Tucson). These locations were chosen because they are where the study buildings are located. Both solar resources were obtained from NASA surface Meteorology and the solar energy website (NASA, 2013). The approximate location for the San Xavier Reservation is 32.2217-degree north and 110.9258-degree west and the approximate location for Sells is 31.9119-degree north and 111.8806-degree west. A solar radiation value of 5.83kWh/m^2/d was measured at both the San Xavier reservation and Sells, while a clearness index of 0.686 was registered at the San Xavier Reservation compare to 0.679 at Sells. Figures 5 and 6 show each location with their respective solar resources.

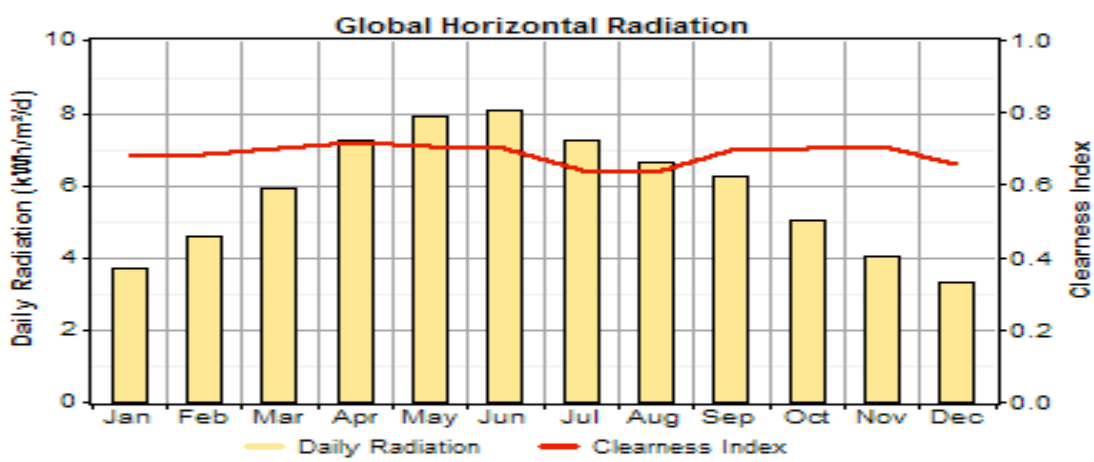

Fig. 5: Daily radiation and clearness index for Sells, AZ

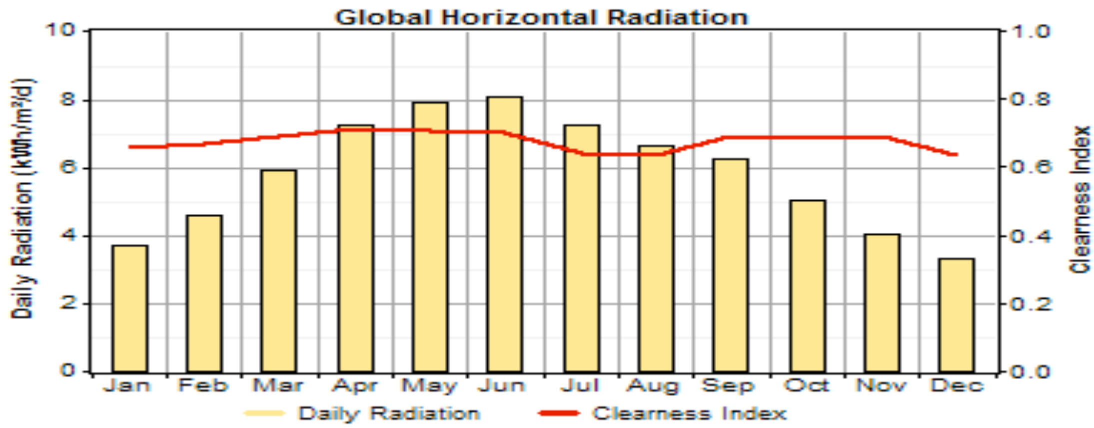

Fig. 6: Daily radiation and clearness index for Tucson, AZ (San Xavier District)

HOMER Requirement Data: Load profile

In the load profile, HOMER allows the user to choose between load types. The user may identify whether or not the energy generated from the energy source is alternative current or direct current. This allows Homer to identify and to suggest if more components need to be added to make the system feasible. After making this choice, Homer then allows the user to plug in 24 hourly values into the load table. Each of these 24 hourly values will correspond to the average electric demand for a single hour of the day. A different load profile can be entered for weekend and weekdays and for different months of the year to account for seasonality.

If the user does not impose differences by month, Homer will just replicate the initial profile throughout the year. However, because this assumption is overly restrictive, Homer allows for random variability between day-to-day and time step to time step. The random variability varies between 0 to 100% of the daily electricity use. This random variability is the standard deviation from the sequence of daily averages. It applies to both the average hourly data and the average daily data. For the hourly data, the random variability is recommended to be 15%, while the random variability for the average daily data, it is recommended to be 20%.

The effects of net metering and tracking were also analyzed. Net metering allows residential and commercial customers who generate their own electricity from renewable energy to feed that electricity back into the grid when they do not need it. In return, those same customers are able to reuse that same amount of electricity at a latter time when the need arises at no cost to them. According to database of state incentives for renewable energy:

> " [N]et metering allows electric customers who generate their own electricity using solar or other forms of renewable energy to bank excess electricity on the grid, usually in the form of kilowatt-hour (kWh) credits. These credits are used to offset electricity consumed by the customer at a different time during the same billing period" (Database of State Incentives for Renewable Energy, 2014).

Net metering allows renewable energy producers to avoid the cost of expensive battery banks for electricity storage and enables them to receive monetary benefits when the overall net electricity generation for their solar photovoltaic is positive.

In the mounting of solar PV systems, there are three options: (a) fixed tilt system, (b) single axis tracking, and (c) dual axis tracking. Each option has its pros and cons. The fixed tilt system is the most widely used setup because of its small space requirement. It can be directly mounted on rooftops or ground mounted at a fixed tilt angle. It also has the lowest installation and maintenance costs. On the downside, its annual energy output is the lowest. Single axis tracking systems are mounted on a North-South axis, which enables them to track the sun from East to West. Its annual energy output is about 24% more than the fixed tilt and it costs about the same for installation. However, it requires constant maintenance for the tracking mechanism and more space than the fixed tilt (Magee, 2010). The dual axis system tracks the sun from sunrise to sunset. It generates about 30% more annual energy than the fixed tilt, but it requires a lot of space (Magee, 2010). This system is also relatively expensive to install and has the highest maintenance cost of the three options.

Analysis considered the effects of installing PV systems to offset grid dependency by 25%, 50% and 75% for the four representative buldings. The effects of the PV systems were considered under two scenarios. In the first, it was assumed the PV systems were installed and operated with the existing features in the official buildings. In the second, it was assumed that the PV systems were installed after different efficiency measures included in the 7th Gen Energy Report were installed.

CHAPTER FOUR: RESULTS

This chapter presents the results of a economic analysis of producing electricity with solar photovoltaic (PV) systems on public buildings within the Tohono O'odham Nation. The analysis accounts for the the fact that these buildings are already connected to the main electricity grid. It also examines the effects of the PV systems with and without installation of the efficiciency measures examined in the 7th Gen report. The HOMER model summarizes the long-term impacts of each systemem in terms of total net present cost (hereafter as TNPC). TNPC measures the net present value of the the stream of costs and revenues over a system's lifetime. TNPC is a single lump sum reported in year-zero dollars, with future cash flows discounted back to year zero, using a discount rate. The analysis reported considered two discount rates, 0% and 6%. Costs may include capital costs, replacement costs, operating and maintenance costs, fuel costs, the cost of buying electricity from the grid, and miscellaneous costs such as penalties resulting from pollutant emissions. Revenues may include income from selling power to the grid (through net metering), plus any salvage value of equipment at the end of the project lifetime. The opportunity to earn some revenues lowers net cost. In all cases, costs are larger than benefits, so that the system with the highest payoff will be the system with the lowest TNPC.

The analysis considered four scenarios:

1. Status quo: the current electricity system (getting electricity from the grid) with no efficiency measures installed
2. Current electricity system (100% from the grid), but with the 7th Gen report efficiency

measures installed.

3. PV systems installed on the buildings, but with no efficiency measures installed
4. Both PV systems and efficiency measures installed together.

For three of the building types considered, Scenario 2 – installing efficiency measures, but not installing PV systems – was the least-cost system, in terms of TNPC. These results were expected because the price per watt for PV generated electricity is still not competitive with electricity produced by coal, natural gas and other conventional technologies. Scenario 2 was the best option both at a 0% and 6% interest rate. For one building type (the police station), the 7th Gen report did not include any efficiency measures with a payback period of five years or less. We therefore did not consider any efficiency measures for this building. Therefore, only Scenarios 1 and 3 were compared. In this case the status quo (Scenario 1) had a lower costs (TNPC) than installing PV systems. In none of the four cases, then, was installing PV systems the option with the lowest TNPC.

Scenarios 3 and 4 were divided into three sub-cases. These sub-cases made different assumptions about how much of a building's electricity would be generated by the PV system and how much would still be obtained from the grid. The sub-cases were (a) 25% of electricity came from the PV systems, (b) 50% from PV systems and (c) 75% from PV systems. Obtaining a greater percentage of electricity from PV requires that more PV panels are installed. So, moving from cases (a) to (b) to (c), costs will increase.

Table 4 shows the TNPC under the different scenarios and sub-cases for two discount rates, 0% and 6% and with no tracking. In all cases, installing PV systems increases costs. This is true when efficiency improments are installed and even when they are not installed. The additional cost of PV systems also increases for all buildings as a greater percentage of a building's electricity comes from the PV system. Installing a PV system that supplies 25% of a buildings electricity on a building that already has efficiency measures installed raises the TNPC from 27% – 41% at a 6% discount rate (comparing Scenarios 2 and 4a). Lowering the discount rate lowers this additional cost somewhat. The additional cost of installing PV (Scenario 4a vs. 2) falls to 6% – 12%. So, installing PV increases TNPC even at a 0% discount rate. Raising interest rates above 6% only increases the relative cost increase of installing PV further.

TNPC (0% discount rate)				
	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
Scenario 1	126,728	341,571	1,065,307	**1,225,701**
Scenario 2	**71,370**	**281,356**	**817,029**	
Scenario 3a 25% PV	134,071	381,913	1,114,314	1,336,282
Scenario 3b 50% PV	146,945	440,008	1,187,860	1,558,383
Scenario 3c 75% PV	163,555	573,243	1,467,381	2,786,262
Scenario 4a 25% PV	79,918	323,065	868,925	
Scenario 4b 50% PV	93,304	383,374	960,534	
Scenario 4c 75% PV	112,694	538,284	1,338,956	

TNPC (6% discount rate)				
	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
Scenario 1	64,800	174,657	544,728	**626,743**
Scenario 2	**39,130**	**146,437**	**426,560**	
Scenario 3a 25% PV	76,908	234,268	656,466	808,589
Scenario 3b 50% PV	94,629	311,311	791,863	1,075,304
Scenario 3c 75% PV	117,045	462,973	1,121,484	2,204,369
Scenario 4a 25% PV	51,855	206,747	539,775	
Scenario 4b 50% PV	69,837	284,922	684,409	
Scenario 4c 75% PV	93,674	477,668	1,064,601	

Table 4 : Shows the TNPC under the different scenarios and sub-cases for two discount rates, 0% and 6% with not tracking.

Effects of Adding Net Metering

Net Metering allows distributed electricity producers to sell back to utilities any electricity there are generating over and above their own use. At specific points in time, such as between 1 p.m. and 3 p.m. a PV system may be generating more electricity than a building needs, even though it is not producing enough electricity throughout the course of an entire day to supply all its needs without relying on the grid. Further, building that are closed on weekends are generating electricity then, but have minimal electricity demands. Net metering allows buildings with PV to generate some revenues that lower their TNPC. The revenues the Tohono O'odham Nation can get from net metering depend on how much electricity above their current use they generate and the price receive for the electricity. Under net metering, they price that they pay to purchase electricity.

Table 5 shows the difference of TNPC under the different sub-cases for two discount rates, 0% and 6% under net metering. Scenario 1 & 2 will not see any difference in their TNPC since they are not affected by the availability of net metering. In all sub-cases, making net metering available reduced the TNPC. This is true when efficiency impromentss are installed and even when they are not installed.

	Difference in TNPC (0% discount rate)			
	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
Scenario 3 25% PV	2,341	13,500	9,332	1,803
Scenario 3 50% PV	8,546	39,001	38,117	9,952
Scenario 3 75% PV	16,819	113,936	232,185	694,809
Scenario 4 25% PV	3,546	14,867	12,222	
Scenario 4 50% PV	10,262	42,582	59,070	
Scenario 4 75% PV	18,721	101,617	280,680	

	Difference in TNPC (6% discount rate)			
	Building 1	Building 2	Building 3	Building 4
Scenario 3 25% PV	1,197	6,903	4,772	922
Scenario 3 50% PV	4,369	19,943	19,490	46,507
Scenario 3 75% PV	8,600	58,260	118,724	355,280
Scenario 4 25% PV	1,814	7,602	6,249	
Scenario 4 50% PV	5,247	21,774	30,204	
Scenario 4 75% PV	9,573	51,960	143,521	

Table 5 : Shows the difference of TNPC under the different sub-cases for two discount rates, 0% and 6% under net metering.

Despite the fact that net metering decreased the TNPC for three of the building types considered, Scenario 2 – installing efficiency measures, but not installing PV systems – was the least-cost system, in terms of TNPC. Scenario 2 was still the best option both at a 0% and 6% interest rate. For one building type (the police station), the 7th Gen report did not include any efficiency measures with a payback period of five years or less. We therefore did not consider any efficiency measures for this building. Therefore, only Scenarios 1 and 3 were compared. In this case the status quo (Scenario 1) had a lower costs (TNPC) than installing PV systems with net metering.

Table 6 a and b show the changes in difference from the use of efficiency measures to the use of efficiency measures with net metering for the sub-cases to scenario 2 at 0% and 6% discount rates. The advantage of scenario 2 over scenario 4a decreased 24%-41% at 0% discount rate when net metering is made available.

TNPC (0% discount rate)

	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 1*
Over Scenario 4a	8,548	41,709	51,896	110,581
Over Scenario 4b	21,934	102,018	143,505	332,682
Over Scenario 4c	41,324	256,928	521,927	1,560,561

* For this case, the comparison is between Scenario 1 and 3a, b, c

* For this case, the comparison is between Scenario 1 and 3a, b, c

TNPC (0% discount rate)

	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
With net metering	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 1*
Over Scenario 4a	5,002	26,842	39,674	108,778
Over Scenario 4b	11,672	59,436	84,435	322,730
Over Scenario 4c	22,603	155,311	241,247	865,752

* For this case, the comparison is between Scenario 1 and 3a, b, c

Table 6a: Shows the changes in difference from the use of efficiency measures to the use of efficiency measures with net metering for the sub-cases to scenario 2 at 0%

TNPC (6% discount rate)

	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 1*
Over Scenario 4a	12,725	60,310	113,215	181,846
Over Scenario 4b	30,707	138,485	257,849	448,561
Over Scenario 4c	54,544	331,231	638,041	1,577,626

* For this case, the comparison is between Scenario 1 and 3a, b, c

TNPC (6% discount rate)

	Family Assistance Building	Department of Education	San Xavier Recreation Center	Police Station
With net metering	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 2	Advantage of Scenario 1*
Over Scenario 4a	10,911	52,708	106,966	180,924
Over Scenario 4b	25,460	116,711	227,645	402 054
Over Scenario 4c	44,971	279,271	494,520	1,222,346

* For this case, the comparison is between Scenario 1 and 3a, b, c

Table 6b: Shows the changes in difference from the use of efficiency measures to the use of efficiency measures with net metering for the sub-cases to scenario 2 at 6%

Effect of Adding Vertical Tracking

In step three, every hybrid system was retrofitted from no tracking to vertical axis with continuous adjustment tracking, which was then added to both step one and step two. In doing the retrofitting, the price per watt needed to be changed as well. According to the US Environmental Protection Agency, tracking adds somewhere from $1.00 to $2.00 to the actual cost per watt for solar photovoltaic (EPA, 2011). Since a capital cost of $5.70/watt was used with no tracking then a price per watt of $6.70 was chosen. The results suggest that including tracking does not add any substantial benefits to the hybrid systems. These results are due to two main factors: initial cost and lifespan. The combination of higher capital cost and same lifespan made it such that no real benefits could be experienced by the hybrid systems. Unlike step three, both step one and two brought no extra cost to the original capital cost of the system. This can be interpreted as pure gain as they only improved the system.

CHAPTER FIVE: SENSITIVITY ANALYSIS

This chapter considers three types of simulation to consider under which circumstances, installing PV might lower electricity costs. The first set of simulations considered effects of changing assumptions about electricity prices, costs of PV systems, and discount rates. The second considered the possibility that the Tohono O'odham Nation might receive carbon offset payments by reducing their CO2 emissions. The third considered the use of subsidy.

Changes in PV costs, electricity prices and discount rates

For all simulations in the first case, it was assumed (a) net metering was in place, (b) efficiency measures were installed in all buildings, except the police department (as discussed above), and (c) PV provided 25, 50 and 75% of at building's electricity. The simulations considered the effect of changing other model parameters on the payoff to installing PV systems in the four different systems. In particular analysis attempted to identify under what conditions installing PV would lower TNPC relative to not installing them. In other words, under what conditions would installing PV lower TNPC.

The simulations considered changing assumptions about the following parameters: (a) whether or not vertical tracking was installed; (b) the future price (per kwh) of electricity, (c) the discount rate, and (d) the cost per watt for PV. The electricity price assumed for the analysis above was the current electricity price quoted by the Tohono O'odham Utility Authority of $0.1085 / kWh. Simulations considered the effects of increasing the price of electricity from this level up to $0.12 / kWh. Discount rates were allow to vary continously between 0% and 6$. Installing vertical tracking allows systems to produce more electricity, but involves higher installation costs. Installing vertical tracking increases costs by roughly $1 per watt. The baseline cost per watt of PV was $5.70. Simulations considered reducing this cost by $1 per watt and by $1.50.

Figure 7a and 7b show a surface where installing PV (Grid/PV) is an improvement (i.e. has a lower TNPC) over not installing PV (Grid) and just relying on the grid for electricity. The results are for the Family Assistance Building. The figures show where installing PV provides a net cost reduction for different levels of the discount rate and electricity price. For Figure 7a, it is assumed that no tracking devices are installed on the PV systems. In this case, installing PV never reduces costs over all assumed ranges of discount rate and electricity price

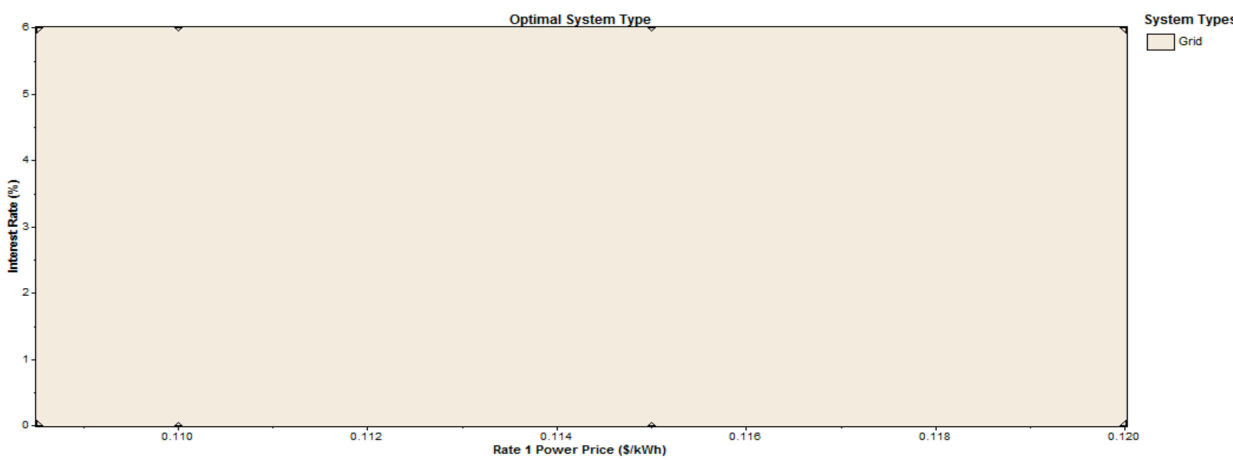

Figure 7a: Result of the simulation with Net Metering, No Tracking and a reduction of $1.00/watt for SPV for the Family Assistance Building. The optimal system is shown as Grid.

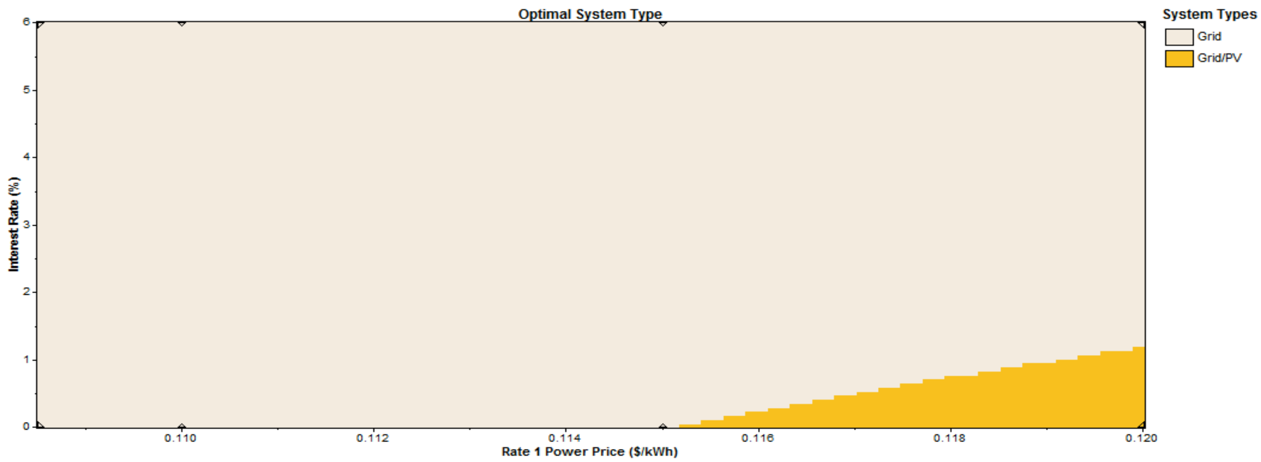

Figure 7b: Result of the simulation with Net Metering, Vertical Tracking and a reduction of $1.00/watt for SPV for the Family Assistance Building.

Figure 7b assumes that vertical tracking is installed. The orange color in the lower righthand corner indicates that installing PV lowers costs (TNPC) at very low discount rates (0% to 1) and for electricity prices rising above $0.115 / kWh.

Figures 8a and 8b show results for the Department of Education without (Figure 8a) and with (Figure 8b) vertical tracking. As before, installing PV does not lower costs

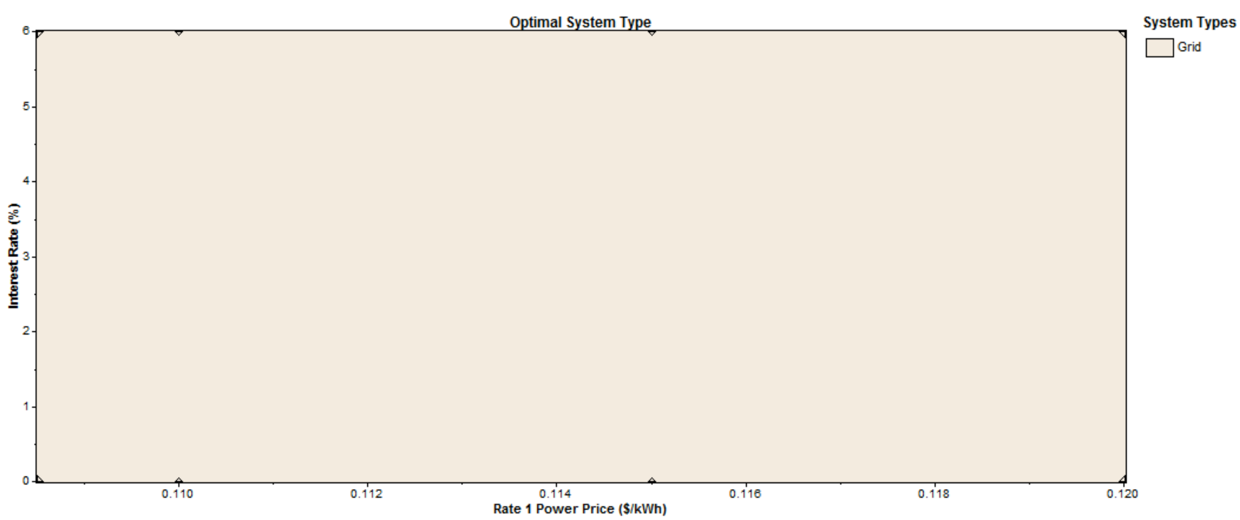

figure 8a: Result of the simulation with Net Metering, No Tracking and a reduction of $1.00/watt for SPV for the Department of Education Building.

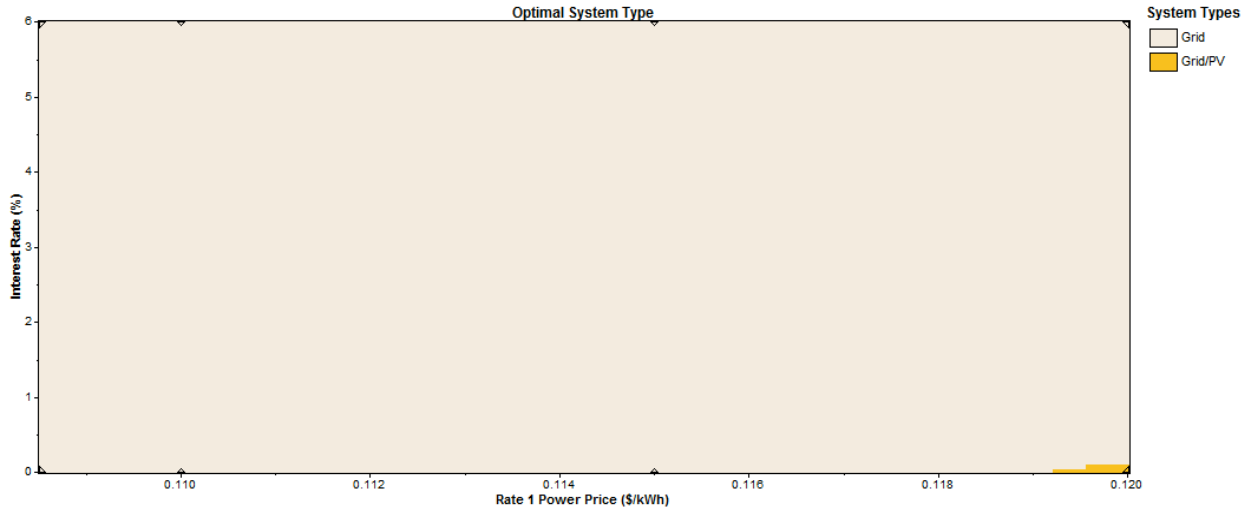

Figure 8b: Result of the simulation with Net Metering, Vertical Tracking and a reduction of $1.00/watt for SPV for the Department of Education Building.

without vertical tracking. In this case, however, even with vertical tracking, PV would only lower costs with a discount rate essentially 0% and with electricity prices very close to $0.12 / kWh. For the Police Department and San Xavier Recreational Center, installing PV did not lower costs even with vertical tracking, a 0% discount rate, and $0.12 / kWh electricity.

Results for the Family Assistance building with (Figure 9a) and without (Figure 9b) vertical tracking were compared. Now, however the cost of solar PV (SPV) was assume to fall by $1.50 / watt instead of just $1.00.

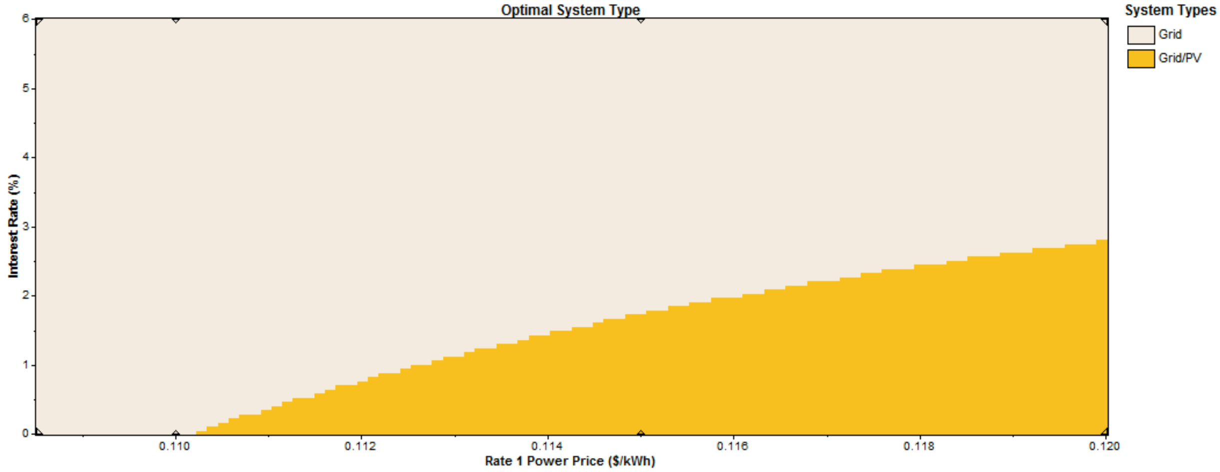

Figure 9a: Result of the simulation with Net Metering, No Tracking and a reduction of $1.50/watt for SPV for the Family Assistance Building.

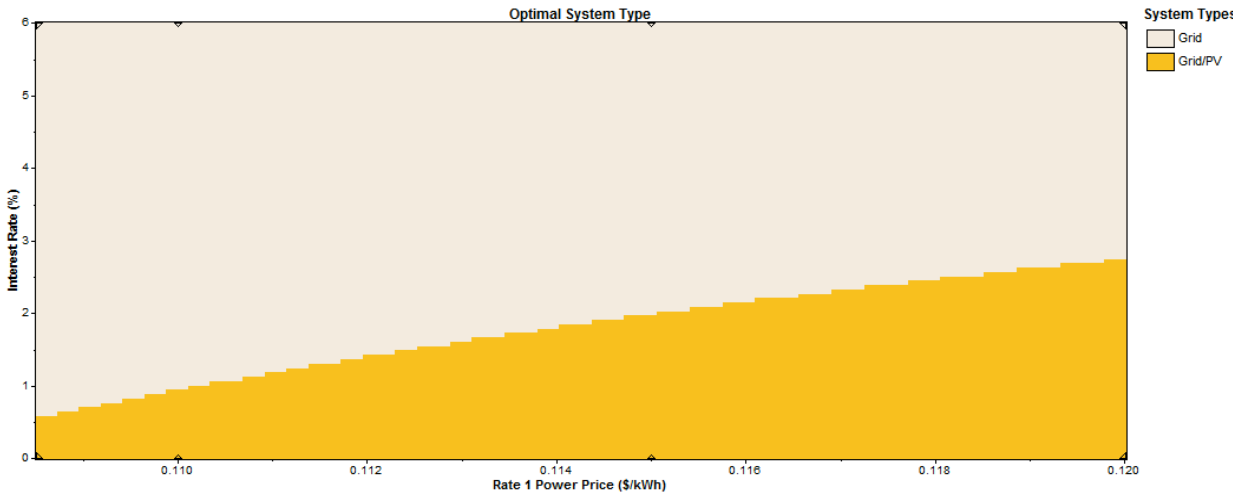

Figure 9b: Result of the simulation with Net Metering, Vertical Tracking and a reduction of $1.50/watt for SPV for the Family Assistance Building.

When PV costs fall by $1.50 / watt there are more combinations of discount rates and electricity prices for which installling PV lowers costs. There are even cases where installing PV lowers costs without net tracking. One finds similar results for the Department of Education Building (Figure 10a and 10b).

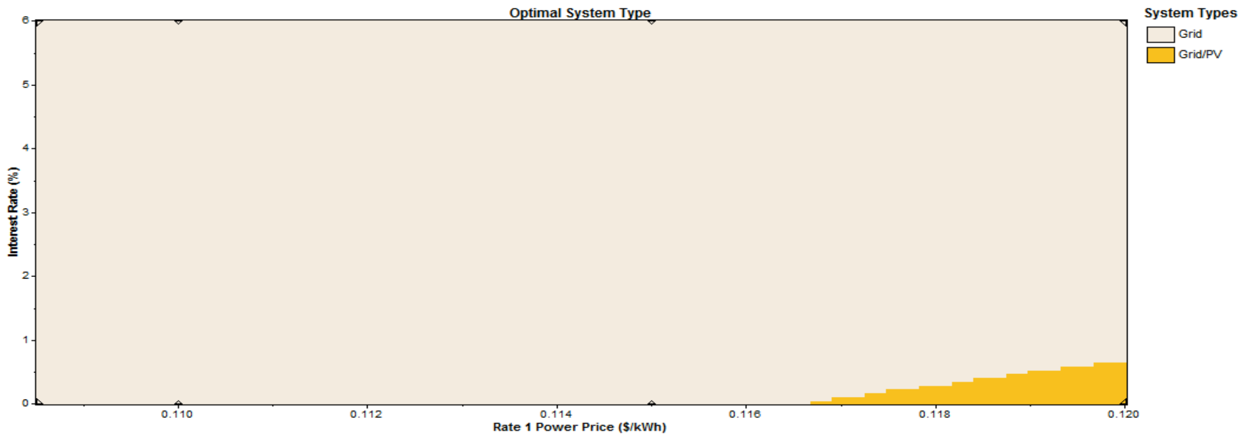

Figure 10a: Result of the simulation with Net Metering, No Tracking and a price of reduction of $1.50/watt for the Department of Education.

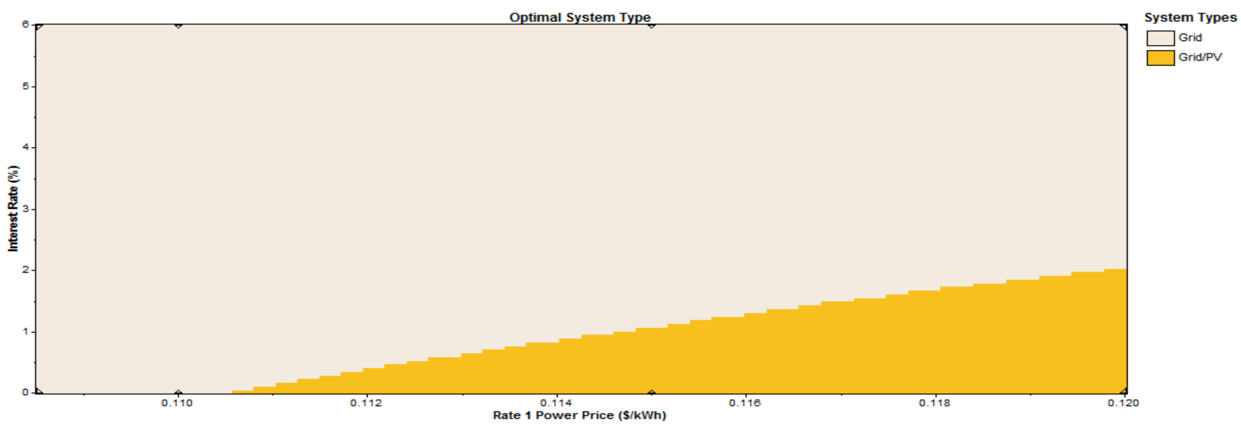

Figure 10b: Result of the simulation with Net Metering, Vertical Tracking and a price of reduction of $1.50/watt for the Department of Education.

For the Police Department and San Xavier Recreational Center a $1.50 reduction in the PV cost per watt still would not lead to a cost reduction with PV if there is no vertical tracking (Figure 11). Installing PV with vertical tracking would lower costs for the Police Department buildings only at a 0% discount rate and electricity prices of $0.12 / kWh (Figure 12). For the San Xavier Recreation Center there are more combinations of low discount rates and high electricity prices for which installing PV with vertical tracking lowers overall electricity costs (Figure 13). One difference between buildings is that efficiency measures were also available for the recreation center.

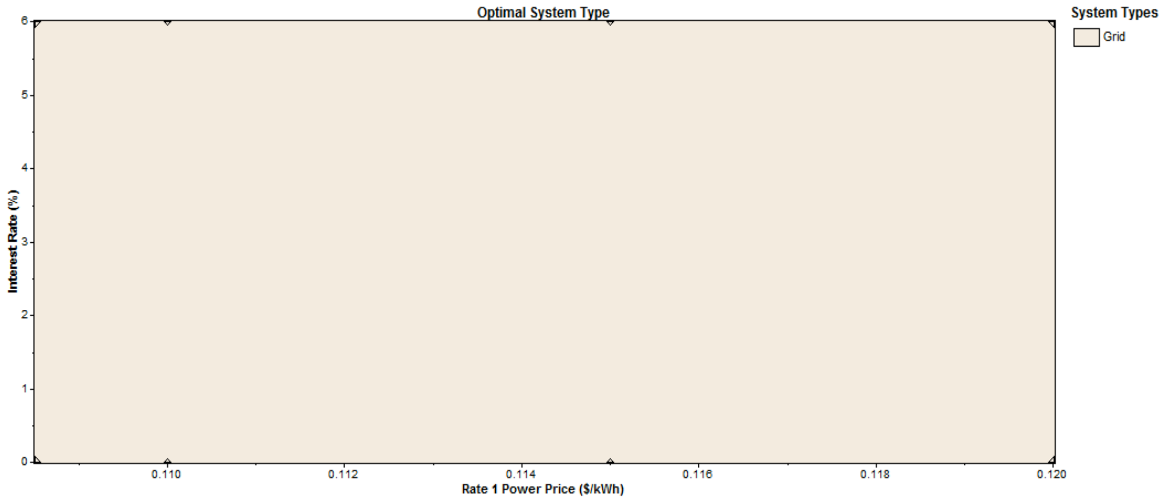

Figure 11: Result of the simulation with Net Metering, No Tracking and a price of reduction of $1.50/watt for the Department of Correction and the San Xavier Recreational Center.

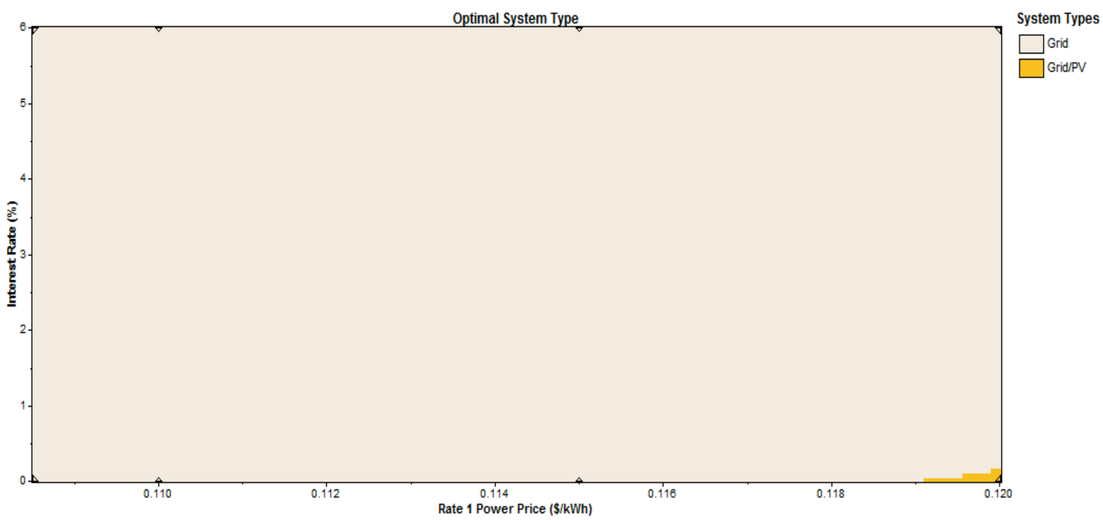

Figure 12: Result of the simulation with Net Metering, Vertical Tracking and a price of reduction of $1.50/watt for the Police Department.

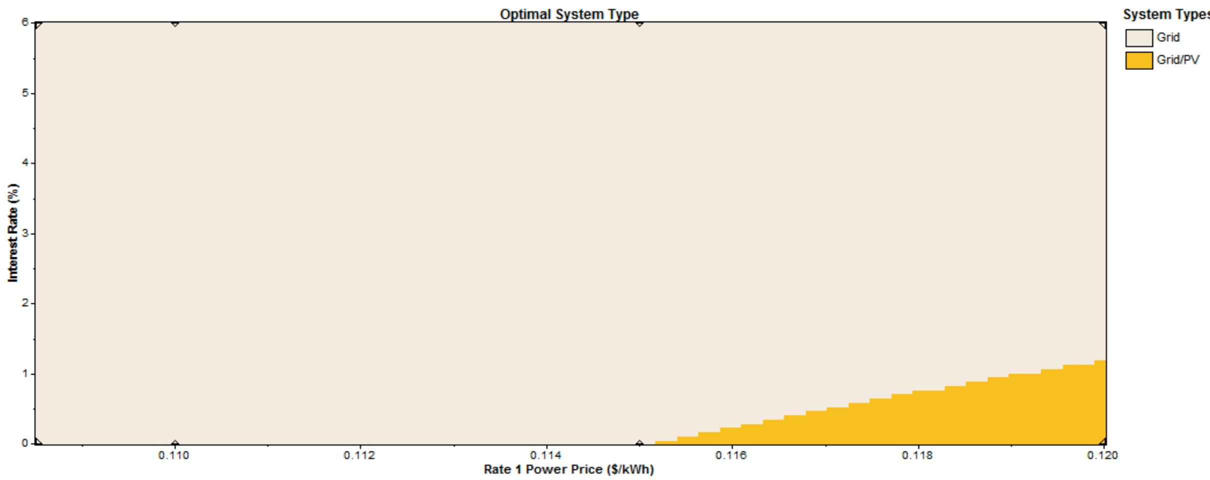

Figure 13: Result of the simulation with Net Metering, Vertical Tracking and a price of reduction of $1.50/watt for the San Xavier Recreational Center.

Effect of Credit Allowances for Reducing CO_2 :

The second simulation examined effects of the Tohono O'odham receiving monetary compensation for reducing CO_2. According to the Energy Information Administration, a credit carbon price of $32 and $65 are projected by 2020 and 2030 respectively for the ACESA Basic Case which represents an environment where key low-emissions technologies, including nuclear, fossil with CCS, and various renewables, are developed and deployed on a large scale in a timeframe consistent with the emissions reduction requirements of ACESA without encountering any major obstacles (EIA, 2009).

The result for the second simulation shows that the level of $C0_2$ reduction is dependent on the offsetting percentage of the hybrid systems. The higher the offsetting percentage is the higher the reduction. Installations of efficiency measures alone saved around 806.718 metric ton of CO_2 per year for the Grid. This reduction of CO_2 increased once solar energy was added to the Grid. The combined reduction of CO_2 by the hybrid systems with efficiency measures were noted at: 1,140, 1,523 and 2,228 metric ton of

CO_2/year at 25%, 50% and 75% dependency level respectively compared with 435, 945 and 2,007 metric ton of CO_2/year otherwise for all the buildings.

If the ACESA Basic Case projected price of CO_2 reduction were to be enacted, the installation of the efficiency measures alone in all the buildings could bring the Tohono O'odham Nation a monetary benefit of $25,814.00 and $52,436.00 per year in 2020 and 2030 respectively. These monetary benefits increase as solar photovoltaic is added to it. The higher the offsetting level is the higher the monetary benefit is. The monetary benefits are also seen to be higher for the hybrid systems with efficiency measures when compared to the hybrid systems without efficiency measures.

Table 7 below represents the total saving of CO_2 generated by using efficiency measures and solar photovoltaic from the twenty-eight buildings. The reduction level was calculated by taking the difference of CO_2 generated from the Grid and each of the hybrids system separately.

O2/kWh/yr	metric ton	Difference	By 2020 expected price $32	By 2030 P=$65	
1,256,863	1256.863	806.718	$25814.976	$52436.67	Grid w EM
923,442	923.442	1140.139	$36484.448	$74109.035	G+EM+25%
540,078	540.078	1523.503	$48752.096	$99027.695	G+EM+50%
-164,807	-164.8069	2228.3879	$71308.4128	$144845.2135	G+EM+75%
1,627,983	1627.983	435.598	$13939.136	$28313.87	G+25%
1,118,319	1118.319	945.262	$30248.384	$61442.03	G+50%
55,701	55.700553	2007.880447	$64252.1743	$130512.2291	G+75%
2,063,581	2063.581				G

Table 7: Represents the total savings of CO2 generated by using efficiency measures and solar photovoltaic from the 28 buildings.

Effect of subsidising the cost of PV systems

The final simulation examined the effect of subsidizing the cost of PV system installation. It was assumed that the cost of installation of PV systems was subsidized by 25% and then 50%. The simulations were run with our preexisting conditions, which are: (a) net metering (b) efficiency measures installed and (c) PV is providing 25%, 50% or 75% are in place, while taking into account the effect (a) discount rates and (b) vertical tracking. These simulations lead to four sets of tables for each level of subsidy.

The analysis considered four scenarios:

1. Status quo: the current electricity system (getting electricity from the grid) with no efficiency measures installed
2. Current electricity system (100% from the grid), but with the 7th Gen report efficiency measures installed.
3. PV systems installed on the buildings, but with no efficiency measures installed
4. Both PV systems and efficiency measures installed together.

PV installation cost subsidized 25% with no tracking

For three of the building types considered, Scenario 2 – installing efficiency measures, but not installing PV systems – was the least-cost system, in terms of TNPC. Scenario 2 was the best option both at 0% and 6% interest rate. For one building type (the police station), the 7th Gen report did not include any efficiency measures with a payback period of five years or less. We therefore did not consider any efficiency measures for this building. Therefore, only Scenarios 1 and 3 were compared. In this case the status quo (Scenario 1) had a lower costs (TNPC) than installing PV systems. Table 8 a and b show the results of subsidising the PV cost by 25% with no tracking at both 6% and 0% interest rates.

6% IR and 25% PV cost Subsidy				
	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	64,800	174,657	544,728	**626,743**
Scenario 2	**39,130**	**146,437**	**426,560**	
Scenario 3 25%	71,436	207,415	640,969	743,542
Scenario 3 50%	80,285	247,193	749,548	886,297
Scenario 3 75%	91,345	317,788	956,835	1,450,089
Scenario 4 25%	45,766	179,195	522,801	
Scenario 4 50%	54,615	218,973	631,380	
scenario 4 75%	67,001	308,783	875,155	

Table 8a: Shows the result of subsidising the PV cost by 25% with no tracking at 6%.

0% IR and 25% PV cost Subsidy				
	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	126,728	341,571	1,065,307	**1,225,701**
Scenario 2	**71,370**	**281,356**	**817,029**	
Scenario 3 25%	127,745	348,463	1,094,257	1,270,354
Scenario 3 50%	128,424	356,832	1,126,918	1,324,931
Scenario 3 75%	129,636	372,382	1,189,271	1,692,453
Scenario 4 25%	72,097	288,248	845,978	
Scenario 4 50%	73,067	296,617	878,639	
scenario 4 75%	76,873	349,742	1,012,351	

Table 8b: Shows the result of subsidising the PV cost by 25% with no tracking at 0%.

PV cost is subsidized by 25% with vertical tracking

At a 6% discount rate, scenario 2 was the least-cost system, for three of the building types considered, and for one building type, only Scenarios 1 and 3 were compared. In this case, scenario 1 had a lowest TNPC. Table 9a shows the results of subsidising the PV cost at 25% with vertical tracking at 6%.

6% IR and 25% PV cost Subsidy

	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	64,800	174,657	544,728	**626,743**
Scenario 2	**39,130**	**146,437**	**426,560**	
Scenario 3 25%	71,726	208,766	644,732	747,884
Scenario 3 50%	80,960	250,184	757,557	895,946
Scenario 3 75%	92,503	349,329	1,002,921	1,659,687
Scenario 4 25%	46,056	180,546	526,564	
Scenario 4 50%	55,290	221,965	639,389	
scenario 4 75%	75,202	354,533	997,445	

Table 9a: Shows the result of subsidising the PV cost by 25% with tracking at 6%.

At a 0% discount rate, scenario 2 had the lowest TNPC for only one of the three building types, and scenario 4 (at 50% grid alleviation) - both PV systems and efficiency measures installed together – was the least cost system for the remaining two types of buildings. For the one building type without efficiency measures, scenario 1 still had a lower TNPC. Table 9b shows the results of subsidising the PV cost at 25% with vertical tracking at 0%.

0% IR and 25% PV cost Subsidy	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dep
Scenario 1	126,728	341,571	1,065,307	**1,225,701**
Scenario 2	71,370	281,356	**817,029**	
Scenario 3 25%	125,871	341,070	1,073,663	1,246,792
Scenario 3 50%	124,728	340,463	1,083,090	1,272,126
Scenario 3 75%	123,299	390,342	1,159,703	1,901,667
Scenario 4 25%	**70,513**	**280,855**	825,385	
Scenario 4 50%	**69,370**	**280,247**	834,812	
scenario 4 75%	84,308	395,306	1,131,813	

Table 9b: Shows the result of subsidising the PV cost by 25% with tracking at 0%.

PV cost is subsidized by 50% with no tracking

At a 6% discount rate, for three of the building types considered, Scenario 2 was the least-cost system, in terms of TNPC. Scenario 2 was the best option. For one building type (the police station), the status quo (Scenario 1) had a lower costs (TNPC) than installing PV systems. Table 10a shows the results of subsidising the PV cost at 50% with no tracking at 6%.

6% IR and 50% PV cost Subsidy	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	64,800	174,657	544,728	**626,743**
Scenario 2	**39,130**	**146,437**	**426,560**	
Scenario 3 25%	67,161	187,465	585,394	679,417
Scenario 3 50%	70,310	203,018	631,273	743,797
Scenario 3 75%	74,245	230,863	718,860	1,051,089
Scenario 4 25%	41,491	159,245	467,226	
Scenario 4 50%	44,640	174,798	513,105	
scenario 4 75%	49,901	221,858	637,180	

Table 10a: Shows the result of subsidising the PV cost by 50% with no tracking at 6%.

At a 0% discount rate, scenario 4 at all level (at 25%, 50% and 75% of grid alleviation by PV) had the least cost system in terms of TNPC for the three types of buildings. And for the one building type, scenario 3 (at 50%) - PV systems installed on the buildings, but with no efficiency measures installed – had lower TNPC followed by scenario 3 (at 25%). Table 10b shows the results of subsidising the PV cost at 50% with no tracking at a 0% discount rate.

0% IR and 50% PV cost Subsidy				
	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	126,728	341,571	1,065,307	1,225,701
Scenario 2	71,370	281,356	817,029	
Scenario 3 25%	123,180	328,513	1,038,682	**1,206,229**
Scenario 3 50%	118,449	312,657	1,008,643	**1,182,431**
Scenario 3 75%	112,536	285,457	951,296	1,293,453
Scenario 4 25%	**67,822**	**268,298**	**790,403**	
Scenario 4 50%	**63,092**	**252,442**	**760,364**	
scenario 4 75%	**59,773**	**262,817**	**774,376**	

Table 10b: Shows the result of subsidising the PV cost by 50% with no tracking at 0%.

PV cost is subsidized by 50% with vertical tracking

At 6% interest rate, for three of the building types considered, Scenario 2 was the least-cost system, in terms of TNPC. Scenario 2 was the best option. For one building type (the police station), the status quo (Scenario 1) had a lower costs (TNPC) than installing PV systems. Table 11a shows the results of subsidising the PV cost at 50% with vertical tracking at 6%.

	6% IR and 50% PV cost Subsidy			
	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	64,800	174,657	544,728	**626,743**
Scenario 2	**39,130**	**146,437**	**426,560**	
Scenario 3 25%	66,701	185,316	579,407	672,509
Scenario 3 50%	69,235	198,259	618,532	728,446
Scenario 3 75%	72,403	247,154	723,196	1,190,687
Scenario 4 25%	41,031	157,096	461,239	
Scenario 4 50%	43,565	170,040	500,364	
scenario 4 75%	55,102	252,262	717,720	

Table 11a: Shows the result of subsidising the PV cost by 50% with tracking at 6%

At a 0% discount rate, scenario 4 (at 25%, 50% of grid alleviation by PV) had the least cost system in terms of TNPC for the three types of buildings. And for the one building type, scenario 3 at all level (at25%, 50% and 75%) - PV systems installed on the buildings, but with no efficiency measures installed – had lower TNPC then the status quo (scenario 1). Table 11b shows the results of subsidising the PV cost at 50% with vertical tracking at 0% discount rate.

0% IR and 50% PV cost Subsidy	Fam. Ass. Bldg.	Dept. of Ed.	San Xavier Rec Center	Police Dept.
Scenario 1	126,728	341,571	1,065,307	1,225,701
Scenario 2	71,370	281,356	817,029	
Scenario 3 25%	120,846	317,620	1,008,338	**1,171,217**
Scenario 3 50%	113,003	288,538	944,055	**1,104,626**
Scenario 3 75%	103,199	288,167	879,977	1,432,667
Scenario 4 25%	**65,488**	**257,405**	**760,060**	
Scenario 4 50%	**57,645**	**228,322**	**695,787**	
scenario 4 75%	**64,208**	293,131	852,088	

Table 11b: Shows the result of subsidising the PV cost by 50% with tracking at 0%

CHAPTER SIX: DISCUSSION

In the economic analysis for this study, the 7th Gen Energy Report for the economizer was seen to save an estimated 30% of energy when air-side economizer is used. The 30% energy savings generated from air-side economizer is higher than what most energy efficiency reports have found (Liescheidt, 2015). In most case, studies regarding the benefits of air side economizer, the studies show an air side economizer energy saving rate of up to 10% in energy consumption (20% in mild and coastal area) (Liescheidt, 2015). Based on this knowledge, the results of this study might be overstating the benefits of energy efficiency measures. Nonetheless, even a 10% reduction rate in energy consumption would have made a positive impact on the hybrid system.

Another issue found regarding the air side economizer is: its reliability factor. This issue could also impact the results since HOMER uses the cost and lifespan of the efficiency measures on top of the capital cost to determine the total NPC. In the study the lifespan was taken to be 12 years for all three of the efficiency measures, but case studies have shown that for the most part, most economizers in use are not fully functional due to negligence (Liescheidt, 2015).

According to Steven Liescheidt from Continuing Education and Development Inc., his estimates indicate that only about one in four economizers work properly, with the remaining three providing sub-par performance or, worse yet, wasting prodigious amounts of energy (Liescheidt, 2015). This report just like many others have come to the same concludions. However, results, but with the advancement in technological parts found within an economizer, the likelihood of these breakdowns can be minimized with better design, controls, installation, monitoring, and maintenance, which can help economizers meet their potential.

In addition, the study did not take into account all of the available federal, state and electric company rebates. These rebates are structured differently. The federal rebate program is the same for all the states. However, the states and power companies have their own individual rebate systems. Among all the states, Arizona's rebate program is very competitively ranked and it offers some of the best rebate programs. Additionally, the rebate programs might be structured differently for the Tohono O'odham Nation. If rebates are available; it could significantly reduce the capital cost of the renewable energy, which will make all the hybrid systems more efficient.

This study showed that Net Metering was highly significant and its availability made the hybrid system a lot more efficient. When net metering was legislated, most states placed a solar cap on it. This solar cap place limits on solar production based on a percentage of a utility's historical peak load. With price per watt of solar going down, most states are edging closer to that quota number, which is starting a new debate whether or not that cap should be increased. Proponents of increasing the cap argue that without it, solar growth will ineventably come to an end (Schoenberg, 2015), opponents believe that the cap should not only be increased, but also that net metering needs to be restructured completely since people with solar installation are not paying their share of maintenance cost generated by net metering (Schoenberg, 2015).

According to a study done by

Heeter, J., Gelman, R., & Bird, L. (2014):

- Just over half of states with net metering policies today include caps on net metered capacity; several states without caps have triggers that when reached enable net metering to be reviewed.

- Currently, most states are substantially below their net metering caps or trigger levels, with the exception of New Jersey and Hawaii. Some utilities in Massachusetts and Vermont recently reached caps, prompting legislative action
- Based on projections of near-term distributed PV capacity additions, a handful of states could reach current cap levels by 2018.
- Considerations for setting and adjusting net metering cap levels may include interaction with other policies as well as potential rate and grid impacts.
- Communication about the status of net metering when installations are nearing the level of the cap is important for providing certainty to solar customers and project developers
- Clear definitions of caps and data sources are important for providing accurate information to the market about progress toward reaching a cap.

These findings are showing that in the near future, debate over net metering will be significant and depending on how that debate goes will dictate in some extent the economic growth of solar energy.

The lack of having appropriate hourly load could have biased the results. Not having the hourly load caused us to make a calculated assumption, which assumed that 90% of the electricity usage happens during operating hours, while the remaining 10% happens during non operating hours. Accordingly, since most buildings in the study are open during daylight, the assumptions made helped the renewable energy in use. Moreover, if the assumption is even 70/30, the impact on the result would be significant if Net Metering were not available because most of the energy produced at higher levels of offsetting the Grid dependency would not be all used.

CHAPTER SEVEN: SUMMARY

The objective of this research was to evaluate different investment options to alleviate the Grid dependency for 28 buildings public buildings on in the Tohono O'odham nation. This was done by comparing the cost and benefits of options, under differing assumptions about the rate of discount, the availability of net metering, and the availability of solar tracking. Alternatives considered included:: alleviating Grid dependency by: (a) implementing energy saving retrofitting, (b) installing solar photovoltaic (PV) systems, and (c) combining options (a) and (b).   . The research relied on an earlier energy efficiency report conducted by 7th Gen Energy Solutions (7th Gen), a consulting energy firm, in 2011. It also made use of the HOMER energy modeling software (Homer, 2012). Combining information from 7th Gen energy report and the modeling capacity of HOMER, we were able to design and analyze different investment options. Analysis was conducted for four building sites, chosen because they were representative of four building types that included all 28 public buildings.

The results showed that the superior option to alleviate Grid dependency was to just retrofit the buildings with the energy efficiency measures. Installing PV systems in combination with installing efficiency measures reduced Grid dependency at lower cost than simply installing PV systems. In none of the majore cases considered, however, did installing PV reduce net present costs below just installing efficiency measures. Allowing net metering improved the cost performance of PV systems, but they still increased costs over installing efficiency measures alone.

The study concluded be examining whether PV might become the preferred option (in terms of lowest cost) if (a) credits for carbon sequestration could be earned or

(b) if they could receive cost-share subsidies on the installation costs for PV systems. Assuming that payments could be received for carbon emission reductions reduced the net costs of PV systems, but not sufficiently to make them a preferred option. This, even with assumptions of extremely large payments for carbon emission reductions. Subsidies for installation costs could tip the balance in favor of PV systems. However, the rate of subsidy would have to be relatively high. Under a wide range of scenarios, a 25% subsidu was insufficient to make PV installation a preferred choice. At a 50% subsidy rate, and assuming a 0% discount rate, PV installation did finally have the potential to reduced net present costs.

REFERENCES

DSIRE, (2014). *Description in DSIRE Solar Portal*. Retrieved 13 May 2015, from http://www.dsireusa.org/solar/solarpolicyguide/?id=17

EIA, (2009). *EIA-Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009 - Executive Summary*. *Eia.gov*. Retrieved 24 June 2015, from http://www.eia.gov/oiaf/servicerpt/hr2454/execsummary.html

EIA (2009), *National Action Plan for Energy Efficiency Sector Collaborative on Energy Efficiency Office Building Energy Use Profile*. Retrieved 18 May 2015, from http://www.iluvtrees.org/wp-content/uploads/2009/05/iltofficebuildingprofile.pdf

EPA, (2011). Solar reuse assessment rockwell International Corp. Site in allegan, michigan. Retrieved from http://www.epa.gov/superfund/programs/recycle/pdf/rockwell-assessment2011.pdf

Heeter, J., Gelman, R., & Bird, L. (2014). *Status of Net Metering: Assessing the Potential to Reach Program Caps*. *National Renewable Energy Laboratory*. Retrieved 18 May 2015, from http://www.nrel.gov/docs/fy14osti/61858.pdf

Homerenergy.com, (2012). *HOMER - Hybrid Renewable and Distributed Generation System Design Software*. Retrieved 13 May 2015, from http://www.homerenergy.com

Governement, U. (2012). *The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK* (1st ed.). London: Department of Energy and Climate Change. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65603/6928-the--energy-efficiency-strategy-statistical-strat.pdf

Institute for European Environmental Policy,. (2013). *REVIEW OF COSTS AND BENEFITS OF ENERGY SAVINGS Task 1 Report 'Energy Savings 2030'*. Retrieved 13 May 2015, from http://www.ieep.eu/assets/1267/Energy_Savings_2030_IEEP_Review_of_Cost_and_Benefits_of_Energy_Savings_2013_published.pdf

Liescheidt, S. *Economizers in Air Handling Systems*. *Economizers in Air Handling Systems*. Retrieved 13 May 2015, from https://www.cedengineering.com/upload/Economizers%20In%20Air%20Handling%20Systems.pdf

Magee, Steven, *Solar Photovoltaic Resource for Residential, Commercial and Utility Systems*, 2010, 102p.

NASA, (2013). *NASA Surface meteorology and Solar Energy - Location*. Retrieved 13 May 2015, from https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip@larc.nasa.gov

Schoenberg, S. (2015). *State cap stalls Massachusetts solar projects*. *masslive.com*. Retrieved 24 June 2015, from http://www.masslive.com/politics/index.ssf/2015/05/massachusetts_solar_projects_s.html

Solarbuzz, Inverter Price Highlights: Oct. 2010. [Online]. Available: http://www.solarbuzz.com/Inverterprices.htm

United Nation, U. (2008). *Policies and Measures to Realise Industrial Energy Efficiency and Mitigate Climate Change | UN-Energy Knowledge Network*. *Un-energy.org*. Retrieved 13 May 2015, from http://www.un-energy.org/publications/45-policies-and-measures-to-realise-industrial-energy-efficiency-and-mitigate-climate-c

University of Arizona News,. (2015). *UA, Tohono O'odham Nation Collaborate on Land-Use Plan*. Retrieved 13 May 2015, from http://uanews.org/story/ua-tohono-oodham-nation-collaborate-land-use-plan

U.S Energy Information Administration (EIA). (2009). *EIA-Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009 - Executive Summary*. Retrieved 13 May 2015, from http://www.eia.gov/oiaf/servicerpt/hr2454/execsummary.html

World Energy Council, (2012). *Energy Efficiency Policies around the World: Review and Evaluation*. Retrieved 13 May 2015, from http://archive-org.com/page/640011/2012-11-12/http://www.worldenergy.org/publications/energy_efficiency_policies_around_the_world_review_and_evaluation/1_introduction/1176.asp