Senior Capstone Project

Implementing Photovoltaic Panels and Thermal Water Heating

The University of Arizona

College of Architecture – Sustainable Built Environments

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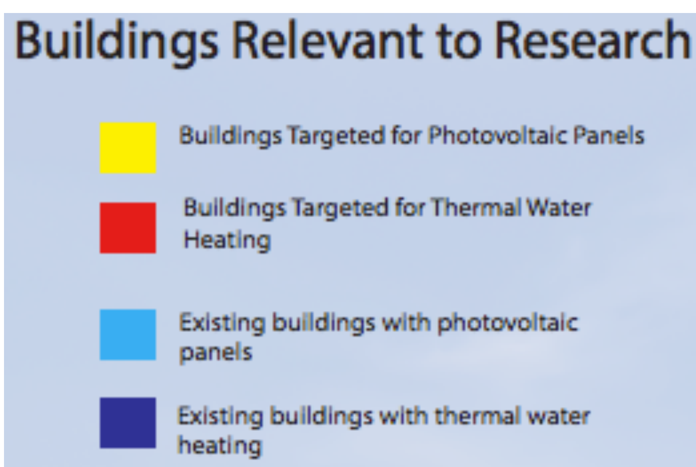
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Acknowledgements

I would like to thank everyone who has contributed to this research paper. I have learned a lot and could not have done this without the help of:

- Steven Marker
- Edward Galda
- Ladd Keith
- Joseph Luliano
- All of my professors over the past four years

Thank you for all of your help and dedication.

Abstract

In today's society we are faced with many problems that result from the use of traditional energy sources. Due to the lack of efficient alternative energy sources we are consistently trying to produce technologically advanced methods and tools to offset our dependency on traditional energy systems that are harming the planet as a whole. Every great accomplishment needs a starting point. The University of Arizona is going to an influential success story that gets the ball rolling. Implementing two energy saving tools known as photovoltaic panels and thermal water heating units will allow advocates to see the benefits that can come from sustainable technology. Through state and federal incentives solar panels are able to pay themselves off over the years in a majority of the states. Without federal or state incentives, the solar panels would not save the consumer enough money to repay their initial investment. Thermal water heating units save the consumer enough money to pay themselves off over the years. Overall both thermal water heating units and photovoltaic panels provide a clean source of energy.

Introduction

In today's society we are starting to witness a huge emphasis on sustainability. Forms of alternative energy production such as solar panels and thermal energy have been implemented into the University of Arizona and all around the world. Is it worth it for the University of Arizona to continue constructing space for solar energy in order to reduce emissions caused by traditional energies? Forms of energy such as fossil fuels, nuclear power, hydroelectric power, wind power, and solar power are all relevant in today's functioning society and infrastructure. Some energy sources are used more frequently then other sources of energy, but still contribute to the momentum and growth of alternative sources of energy. Fossil Fuels have been used throughout history and led to a global dependency on this energy source. The goal of this paper is to find out why we are not utilizing cleanlier forms of energy. What is stopping people from integrating solar and thermal water heating into every infrastructure? Will these alternative methods reduce the use of traditional forms of energy? Where should photovoltaic panels and thermal water heating units be implemented on the University of Arizona campus?

In the United States, the major energy sources are natural gas, petroleum oil, nuclear, coal, and renewable energy. The United States depends on coal to produce 40% of the electricity. Coal produces emissions that are linked to acid rain, smog, global warming, and health issues. In 2011, Petroleum produced 42% of the energy related carbon emissions while coal produces 34% and natural gas produces 24%. If the growth rates of alternative energy were met by 2030, the carbon dioxide emissions would decrease by 4 billion metric tons. These are some of the facts that will come into play when comparing energy sources. Pros and Cons will be measured and brought to light.

Solar water heating systems and photovoltaic panels are able to offset energy consumer's dependency on traditional forms of energy that are considered environmentally unfriendly. Solar water heaters are considered a cost effective way to provide hot water for domestic uses. They can be used in any climate and are fueled by the sun. Two types of passive solar water heating systems currently exist, direct and indirect circulation systems. Direct circulation pumps circulate water through the collectors and into the building. Indirect circulation systems circulate a heat transfer fluid through the collectors and a heat exchanger (E.GOV). This process heats the water, and then it flows into the building.

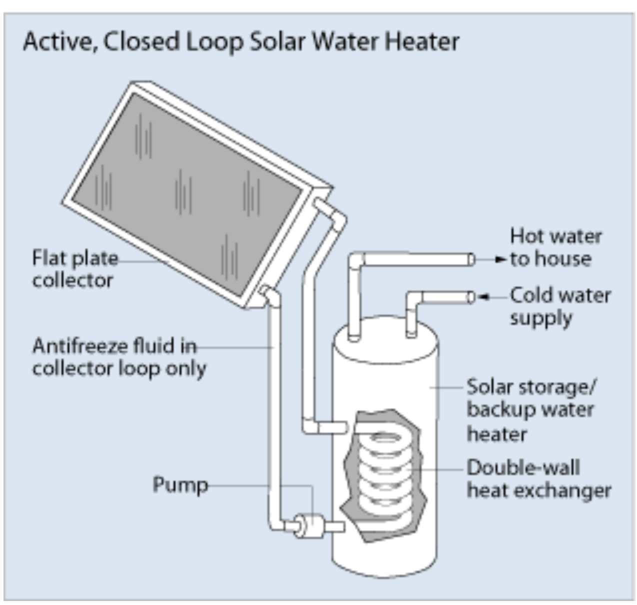


Figure 1- *The image above is a representation of how an active, closed loop solar water heater works provided by energy.gov.*

Passive solar water heating systems are known to be less expensive and less efficient than active systems, but they have been known to last longer and be more reliable. There are two types of passive systems, integral collector storage passive systems and thermosyphon systems. Integral collector storage passive systems are notorious to be the most effective in areas where the temperature infrequently drops below freezing. Buildings with daytime and evening hot water needs benefit from integral collector storage passive systems more than others. Thermosyphon systems have water flow through the system as warm water escalates and cool water descends. The batch collector is installed bellow the tank in order for the warm water to rise. These systems haven proven to be reliable but are usually more expensive then integral collector storage passive systems. (E.GOV)

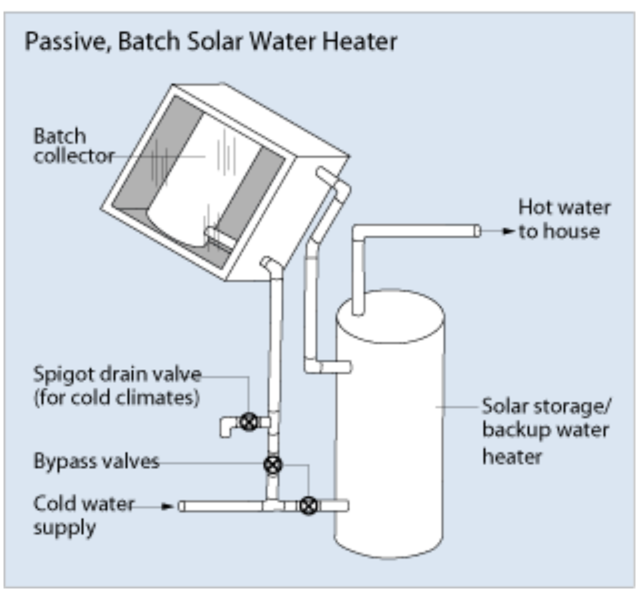


Figure 2 – *The image above is a representation of how a passive, batch solar water heater works provided by energy.gov.*

Photovoltaic panels convert light into electricity at the atomic level. Some panels consist of a property referred to as photoelectric effect. According to NASA, the photoelectric effect causes the panels to absorb the photons of light and release electrons. Once the electrons are captured, they can produce electric currents that can be used as electricity. The solar cells are made up of a semiconductor material such as silicon. A thin semiconductor wafer is treated to form fit an electric field that is positive on one side and negative on the other. Electrons are pounded loose from the atoms in the semiconductor once the light candidly hits the solar cell. The electrons are captured in the form of an electric current by attaching electrical conductors to the positive and negative sides. A solar module is made up of cells. In cases where there is more than one module, it is considered an array.

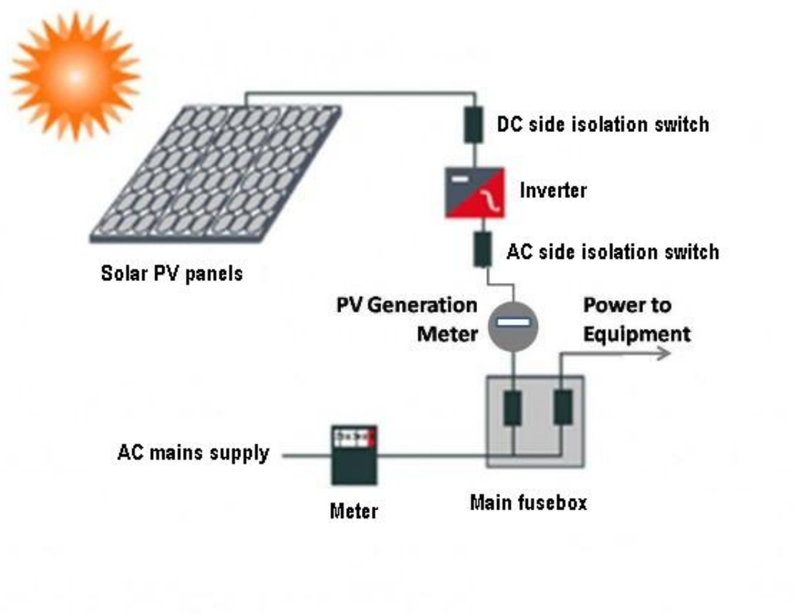


Figure 3- *The Image provided by CITIGAS represents how solar panels supply energy.*

The University of Arizona's current energy usage will be the area of study. Multiple buildings with high-energy and hot water consumption rates on the University's campus will be the primary focus. Each building will be analyzed to see if solar and thermal water heating could benefit the structure itself and others around it. If the buildings do not have these systems implemented, then figurative measurements will be taken. Analyzing what sources of energies are used within the building, and why some energy sources are used more then others will help relate this to a global standpoint. The campus has incorporated multiple energy sources over the years but is currently venturing into new sources at a small scale. Solar panels and thermal water heating systems have been implemented into a couple of the buildings on campus today. These buildings and parking structures with thermal water heating and photovoltaic panels will be used as examples. Through a carefully planned research approach, the factual and statistical information will lead to a conclusion. Buildings and other structures will be closely organized in order too see if thermal water heating and solar panels can be implemented.

Literary Review

"Solar power is energy from the sun that is converted into thermal or electrical energy." (SEIA)

Every day the sun beams down on Earth with more than enough energy to fulfill the global energy demand. The use of solar panels allows us to channel the suns energy and make it accessible. Today, we are familiar with photovoltaic cells, also known as solar panels. These panels are constructed of semiconductor materials similar to ones found in computer hardware. These semiconductors are able to consume the energy that is produced by the sun and provide an efficient and clean energy system. Current solar energy technology allows solar power to generate electricity, providing lighting and heating water for industrial, commercial, or domestic use. Solar energy is the cleanest and most abundant renewable energy source available on the market today. (SEIA)

The Institute for Energy Research provides the benefits that can come from this alternative energy source. The institute made it clear that solar energy only makes up 0.3% of the energy we use in the United States. Additionally, it only accounts for one tenth of one percent on a global scale. This is an extremely low percentile compared to fossil fuels. Reliability seems to be a very common word when it comes to explaining the pros and cons of energy sources. Solar energy is not considered very reliable due the availability of the source. Atmospheric conditions such as clouds and dust are some of the factors that play a role in the inconsistent energy production. The location of the earth relative to the sun is another inconsistency. There are plenty of factors that can affect the amount of energy gathered. Solar energy is often referred to as weak compared to other energy sources because it must pass through the atmosphere. The atmosphere is what protects the earth from the sun's intensity. The sun may produce more solar energy depending upon the atmosphere's conditions. (EPA)

The U.S. faces a dilemma; the industry is trying to provide economical manufacturing and installation costs while scaling up production of solar technology. Once this feat can be concurred, solar power and thermal water heating can be implemented into commercial, residential structures. Each of these forms is considered active solar systems, they use mechanical or electrical devices to translate the suns light or heat into usable energy that can be utilized for multiple purposes. Once the energy is collected it can be constructed as a central station or as a distributed generation. The difference between the two is that a central station is similar to a traditional power plant and distributed generation is located at or near the point of use. Mixed uses will determine which use is the most suitable for the designated site of interest. (SCITY)

Even though the United States faces the dilemma of providing economically affordable products, the U.S. solar industry is growing at a record breaking rate. According to the Progress Report: Advancing Solar Energy Across America, provided the United States Energy Department, the solar industry is becoming more affordable and accessible then ever before. The Energy Department believes that the industry's progress is partially due to the SunShot Initiative. The SunShot Initiative is a program that is dedicated to the development of low cost, highly efficient Photovoltaic technology. The U.S. Department of Energy has set a goal to make solar energy cost competitive with other forms of energy by 2020. After only a couple of years into the initiative, the solar industry is a little over 60% of the way toward accomplishing their goal of $0.06 per kilowatt-hour on a utility scale for photovoltaic panels. SunShot was established in 2011 in order to restore U.S. dominance in the solar marketplace by partnering with universities, industries, and local communities to decrease the cost of generating solar powered electricity. Since the beginning of the SunShot initiative, the average price per kWh has dropped from $0.21 to $0.11. (E.GOV)

In order to increase America's solar manufacturing and job growth, the United States Energy Department has invested $25 million dollars into the industry.

Most importantly the money invested is to keep America a competitor in expanding solar manufacturing. One of the positive aspects of the expanding industry is the employment that comes from it. Today, there are more than 140,000 solar workers in the United States. The industry has exceeded the growth exceptions and set the momentum for New Year with an expected 50% higher hiring rate. (

In the second quarter of 2014, The United States installed 1,133 megawatts of solar photovoltaic's to amount to a total of 15.9 gigawatts. To put this into perspective, this is enough energy to power 3.2 million homes. The U.S. Department of Energy has a long history in supporting photovoltaic's. They have invested a lot of time and money into creating technological advancements. Over the past 30 years the U.S. department of energy has fully or partially supported 50% of the records set for photovoltaic efficiency. This is just one of the large contributors to the movement of technological advancements in order to provide more efficient photovoltaic's. Money that is contributed toward the progress is a great reassurance for those who want to see solar energy become more prevalent in the United States.

States throughout the United States have started to role out incentive programs that emphasize the use of solar within buildings. According to the U.S. Solar Market Insight Report, small commercial used to be difficult to finance; today we are seeing a decrease in difficulty. There are more solar installations constructed on smaller residential spaces today then ever before. These statements account for non-residential buildings. Residential, non-residential and utility PV use have increased and shown evidence of becoming increasingly mainstream. Two major utilities, formally know as Arizona Public Service and Tucson Electric Power, have become the first utilities in the United States to propose a plan where they will own rooftops on their customers residential homes. Solar panels and solar water heating has become more desirable due to financial incentives for renewable energy. Every state in the United States offers some sort of incentive. Some states offer more incentives then others. Some incentives include personal tax, corporate tax, sales tax, property tax, rebates, grants, loans, industry support, bonds, and performance based incentives that will all save you money. These incentives can be offered by federal, state, utility companies, local and non-profit depending upon which state you are implementing solar.

The state of Arizona is said to have installed the third highest photovoltaic system installers in the United States of America according to the official Solar Market Insight Report provided by the Solar Energy Industries Association. California was ranked number one. The University of Arizona's largest contribution of photovoltaic research was organized by the Arizona Research Institute for Solar Energy, also known as AzRISE. AzRise is developing a portfolio of storage solutions to address the call for for dependable and efficient systems to deliver solar energy. Tucson Electric Power has partnered up with AzRise in order to expand the use of renewable resources in the southern region of Arizona. This partnership is known as the Bright Tucson project. It will be able to produce commission as well as a testing facility to further the progress of solar power. "Partnerships like these show an immediate return on research and solve problems in the widespread use of solar energy."(AzRise) This project uses a community based partnership that allows beneficial research to help others progress and critique the key issues that they may face in their process.

The Solar Zone, located at the UA Science and Technology Park, allows developers to test a plethora of solar technologies. Solar technologies can be closely analyzed inside of the park. The park is approximately 1.9 million square feet of facilities and space dedicated to studies. Within the park, there is research and development, lab space, and the business side of solar power. The close quarters allow the solar technologies to be evaluated and graded among others. Conclusions from these studies allow researchers to conclude which technology may be more reliable and economically reasonable. The Solar Zone allows solar technology to come out of development and into production. Once it is in production, consumers are able to apply a product that is going to provide one of the most efficient products on the market.(UA)

Facilities at Arizona State University and Northern Arizona University have developed and contributed research vital to the progress of this sustainable method of producing energy. ASU has partnered with TUV Rheinland Group to create TUV Rheinland PTL, LLC. This is a revolutionary certified facility constructed to test solar energy products from around the globe. This is very similar to the Tech Park at the University of Arizona. The testing facility is a new and improved version of the first

Photovoltaic Testing Laboratory, which was a pioneer in photovoltaic design and certification. Certification is provided for photovoltaic panels from North America, Asia, and Europe. ASU's photovoltaic testing lab has provided a multitude of services for many companies since 1992.(ASU)

Northern Arizona University is another contributor to the progression of solar technology. In 2008, Northern Arizona University created the third greenest building in the world. In 2011, NAU implanted a solar thermal system that provided hot water throughout their Health and Learning building. The EPA recently announced that they gave NAU a $15,000 grant to design an extremely low cost, non-polluting solar water heater for consumers. NAU is one of forty teams that have received a grant from the EPA to develop a solution to present day environmental issues. In the winter of 2014 the EPA will grant a phase 2 grant of $90,000 at a design expo.(NAU)

In 2009, the UA acquired fifteen million dollars from the US department of Energy to fund the Energy Frontier Center. This unique center will focus on the development of solar energy storage and transmission by collecting research and data from photovoltaic advancements. The University has a couple researchers involved in a new study that will bring biofuels to the market. The project was granted forty- four million dollars by the US Department of Energy. University of Arizona is a global leader in renewable energy research. They are currently pushing for a new material for solar cells that will allow them to become more efficient as well as economical.(UA)

University of Arizona's Planning, Construction, and Design department has completed research and studies that designate buildings with historical value. Buildings that are considered historical will not be able to have solar panels or thermal water heating units implemented on the rooftops. Due to the historical significance of these buildings, the University has banned any new construction that will diminish the historical value of these structures. Factors such as slanted tile roofs will prevent the photovoltaic panels from being placed on the roofs and create an "eye soar". The PDC department does not want to ruin the historical characteristics of the building on campus. (PDC)

The University of Arizona has already taken the initiative to implement a photovoltaic solar array on the second street garage on campus. This is one of the few existing infrastructures on campus that has been approved to harvest solar energy on the rooftop. These solar panels are able to create power and provide a Ramada for the busy rooftop. The photovoltaic array is 26,000 square feet, and consists of 1,152 PV modules facing south at a 10-degree angle. 200 kW of AC power will be used by the garage or fed into the University's electrical grid. The University claims, "future solar installations are planned for McClelland Hall, McClelland Park, Hillenbrand Aquatic Center and the Student Recreation center that will include both solar photovoltaic and solar water heating technology.(UA)

Current trends have shown that solar energy is rapidly being implemented into commercial buildings. One of the solar power powered tools is thermal water heating. It is becoming more prevalent due to the rise in energy costs and influence from the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED). Dormitories have become a desirable target by many College campuses for thermal water heating. The University of Arizona has made an effort to incorporate solar water heating as well as practice water efficiency. The University uses drought tolerant landscape designs in order to save water. Reclaimed water is used for irrigation and highly efficient irrigation system controls. Rainwater harvesting through the use of micro basins have been implemented in their water efficient framework. The University has emphasized that they will implement sustainable elements.(UA)

Apache/Santa Cruz Halls, Graham/Grenlee Halls, Kaibab/Huachuca Halls, and Arizona/Sonora Halls and Park Student Union are all buildings that have been are going to be emphasized. These buildings have a high demand for domestic hot water and therefore can use alternative forms of clean energy to heat the water. Instead of depending on fossil fuels, thermal energy can help provide a clean energy source that is efficient enough to give these buildings the hot water needed. Mechanical Engineers the PDC department at the University of Arizona believe that this is an economically reasonable technology to help heat water for kitchens, showers, faucets, and overall domestic use. The University of Arizona has cut off hot water to buildings that don't necessarily need it. It is considered a waste of money and energy to the school. It is proven that washing your hands with strong enough anti-bacterial soap does not require hot water to be effective. The water coming out of the faucet does not need to be a certain temperature to be FDA approved. This means that the University of Arizona can use thermal water heaters in order to provide hot water in the cafeterias without breaking any FDA regulations. (FDA,UA)

Point Loma Nazarene University has integrated solar water heating into their student housing. They have estimated that they will save $83,746 over 25 years. The total installed system cost came out to be $78,900. The CSI thermal incentive rebate was $48,465(PLNU official website). They implemented a Haase 940 gallon twin coil solar storage tank, and 36 Bosch-Buderas SKN 3.0 high-efficiency flat plate solar collectors. The project plans to avoid emitting 289 metric tons of carbon dioxide. That is equivalent to taking 57 cars off the road permanently, planting 7,405 trees to maturity, and offsetting the energy use of 25 years for one year. This project was made possible by the California Solar Initiative Thermal Program and the PLNU green fund. Now there are over 100 residents in the Nease Hall that receive solar heated hot water for the showers and laundry machines. PLNU was able to save energy and money while moving their campus toward an environmentally friendly campus. The advancements made in thermal energy have made it possible to mitigate environmental impacts and provide efficient and clean energy systems.(PLNU)

Marietta College has created a dormitory that they call the "sustainability dorm". The college's goal was to educate the students on sustainability by providing hands on experience. Marietta College approached Pickering Energy Solutions to provide photovoltaic panels as well as a thermal water-heating unit. They were able to successfully make their money back through incentives and energy production. This proved to be a successful demonstration for students and has led them to expand these practices throughout the campus. Marietta College is now expanding and pursuing other alternative energy sources in order to emphasize the importance of offsetting their carbon footprint. Pursuing a sustainable campus was highlighted as a very important aspect in the schools news. They have continued to openly emphasize the importance of alternative forms of energy available on the market. Marietta College believes that the cost of the solar energy powered tools is worth it to leave a smaller carbon footprint. (MC)

Colleges all over the United States have started to install thermal water heating units. Residence halls are the most popular thermal water heating installations on college campuses across America. Another popular use for solar water heating is for heating pools. Wisconsin-Green Bay and the University of Arizona are one of the many who have integrated solar water heating units into their pool. Harvesting the suns energy allows the heating units to keep the pool warm. Wisconsin-Green Bay saved 6.540 therms of natural gas in 2005. To put this into perspective that is the equivelent of producing hot water for 22 homes.

Technological advancements in thermal water heating units allow more energy to be saved.

A simple case study and "take off" has been carried out on the following buildings to help conclude what factors make these buildings able to inhabit solar panels or thermal water heating units. This will ultimately help provide the answer to where thermal water heating units and solar panels should be located throughout the University of Arizona Campus.

Building #1-Park Student Union, is a multi purpose building that provides space for multiple kitchens. This building demands a lot of hot water due to the kitchens. This is a great opportunity to implement thermal water heating. Since there is a high demand for hot water, thermal water heating could save energy and be used frequently (washing dishes, cooking purposes, etc). Fortunately, there are no rules or regulations provided by the FDA that have been found on the requirements for the heat of the water. There is plenty of room for photovoltaic panels and thermal water heating units on the roof. Air conditioning units and other appliances take up about 15% of the available space. 10% of the roof goes to space for functionality and concrete barriers. This allows roughly 75% of the roof to be inhabited by these solar tools if chosen.

Building #2-Student Union Memorial Center, is a multi purpose building that facilitates offices, a cafeteria, study rooms, and meeting halls. Hot water is used by the cafeteria for cleaning, cooking, etc. The roof is very large and flat, making it easy to implement solar panels. Since there is hot water being used in the building, thermal water heating would be a great way to offset energy costs that go toward heating hot water.

Building #3 - Likins Hall is student housing located on the University of Arizona campus. 369 can is the maximum capacity of students that can live in this living hall. Likins hall has a flat roof that already has solar panels located on the northern rooftops. Thermal water heating would be great for this Hall due to the amount of hot water being used for showers, laundry, etc. There is not too much room for solar panels to contribute a large offset.

Building #4 Coronado Hall is student housing located on the University of Arizona campus. Coronado is able to house 776 students within the building. This means that 776 are more than likely showering everyday and doing laundry 3 times a month on average. Hot water is in high demand within this building and would definitely benefit from thermal water heating. Solar panels could offset the energy used in order to produce the hot water, but thermal water heating units would be more efficient.

Building #5 - Puebla De La Cienega, Posada San Pedro, and Villa Del Puente are all student-housing units. All together these buildings can house 776 students. Four thermal water-heating units have been implemented onto the roof of Villa Del

Puente. The University of Arizona has reported that the thermal water heating units have proven to be very beneficial and environmentally friendly.

Building #6 Second street garage is a parking structure located on the University of Arizona Campus. Photovoltaic panels have already been implemented onto the roof of the parking structure. Due to the constructed canopy, the photovoltaic array of panels has plenty of exposure to light. Since there is no need for thermal water heating in this structure, it seems to be quite pointless to add a heating unit. The solar panels are able to provide the parking structure with enough energy to power the lights. Whatever energy is leftover goes into the University power grid. The second street garage is 19,000 square feet and is able to provide parking for hundreds of cars. (UA)

Methodology

The information gathered for this research paper will strategically use ways of gathering beneficial information to conclude the purpose of this paper. This information will be vital to the successful outcome of this research paper. Through the use of interviews and academic resources, the paper will prove reliable and beneficial for those who seek to educate themselves on the matter at hand. The academic sources used will consist of articles, professionals, and statistics gathered from reliable sources. Cost-benefit analysis will be a key factor in the conclusion of the paper. In the case of this study, government incentives and the cost of photovoltaic panels and thermal water heating systems will be key factors in concluding the decision.

Cost-Benefit Analysis- Also known as cost-effectiveness analysis, cost-benefit analysis involves a comparison of the cost of inputs of an intervention or initiative, with the outputs and outcomes of that intervention. It is used in all areas of strategic decision-making. The focus here is on cost-benefit analysis by public bodies rather than commercial enterprises. (B.INS)

Cost benefit analysis is typically applied in research and evaluations. The purpose is to help inform individual or multiple prospects about the decisions and resource allocation concerning changing options. Cost benefit analysis has been known to provide the "best value" or "best practice" guidelines. It allows the topic at hand to be compared by using the inputs and outputs/outcomes of an initiative. This approach will only be used as part of a wider evaluation of the impacts of this project. Cost benefit analysis will help summarize the overall outcome of the project before it takes places. Benefits may vary from each investor due to their set of values and what they consider as a benefit. In this case some people may be looking to benefit themselves or the environment as a whole. Photovoltaic panels and thermal water heating systems are considered "green" or sustainable forms of energy.

Solar panels/alternative forms of energy will be compared to traditional forms such as coal, gas, nuclear, etc. This process will ultimately help distinguish the pros and cons of alternative energy sources. Although they will be compared, there is no alternative source of energy that can supply enough energy to the buildings on the University of Arizona without somewhat relying on traditional sources. The University of Arizona has implemented solar and thermal energy into buildings on the campus. UA's campus planner provides detailed maps that visually assist the location of current technologies and where they can be implemented. Engineers in the UA's PDC department have provided data that was collected by calculating the available square footage on campus for solar and thermal energy. These maps are able to provide the whereabouts of current solar panels and thermal water heating units. Edward Galda is the Campus Planner for the University of Arizona who will also be a key factor in the grand scheme of this thesis. Steven Marker, the senior staff electrical engineer, will be providing current data on alternative forms of energy as well as his experience with every source of energy on the campus.

A "take-off" of each building will take place either on site or by using a GIS map provided by the city of Tucson. The term "take-off" is a part of the cost estimating process in the construction industry. Estimations will be made electronically or manually using construction blueprints. This process will provide available open space for solar panels or thermal equipment. Summarizes the pros and cons of each building will help distinguish whether the building is suitable for these amenities.

The plan of approach is to keep an open mind and not let any information attained from the past turn this into a bias paper. In today's society we are constantly hearing about sustainability and consistently trying to find options that will positively impact the world we live in. With that being said, we know that there are alternative forms of energy out there, but are they worth the money? Green labeling seems to be a problem and every solar panel on the market today is not as effective as their competitor. Technology is continuously on the rise and the products are only improving. Multiple solar panel companies will be reviewed and analyzed in order to produce the honest reality of their product. Calculating this information can reveal which company's product seems to be the best choice when it comes to purchasing solar panels. A solar panel that meets the requirements will be used to produce cost analysis.

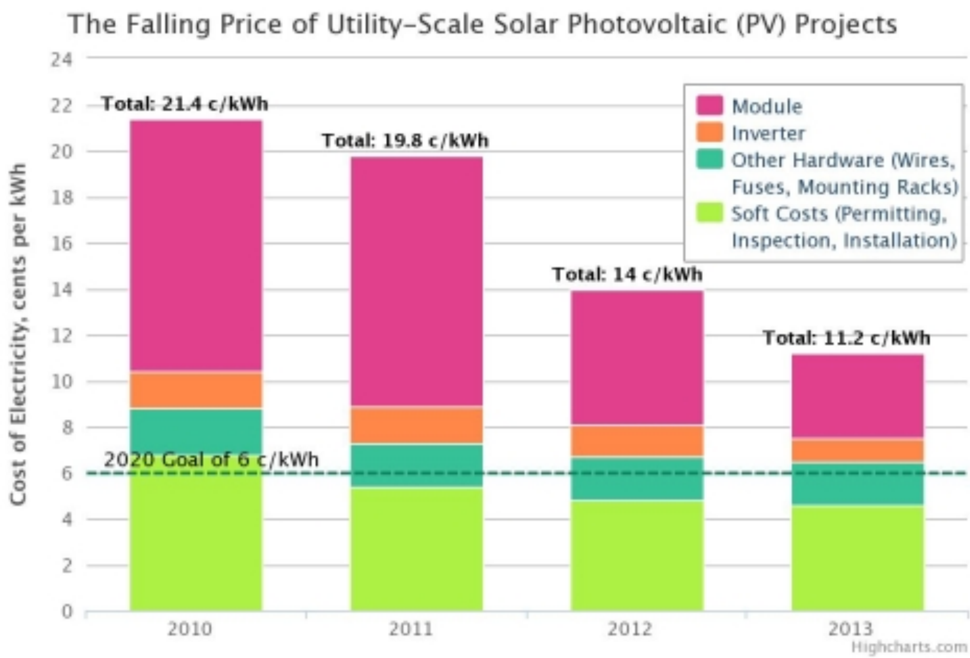
After the careful analysis of studies and statistics related to solar panels and thermal water heating, a great deal of beneficial information has been gathered to carry out along with the cost benefit analysis. Relating the information to the designated buildings allows the information to show how thermal water heating and solar energy can effect the energy consumption. The Planning, Design, and Construction (PDC) website is able to provide the energy usage for most of the designated building in this project. Sources within the PDC department have provided information regarding monthly energy usage and costs. These numbers are crucial to the cost benefit analysis and will allow a conclusion to be drawn.

The thermal water heating unit will be drawn from the energy star website. The photovoltaic panels that will be implemented will be very difficult due to the continual innovations being made. The photovoltaic panel used in the analysis will be a product that meets the requirements. All buildings will be analyzed through GIS systems to configure the open space on the rooftops to implement photovoltaic panels or thermal water heating units. Each building will be visited, as well as, analyzed from an aerial view. This will help conclude which, if not both, alternative energy forms will be implemented into each building/structure. Energy star qualified solar water heating systems were used in order to analyze the systems that have been installed all over the United States. The systems that have already been implemented into the current commercial sized buildings will be compared to similar solar water heating systems. Although these systems may ultimately produce the same outcome, they most likely differentiate in functionality or efficiency.

Results

The information below is meant to give an idea of what can come from the use of solar panels. Fortunately, technological advancements are consistently making solar panels more efficient and affordable.

Table 2



The National Renewable Energy Laboratory provided the data above. This table is able to show how the overall costs of utility-scale solar photolytic projects are decreasing. Modules are decreasing along with the soft costs, which include inspection, permitting, and installation. The prices that have not dramatically decreased include the inverters and other hardware such as wires, fuses, and mounting racks. To give an idea of what the average solar module is the information below describes the average PV module on the market in 2013.

-A typical PV Module: 59x39x1.5" weight 40lbs - rated at 210W DCPV Array

- Production: 415,000 Kilowatt Hours (kWh) per year.

- Greenhouse Gas: Reduction of 300 metric Tons - equivalent to removing 55 passenger vehicles from Tucson's roads per year

The table below is an on-site assessment/analysis of the structures at the University to determine the solar production potential and appropriateness to receive PV systems. To help facilitate this requirement, a preliminary list of 23 buildings/parking structures totaling an estimated 505,000 square feet of rooftop space have been identified as potential candidates for assessment/analysis.

Table 2- Information Provided by The University of Arizona

Building Name	**Building Number**	**Square Footage**
McClelland Park	78	8,300
Parking & Transportation	181	5,200
Highland Commons	95	12,000
Apache/Santa Cruz Halls	50A, 50	6,000
Graham/Grenlee Halls	53, 52	12,000

Campus Recreation Center	117	30,000
Main Library	55	39,000
Kaibab/Huachuca Halls	79A, 79	7,500
Park Student Union	87	7,000
Arizona/Sonora Halls	84, 83	6,000
McClelland Hall	108	28,000
AHSC Library	201	14,000
Roy P. Drachman Hall	202	23,000
Highland Avenue Garage	190	60,000
Park Avenue Garage	116	45,000
Main Gate Garage	159	30,000
Tyndall Avenue Garage	160	60,000
Second Street Garage	114	19,000
Cherry Avenue Garage	115	40,000
Sixth St. Garage	180	34,000
	total	505,000

The information on the next page was collected by the UA's, PDC department. The numbers below are meant to serve as a reference to aid in the visualization of this research. Due to the fluctuation of energy usage, the numbers are strictly meant to provide an idea of the energy used while students and many others utilize these structures. The information about energy usage below can be subtracted by the University of Arizona solar energy production. That will lead to a number that is smaller than the original number. Overall this means that solar panels are able to offset the traditional forms of energy leading to an environmentally friendly solution.

Table 2- Information Provided by The University of Arizona

McClelland Hall	557,000 kWh	385 metric tons
Second Street Parking Structure	415,000 kWh	287 metric tons
McClelland Park	130,100 kWh	90 metric tons
Student Rec Center	1,905,750 kWh	1,317 metric tons
Hillandbrand Diving Center	155,750 kWh	108 metric tons
Yuma Agricultural Center	10 kWh	
Red Rock Agricultural Center	546,000 kWh	378 metric tons
Campus Agricultural Center	218,400 kWh	151 metric tons
Controlled Environmental Agricultural Center	89,544 kWh	62 metric tons
West Campus Agricultural Center	205,296 kWh	142 metric tons

Ville Del Puente Residence Hall	45,864 kWh	32 metric tons
Posada San Pedro Residence Hall	26,208 kWh	18 metric tons

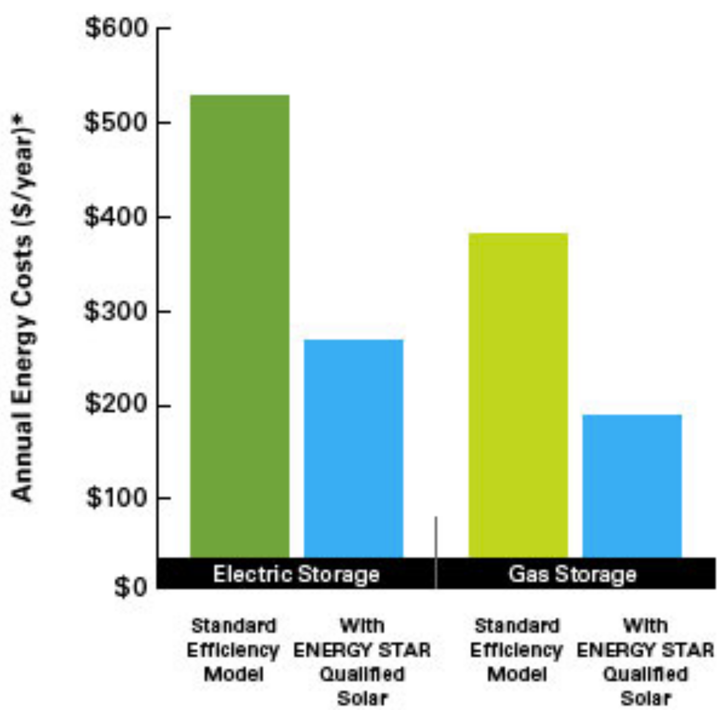
The information above is crucial in order to understand how much energy each building on the University of Arizona is using. With alternative energy sources these number can dramatically decrease and offset natural gas consumption. Decreasing the use of natural gas consumption in each building will lead to a smaller carbon footprint. Since all of these buildings may not have enough roof space, they can benefit from other buildings with solar panels through an energy grid.

A customized survey was created in order to get an idea of how often students living in the on campus dormitories use hot water. The average shower per person is said to use 10 gallons of water per use. Shaving is said to require .5 gallons of hot water per miniute and a washing machine requires an average of 7 gallons of hot water. After taking this into consideration the survey was created and presented to 19 students at the University of Arizona living in Likins Hall, Pasado Del Centro and Villa Del Puente.

Use	Average gallons of hot water per usage		Times used a day		Gallons used in a day
Shower	10	x		=	
Shaving	2	x		=	
Clothes washer	7	x		=	
			Total gallons of hot water	=	

The table above is the survey that was used to provide a better understanding of how much hot water students are using in the dorms. 13 woman and 6 men were interviewed in this process. 4/6 of the men take one shower a day and the other 2 take 2 showers a day. 6/6 of the men shave at least once a week. 3/6 wash their clothes weekly and the other 3 wash them every 2 weeks. 12/13 of the women shower twice a day, leaving only 1 woman to shower once a day. All of the women consider showering and shaving a dual purpose. 10/13 of the women wash their clothes weekly and the other 2 wash there clothes once every 1.5 weeks. This information was able to show how gender has an impact on the amount of hot water being used. If the dorm is a gender specific dorm then they may need to prepare for an increase in hot water use depending on the gender. This info was also able to display that each individual uses amenities at a different rate.

Solar water heating units tend to cost more to purchase and install than the average water-heating unit. Traditional water heaters are more expensive after evaluating the pros and cons of a solar water heater. In order for a thermal water heater to be more efficient and less expensive, the flowing must be taken into consideration; amount of water used, system's performance, geographic location, financing and incentives, and the cost of conventional fuels. For the most part they save you money, but if these factors amount to a higher price then they are not as efficient. Comparing several solar water heaters and estimating the annual operating costs is crucial piece of information in order to have a full understanding of which is more efficient.



The table above was made by ENERGY STAR to display how adding a solar water heater can cut energy costs in half.

Fortunately for the consumer, if they chose to install a solar water heater, their water-heating bill will drop 50%-80% on average. In order to put this into perspective, here is an example. If someone were to include a solar water heater in their 30-year mortgage, they would be paying $13 to $18 per month depending upon the solar water-heating unit they chose. They save $3-$5 per month after receiving a federal income tax deduction for mortgage interest regarding the solar heating unit. This leaves them with a payment of ranging from $15 to $8 per month. If the individual who purchased the unit saved $15 in fuel, then the solar water-heating unit became profitable. In this case you are saving more money than you are paying for the unit.

Conclusion:

After careful analysis of data from different perspectives, many conclusions were drawn. Photovoltaic panels will continue to be implemented throughout the University of Arizona. Although they may not be as effective now as they will be in the future, they still contribute to the energy grid and the Universities goal of becoming sustainable. Technological advancements are consistently making photovoltaic panels more effective and affordable. Prices for solar energy are decreasing due to technological advancements and a strong desire to produce an end product that can be considered affordable. Affordability is crucial for this product due to the fact that solar panels do not pay for themselves without the help of federal and state incentives. Photovoltaic panels are able to produce energy, but all buildings require traditional forms of energy such as natural gas. Even though traditional forms of energy are required to power the commercial sized University of Arizona buildings, photovoltaic panels are able to offset the use of natural gas needed to produce energy.

Due to the lack of knowledge regarding which solar panels the University plans on using in future instillations, the cost benefit analysis is difficult to implement into the calculations. There was also no record found in the research related to the total price of each project that already exists on campus. The only way to see if the existing panels and heating units had a return in investment was to use common knowledge attained through the process of this paper. The alternative energy sources were able to pay themselves off because of federal, state, and private incentives. Since these incentives are constantly changing it made it difficult to provide an exact number that will not change. Plenty of information was able to be found on thermal water heating systems, but the size of the units were not large enough to have a single unit supply hot water for the size of the dorms on the University of Arizona's campus. Residence halls with solar water heater still require natural gas to heat water. Overall, solar water heating units would be great for the University of Arizona residence halls and cafeterias. They are able to save enough money and the University will have a return on their investment.

The future is promising for photovoltaic panels and solar water heating units. Technological advancements will allow solar panels to become more efficient and supply cheap energy for multiple purposes. Solar water heating units are already efficient, but companies and investors seek new technological advancements that will make them even more efficient. Over the years these systems have only progressed. The importance of photovoltaic panels and solar water heating units have become more relevant in many communities throughout the world. Natural gas has proven to emit carbon and affect our planet in a negative way. When photovoltaic panels and solar water heating units are affordable and efficient enough for the general public, there will no longer be a need for natural gas or traditional forms of energy.

After careful analysis of the benefits and efficient factors that come from the use of photovoltaic panels, most buildings with a flat roof without too much congestion will make a great candidate. Parking structures are included in the candidacy for the University of Arizona's next campus solar project. Implementing these tools can set the pace for years to come. Solar energy can be seen as beneficial utility to people all over the world. It can reduce our carbon footprint and benefit the environment we inhabit.

Appendix

E Chauncey Ln
E Elm St
E Lee St
N Tyndall Ave
Mountain Avenue
Speedway Boulevard
6th Street
Buildings Relevant to Research
Buildings Targeted for Photovoltaic Panels
Buildings Targeted for Thermal Water Heating
Existing buildings with photovoltaic panels
Existing buildings with thermal water heating

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