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Community Sustainability Partnership Program, Spring 2020

Solar Energy Feasibility Study for Manatee County, Florida

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About the Office of Community Engagement and Partnerships

OCEP exists to expand and strengthen university–community engagement locally and globally in support of ***University of South Florida's*** strategic priorities to:

- Change lives for the better, improve health, and foster sustainable development and positive societal change through high-impact practice and innovation, including community-engaged scholarship and creative activities that benefit all members of society.
- Produce well-educated and highly skilled global citizens through a continued commitment to student success, including enhancing opportunities for all students by providing transformational learning that develops relevant applied skills and engaged outcomes.
- Create new partnerships to build a strong and sustainable future for Florida in the global economy by establishing mutually beneficial partnerships (internal and external) that enhance student access to academic programs, research, and employment opportunities.

Director Lillian Wichinsky, Ph.D., LMSW

About the Community Sustainability Partnership Program

The Community Sustainability Partnership Program (CSPP) is an ***EPIC Network*** program hosted and supported by the University of South Florida. CSPP is an initiative with the goal to improve the quality of life and social wealth of all involved, whether by expanding social or economic inclusion, increasing environmental sustainability, enhancing livability or spreading democratic self-government. CSPP works with university and community administrative structures to harnesses USF resources, faculty expertise, and student innovation to create change through community-identified projects. These collaborations are at the forefront of solving important issues that strengthen Florida communities.

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About Manatee County, Florida

Manatee County is located on Florida's breathtaking Gulf Coast. It is bordered by Tampa Bay and St. Petersburg to the north, Hardee and DeSoto counties to the east and Sarasota County to the south. The beautiful beaches of Anna Maria Island fade into the Gulf of Mexico to the west.

Many believe the shores of Manatee County were the initial landing spot for Spanish explorer Hernando de Soto in 1539. Manatee County – so named for the slow-moving sea cow known as the manatee – was founded in 1855, and included a vast expanse of more than 5,000 square miles. That huge area was eventually divided into seven different counties, leaving Manatee County at 741 square miles. Old Florida still exists. Before the high rises, and theme parks, there was simply this. Uncover the Beauty!

Manatee County now boast a population of more than 385,000. With miles of gorgeous beaches, bike paths, trails, greenways, boating, fabulous shopping and great food. Manatee County has something for everyone.

Chair Betsy Benac

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Executive Summary

Manatee County, Florida attracts tourists and visitors from across the globe to enjoy clean beaches, historical museums, and state parks. However, Manatee County sits on the coastline of the Gulf of Mexico, and with sea-level rise, temperature increase, and land degradation being massive side effects of climate change, related environmental impacts can have potential negative effects on the quality of the lives of local residents and the stability of the local economy. As climate change becomes more apparent in this part of the world, there will need to be larger steps taken to lessen regional carbon outputs. Manatee County is currently taking steps towards going net-zero in all public buildings through solar siting based on the Sierra Club's "Ready for 100 Initiative" and increase the county's rating in the built environment energy category within the Florida Green Building Coalition (FGBC). In light of these shifting priorities, Manatee County officials formed a working partnership with the University of South Florida's Community Sustainability Partnership Program (CSPP) and the Patel College of Global Sustainability (PCGS) to boost their public buildings' energy efficiency through solar arrays and enhance county-wide readiness and resiliency efforts.

The Manatee County Solar Energy Leadership project is a collaboration between Manatee County Government and PCGS graduate students to research innovative ways to approach the implementation of solar energy sites in Manatee County. The mission of this research project was to establish the operational feasibility and economic viability of converting public owned government buildings to solar energy as a tactic to become a net-zero municipality. Student teams in the course *Concept and Principles of Sustainability* explored the potential for solar technologies to be retrofitted or installed in high priority public owned buildings; these buildings included: public safety, judicial and administrative buildings, health clinics, public schools, police departments, EMS stations, marine units, water treatment facilities, and utility operations. This faculty lead research project evaluated the solar energy capability and capacity in Manatee County in order to understand the need and practicality on renewable power sources. The sustainability aspects that were assessed are as follows: background of solar fields, technology, feasibility, location, policy procedures, return on investment, financing, economic costs and benefits, environmental impacts, and a review of other solar city models. After extensive investigation, quantitative, qualitative, and spatial data was interpreted and presented as well as recommendations and solutions were provided to the challenges or limitations to project execution and solar energy conversion.

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Introduction

Description of Manatee County

Located on Florida's west coast, Manatee County is a rapidly growing municipality facing several sustainability challenges from increasing economic, environmental, and social pressures. Manatee County is located just south of Tampa and St. Petersburg and borders the Gulf of Mexico. The geological makeup of the county includes 6 major watersheds that open up into the Gulf of Mexico (Manatee County Water Atlas, n.d.). This geography has historically allowed the county to be economically rich in agricultural production and recreational activities that are available for residents and tourists (Manatee County, 2015).

With a population of around 385,450 people and a growth rate of 2.68% in the past year, Manatee County is the 15th most populous county in Florida. Covering 741 square miles this county contains 1.8% of Florida's population, according to Florida's Office of Economic and Demographic Research (Manatee County, 2020). Manatee County employs 171,000 people (43% employment rate) and the median household income is approximately $60,000. As a gauge of economic inequality based upon the Gini Index, Manatee County equals 0.474 for income equality, which is below the national average. As well, the county suffers from a slightly higher poverty rate than the national average (13.1%), at 13.4% (Data USA, 2018). According to Laura Finaldi (2020), Manatee County is unique because many people are moving to the area from other parts of the United States, rather than other countries. The influx of new residents has continued to build the county's economy and increase profits for local businesses, professional services, tourism, health care, and education. These increases in economic growth are believed to be due to the tax-cutting policies, tariffs, and reductions in regulations that are supported by the government of Manatee County (Finaldi, 2020).

Currently, Florida Power & Light (FPL) Company supplies all of Manatee County government's power requirements in the following energy mix: 72.9 % natural gas; 21.0 % nuclear; 2.3 % coal; 1.8 % purchased power; 1.7 % solar; and 0.3 % oil (E. Caplan, personal communication, Feb. 28, 2020). The burning of fossil fuels provides for most of Florida's electricity generation. In fact, fossil fuels make up over three-quarters (approximately 82%) of the state's electrical usage (WINDExchange, 2019). However, fossil fuel combustion has many negative consequences including carbon dioxide emissions and subsequent climate change (Perera, 2017).

In addition, there are growing concerns about the environmental safety of the people inhabiting Manatee County. Many parts of the county, including its major cities—Longboat Key, Siesta Key, Anna Maria, and Bradenton—are 5 ft. below sea level (See your local sea level and coastal flood risk, n.d.). Due to its location and geology, Manatee County is the most at-risk county for the impacts of climate change in the nation (Four Twenty Seven, 2018). This situation can promote intense flooding and loss of coastlines within the county. With such a fast-growing population, forecasts predict many negative outcomes if carbon emissions are not reduced. The county's rampant use of fossil fuels is one of the main contributors to current issues such as air and noise pollution, higher tides, harsh storms, increased flooding, etc. It is estimated that by 2050, Manatee County may experience a sea-level rise of about 2 feet, and by 2100 it will experience a sea-level rise of approximately 3 to 8.5 feet (White, 2019).

As carbon dioxide emissions are increasing, so are the efforts of the county to implement solar energy to reduce damages and mitigate the current risk. There are efforts "to get local governments [in Manatee County] to convert to solar and wind power." In 2017, the Sarasota City Commission accepted the challenge—pledging to get 100% of its municipal operations on renewable energy by 2030 and the municipality's private sector doing the same by 2040. The county is already taking the first step in fulfilling its pledge by conducting this feasibility analysis. A proactive approach for a more sustainable and resilient community, implementing solar energy, innovative technology, and adaptation efforts can fulfill Net Zero municipality goals.

Current Policy and Renewable Energy Upgrades

Manatee County has already taken huge steps in reaching a goal of 100% renewable energy and a more sustainable future. In the past they have worked with the Florida Green Building Coalition to achieve the certifications of Silver level in 2011, Gold level in 2013, and the highest level, Platinum, in 2017 ("Energy & Sustainability," 2018). If you are not familiar with the program, the Florida Green Building Coalition's Green Local Government Standard awards local governments for taking extra steps to be more environmentally friendly. This certification gives green cities and county governments recognition and publicity and allows them to function in a more efficient manner through better internal communication, cost reductions, and effective risk and asset management (Local Governments, n.d.).

The county commissioners also recently passed an amendment to a law that will help encourage more solar plant investment in Manatee County. The amendment would be to the comprehensive land-use plan that allows "a facility that utilizes photovoltaic solar power to generate electricity" (White, 2018a). This plan will allow solar energy to designate a utility differently from non-renewable power plants, essentially making it easier to make a solar energy plant. The change will allow a solar plant to have different regulations from a non-renewable plant. Before this change the law which passed in 1989 did not distinguish between renewable and non-renewable plants (White, 2018b). This change will amplify Manatee County to reach their renewable energy goals.

Not only is Manatee County getting into renewable energy, but the League of Women Voters of Manatee County and the South Florida Museum announced in January of 2018 that they would be starting Florida's 21st solar co-op in Manatee County (Putterman, 2018). The project is called Solar United Neighbors of Florida. A solar co-op lets a group of homeowners buy solar for their house without putting panels on the house. This co-op will allow residents to buy solar energy, even if they do not want to buy solar panels or cannot get them on their house. The average investor in this project spent between $14,000 and $23,000 each (Morse, 2017). Co-ops are the missing link to help people obtain renewable energy even if it is not feasible in their area.

Also, Florida Power and Light (FPL) has joined the solar party, announcing the world's largest solar battery system will be installed in Manatee County. The system will be 409 Megawatts of capacity and take 40 acres of land. For some clarity on what that compares to, it is a 100 million iphone batteries worth of capacity (Wille, 2019). In addition to reducing the cost of buying nonrenewable sources of energy, the plant promises to reduce carbon emissions by about one million tons. The battery plant will allow FPL to store up solar energy during the day for use at night. Possibly the best thing about this behemoth of a battery is it will only hold renewable energy. The power will come from a solar array in Parrish, Florida (Levey-Baker, 2019). The new battery will put two natural gas plants out of commission as soon as the new battery comes online (Levey-Baker, 2019). It will symbolize a changing of the guards in Manatee County.

Along with the massive battery plant there are also plans for another solar array called the "Southfork Solar Energy Center, to be located on County Road 62 just outside Duette on 630 acres. It will generate 74.5 megawatts of energy. It will generate enough power to supply approximately 15,000 homes" (Owens, 2019). Also, the Florida Department of Environmental Protection makes consumers get a permit for solar facilities larger than 75 MW (Blockstein, 2019). This is why solar power plants will typically build 74.5 MW plants, because all that is needed is proof that the plant will be profitable. These dual plants also give the power company better coverage with solar. Being that one plant could go out because of the rain or clouds and they can take power from another nearby. Manatee County is truly well on their way to a 100% renewable future with these upgrades in their power grid.

Buildings have shown to be one of the major sources of energy consumption at approximately 31%. Having buildings derive their energy from renewables will help reduce their carbon footprint and help energy supply security (Üçtuğ and Azapagic, 2018). So, another way to cut energy costs for Manatee County is by integrating smart systems and green building methods within governmental facilities. A smart building that can control the energy consumption from areas like lighting, air conditioning and water, can further make a building efficient and be less reliable on renewable energy availability. In order for Manatee County to fully achieve its net-zero goals, all factors of how a building is utilized needs to be looked into consideration for positive alteration. Adding smart technology to Manatee County's governmental buildings will help reduce the need for energy, therefore cutting down on extra greenhouse gas emissions that it takes from acquiring solar panels as well.

Where solar panels are placed and where the energy that is created goes is vital. The article "A Cellular Approach to Net-Zero Energy Cities" by Amado, Poggi, Ribeiro Amado and Breu (2017) highlights how cities, very much like Manatee County, can take a "cellular approach" to accomplish a goal of transforming into a net-zero community. Manatee County is like a living and breathing organism that has active and inactive parts of its area. If an analysis of the county can be made that gathers information on where the most amount of sun takes place and what building uses the most and least amount of energy, this can be used to the county's advantage (see Figure 1). By placing solar panels in strategic locations that maximize the production of renewable energy, Manatee County can further improve its net-zero goals and have more efficient energy management. Also, with the knowledge of each governmental building usage, nearby buildings can have a consultative flow of synergy that helps buildings that may be better located for solar panels but does not use as much energy as another nearby building and vice versa.

Fig. 1: Geographical Urban Units Delimitation Model

Being that Manatee County is well over a hundred years old, many of their buildings can be historical. This does not inhibit their ability of being net zero. Market One is a three-story office building that is over one hundred years old in Iowa that has a "net-zero design" that "utilizes several energy-saving strategies" which was capable with the help of the Modus Engineering company (Market One, n.d.)(see Figure 2). This shows that age in buildings, or counties, does not limit the possibilities of achieving a net-zero goal. The type of building should not matter either, whether it is an office building or a police station. Salt Lake City opened up the first net-zero fire station in the nation two years ago (Salt Lake City Opens the First

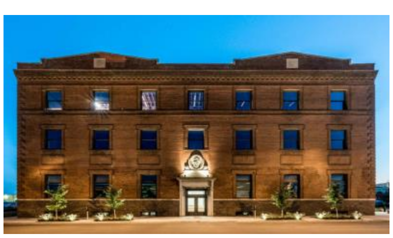


Fig. 2: Market One Building

Net Zero Fire Station in the Country, 2018). By having enough solar panels on the roof to power the energy-efficient building, Fire Station 14 makes going net-zero easy along with being environmentally friendly with countless other green methods of saving water and waste (see Figure 3).

Fig. 3: Salt Lake City's Fire Station 14

We researched individual buildings that have gone net-zero to identify criteria such as the amount of solar materials needed, retrofits and modifications, or energy efficiency strategies. But it is also important to look at Manatee County's system as a whole and how it's functioning. The idea of industrial ecology and industrial symbiosis uses one company's waste to power another company's process that would otherwise be powered externally, thus creating a closed-loop system or a series of web-like interactions. One strategy Manatee County could use is a systematic approach to reducing excess waste, allowing the county to still achieve net-zero. Renewable energy is just a part of the path to net-zero energy and it can sometimes be a costly start. But once the community is working as a whole, and processes are broken down into parts, we can identify strategies.

Implementing net-zero energy buildings in pre-existing buildings requires retrofitting strategies that are different from strategies for constructing new buildings. Analyzing the building's life cycle is important to ensure that the proposed installations keep the building at the net-zero energy level until the end of its cycle, without losing efficiency over time (Thomas, Menassa & Kamat, 2018). Proposed installations could be sensors, LED lighting, up-graded air condition systems, Energy Star appliances and much more. An individual high-performing building by itself does not mean much, so Manatee County must standardize building requirements to provide county-wide standards.

The Manatee County government has already made efforts to establish its orientation towards sustainability. The county takes numerous opportunities to make its green government's efforts known. For example, the county has used an Earth Day exposition and a Recycled Fashion Show to present sustainability activities and promote awareness of environmentally friendly behavior (D. L. White, 2018). The use of local sustainability experts, guest speakers, information booths, and giveaways allowed for communication of environmental values to the public. These sustainability efforts enable locals to shift to a mindset that places greater value on sustainability (D. L. White, 2018). As part of Manatee County's Comprehensive Plan, a publication was ordered by the Board of County Commissioners to highlight energy conservation, environmental stewardship and sustainability as some of its top priorities (eLaws, 2019). The extensive plan was made readily accessible online so that county residents could view it. This would enable citizens to remain knowledgeable of the county administration's policies (eLaws, 2019). This is a good example of the Manatee County government's initiative to keep its citizens informed on matters of sustainability.

Still, Manatee County becoming net-zero will be a challenge, partially due to it being a governmental entity. The process involves critical infrastructure changes, starting with facilities that are deemed a top priority. Multiple actors in the government structure of Manatee County can be involved in sustainability projects. Different actors may have different roles, but they must work together for a project to be realized. There are a number of sustainability principles that may be beneficial to the county and to the government structure. The principle of renewable resources considers the usage of resources that can renew themselves and so are not finite (Glavic & Lukman, 2007). This principle includes solar power and can play a significant part in reducing carbon dioxide emissions and mitigating climate change. This project would address renewable resources by promoting its utilization in the county and improve awareness of solar energy's advantages among actors. The principle of mutualism can be greatly rewarding in human systems (Glavic & Lukman, 2007). Mutualistic relationships can benefit all involved actors and encourage better resource use. If all actors can work together cohesively, the project would have a greater chance of success. Case studies, a review of the literature, and past experiences will serve important roles in planning Manatee County's energy initiative goals. By analyzing the data and information from net zero cities and countries, Manatee County can gain insight and possibly avoid certain problems. Looking at successful examples of Zero-Net-Energy (ZNE) buildings can encourage the success of Manatee county's own government facilities.

Manatee County's will to become more sustainable has also shown through its "Green Team." The county's "Green Team" is a committee consisting of county employees from each department who volunteer to discuss sustainability ideas regarding energy and financial savings (Nudi, 2011). Changes that were suggested and implemented included altering equipment, rewiring facilities, and ensuring that equipment remained off when not needed to increase energy savings (Nudi, 2011). The renewable energy that Manatee County uses does not necessarily have to come from the government buildings themselves. If there is inadequate space for enough solar panels, there are alternatives such as solar farms or exchanging energy credits from suppliers. This can cut out the cost of installation, maintenance, and preventative care. By supporting local solar energy, municipalities can also assist low and moderate-income communities (SOLAR INITIATIVE POLICY BRIEF). When municipalities install solar energy systems, the government provides direct and indirect benefits to everyone in the community. Residents who may not be able to afford systems, typically spend a larger percentage of their income on electricity bills and benefit when municipalities install systems as it can lower electricity bills. Local community members also benefit from solar installation as it introduces more jobs into the economy (SOLAR INITIATIVE POLICY BRIEF).

Solar Background and Technologies

Technology and Engineering

One of the more mature renewable energy sources is solar energy. Solar energy has been studied for many years and is proving to be a promising alternative to fossil fuels. Energy demand is expected to increase by 40% by 2040, therefore the importance of shifting towards renewable and sustainable energy is a must (Üçtuğ and Azapagic, 2018).

A primary shift toward of solar technology is through the use of Photovoltaics (PV). This method converts reoccurring solar energy into electrical energy using light from the sun (Khan & Arsalan, 2016). Power generation through this technology is often done through the use of solar cells. Solar energy cells are typically a small electricity generation device. In order for this technology to be used on a larger scale, these smaller solar cells are combined to form a larger module of multiple cells. These larger modules are then connected to form large PV panels (Khan & Arsalan, 2016). For a larger scale utility use, hundreds of these solar array panels are then combined to form a large system of solar electricity generation, such as at Solar Star (see Figure 4). Most PV panels used on a commercial scale are fixed frames, however, some installations use solar tracking to track the trajectory of the sun throughout the day (The future of energy: Large-scale solar worldwide, 2016 p.24).

Fig. 4: Solar Star, the world's largest solar farm (3,200 acres) located in the California desert (Google Maps, 2020)

While these solar tracking PV panels are an efficient way to gather solar energy (see Figure 5), they do have the downside of requiring more maintenance to ensure they are operating at the most optimum efficiency (- p.25). Over the past few years, PV technology has experienced a steep reduction in cost (Tagliapietra, 2015 p. 79). This has made it appealing to companies and private citizens looking to make a change to more sustainable energy sources.

Fig. 5: Florida's Largest Rooftop Solar at Greatbay Distributors, Inc, Saint Petersburg, Florida. Comparable in size to the Manatee County Public Safety Department Building. (Google Earth, 2020)

The National Renewable Energy Laboratory (NREL) is a federally funded research organization that spearheads much of the development of renewable energy technologies within the United States (About NREL, n.d.). That research includes information relevant to photovoltaic (PV) solar energy technologies, such as their published irradiance charts and tools like the PVWatts Calculator. The understanding and use of the various information and tools that NREL publishes can help build an initial feasibility report of any location across the country. Specifically, understanding of the PVWatts Calculator will allow anyone considering implementing PV to tailor variables of their planned system to receive accurate approximations of annual and monthly energy generation of said system. This tool will be used heavily throughout this report to provide expected energy generation at each of the mentioned county locations. As such, this section will focus on explaining the terminology and/or assumptions made within the calculator so that the reported results can be replicated.

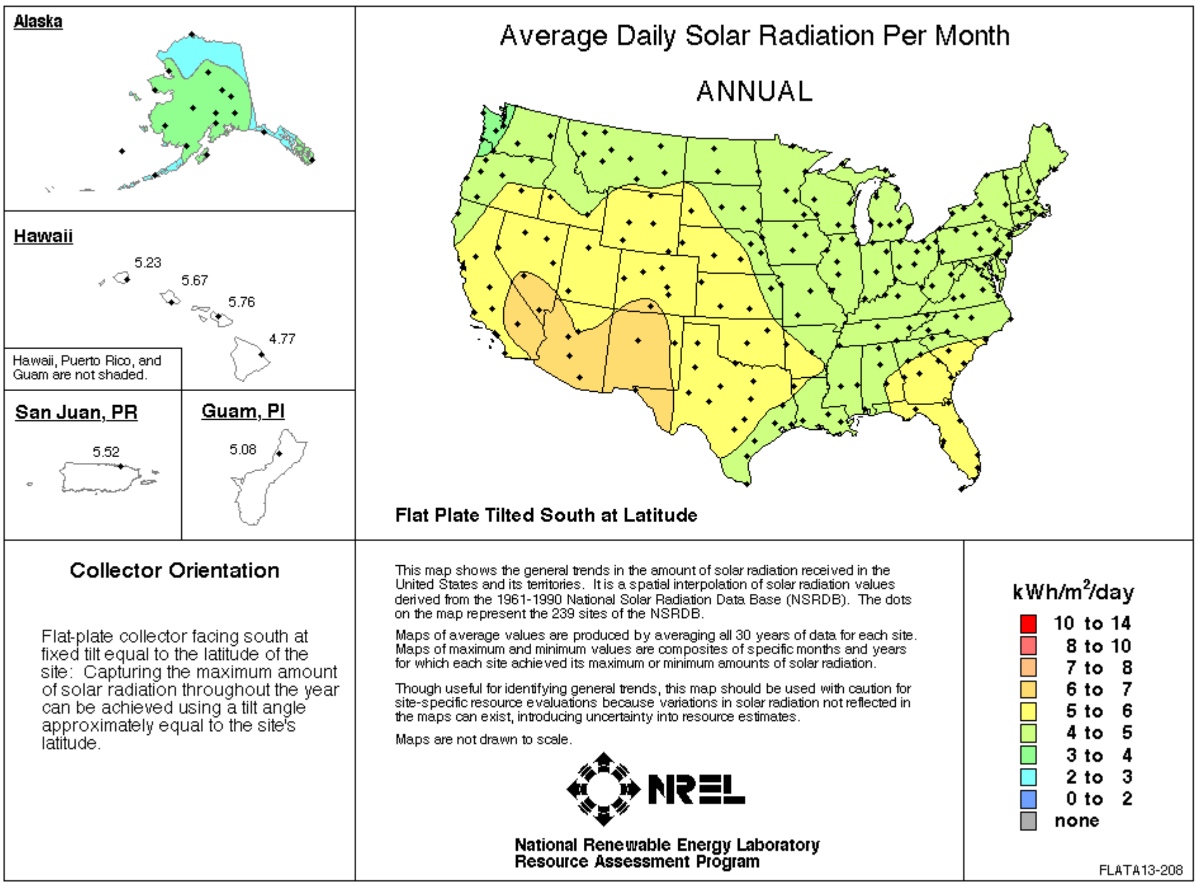
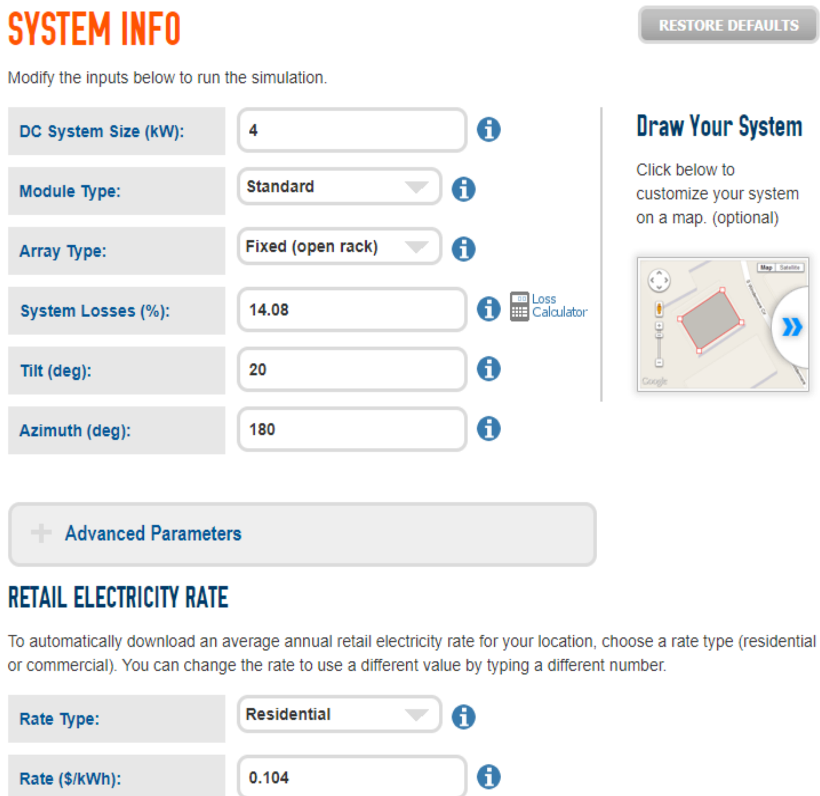


Fig. 6: NREL Solar Radiation Map. Retrieved from https://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/atlas/

To begin using the calculator, the address of the planned system's location must be entered. Using that location, the calculator will reference irradiance information gathered by the National Solar Radiation Database (n.d.), a research section of NREL that has accumulated decades of data on the various types of irradiance (global horizontal, direct normal, and diffuse horizontal irradiance).

Of note, the calculator will also provide the latitude of the system's location, an important variable that affects system efficiency and will be explained later.

Next, the proposed system information may be entered. If multiple systems are planned, each must be entered individually. Since the specifications of the final system are unknown at this time, the drawing tool may be used to approximate the area occupied by the system. Each of the buildings examined within this report will have their system sizes approximated in this fashion, however, limiting factors such as roof-mounted air conditioning or other such obstructions will present higher than realistic results. In this manner, the *maximum* expected energy generation can be reported for each system based on its occupied space, which is precisely how PVWatts calculates these estimates. Individual feasibility studies must be conducted at each location to determine realistic values, as there are other considerations, such as shading, that cannot be accurately represented in these approximations without conducting a site survey.



Once the size of the system has been determined, individual characteristics of the system may be entered. Module type includes three common types of modules used in PV: thin-film, standard crystalline silicon, and premium crystalline silicon. As stated in the PVWatts Manual (Dobos, 2014), these module types are detailed in this manner:

Table 3. Assumptions for different module types

Module type	Efficiency	Cover type	Temperature coefficient
Standard	~15 %	Glass	-0.47 %/°C
Premium	~19 %	Anti-reflective	-0.35 %/°C
Thin film	~10 %	Glass	-0.20 %/°C

Fig. 8: Different module types of PV panels (Table 3)

This information represents approximations based on an examination of average values of PV modules available on the market. More efficient modules can be expected to entail a higher price but will also bring higher energy generation. This report will present the approximations for only the standard module type.

In the same manner, the array type details different methods of PV mounting systems. The fixed (open rack) type will be used for any systems located on fields. This method of mounting leaves adequate space between panels to allow air-cooling, resulting in fewer modules being used, but higher efficiency due to better operating temperatures. The fixed (roof mount) type will be used for both roof-mounted and carport systems. These do not leave spaces for air-cooling and instead focus on using the maximum amount of space possible. One and two axis systems will not be examined due to the higher inherent maintenance requirements of such systems.

System losses represent power that will be lost as the system operates nominally. The default value presented by the calculator represents typical balance-of-system losses associated with grid-tied PV and no battery system. If a battery back-up will be used with the system, those losses, such as charge controller and battery efficiency, must be accounted for separately (Dunlop, 2012, p. 248). Of extreme importance, these losses assume no shading of the PV modules, whether that be from inter-row shading or outside sources like trees. Herein lies the extreme importance of conducting a site survey to determine the system's feasibility. Tools like a solar shading calculator can determine the approximate obstruction an individual location will receive throughout the day (Dunlop, 2012, p. 70). A site that receives shading can expect to have reduced output, possibly negating site feasibility.

Tilt relates to how the modules are oriented within a system. Mounting systems for modules have a variety of available tilt angles, but maximum energy output for fixed-tilt systems may be achieved by setting the tilt angle to match the latitude (Dunlop, 2012, p. 50). Therefore, the local latitude value of 27 will be used for all systems. Exceptions to this would be carports and floating panels, which typically have lower tilt angles due to construction considerations, and those mounted on roofs that have a pitch (EnergySage, n.d). This determination was made in keeping with the desire to find maximum approximations of energy output for each location. It is important to note however, that increased tilt angles cause higher wind loads (Dunlop, 2012, p. 292). This will likely lead to a direct increase in cost, as the mounting systems will need to be stronger to handle the increased loads. Such cost-benefit analyses should be conducted to determine the preferences of the county.

The azimuth of a system plainly means the direction the modules are facing in regard to a compass reading in degrees. For maximum energy output, the suggested azimuth angle would be due south (Dunlop, 2012, p. 51). It is for that reason that the calculator has a default value of 180 degrees and will be used in all the calculations within this report unless otherwise specified. Variations from the prescribed tilt and azimuth angles will directly result in lower energy output by lowering a value known as the Tilt Orientation Factor (TOF) (Solmetric, n.d.). The severity of these losses can be seen through resource websites, such as Solmetric, that use data from the National Solar Radiation Database to calculate what affects different values of TOF will have on a system (Figure 9).

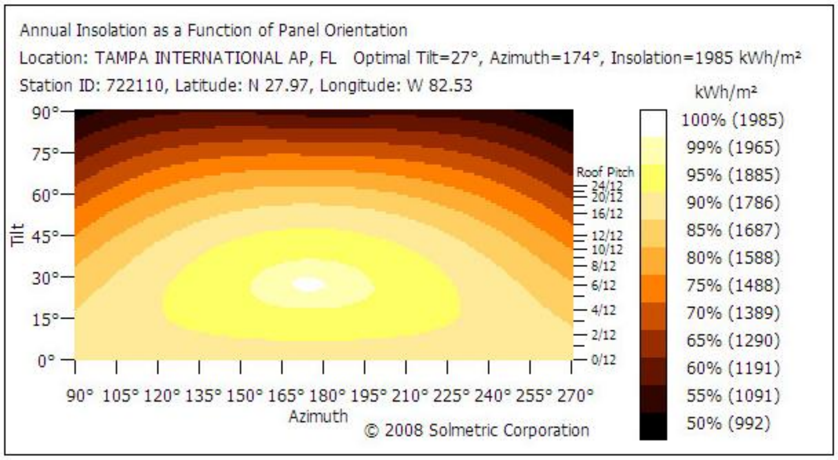


Fig. 9: Solmetric TOF. Retrieved from http://www1.solmetric.com/cgi/insolation_lookup/go.cgi

For system inputs in the calculator, there's a section for advanced parameters. Due to the nature of these values, they cannot truly be determined until hardware has been chosen for the system. As such, these variables will be left to their default values.

Finally, the calculator asks for the retail electricity rate of the system's location. The rate type input serves as a placeholder if the actual electricity rate is unknown. Referencing the information provided by the county, an average rate can be determined thanks to two years of data for each location found within the FPL account summaries. Those average rates will be used for each calculation for the location in question.

The total of this information is then used by the calculator to build a report that details the expected range of energy output for the location. Using the electricity rates, the report also includes expected savings that the system will produce. The default report has a monthly breakdown of the results with an annual summation. If required, this data can be further decomposed into daily and hourly values, but the accuracy of these values decreases as the timescale becomes smaller.

Given this rising interest in solar PV, studies need to be done to determine the durability of these solar PVs when exposed to the environment for extended periods of time. These solar cells are semiconductor devices which are exposed to high temperatures, moisture, and ultraviolet (UV) radiation resulting in possible decreases in solar cell performance and even destruction of the solar cell (Packa et al., 2016). It should be noted that studying the relation between exposure to the environment and the deterioration of PVs over time is incredibly complex and time consuming, and in many cases is an aspect that is overlooked.

The study conducted by Packa et al. (2016) used a simulated aging process where the following three tests were conducted: dry air at 85Cº, 100% humidity at 85Cº, submerged in water. The PV that was submerged was completely destroyed after just 25 days, the PV exposed to dry air showed no significant changes, the PV tested in 100% humidity showed significant changes in measured performance. Even though this experiment was based on a simulated aging process, the results do raise concerns to the durability of PVs in humid air environments or at the least constant monitoring of solar cell health.

Solar panel efficiency is a measurement of a solar panel's ability to convert sunlight into usable electricity at a low cost with a high supply rate. Of course, this is not the only criterion to consider while evaluating solar panels. Some others are materials, wiring, busbars and reflection (Aggarwal, 2020). More recent developments like bifacial and multijunction solar panels will affect the efficiency too.

There are more than a hundred different brands of solar panels and other solar equipment on the market right now. Based on high efficiencies, competitive pricing, and stellar 25-year warranty SunPower, LG, and Panasonic are considered to be the top of the line in 2020 (see Table1). The industry standard for panel materials warranties is 10 years. The aforementioned companies combine durability and reliability with premium protection and fair prices, making them the brands with the best solar panels available (energysage.com). In almost all cases, the best solar panels are made with premium monocrystalline solar cells. Instead of many silicon fragments melted together as in polycrystalline cells, these are made with a single crystal of silicon. While this does make them more expensive, it also gives them higher efficiency and a sleek black tint. Efficiency of a solar panel is measured in terms of how well it converts sunlight into electricity.

Table 1: *Rank and Efficiency of Leading Brands of Solar Panels*

Rank	**Efficiency percentage**	**Manufacturer**
1.	22.8	Sunpower
2.	21.7	LG
2.	21.7	REC group
3.	21.2	CSUN
4.	10.5	Solaria

Solar Farms, Rooftop Panels and Carports

Adaptive techniques have led to a paradigm shift in traditional solar farm ideas and have shifted from large scale open areas to carports and rooftops hosting panels. This idea is enticing especially since the topography of Manatee County is on a downwards slope towards the Tampa Bay area. Furthermore, when looking at maps, most of the large unoccupied land masses that would ideally host solar farms is privately owned property. Most of the ideal places to put large scale solar farms are marsh lands, perennial swamp lands, or low in elevation and act as drainage systems for surrounding areas. Solar farms provide a lot of power and do so effectively. However, reducing the land requirement for solar farms should be considered. Therefore, maximizing the use of smaller scale farms in the forms of carports and rooftops should be accomplished to help reduce the size of the required solar array.

Rooftop Panels

The roof slab works through three main steps. First, the panels absorb the sunlight's energy and produce direct current. Then, direct current flows to an inverter that converts the energy into alternating current. Finally, the alternating current is used to power your home or business.

Fig.10: Rooftop Solar PV Panels (tilted)

The solar panels on the roof work whenever the sun shines, and they produce more energy when the sun shines directly instead of tilting (see Figure 10). Florida's net metering rules enable power customers to connect approved renewable energy generation systems, such as rooftop solar panels, to the grid, so you can not only buy electricity from utilities, but also sell excess power to utilities through the grid. The cost of solar panels has fallen sharply in recent years, making it easier for Florida families, business owners and small farmers to choose solar panel systems. At the same time, all these empty roofs of houses and shopping malls remain an almost untapped resource. Other solar incentives could also make home solar panel systems a very attractive investment. As a result, the net price users will pay for solar in the future could drop by thousands of dollars. Therefore, these will be favorable factors for the development of rooftop solar panels in Manatee County.

This report analyzed several buildings in Manatee County with the Public Safety Center as a case study. NREL’s PVWatts calculator was used to determine the energy output of standard modules for each location. The county’s GIS information was used to see what various mounting options are available per building (Manatee County Government, n.d.). There are many ways to go about installing solar panels. Depending on the energy usage of each individual building, there may or may not be adequate space. Therefore, the feasibility of roof mounted systems, building additional roofing such as carports, floating panels in ponds and lakes, and open field areas was explored.

Roof Mounted Solar

Roof mounted solar panels are one of the most common forms of photovoltaics (see Figure 11). The differences mostly involve the mounting system being used. In the case of the Public Safety Complex, the rooftop is flat, so the installation is relatively simple and may allow pre-assembly before installation. Flat rooftop mounted systems are most commonly ballasted. Flat rooftop solar systems involved a basket-like mounting system that sits on the roof at an angle with ballast blocks. The roof's load limit will determine the amount of ballast. Flat roof mounted systems typically do best at an angle between 5^{o} and 15^{o}. The most efficient way to orient roof mounted solar panels is south; however, some energy can still be produced using an east-west orientation, when south-facing is not possible. Flat roof mounted systems can be steel or aluminum, but there are lighter weight options using materials such as plastic and polymers which are less strenuous to install (Pickerel, 2017).

Fig. 11: Ballasted Flat Roof Mounted Solar System (Gupta, 2018)

Other rooftops may have a slope, which require mounting systems that are railed, rail-less, or shared rail. Railed systems are clamped onto each rail, usually in a vertical fashion. For rail-less, the modules are considered the base of the structure and are directly bolted into the roof. Rail-less systems are typically less expensive with fewer parts which make installation quicker. For shared rail systems, the modules are connected to the same rails. Shown in the image to the right (Figure 12), where one module ends, another starts. Ballasted and non-penetrating systems use strain-based loading by distributing the weight over the top of the roof thus equalizing the weight between both sides. Non-penetrating mounting systems may or may not have ballasts (Pickerel, 2017).

Fig. 12: Shared-rail Slope Roof Mounted Solar Modules (Pickerel, 2017)

Solar Carports

For the Public Safety Center, there is not adequate roof space to install the number of modules required to meet net-zero. By building a cover over all parking spaces, the county can expand their mounting options. And, there are other considerations if solar carports are to be built. Primarily, the new construction would require the removal of any nearby objects that would shade the PV modules. Failure to do so would likely cause the system to underperform and not be feasible. Additionally, the carports themselves may increase the amount of shade covering for cars that an open parking lot will not provide (Fig. 13), thus protecting the vehicles from direct sun heat while harnessing solar energy.

For the Public Safety Center, there is a large parking lot north of the building and another on the southwest side. The combined area of these lots can provide about the same energy output as the system on the roof. In the case that only one lot may be used, the one to the north of the building provides the optimal azimuth orientation (Figure 14). Likewise, this approach may be used for other locations to supplement total system energy production.

Fig. 14: Example of Solar Carports (Madaleno)

Floating Solar Panels

Floating solar panels are a new technology that has been mainly used in Asia and the UK. This gives alternative placement for modules when there is not enough room on land or rooftops. Floating solar panels are fixed atop a buoyant structure and use a cooling system with the water (Figure 15). This allows the use of more efficient modules that would in other situations overheat. They help to save water because they decrease evaporation, and they create a place for algae to bloom, preserving the natural integrity of the body of water (Eureka, 2011). Of the buildings looked at, only the Public Safety Center may make use of this technology. Being an uncommon type of PV system, it may or may not be easily constructed due to limited suppliers and installers.

Fig. 15: Floating Solar Panels (Harrington, 2016)

Ground Mounted Solar Panels

Nearby fields may be considered for ground mounted solar panels (Figure 16). However, the extra mounting surfaces may be necessary for a location to reach the required energy produced to reach net-zero. Ground mounted PV systems consist of modules attached to a mounting system that allow easy planning of the system's tilt and azimuth, as it does not depend on the characteristics of a roof (Dunlop, 2012, p. 285). Anchored into the ground via an anchoring system, they are also not limited by how much weight a roof can support. However, due to their proximity to the ground, shading becomes a much more common issue for them. Planning the system's layout requires a great deal of consideration and may require additional steps not inherent to roof mounted systems: removal of underbrush, trees, and grading the site of installation.

Fig. 16: Ground Mounted Solar Modules in a Field (Darcey)

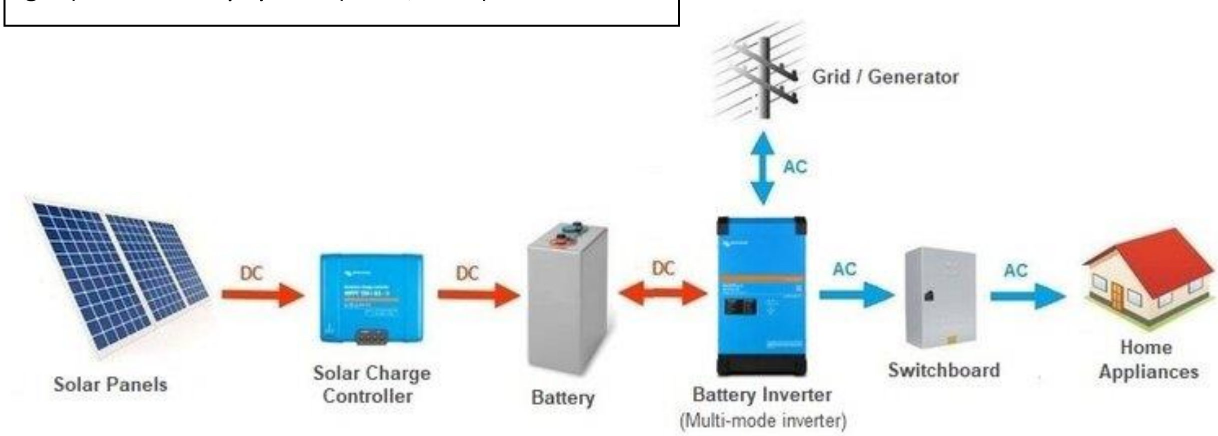
The Public Safety Center has a small field in the north-west and a larger one to the east of the building. The northwest plot is across a small street which may be more expensive to run transmission lines under or above. There also appears to be a helipad next to the southeast parking lot. If this is an active spot, codes for building around it would need to be reviewed. If the county is willing to build a small solar field in the grassy areas, they could produce enough energy to accommodate the energy usage of the Public Safety Center. However, driving paths of emergency vehicles and visual aesthetics will need to be accounted for. In the same vein, other buildings will have to be approached individually to determine the value of a PV system versus other uses of the fields.

Battery Back-up Systems

Battery back-up systems are an important part of solar power. The main factors affecting the performance of photovoltaic systems are temperature, seasonality and regional solar "peak hours" (Kazem et al., 2013). During times with heavy cloud coverage, the sun does not guarantee enough daylight, thus there is not enough sunlight to provide the required energy throughout the day. Additionally, PV systems cannot generate energy at night. For locations that rely solely on PV energy generation, these factors can lead to large periods of electrical outage. Due to the intermittent nature of PV systems, it may be necessary to install a battery back-up system (Figure 17). During periods of PV energy generation where more is produced than needed, the excess energy will be stored within the back-up battery. This stored energy can then be used during the periods of intermittence. This effectively helps ensure the overall stability of energy provided by the photovoltaic system but comes at a higher overall system cost that increases with how high the battery capacity must be.

When designing the system, in order to prevent the battery from being overcharged and deeply discharged, a charge controller should be added to the system. Additionally, the design of the total battery energy should be calculated based on night and cloudy loads to ensure enough energy can be supplied for the expected durations of no PV energy generation, which is defined as the critical design criteria (Kazem et al., 2013). Additionally, these systems may be supplemented with a gasoline generator if deemed necessary.

Fig. 17: Basic layout diagram of a DC coupled (off-grid) solar battery system (Svarc, 2019)



With the steady rise in solar usage, consumers are also looking for ways to store this energy for use when conditions are not favorable. Not all systems are designed to have grid backup, but these systems are becoming more common as consumers desire flexibility in their solar energy system. Most consumers wish to attain a level of functioning completely off the traditional grid (Turner, 2016 p. 26).

Lithium-ion batteries have advanced in efficiency and dropped in cost in the last several years. This trend makes solar-plus-battery options more attractive. Lithium batteries are lightweight and have a high energy density compared to their lead-acid counterpart. Their small size allows them to be placed in tighter spaces. These batteries are also expected to have a longer lifespan than the lead-acid storage battery (Turner, 2016 p.27). The Tesla Powerwall is an example of solar battery storage.

Energy Storage

In some cases it may be advantageous to store a portion of the generated solar energy in batteries. There are several off-the-shelf systems that provide reliable battery power, easy installation, and a similar payback period as solar panels. Tesla's Powerwall, the Sunrun Brightbox, and Panasonic's EverVolt are examples, to name a few. These units typically start at around 5 kWh and can scale up by adding modular sections. Each section is typically just 4 ft. by 3 ft.

Battery banks as shown in Figure 18, left, or smaller modular systems like the Tesla Powerwall shown in Figure 19, can be connected to one or more circuits. Typical uses for small solar plus storage is similar in nature to an uninterrupted power supply, but on a larger scale (EnergySage, 2020; DoE, n.d.).

Fig. 18: Lithium Battery Bank. Schroeder, D. (n.d.)

Fig. 19: The Tesla Powerwall is one of the most popular battery storage systems for solar. This relatively small container can supply an average-size house for one day. (Leon, 2018)

Solar Hydronic Heating and Hydro Pumping

In order for solar technology to penetrate the fossil fuel-based energy supply chain, the technology has had to diversify. One of those solar technologies is solar thermal (ST) collectors. These ST collectors can be used to heat water and displace the use of fossil fuel energy. This can help solar technology deal with its disadvantageous intermittent electricity production as nearly half of global energy is used for heat (Mellor et al., 2018). It may be useful to consider solar thermal energy collection or a combination of photovoltaic and solar thermal as an alternative to using only photovoltaic arrays. Space heating and cooling in commercial buildings account for 34% of the total energy used. It may be possible to offset additional energy use by heating occupied space and water using direct thermal energy collection. In addition to heating air and water, the technology exists for using heat for cooling ("U.S. Energy Information Administration - EIA - Independent Statistics and Analysis", 2012).

For a comparison between photovoltaic and thermal solar, it is necessary to convert both types of panels to their equivalent output per square foot. When both forms of solar energy were converted to the same unit of measure the result showed that thermal solar collectors are over seven times more efficient than photovoltaic panels[1]. Solar Hydronic Heating and Hydro Pumping is a low energy product that can be used to achieve maximum heating in climates that have bouts of cold weather and utilizes water that is heated by the sun (Figure 20). This hot water is then used to heat buildings. This process can be done by using convection radiators or through pipes embedded underneath the floor. Either one of these methods helps radiate warmth to the occupants within a space (Clarke, 2014, p. 82).

Fig. 20: Residential Solar Hydronic Radiant Heating. ("Radiant Heating", n. d.)

For newer builds, a rectilinear spiral of plastic tubes is often embedded into a concrete floor. These same tubes can also be installed into the framing of interior walls, while exterior walls require insulation. The insulation on one side is used to direct the heat inside. Internally, heat can be delivered through the walls if they are in contact with surfaces on either side of the wall. It is also an option to have the same tubing system utilized in renovations as it has been found fairly easy to retrofit existing structures with these hydronic tubes (Clarke, 2014 p.84). Heat pumps move heat from one medium to another. These systems concentrate low-grade heat from the air and “dump” it into a water storage tank. Heat pumps are quite more efficient than conventional electric water heaters, even though these systems still use electricity to operate (Hot water savings: Efficient hot water buyers guide, 2017 p. 72).

Additionally, heat pumps are capable of reducing the year-round energy requirement for hot water by at least fifty percent. Heat pump hot water systems are configured as either integrated or split. In the integrated system, equipment such as an evaporator and fan are mounted on top of or beside the water tank. In a split system, the heat pump mechanism is housed in a separate unit. Integrated units have the benefit of simpler installation and compactness, whereas split systems allow for greater flexibility in the location of the two necessary components. Overall, heat pumps are much more efficient than the conventional water heaters (Hot water savings: Efficient hot water buyers guide, 2017 p.73).

However, one of the main factors to consider with PVs and ST collectors is that the use of both as separate systems would cause issues if available space is limited, i.e. the roof of a building or house. Once again, the hybrid system poses a possible solution, in this case the system would be a hybrid photovoltaic-thermal (PVT) collector. PVTs have already shown to address the storage challenge and have greater economic value with regards to produced energy per unit area (Mellor et al., 2018). One of the major drawbacks of PVTs is the decrease in electrical and thermal efficiencies with rise in PV-cell temperature (Mellor et al., 2018). These high temperatures also pose threats the overall lifespan of the PV-cells. And, because of this, PVTs deliver low temperature heat (<40ºC) in order to maintain a relatively suitable balance between the electrical and thermal efficiencies (Mellor et al., 2018). In order to make PVTs more competitive with its stand-alone counter parts, the PV and ST collectors, PVTs have to deliver thermal energy capable of temperatures near 60ºC, this is what is a value typically found for domestic hot water (Mellor et al., 2018).

Utility-Scale Solar Energy Systems

Concentrated Solar Power (CSP)

CSP systems use mirrors to concentrate a large area naturally occurring sunlight onto a small area (Khan & Arsalan, 2016 p.418). This concentrated sunlight is used to produce high temperatures (The future of energy: Large-scale solar worldwide, 2016 p.25). Simply put, solar thermal power plants use this direct solar energy from the sun to create steam. This steam then drives a turbine which is then used to generate electrical power for use (Müller-Steinhagen, 2013 p.2).

Solar thermal energy plants are often recognized for their efficiency in collecting electric power in bulk. Thermal energy can also be integrated into existing or new thermal power plants. They also have the capacity to have adequate storage capabilities and can have a fossil fuel backup, if needed (Müller-Steinhagen, 2013 p.2). CSP plants can be equipped with heat storage systems that can generate electricity under conditions where there is little to no sunlight. This thermal storage can have a significant increase in the overall capacity and efficiency in comparison to PV technology (Tagliapietra, 2015 p.76).

There are currently four different basic design options for Concentrated Solar Power technologies. These four types are linear Fresnel, parabolic trough, solar power tower, and dish-Stirling, also known as a parabolic solar dish (Figures 21, 22, 23 and 24) (Müller-Steinhagen, 2013 p.3). However, one of the most critical issues with the CSP method is the amount of water that is needed. This water is to help in cooling down the condensers in these solar thermal power plants. This is in addition to cleaning the mirrors, used to gather the sun's heat. This cleaning process is often done in one to two-week intervals to ensure that the mirrors are operating at maximum efficiency (Müller-Steinhagen, 2013). While large water use may be a potential problem in geographic areas that have little water, to begin with, this solar power source may be an option for areas that do have an abundance of easy access to water sources.

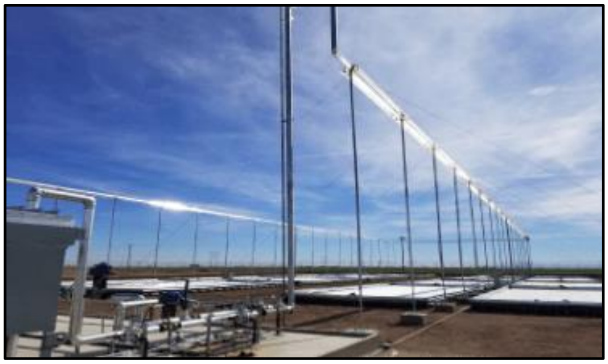


Fig 21: Linear Fresnel. Concentrates light using a series of angled mirrors, generating heat. (Mehos, "Concentrating Solar Power (CSP) Overview", n. d.)

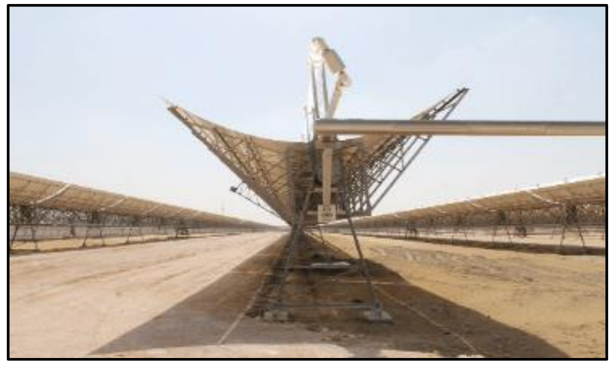


Fig.22: The Parabolic Trough is a long trough in the shape of a parabola with a reflective surface. Light converges on a point, generating heat. (Irena, 2015)

Fig. 23: The Power Tower uses thousands of ground-mounted mirrors that adjust their tracking as the sun moves across the sky. Ivanpah Solar Power Plant (srose15, 2016)

Fig. 24: A Parabolic Solar Dish is a mirrored shape like a satellite antenna. It concentrates light energy on a receiver. - Solar power at White Cliffs (Dpi, 2009)

Manatee County Solar Project Feasibility Locations (Buildings & ROI)

The main goal of this project is to conduct a targeted research analysis to determine the feasibility of retrofitting Manatee's County pre-existing government buildings to become Net-Zero through sustainable solar initiatives. The county has demonstrated solar energy leadership by initiating this partnership with USF to further its environmental stewardship to include solar energy. To determine the possibility, research was conducted to determine the appropriate Return on Investment (ROI) methodology. The proposed ROI methodology notes the importance of factors such as solar installation method and cost. Furthermore, it is recommended that an extensive EROI methodology be executed by the government through the use of sustainability consultants to supplement the ROI delivered within this project.

Many factors were considered when developing strategies such as the gathering of preliminary data and conducting appropriate research methods for retrofitting pre-existing infrastructures. The scope of the ROI research includes identifying documented research methodologies for capturing ROI. Only government owned buildings with data for identifying the current electricity rate will be considered in-scope. Furthermore, special consideration will be given to buildings that are considered critical facilities.

The deliverable includes the **ROI Excel Document** which has been constructed to allow Manatee County administration the ability to carry out the ROI Research for future use (see attached Excel file). Out of scope facilities include buildings not owned by the government. The constraints for in-scope facilities are highly dependent on data available at the time of analysis. Other constraints prevail as solar installation cost varies by method and the county has not specified their desired method. Furthermore, the assumption is that any building with reported meter data may be considered for this project.

Relevant terms for this analysis are defined in ***Table 2*** below:

Table 2*: Relevant Terms and Definitions*

Net-Zero, or Zero Net buildings	Occurs when a "building produces as much energy as it consumes, usually through a mix of high efficiency and clean onsite power generation." (Boulder County, 2020).
Return On Investment (ROI)	"A useful means of comparing companies, or corporate divisions, in terms of efficiency of management and viability of product lines." (Dictionary of Finance and Investment Terms).
Energy Return on Investment (EROI)	"The ratio of energy returned from an energy-gathering activity compared to the energy invested in that process." (Hall, 2012).

Return on Investment (ROI) and Energy Return on Investment (EROI)

It is clear today that ROI is not just pertinent to the finance industry or profitable organizations; it is key to sustainability (Ralser, 2007). ROI is determined by the formula: $ROI = SUM(Return)/Sum(Investment)$. Cohen, Eimicke & Miller (2015) defended the importance of organizations calculating ROI for sustainability practices and policies. These practices may be slow to develop, as many sustainability initiatives are considered first movers. The benefit, however, is that this calculation can lead to holistic thinking, which contributes to the overall migration to sustainability management.

Energy Return On Investment (EROI), proposed by Charles Hall in the 1970s, evaluates a system of inputs versus outputs as $EROI = Societal\ Energy\ Returned\ /Required\ Energy\ To\ Obtain$. An investment is considered a net energy gainer if $Energy\ Returned > Energy\ Required$ whereas an investment is a net energy loser if $Energy\ Returned < Energy\ Required$. Carbajales-Dale, Raugei, Fthenakis & Barnhart (2015) consider EROI as a useful metric for assessing the long-term viability of energy-dependent systems, focusing on solar power and solar energy technologies.

Clarifying the goal and the scope of the organization's projects before determining a formula to calculate EROI is crucial because each goal and scope requires a unique method of calculation. Transparency of all research methods and calculation formation is required when presenting EROI results because providing an accessible analysis allows peers to interpret, apply, or replicate the study, thus, giving it credibility. To align with industry best practices, this deliverable provides transparent research methods and calculations to support the ROI methodology. EROI should be conducted in further studies by sustainability consultants.

Strategic Approach to ROI

The strategic approach for this ROI proposal defines the roadmap used to successfully conduct an ROI. To ensure valid results are produced the following steps include:

1. Analyze data to determine strategic building locations and current electricity consumption
Qualitative and quantitative data was constructed to determine strategic building locations. In addition to the high-risk buildings identified by Mr. Caplan, other conditions were considered such as roof usable size and additional space availability, usage and occupancy, and ownership.

2. Calculate expected solar energy output from solar installations
Calculating the energy output using PVWatts Calculator will help provide accurate information on expected solar out from solar installation. Using this information, we will decide which locations will benefit from solar. This will be conducted on various building locations provided in Step 2 and it will support the initial feasibility analysis conducted in Step 1 on the various building locations.

3. Select optimal solar panel installation locations to maximize energy output
After analyzing data from the PVWatts Calculator, specific locations can be selected through a cross-reference analysis. This analysis will review the amount of energy produced to the energy consumed to further target locations that are high-risk and high-reward.

4. Calculate ROI on the selected buildings
Calculating the ROI for solar installation on selected buildings is crucial to determine the overall feasibility for each location.

Research Methods for ROI aspect of the Project

Various research methods were utilized to determine ROI from retrofitting government-owned buildings to become Net-Zero. This included a comprehensive qualitative and quantitative methodology to close the gap between solar output and energy consumption. Because the goal of this project is to determine the feasibility of Net-Zero buildings, additional retrofitting alterations will be recommended.

By definition, Return on Investment (ROI) measures the benefit an investor will receive in relation to their investment cost. In this study, the ROI will be calculated by the rate between the investment gain and the investment base. It can also be obtained by dividing the net income by the cost of the investment. The net income, in this case, will be presented as the energy cost saving throughout the financial loan period. In other words, it will be considered as income the amount of money saved from the electricity bill cost. This approach allows the investor to use the same budget cost estimated in the forecasts and projections to pay for investment instead of service cost. It creates values and builds real estate assets for the county ownership.

Data Construction

To provide accurate and reliable ROI, the following data were collected: critical facilities from Eric Caplan (Manager in Energy & Sustainability Division - Manatee County), meter entries from Professor Ghebremichael, and solar output from the National Renewable Energy Laboratory (NREL). As mentioned earlier, NREL is a research institution that provides the PVWatts Calculator used for solar simulations.

The data construction involved creating data sources at the same level of aggregations for the quantitative data, such as determining annual and current electricity costs and usage from monthly meter entries. The DC system size, system output, and system cost are required to determine the investment payback period and return on investment. The solar data was collected from the PVWatt calculator.

The data sources constructed for the analysis are listed in the "Data Source Name (DS#)" (See Figure 25). To calculate the ROI for solar installation the following procedure was conducted:

Data Source Name (DS#)
1. Critical Facilities
2. Energy Portfolio
3. Solar Simulation
4. Analysis File

*DS1 was provided to this course and DS2 was provided to Systems Thinking from the county - the sheets in the Excel workbooks were joined using a unique identifier. DS3 was collected from PVWatts. DS4 was created from DS1 and DS2.

1. **Determine the locations**

   DS4 was created by joining DS1 and DS2 on Address. Joining the data provided metrics such as cost, square foot, and usage for critical facilities identified by the county. Locations with high priority, critical roles, large cost, and large square footage were identified (See *Appendix B*).

2. **Determine the annual electricity cost and usage**

   Using DS2, the annual electricity cost and usage were calculated for each selected location in 2018 (Billing End Date Jan. 2018 - Nov. 2018).

$$Electricity\ Cost_{Year,Address} = SUM(SUM(Electricity\ Cost_{Month}))$$
$$Electricity\ Usage_{Year,Address} = SUM(SUM(Electricity\ Usage_{Month}))$$

3. **Determine the current electricity rate usage**

   For this analysis, DS2 was filtered to include the identified locations with data for 2018 (as done in step 2). For each Address, for each Billing End Date, the Cost and Usage were used to calculate Electricity Rate.

$$Electricity\ Rate_{Year,Address} = AVG((SUM(Electricity\ Cost_{Month})/SUM(Usage_{Month})))$$

   For each month, the electricity rate was calculated. The electricity rate for the months Jan - Nov were averaged to determine the electricity rate for each location for the year of 2018.

4. **Determine the DC System Size**

   By entering appropriate information into PVWatts, the DC System Size is estimated.

5. **Determine the System Output**

   Running the simulation provides the annual system output, which is used for EROI.

6. **Determine the System Cost**

$$System\ Cost = SUM(DC\ System\ Size)\ x\ (\$1{,}830\ Watts\ *)$$

*(U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018. Golden, CO: National Renewable Energy Laboratory, 2018)

7. **Determine the Payback Period**

$$Payback\ Period = SUM(System\ Cost)/SUM(Electricity\ Cost)$$

8. Determine the Opportunity Cost of not switching to solar

$$Opportunity\ Cost\ =\ (Payback\ Period) * (Annual\ Electricity\ Usage * Electricity\ Rate)$$

9. Determine the ROI

$$ROI\ =\ ((Energy\ Cost\ Savings\ *\ Financial\ Loan\ Period)\ /\ Total\ Installation\ Cost) - 1$$

Energy Cost Savings is annual dollar savings from the electricity bill. The Financial Loan Period is the time it takes to pay back the loan. The Total Installation Cost is the cost of the system plus, installation, and any other additional fees.

Data Analysis

The analysis was conducted on the Public Safety Building to determine the ROI. From the ROI analysis, it is clear that public safety has the potential to become net-zero through solar installation. Listed in the *Appendix B* is the Hub Selection which suggests the priority and grouping addresses that the county should consider for further analysis.

To continue this analysis, the county government will need to collect the following variables to input into the Excel file: Actual Energy Meter Use (kWh), average Energy Rate ($kWh), Roof DC System Size (kW) availability, Additional DC System Size (kW), Solar Panel UN Installation Cost, Solar Energy Roof Generation (Year estimate), Solar Energy Additional structure Generation (Year estimate), and Financial Loan Period (Years). If any of the variables are not readily available, the county should refer to the data construction steps for creating the variables.

The county analysis should also seek to determine the EROI. Conducting an EROI analysis will help determine if a hub is considered a net gainer or net looser. A hub would be considered Net Gainer if $Opportunity\ Cost\ >\ System\ Cost$ then the investment is a Net Gainer and an implementation plan should be curated. If $Opportunity\ Cost\ <\ System\ Cost$ then the investment is a Net Looser and the estimate should be re-evaluated.

Results and Findings

The initial analysis was conducted on the Public Safety Complex (PSC) (See Figure 26). The PSC incorporates all parameters of prioritization proposed in this study. Besides being pointed by the county as one of the priority buildings, it presents a good roof surface and additional available land space. Moreover, the system estimated outcome projects a net-zero capability, when compared to the 2018 electricity usage. In addition, the PSC is a building owned by the County. That last fact contributes to the financial aspect of its implementation and makes the system investment, as a whole, less complex to achieve. Although possible, financial models can be very complex and risky when systems are implemented in third-party properties.

2101 47th Terrace E, Bradenton, FL 34203

Annual Electricity Usage (kWH)	3,463,680
Annual Electricity Cost	$220,691.10
Current Electricity Rate	$0.06
Roof System Output	1,177,891
Roof Cost	$1,409,100.00
Additional Cost	$2,664,663.00
Total DC Size (kWH)	3,464,989
Total Annual Energy Cost Save	$221,759.30
ROI (Years)	18
EROI Surplus (KWH)	1,309
Additional DC Size	1,456
Roof DC Size	770
Total System Output (kWH)	2,287,098

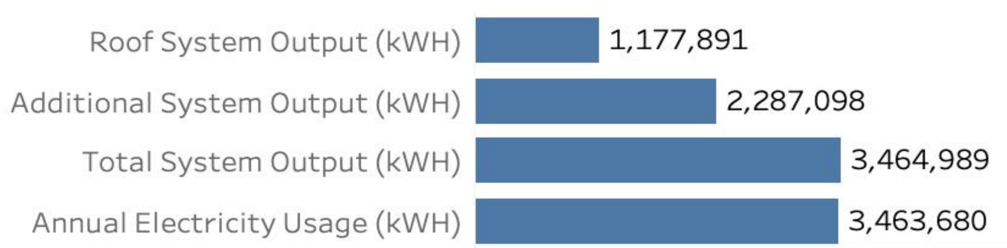


Fig. 26: Initial ROI analysis conducted on the Public Safety Complex (PSC)

Other buildings identified by the county as priority present excellent surface available areas are not county-owned properties. It makes the model much more complex, and further studies and considerations are needed. But, based on our preliminary analysis, it may not be possible for all buildings to become Net-Zero by implementing solar initiatives alone. Available roof area and the availability of additional areas represent a limiting factor. By analyzing buildings available areas and using PVWatts estimator to project energy output by solar systems, it was possible to compare needs and projected energy generation. By doing so, the study shows a gap between those two parameters for many of the county buildings. Implementing solar along with other modifications aimed to reduce electricity demand is recommended.

The ROI analysis provides a transparent, reliable, and repeatable estimate that can be used to determine the feasibility of solar installation for the recommended hubs. The payback period is provided the exact number of years to recoup the investment. The current electricity rate was derived from the monthly meter entries for each location to be highly accurate. The factors with the potential to vary create the weakest points of the analysis. Because the cost of solar installation varies by method and company this estimate should be provided by solar installation professionals to improve accuracy. The biggest limitation when interpreting the data is a result of the lack of data provided for analysis as well as varying costs for solar installation.

This document includes a completed analysis of strategic locations, also known as Hubs, which includes ROI for each system installation and the payback period, which is the time needed to recoup the initial investment. The addresses should be grouped into Hubs so the solar panels installed can be maximized. The hub locations include county addresses that are close in proximity (*See "Hub Selection" in *Appendix B*). The purpose of this deliverable is to provide Manatee County with the information needed to finalize the feasibility analysis and move into the planning cycle for securing investments to fulfill the Net-Zero building proposal.

Appendix A presents an Excel model elaborated in this study. In this spreadsheet, all needed information can be plugged in, and the ROI will be calculated, along with the payback time. Furthermore, the comparison between solar system generation and the building needs can be obtained. Such comparison can lead the county to better evaluate investment decisions.

PV Systems for Other Public Buildings in Manatee County

The following sections will detail the recommendations of possible PV systems for each building and their tabulated results after being calculated for in PVWatts. Unique considerations for each building will also be addressed. All systems were placed within the borders of each locations' specific parcel as per the Manatee County GIS Property Locator. If additional neighboring land may be used for the purposes of installing PV, achieving net-zero may be easier to achieve for some locations, such as the Lake Manatee and Dam Reservoir.

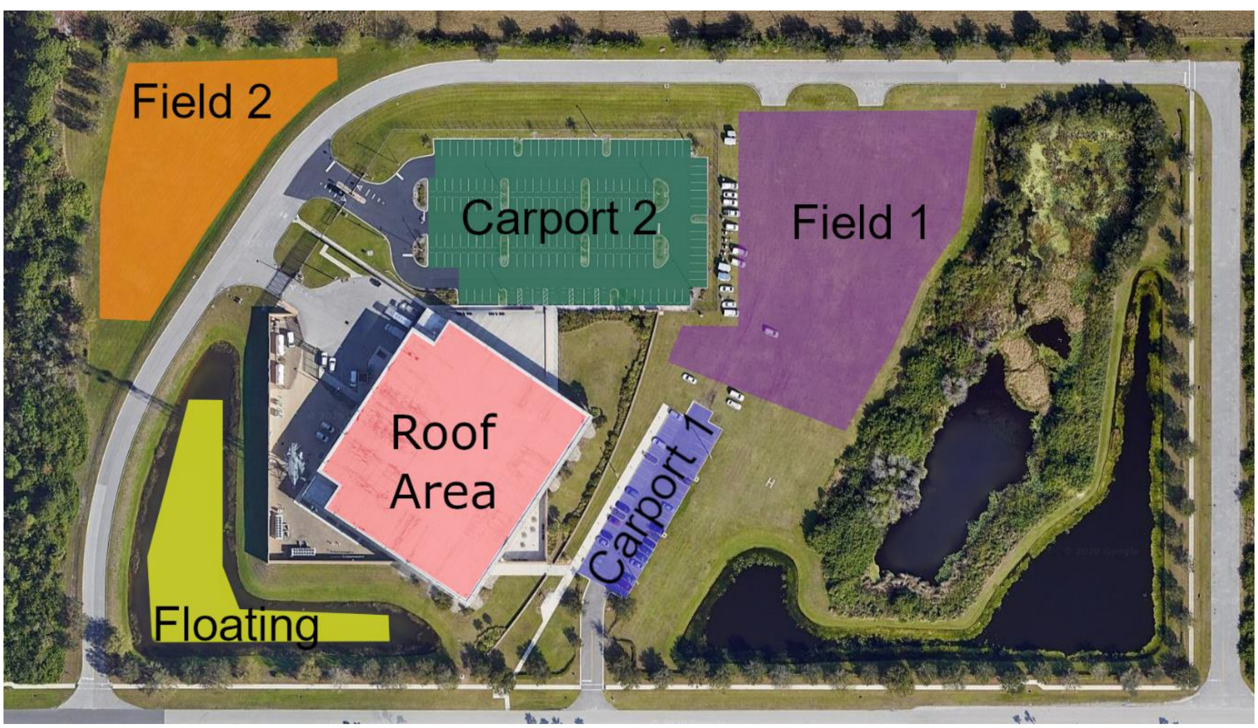
The rooftops that were assessed to be reasonable candidates for solar were measured using the Google Earth area tool. The usable area in square feet of each rooftop was then recorded in a spreadsheet. The average kWh per day for all facilities was recorded. With a known size and output of photovoltaic panels, it was then possible to analyze the potential of each facility for producing electricity from a rooftop solar array. A spreadsheet was created to facilitate dataset construction. Each facility's energy usage was listed on a separate page and transcribed to the spreadsheet. The addresses of each facility were entered into Google Earth to produce a satellite view for each facility. The Google Earth area tool was then used for each building to estimate the square feet available on each rooftop.

Additionally, county zoning maps were examined during data construction. This was done for the purpose of locating a suitable site for a large land-based array.

The last two columns for each set of data provide an estimate for the Return-on-Investment, or ROI. This was calculated by multiplying the system size by the reported cost per watt of a PV system, and then dividing by the expected annual savings. The reported cost per watt was retrieved from NREL's U.S. Solar Photovoltaic System Cost Benchmark (Fu et al, 2018, p. 8). Using a bottom-up approach to identify costs, the report gives the expected combined cost of the module, inverter, hardware balance of system, and various soft costs (Fu et al, 2018, p. 6). These considerations do not include tax incentives or other such cost reductions due to the varying nature of these across the country. The rates also vary across system sizes; this report assumes that the costs would fall under the 200 kW to 100 MW system costs or $1.83 and $1.06 per watt respectively.

Public Safety Center – 2101 47th Terrace East, Bradenton, FL 342 (Aerial Map 1)

The Public Safety Center has the possibility to install multiple types of PV systems on location. The highest roof provides a great deal of space with little in the way to hamper a roof mounted system. It should be noted however, that the building has parapets which cast shadows. These must be accounted for to ensure that no module shading occurs. Additionally, the roof may allow a large system in terms of area, but the structural strength must also be able to hold the system. As mentioned before, there are two fields that may be used, with the larger providing the highest system size for the location. Likewise, the carports offer a great deal of space to install PV, but it may be costly to install over the entirety of the lots. The southwest retention pond may be used for floating modules, but the limitations of such a system must be considered. From the listed systems, approximately 5,897,871 kWh may be expected annually. In comparison to the buildings 3,813,120 kWh average annual use, net-zero may be achieved.



	DC System Size (kW)	Array Type	Tilt (deg)	Azimuth (deg)	Rate ($/kWh)	**Annual kWh (AC)**	Annual Savings	ROI (low)	ROI (high)
Roof	733.5	Roof	27	135	0.065	**1,104,859**	$71,815	18.69	10.83
Carport 1	187.9	Roof	10	135	0.065	**276,966**	$18,002	19.10	11.06
Carport 2	778.7	Roof	10	180	0.065	**1,164,213**	$75,674	18.83	10.91
Field 1	1099.5	Open Rack	27	180	0.065	**1,735,291**	$112,794	17.84	10.33
Field 2	654.5	Open Rack	27	180	0.065	**1,032,968**	$67,144	17.84	10.33
Floating	384.5	Open Rack	10	180	0.065	**583,574**	$37,933	18.55	10.74
					Total:	**5,897,871**			

Table 3: *Public Safety Center ROI*

MSO Judicial Center – 1051 Manatee Ave W, Bradenton, FL 34205 (Aerial Map 2)

Being located within the city, there is little room to install PV other than on the roof of the building. However, the building's construction causes a great deal of self-shadowing across much of the roof. The two areas detailed below serve as the most likely areas where systems may be installed, but considerations such as parapet shadows and obstructions on the roof will greatly reduce the actual system size. With these two systems, only 170,587 kWh will be generated each year compared to the 4,483,382.5 kWh consumed by the building. As such, reaching net-zero is not feasible.

	DC System Size (kW)	Array Type	Tilt (deg)	Azimuth (deg)	Rate ($/kWh)	**Annual kWh (AC)**	Annual Savings	ROI (low)	ROI (high)
Roof 1	78.1	Roof	27	180	0.096	**123,933**	$11,898	12.01	6.96
Roof 2	29.4	Roof	27	180	0.096	**46,654**	$4,479	12.01	6.96
					Total:	**170,587**			

Table 4: *MSO Judicial Center ROI*

County Administration Building - 1112 Manatee Ave W, Bradenton, FL 34205 (Aerial Map 3)

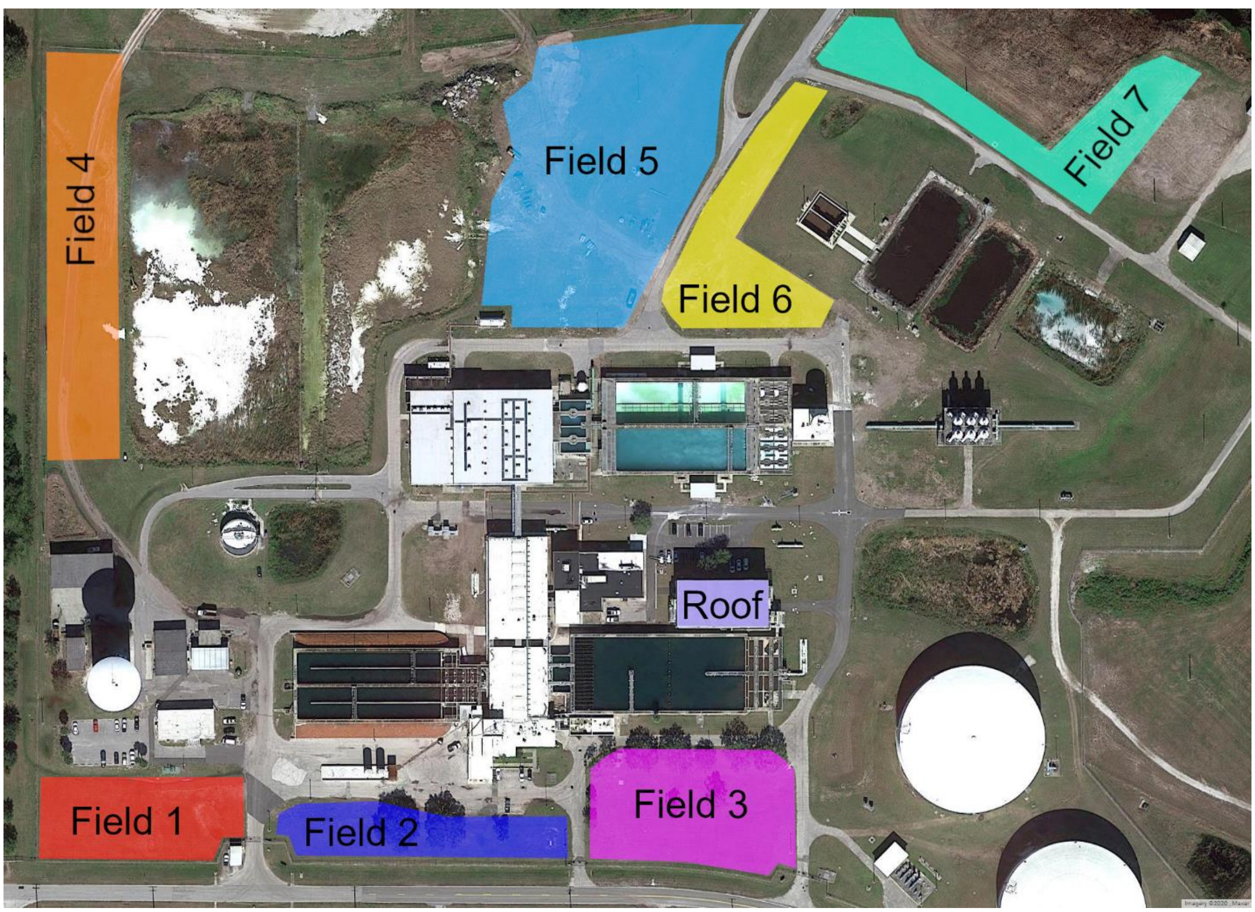
Like the Judicial Center, the County Administration Building resides within the city and leaves only the roof as the ideal location for solar. The eastern side of the roof holds a great deal of hardware that will reduce actual system size as well. The parking garage may serve as an ideal location for a solar carport, but it was not included within this report due to the complex structural requirements that need to be considered and then enacted to install such a system. Generating 263,225 kWh a year, the suggested system will only provide a fraction of the 1,647,840 kWh consumed by the building. As such, net-zero will not be feasible.

	DC System Size (kW)	Array Type	Tilt (deg)	Azimuth (deg)	Rate ($/kWh)	Annual kWh (AC)	Annual Savings	ROI (low)	ROI (high)
Roof	163.3	Roof	27	180	0.08	**263,225**	$21,084	14.17	8.21

Table 5: *County Administrative Building ROI*

Lake Manatee and Dam Reservoir - 17915 Waterline Rd, Bradenton, FL 34212 (Aerial Map 4)

The Dam Reservoir provides several opportunities for ground mounted systems within its various fields, along with one roof. However, some fields currently appear to have other uses as service roads or dirt parking lots. The removal of these may not be possible if it hampers site operation. To the north of the parcel though, the county owns a great deal of land, some clear, but mostly forested. This land may be converted to provide supplemental generation to overcome the site's rather large power consumption in order to achieve net-zero. That said, it would require increased costs in the way of tree removal and ground grading, something that many of these listed fields will also require in a limited fashion. Regardless, the recommendations for this parcel only generate 7,558,170 kWh of the required 18,621,600 kWh to achieve net-zero.

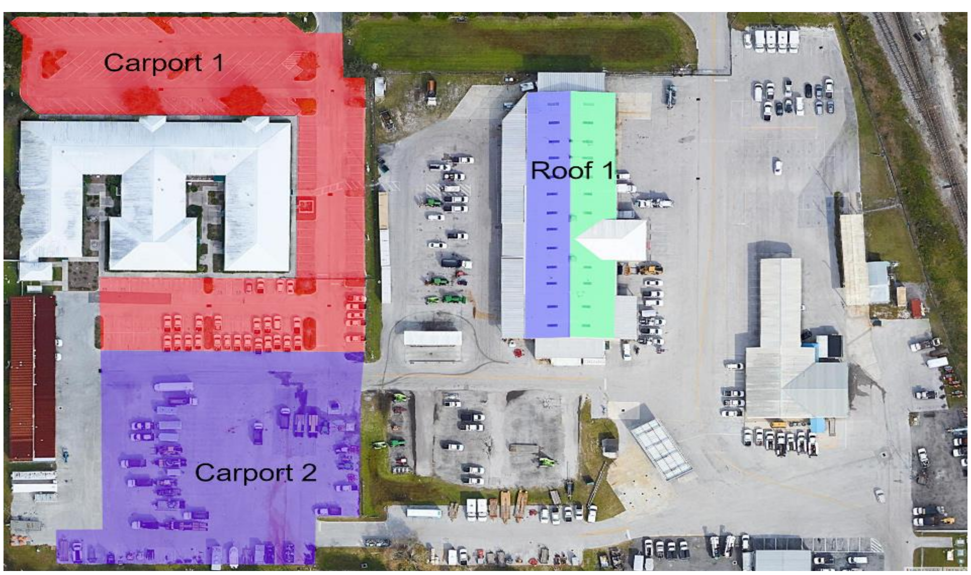


	DC System Size (kW)	Array Type	Tilt (deg)	Azimuth (deg)	Rate ($/kWh)	**Annual kWh (AC)**	Annual Savings	ROI (low)	ROI (high)
Roof	113.1	Roof	27	180	0.057	**173,098**	$9,866	20.98	12.15
Field 1	429.1	Open Rack	27	180	0.057	**666,877**	$38,112	20.60	11.93
Field 2	355.7	Open Rack	27	180	0.057	**552,804**	$31,593	20.60	11.93
Field 3	621.2	Open Rack	27	180	0.057	**965,426**	$55,174	20.60	11.93
Field 4	767.4	Open Rack	27	180	0.057	**1,192,640**	$68,159	20.60	11.93
Field 5	1486.5	Open Rack	27	180	0.057	**2,310,215**	$132,029	20.60	11.93
Field 6	540.1	Open Rack	27	180	0.057	**839,385**	$47,970	20.60	11.93
Field 7	551.9	Open Rack	27	180	0.057	**857,725**	$49,019	20.60	11.93
					Total:	**7,558,170**			

Table 6: *Lake Manatee and Dam Reservoir ROI*

Public Works Administration - 1022 26th Ave E, Bradenton, FL 34208 (Aerial Map 5)

The Public Works Administration presents a huge opportunity for solar carports due to the large space of unobstructed area. However, the vehicles that can be seen on location appear to include heavy-duty commercial vehicles. These will likely require a higher elevated carport, leading to increased costs. That said, the energy use is relatively low compared to the size of the parcel. To reach net-zero, it was found that using only the suggested roof will provide more than enough energy, despite its unideal azimuth. If the roof can support the estimated systems, it would generate 402,853 kWh compared to the 275,940 kWh consumed.



	DC System Size (kW)	Array Type	Tilt (deg)	Azimuth (deg)	Rate ($/kWh)	**Annual kWh (AC)**	Annual Savings	ROI (low)	ROI (high)
Carport 1	857.3	Roof	10	180	0.087	**1,274,844**	$111,167	14.11	8.17
Carport 2	797.4	Roof	10	180	0.087	**1,185,770**	$103,399	14.11	8.17
Western Roof	155.1	Roof	18.4	180	0.087	**209,195**	$18,242	15.56	9.01
Eastern Roof	139	Roof	18.4	180	0.087	**193,658**	$16,886	15.06	8.73
					Total:	**2,863,467**			

Table 7: *Public Works Administration ROI*

The above recommendations involve a great deal of assumptions based on information provided by the county and the limited nature of GIS and satellite imagery. Each system must be examined individually by conducting an on-site survey. Until the data from such surveys is known, these remain only estimations and recommendations.

After compiling and reviewing the Manatee County data on the energy usage and energy consumption costs of all facility buildings it has been determined that on average from the last two years Manatee County facility buildings have used 68,021,545 kWh of energy which has costed the county $5,027,784.80.

As discussed above the efficiency of a solar panel can vary; however, on average, when one 250-watt STC rated panel receives an average of 4 hours of direct sun, it produces an estimated 1000 watts or 1 kWh per day (Zientara, 2012). Simple math tells us this would be an average of 365 kWh per year per one 250-watt solar panel. With this information, Manatee County would need approximately 186,361 panels to produce enough energy for all the county facility buildings.

According to an EnergySage article by Sara Matasci, the average cost of one solar panel in 2020 is $187.50. Therefore, the estimated cost just for the required 186,361 solar panels for Manatee County facility buildings is $34,942,687.50. This price does not include other installation, maintenance fees or operational costs such or labor or incentive savings. According to another EnergySage article by Kerry Thoubborn, maintenance fees cost approximately $10 per panel per year, which would amount to $1,863,610 per year for the county.

To recap, the installation of a solar system for all of Manatee County's facility buildings will cost approximately $34,942,687.50 if purchased outright. Given the county's current yearly energy usage costs of $5,027,784.80, not including inflation costs and without accounting for incentives or applicable taxes they can expect to see a payback in approximately 7 years. The estimated ROI on a solar system with a lifetime of 25 years for Manatee County including approximated yearly maintenance fees would be $45,773,486.40. These numbers reflect a direct financing scenario when the solar system is purchased outright and not financed. These numbers would need to be updated to reflect interest costs if any bond financed or loan options are taken.

Estimating the number of solar panels depend on the panel's watt rating. Note that Table 18 calculated the number of panels needed using 350-watt panels resulted in an estimate of 117,225 panels, taking into account Tampa's 5.67 hours of average sunlight per day. As solar technology continues to advance, higher rated panels will certainly become more cost effective and reduce the number of solar panels required. And, installation and maintenance costs should not be a major issue once a set volume of panels has been decided upon.

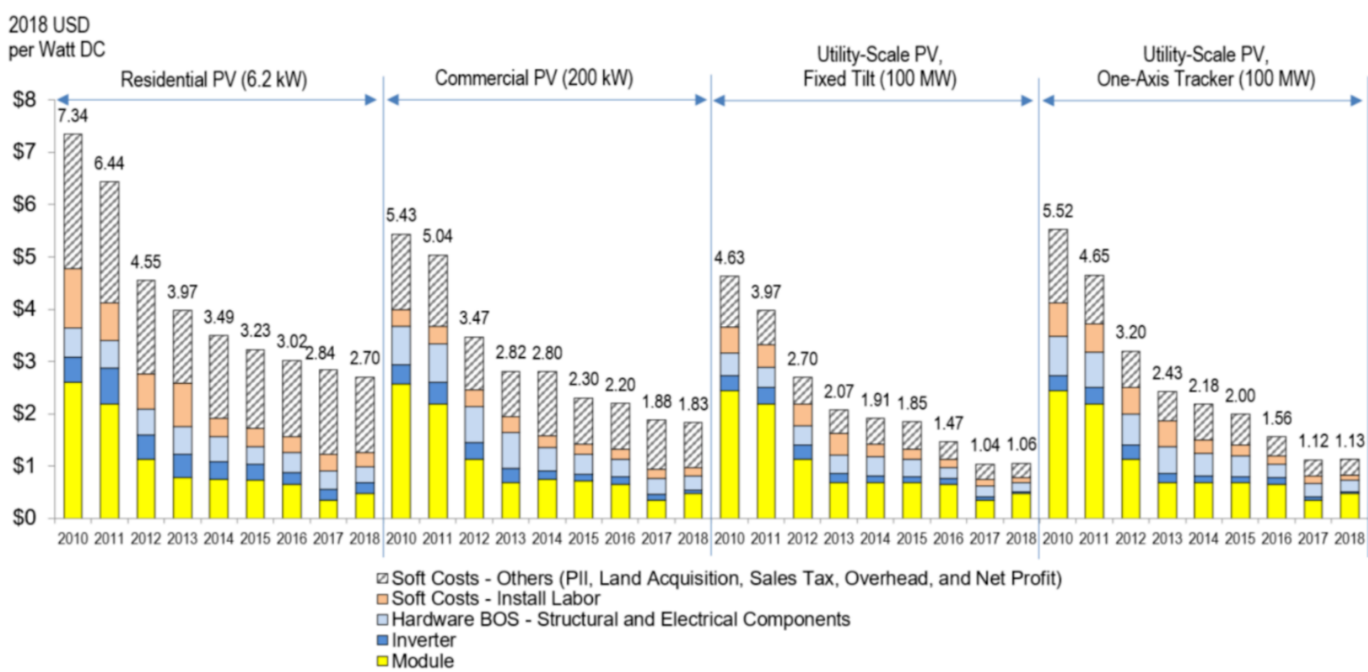
Financing Options

Solar System Cost

The cost of solar installation has decreased over the years as market expansion has increased its affordability. According to the International Energy Agency, global energy demand (gigawatts) will increase by 50% from 2018-2024. With increasing affordability, Manatee County should execute a bulk order for multiple projects at once to help drive the cost down even further (National Renewable Energy Laboratory, 2018). The cost per watt will be estimated at $1,830 (Fu, Ran, David Feldman & Robert Margolis, 2018). (See Figure 27)

Figure 2

PV system cost benchmark summary (inflation adjusted), 2010-2018



SOURCE: NATIONAL RENEWABLE ENERGY, 2018.

Fig. 27: PV system cost benchmark summary, 2010-2018 (**Figure 2**)

Project Financing Significance and Scope

Renewable Energy (RE) development is complex in nature and requires long-term planning for effective and successful implementation. Cost management and financing options set the baseline for any project. Financing RE is quintessential to the success of the entire project, from budgeting, cost analysis, to allocating resources and funds, it ensures the project is within the financial capabilities of the government. Analyzing and weighing current energy costs to potential spending in the project would also give insights to determine whether to pursue the solar project in the first place.

In this mixed method study, analyzing current development of solar energy trends on a national and international level as a background study through qualitative data analysis. Reviewing case studies from federal, state, and local level regulatory frameworks on RE development, are used as comparisons for government solar projects in the state of Florida. A quantitative study was done as an evaluation of the current energy consumption patterns and costs of electricity for government facilities in Manatee County. Based on results, sustainability strategies and financing recommendations are proposed later in the report.

Solar Technology and Costs

Solar technology produces energy from sunlight, which can be used for the provision of heat, light, water, electricity, and cooling. Solar technology is widely used for residential housing systems, commonly found on rooftops, which provides long-term cost savings to residents; businesses which wish to offset their energy costs; and utility companies that build large-scale solar power plants to provide clean energy options to their customers over the grid. The cost of solar systems involves several elements: system module cost consisting of raw material, manufacturing, and assembly costs; balance of system cost including the structural, electrical, and battery or storage system costs (Mohamed Rashad, n.d.) and operational and maintenance costs (IRENA, 2016).

Solar Installation

Renewable energy (RE) is key to addressing rising energy needs and alleviate the effects of climate change. However, high initial costs of solar installation and long return on investment timeframe (compared to a conventional energy source), act as a deterrent for RE projects (Miller et al., 2017). According to Miller et al.'s study (2017), "Overnight capital cost for renewables, compared per megawatt (MW), can be twice as those for conventional energy sources" (p. 121). Ensuring funding for RE projects is the first step in increasing clean energy in the energy mix and there are various financing vehicles available. Feasibility of each funding option needs to be examined to determine the best options for solar, as a unique source in an ever-changing renewable technological space.

Cost Benefit Analysis

Bottom-Up Method

Bottom-up Methodology can be used to account for all solar project-development and system costs incurred. Solar project pricing is highly dependent on regional project elements such as local retail rate structures, local incentives and rebates, competitive market environment structure, and project transaction agreements. Based upon Fu et al. bottom-up approach, the 2017 Q1 PV cost benchmarks for various sector size ranges are:

- $2.80 per watt DC (Wdc) (or $3.22 per watt AC [Wac]) for 3-10 kW residual
- $1.85/Wdc (or $2.13/Wac) for 10 kW-2MW commercial systems
- $1.03/Wdc (or $1.34/ Wac) for >2 MW fixed-tilt utility scale systems
- $1.11/Wdc (or $1.44/Wac) for >2 MW one axis tracking utility-scale systems

Over the last decade, PV installation costs have followed a declining curve. Based upon this benchmarking analysis, the Consumer Price Index (CPI) includes present adjustments as real US$ (instead of nominal US$), aggregated costs and is inflation-adjusted to calculate declining installation rates. Aggregated costs include permitting, inspection, land acquisition, sales tax, developer overhead, and net profit (Fu et. al, 2017).

NZEB Energy Efficiency Strategies

Increasing climate change awareness has shifted the world to adopt decarbonization strategies for a more sustainable and secure future economy to include substituting fossil fuel production with RE, which indirectly creates employment opportunities. Achieving Net-Zero Energy Building (NZEB) incorporates minimizing energy consumption and managing local energy production to reduce energy delivery costs. The table below, shows how NZEB can be achieved using site based RE power dependent on energy performance certification (EPC); which is supported in the Green New Deal as an indication of energy efficiency and a way to reduce energy use.

Table 8: *Energy requirements, differences between Energy Performance Certification (EPC) A and B, and the average annual new construction capacity projection between 2017 and 2026.*

Building Type	EPC A (nZEB)	EPC B (low energy)	Difference	Annual Net Average Construction of New Buildings Between 2017 and 2026	Average Net Area of a Single Building
	≤ kWh/(m² a)	≤ kWh/(m² a)	kWh/(m² a)	m²	m²
Single Family House	50	120	70	187875	179
Multi-family Dwellings/Apartment building	100	120	20	203531	1605
Office building	100	130	30	87870	4771
Other[a]	100	130	30	601343	743
			Total:	1080619	7298

Note. From “Cost-benefit Analysis of NZEB Energy Efficiency Strategies with on-site PV Generation,” by Pikas, E., Kurnitski, J., Thalfeldt, M., and Koskela, L., 2017, Energy, 128, 291–301. (doi: 10.1016/j.energy.2017.03.158). Copyright 2017 by the Elsevier Ltd.

The above values can be used to calculate PV system power generation and capacity from single to national scale. Net Present Value (NPV) can be derived by computing future cash flows; sum of future values with the assumption of 2.5% as a constant interest rate (which is the current market rate in the U.S. as of March 2020) for life cycle costs and savings, and revenue produced from energy sold.

Over a 20-year period, the income and outcome cash flow analysis results in a loss, which makes grid, partnerships, and federal government support necessary to optimally turn a profit or break even long-term with the adoption of solar power technology. As expected, due to increasing efficiency and demand and decreasing costs, over time NZEB investments are projected to become cost optimal in the market without the use of subsidies (Pikas et al., 2017).

Weighted Average Cost of Capital (WACC)

Although growth in solar PV has driven down market costs, to become fully unsubsidized and cost competitive, there needs to be substantially more growth in the solar market. Growth has been possible due to technological advancements and cost reductions mainly driven by subsidies; feed-in tariffs, tax credits, and rebates. In 2011, renewable subsidies equaled $88 billion globally and are predicted to rise to $240 billion by 2035, while fossil fuel subsidies totaled $544 billion in 2012. Under the global horizontal irradiance (GHI) measurement, a fundamental factor to consider is total sunshine as a primary external driving factor for average costs, over cost of capital, investment, and operating costs. Although total sunshine strength is a factor to consider, it is not the predominant indicator for cost modules. To calculate the levelized cost of electricity (LCOE), the cost of capital and WACC is used to determine the rate by which economic costs and electricity yields are discounted over the lifespan of a solar PV system. LCOE values are highly dependent on location because of differences in location cost and energy output based on sun strength variations.

Installing PV panels needs to be highly supported by initial financing; usually as a combination of equity and money borrowed from investors/lenders. If borrowing money is not in the project planning process, opportunity costs need to be valued; the interest rate or return on equity that money could have been invested differently. Another measure to include in initiating a solar project is the measurement of competitiveness, in this case is the levelized cost of electricity. This levelized cost calculation is derived from the average cost per unit of electricity over the investment lifespan, discounting costs to their net present value at installation and dividing by projected energy output total. This comparison can be used to decide if the long-term renewable investment can be justified over continuing non-renewable, business as usual energy practices (Ondraczek et al., 2014).

The best instruments to build solar fields, carports, and rooftops in Manatee County were determined by analyzing the cost and the kWh produced. The Fixed-Tilt Solar Array system is the best method to build a solar field or carport in Manatee County with an annual energy output of 1,521 kWh and levelized cost of energy (LCOE) worth 0.0447 $/kWh. After comparison between photovoltaic panels companies in the state, it can be concluded that the Q CELLS Q.PEAK DUO-G5 325 has high efficiency and a reasonable cost with 325W nominal power and $0.57/w*. Finally, SMA- SUNNY TRIPOWER CORE1/US is the optimal inverter due to its low total cost of $128,520 and unit cost of $6,426.

Financing Solar Systems

Market-based incentives and policies have been put in place to encourage the development of renewable projects and bridge the gap in price differences between clean and conventional electricity. However, these methods typically fail due to future market uncertainties since the benefits of clean solar electricity generation are often not seen immediately and incentives do not cross the high capital cost hurdle. External investments are crucial for clean energy development; however, debt financiers are cautious towards newer technology due to vulnerability to external threats (Miller et al., 2017). With that being said, creative and alternative funding is still very viable. Mechanisms like “system performance insurance” address risk (Miller et al., 2017), government funding, and loan programs are available for RE projects; however, due to the various programs available, choosing the suitable option might not be an easy task and uncertainties are present when the programs mature or when available funds reduce in the future. Innovative financing solutions are much needed to close the gap. Utilizing case studies, Miller et al. (2017) discussed: public market capital, hybrid bond, sale of green attributes, corporate power purchase agreements (PPAs) and crowdfunding.

PPAs are also discussed in Sener and Fthenakis’s study (2014) as a favorable financing mechanism. Long-term power purchase contracts come with fixed prices and this lowers the risk of utility pricing fluctuations and solar revenue uncertainties over the whole period of the project. As a new business model, third-party funding has historically been funded by the energy sector, banks, and the federal level of government, to introduce solar projects. SunCap Financial and Clean Power Finance are two examples of such companies that give out 20-year financing plans for rooftop solar panel installation (Sener & Fthenakis, 2014).

Life Cycle Cost Analysis (LCCA)

The life-cycle cost analysis (LCCA) is a method of economic analysis to define the total cost of involved ownership over the lifetime of an asset, including costs for R&D, design, production, marketing, distribution, and after-sales service and disposal. This method helps to determine total costs of existing systems and the alternatively designed system(s) that may save costs and maintain quality, and the resulting report would enable the county management to make an informed decision on selecting an alternative system to pursue. It is important to perform LCCA in the initial stage of a RE project through the four phases: defining goal, scope, and functional units; inventory costs; aggregate costs by cost categories; and interpretation of results. The results would give insights to where would be an effective cost reduction area, and to provide opportunities for modification design to keep the cost low (Fuller, 2016).

The Florida Solar Energy Center (FSEC) monitored 124 solar systems. During this analysis, tracking cost, performance, and data reliability were measured within the systems, which also included replacement cost, operating, and maintenance cost. The results indicated the default life cycle of the PV system ranges between 20 to 30 years and considered a positive life cycle. The total energy saving of the system over a lifetime is approximately 3.7¢/kWh from the total average costs of 32.4¢/kWh. As a result, a life-cycle cost of 28.7¢/kWh was established. The life-cycle cost is calculated by identifying all costs over the service life and discounting costs to present value (Larsen et al., 2008). According to Fuller (2016), below is the total life-cycle cost formula:

> “LCC = I + Repl - Res + E + W + OM&R + O
> Repl = PV capital replacement costs, Res = PV residual value (resale value, salvage value) less disposal costs, E = PV of energy costs, W = PV of water costs, OM&R = PV of non-fuel operating, maintenance and repair costs, O = PV of other costs (e.g., contract costs for ESPCs or UESCs)” (para. 33).

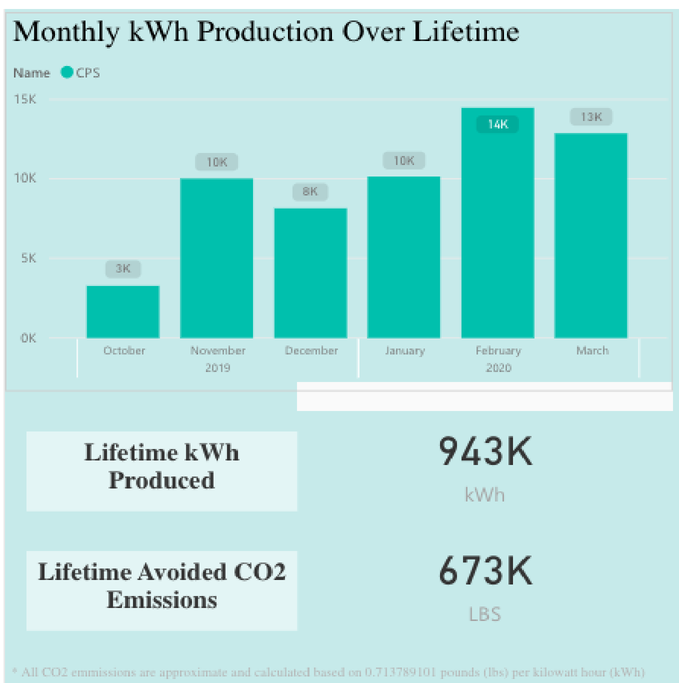
LCCA can be used as an element in the Life Cycle Sustainability Analysis (LCSA) calculation to determine the aggregated environmental, social and economic impacts of the product over its entire life cycle. A review of previous studies on solar energy implementation revealed that often the existing papers focused on technology and policy perspectives. Costing and financing are also discussed, but with emphasis placed on large-scale commercial and residential projects, in western America, instead of solar readiness in local governments around the country. Little research has been done around how municipalities fund solar technology for their own properties.

Solar Energy Project Financing in Manatee County, Florida

Background Information

In 2020, the average monthly solar productivity of Manatee County is about 12,000 kWh (Figure 28). In order to reduce global warming and achieve net zero emissions, Manatee County plans to build solar energy on public facilities including schools, hospitals, and fire stations. However, due to the policies of the Florida state government, Manatee County will encounter some restrictions in the process of building solar energy, especially funding issues: the cost of building solar energy in Manatee County is higher than other states. In addition, according to regulations, any seller of electricity in Florida is considered a "public utility" and is subject to the same rules as a large multi-billion-dollar energy group. In order to obtain funds to support the construction of solar energy, several feasible strategies will be listed in the next section.

Fig. 28: Monthly Solar Productivity of Manatee County from Power BI Report



Note. Solar production in Manatee County comes from two solar-ready buildings and the Bigbelly Solar trash compactors in County parks. Adapted from the Solar Energy Dashboard from https://www.mymanatee.org/departments/property_management/sustainability/energy

Strategic Approach to Project Financing

Utilizing multiple forms of funding can diversify strategies and create more opportunities for revenue to be used for alternative sustainability and resiliency projects and efforts. To ensure solar transformation is actively and efficiently managed, a rollout strategy can create a highly concentrated scope and minimize high start-up costs. For long-term success, initiating solar can support net-zero goals within this municipality. To ensure environmental impacts are managed appropriately and achievable goals are set during the process, a well-crafted timeline should be in place to highlight the progressive goals and target timeframe. When or if new funding becomes available for county use, phasal developments can be achieved towards the eventual net-zero goal.

Research Methods for Project Financing

A combination of research methods was used to investigate different aspects of financing solar systems for government buildings in Manatee County. Statistical analysis was done to collate and analyze current energy consumption patterns of the county. Cost-benefit analysis and life cycle cost analysis were employed to evaluate net profitability of equipping solar in county premises. Furthermore, policy analyses were explored to specifically pinpoint RE related policies in the federal, state and local government level. Lastly, case study comparisons were made to draw insights from nearby local governments such as Orlando and Sarasota.

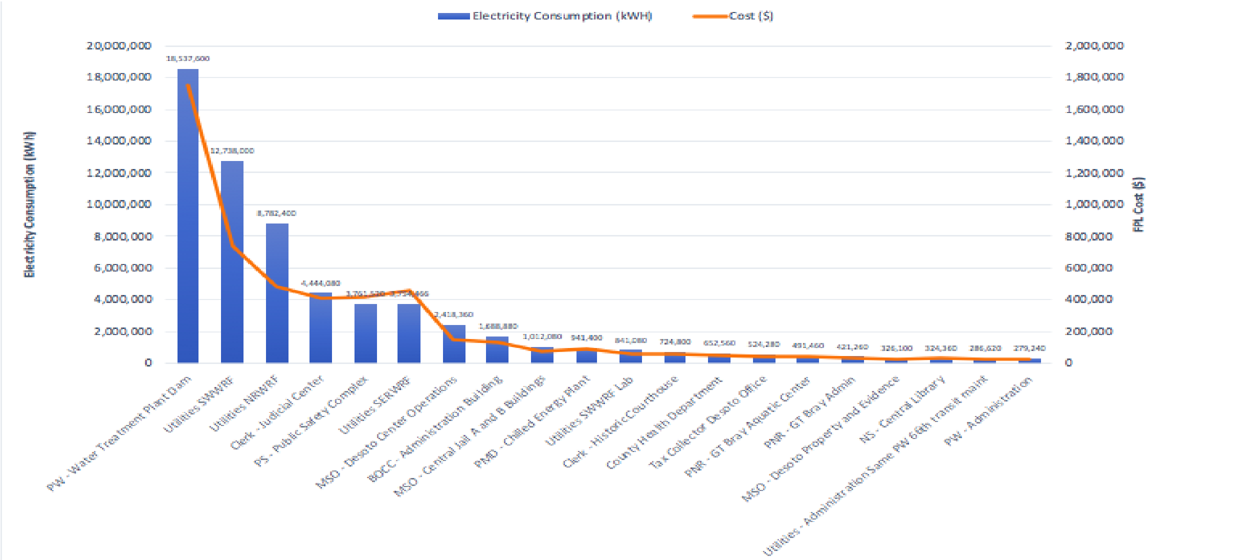
Data Construction

According to the purchased electricity consumption data from FPL provided by the county representative, available meter readings in the calendar year (CY) 2018 were analyzed. There was incomplete data for CY 2019 thus 2018 was used to get a general sensing of energy usage patterns in county owned facilities. A total of 69 buildings with available energy data are identified based on available meter readings. A few meters were missing readings from the last one or two months. An assumption was made to ensure the data for a full year was captured: the energy consumption pattern is similar for each month despite different calendar year due to similar seasonal usage patterns; thus, if a particular meter is missing December entry, the reading from December in the previous year was used to substitute it.

Data Analysis

The total amount of purchased electricity for the top 20 facilities was 62,950,542 kWh and the total cost was $5,116,143, which gives an average cost of 8.13 cents per kWh. The highest energy consumption facilities were the water and wastewater treatment facilities, Judicial Center, and Public Safety Complex, as seen in Figure 29.

Fig. 29: Electricity and its Cost in Top 20 Manatee County Government Facilities in 2018



Note. Manatee County has indicated 32 priority buildings to focus on for solar implementation (graph was created from FPL raw data provided by Manatee County government).

To make the project even more feasible, starting with the 13 county owned facilities (Table 9) and then scale up would be a wise choice. To ensure solar transformation is actively and efficiently managed, a rollout strategy can create a highly concentrated scope and minimize high start-up costs. For long-term success, initiating solar can support net-zero goals within this municipality.

Table 9: *Priority Buildings Identified by Manatee County*

Priority Buildings Identified by Manatee County			
COUNTY OWNED	**Type of Facilities**	**NOT COUNTY OWNED**	**Type of Facilities**
Manatee County Sheriff- Desoto Center Property & E	Nil	Ciry of Bradenten - Police Department	Fire /EMS/ Police
Manatee County Public Health Clinic	Nil	Kinnan Elementary School	Emergency Shelters
Manatee County Utilities Operations WTP	Nil	Bayshore Elementary School	Emergency Shelters
MSO - Corrections Complex	Nil	McNeal Elementary School	Emergency Shelters
Public Works - Administration	Manatee County Property Management	Mills Elementary School	Emergency Shelters
BOCC - Administration Building	Manatee County Property Management	Willis Elementary School	Emergency Shelters
Public Safety Complex	Manatee County Property Management	Tillman Elementary School	Emergency Shelters
MSO - Judicial Center	Manatee County Property Management	Braden River Middle School	Emergency Shelters
		Prine Elementary School	Emergency Shelters
MSO - Marine Unit	Fire /EMS/ Police	Witt Elementary School	Emergency Shelters
		Seabreeze Elementary School	Emergency Shelters
MC EMS Station 16	Fire /EMS/ Police	Braden River High School	Emergency Shelters
		Myakka City Elementary School	Emergency Shelters
MC EMS Station 5	Fire /EMS/ Police	Manatee High School	Emergency Shelters
		Oneco Elementary School	Emergency Shelters
MC Marine Rescue	Fire /EMS/ Police	Freedom Elementary School	Emergency Shelters
		Haile Middle School	Emergency Shelters
Lake Manatee Dam	Water Treatment Plant	Lee Middle School	Emergency Shelters
		Lakewood Ranch Medical Center	Hospital

Results and Findings

Taken from fiscal year 2018, a total cost of $.08 per kWh was calculated by averaging the total kWh generated and the cost of current purchased electricity within government owned Manatee County buildings. From the U.S. Department of Energy 2030 Sunshot Initiative, commercial solar cost targets have dropped to $0.11 per kWh in 2017. The cost difference is $0.03 per kWh, making solar energy, three cents more expensive over current fossil fuel energy generation. Sunshot has shown great progress in reducing commercial solar pricing from $0.40 in 2010 and has a levelized cost of energy initiative to reach $0.04 by 2030, which would contribute to a lower cost and greater affordability for solar power ("Sunshot 2030," n.d.). This projection in 2030 shows over time and streamlining of market solar processes, solar energy is forecasted to become a cheaper option over fossil fuels.

Taking the priority buildings and also the top energy consumer in CY 2018 for instance, for them to go solar based on their CY 2018 energy consumption, the amount of investment needed would range from $30,716 for the "PW-Administration" building to $2.04 million for the "PW-Water Treatment Plant" facility. This shows that even just focusing on priority buildings might require a sizable amount of funding.

Sustainability Plan

Solar energy projects are usually longitudinal in nature and involve a wide spectrum of considerations. It is recommended that a climate change action plan be put in place, which spells out in detail the targets to achieve short term and long-term sustainability goals. It is essential for any governing body who is considering the implementation of solar energy to set aspirational but achievable RE targets. These targets should act as a reference point when planning for programs and policies for clean energy projects. Generally, there are two main ways of generating solar energy for a project, namely, through direct ownership of solar systems and PPAs (Southern Environmental Law Center, n.d.).

Despite being the "Sunshine State", Florida does not have the top potential for solar according to The U.S. Department of Energy; rather, deserts of the southwest, namely Arizona, New Mexico, California and Texas, are high potential areas that the country is focused upon developing. Moreover, Florida is missing the regulatory reform to allow for solar development to propagate throughout the state; to be exact, the prevention of third-party solar PPAs is a major drawback. For Manatee County to go solar, it has to address the current challenges to be able to develop a plausible roadmap (Sweeney, 2019). While Manatee County plans for solar implementation as part of the sustainability plan, it is important to review the whole RE environment as a county, including educating the community and expanding commercial and residential solar readiness as well.

Fiscal Funding

Being a government entity, Manatee County can implement or utilize a number of funding solutions to attain net zero energy parity. The first would be funded from budget surpluses (i.e. excess income from taxes from the property, sales, business, fines, and federal government grants/programs initiatives). Assessment of the costs to build will be a key metric to determine overall cost versus surplus funds. Reprioritizing current or future projects can also create critical cash flow and should be considered with an eye on ROI. The savings from energy creation may outweigh those of funded projects which could, in turn, revise the scope to increase the likelihood of initiating those projects.

Grants and Programs

With global warming becoming more severe, the federal government has elevated its attention to support and encourage RE developments. DOE has released many projects to assist in expanding the solar market. Grants are the most direct and effective way to reduce costs. Considerable cash rewards can help ease the burden for solar energy development in local governments. Policies and grant programs related to RE tend to have a certain cycle period or expiration date, thus it is important for Manatee County to check on the latest updates for the availability of programs.

State Energy Program

The US Department of Energy (DOE) has been running a State Energy Program (SEP) in the last thirty years and has provided a large amount of funds and technical assistance to various states. The SEP funds are meant for states to develop plans and advancement in energy solutions (DOE, n.d.). The local governments can make use of available SEP funds to create a series of energy-related programs or direct grants to support and incentivize the construction of new energy initiatives. As an example, SEP provided funding to support Delmar to install a 62.6-kilowatt PV system and a 120-kWh battery energy storage system on the roof of its city hall building (DOE, 2019). In line with national and state-specific goals, Florida has a wide range of energy-related programs with SEP American Recovery and Reinvestment Act (ARRA) funds. Designed to create jobs, improve energy efficiency through renewable technologies, promote economic progress and reduce environmental impacts (Florida Department of Agriculture and Consumer Services, 2020). The below grants/programs are available for local governments:

- Florida Clean Energy Grants
- Clean Energy Florida RE Efficiency Conservation Grants
- Florida Energy Opportunity Fund - Clean Energy Investment Program

Leveraged Funds

The Energy Efficiency & Energy Conservation Block Grant Program provided $3.2 billion in block grants to develop energy efficiency and conservation projects that ultimately created jobs (DOE, n.d.). Additionally, through the Energy Efficiency & Conservation Block Grant (EECBG), Florida leveraged funds are available for state and local addressing conservation priorities and energy efficiency.

Loans and Financing Programs

Due to high capital and multi-stage processes needed for equipping facilities with solar energy from scratch, it is known that a long period of time is needed to reap the benefits of solar investment environmentally and economically. Therefore, finding suitable loans with low-interest rates is another important strategy.

Loan Guarantee Program

Loans are also an important source of funding. Local governments can use loans to obtain financial support from banks or funds to support the construction of solar projects. However, the most important aspect in receiving a loan is the loan guarantee. To this end, the US Department of Energy has proposed a loan guarantee program. Through this program, up to $3 billion loan guarantee is available for projects including RE development (DSIRE, 2016).

Revolving Loan Funds

Revolving loan funds can provide financing for clean energy projects and is a low-interest loan. These funds can be tapped on by local governments and used to support the construction and upgrades for publicly owned buildings or facilities to enhance energy efficiency (DOE, n.d.).

Property Assessed Clean Energy (PACE) Program

In June of 2010, the Property Assessed Clean Energy (PACE) Program was passed at the state level by then Governor Charlie Crist (Gagliano, 2010). The program assists businesses and homeowners cope with the high initial costs that are typical with solar installations. This is done by having a financial program pay for the upfront costs for approved systems. The consumer instead pays over several years via increased property tax. The inherent problem with the program comes from requiring each county government to devise their own financing system to pay the upfront costs.

Although initially hesitant to adopt the program following the housing crash in 2008, Manatee County now has a functioning variant of the PACE Program. In total, the county has approved five providers for PACE that may be used for any approved construction that improves energy efficiency, generates renewable energy, and/or increases wind resistance. For example, the Florida Green Finance Authority has established a financing system that will pay for the entirety of an installation with an agreed upon payback window of 5-25 years (2019). Within their same program, they have additional offerings for those installing on commercial properties as part of their partnership with Petros PACE Finance, a financial institution involved in PACE programs across the nation.

According to Devesh Nirmul, Vice President at Counterpoint Energy Solutions and PACE representative, "PACE will typically finance up to 25% of the valuation provided by a current appraisal so long as there is adequate equity in the property to be able to accommodate this amount of PACE. Then we will qualify those construction / project cost line items that impact the energy consumption and Trane's assessments and proposed equipment upgrades can help inform our qualifying process. The soft (design, audits, etc.) and ancillary costs can be included in the PACE financing so long as it falls within the 25% limit above. We can provide a quote within 48 hours and follow that up with a term-sheet based on the determination of what you actually want to finance with PACE and what qualifies for PACE. Once we have a signed term sheet, we can close within 45-60 days." The county itself is qualified to use this program as well in its quest for 100% renewable energy.

Bonds

Municipal Bonds

Another cost-effective method would be to borrow funds from investors in the form of issuing municipal (Muni) bonds. Muni bonds give the county the ability to issue bond notes to investors to cover costs associated with the project. Manatee County could gain the capital required for the energy investments today and repay the debt over a long period, generally up to 30 years. The bond interest is tax-exempt, creating additional appeal to investors seeking stable tax-sheltered income. Current interest rates in the muni bond market are at historic lows, making this one of the cheapest sources of capital available for local governments (Bloomberg, n.d.).

Crowdsourced Bonds

Bonds are also a main method of fundraising from the crowd. RE bonds have received increasing attention due to potential benefits enabling projects at a lower cost of capital and diversification of an investment portfolio. New Clean Renewable Energy Bond (New CREB) is one of several tax credit bonds authorized, which allows credits to be held by investors holding such bonds on one or more quarterly credit relief dates. Qualified Energy Conservation Bond (QECB) is another qualifying tax credit bond, which was repealed in 2017 by the federal government, but could be used possibly in the future with policy change. These federal conservation bonds give low-interest or state, local, and tribal governments for qualified energy projects, which includes RE installations ("Florida Department of Agriculture and Consumer Services," 2020).

Green Bonds

In addition to general municipal bonds, municipalities can issue Green Bonds. The first green bond was issued in 2007 by the European Investment Bank. Green bonds provide a lower yield than general bonds, on average 0.60 percent but provide the bondholder comfort they are being socially and environmentally responsible. Green bonds have been on a steady rise since 2010. Green bonds have risen from less than 500 million yearly in 2010 to 6.5 billion in 2016 (Schuele/Wessel, 2018). Figure 30 below shows the typical municipal projects that can be certified as green.

Fig. 30: This figure illustrates the typical uses of funds raised by green bonds

To quote Christine LaFrance (Fidelity Investments) "U.S. Investors are becoming more socially and environmentally conscious and are open to investment options that reflect their 'green' preferences." If a subset of investors is willing to give up returns in order to hold green bonds, municipalities could save money by issuing green rather than ordinary bonds (Schuele/Wessel, 2018). At 0.06 percent from Manatee's perspective will represent significant savings at bond maturity versus issuing a general municipal bond.

Tax Credits

Providing incentives in the form of tax credits is also a solution to gain revenue for this project. Providing tax credits to builders and suppliers can help offset costs for the county. The cost of the tax credit must be considered in the ROI calculation. Along with tax credits, cutting administrative time and costs associated with permitting and other governmental items will fast track the project and help minimize the effect on the community.

The Solar Investment Tax Credit (SITC) was passed in 2005 by a Republican led Congress and President to stimulate the growth of the renewable energy and energy efficiency markets. According to SEIA.org, it has done its job. "Since the SITC was enacted in 2006, the U.S. solar industry has grown by more than 10,000%" (Solar Investment Tax Credit, n.d.). In 2015 the program was updated through 2022. The 30% Solar Investment Tax Credit is still available through the end of 2019 at which time it will be reduced to 26% in 2020. If it is not renewed by a new administration in 2020, the tax credit is reduced to 22% in 2021. In its final year of the program, 2022, the tax credit goes down to a menial 10% for commercial and utility solar and 0% for residential (Investment tax credit for solar power, 2019). The current administration has not been kind to renewable energy, so there are currently no new federal grant programs for Manatee County to use in its quest for 100% renewable energy.

Partnerships and Other Alternative Models

Solsmart is a nationally distinguished program that promotes cities, counties, and regional organizations that implement mature local solar markets. Local governments have tremendous power over potential growth of solar energy. To encourage solar development, Solsmart streamlines the development process and if a community meets the criteria requirements, can be eligible for fully funded advisors for consulting services over the course of 6 months. Communities receive designations of Solsmart Bronze, Silver, and Gold. Since the Solsmart launch in 2016, more than 350 regional organizations, counties, and cities have received this national designation ("What is Solsmart?," 2020).

Partnership with Florida Power and Light (FPL)

A close-knit partnership with FPL could be explored, perhaps as a last resort, to tap on the existing technological expertise and infrastructures that are and will become available in Florida, such as FPL's brand new Manatee Energy Storage Center which will be the world's largest solar-powered battery system upon completion in 2021 (Roselund, 2019). A study of Sarasota County has led us to know that the county government has established a formal cooperation agreement with FPL. FPL is responsible for publicity and construction of solar installations, while the government is responsible for educating and popularizing solar energy knowledge to the residents. The government also provides preferential policies to encourage the construction of solar energy. In addition, the Sarasota region has hosted two solar co-op programs through Solar United Neighbors and its partners. Due to the large purchasing power of groups, solar co-ops can obtain lower PV installation costs through competitive bidding. Buildings that do not want to own solar equipment can be offered a PPA with the utility company, as FPL being in the picture.

Lowering Cost by Recycling

To lower the costs of solar development, recycling programs might be valuable. With rapid growth in solar energy demand, waste disposal of panels is an issue for the environment. Recycling PV can create upcycled panel materials, which in turn could lower total initial material costs. Through recycling three metrics of sustainability; low cost, resource abundance, and lowering environmental impact can be addressed (Sener & Fthenakis, 2014).

Limitations

Policy and Market Uncertainties

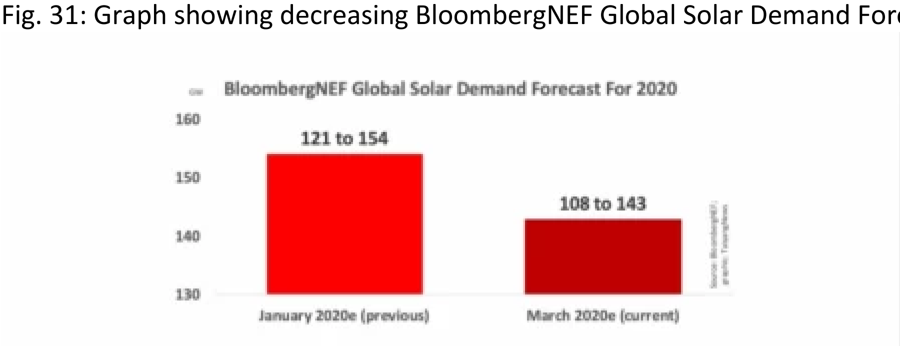
One of the greatest limitations of financing solar energy, is the lack of federal government support and the discontinuation of federal grants and bonds for state and local municipalities. This creates added pressure on more localized governments to come up with their own funding for research and development and renewable energy projects, which can be a high cost and challenging task. However, these funding options have the possibility to reappear with ever-changing policies and leadership.

Renewable power markets have momentum on their side, but from a financial standpoint, the outlook is risky. Volatility of volumes and prices for solar energy are difficult to predict. Historically, a downward cost curve has occurred within solar energy and is predicted to continue downward and eventually hit a cheaper price than conventional fossil fuel generation. As a finite resource, fossil fuel generation will need to fade out and solar power will most likely exponentially increase to fulfill this gap.

Short-Term Oil Price Volatility

As oil prices fall below zero for the first time in history due to the global pandemic in April 2020, it adds to the uncertainty of renewable energy development in terms of policy support and funding opportunities. Fundamentally, a drop in oil prices would lead to cheaper fossil fuel-based energy sources, thus reducing management's focus on switching to renewable energy (Figure 31). With the government adjusting immediate policies to provide stimuli for healthcare, households, and keep oil companies afloat, if spending were to be cut, RE developments will probably be the sacrificial lamb in the short term. The US has already suspended enforcement of environmental laws as of March 2020 and no end date was set for release (Milman & Holden, 2020). The head of the International Energy Agency, Fatih Birol, has spoken about the current situation and shared that the oil price crash "will definitely put downward pressure on the appetite for a cleaner energy transition" (as cited in Owens, 2020). Negative impacts on global energy transition are likely to be felt during and after the global economic slowdown and the resulting oil price war.

Fig. 31: Graph showing decreasing BloombergNEF Global Solar Demand Forecast



Note. Image adapted from https://oilprice.com/Energy/Oil-Prices/Is-The-Oil-Price-Crash-Good-For-Renewable-Energy.html.

Current oil producers are paying people to get rid of the crude oil on hand, while many smaller businesses are going out of business. Not all is bleak as this crisis might well mean a boost for the major energy industry players to diversify their energy portfolio in the long term. In view of the interconnectedness with current economic factors, developing solar capability in Manatee County would very much depend on the availability of intricate grant and loan programs as they are essential to project success.

Estimated Financial Cost to implement Solar PV Solutions for High Priority Buildings in Manatee County

The following approach includes the proposed methods in arriving at the estimated financial cost in implementing net-zero solar PV solutions for specific high priority buildings in Manatee County: Administration Building, Public Safety Complex, and Judicial Center. These high priority buildings have been highlighted by Manatee's county energy representatives and the associated energy bills have been obtained. Using these resources we will be able to look at the usage of energy from three government buildings to see how much electricity will be used in each of these locations on how much solar radiation is on these buildings to see the outcome of return on investment after installing PV panels on these high priority buildings.

For basic assessments, collecting the maximum kilowatts per day (kWh) energy data by month for one year is sufficient to get a rough understanding of load profile (Dodson et al., n.d.). The energy bills will be analyzed to form the baseline energy consumption for each location. Other metrics from the utility bills will be helpful in developing the energy profile for each facility, these metrics include the maximum kilowatts per day (kW/D) which is the maximum power the facility used per day during the billing cycle.

The average kilowatts per day (Avg kW/D) is a measurement which covers an average power used at the facility per day during the billing cycle. Percent Load Factor (%LF) measures how efficiently the facility is using the energy being supplied to it. A high %LF is desirable and a low %LF indicates that there are inefficiencies at the facility. Finally, cost per kilowatts hour ($/kWh) gives us the cost of electricity at the facility. It can be broken down to determine the cost of electricity before taxes and can help us set future benchmarks on the cost of electricity.

Data Collection

Using these metrics, we relied on engineering guidelines and solar calculator tools available in order to estimate the required size of the PV system by using the National Renewable Energy Lab (NREL) "PV Watts Calculator." This online module allowed us to enter the facilities zip code and it provided solar resource data for that area including annual solar radiation, annual energy production and the cost of energy. This module can be adjusted for various real-life scenarios in order to get more accurate results.

Once the size of the required solar PV system was established, we looked at current market trends and arrived at a cost per kW for constructing and installing the solar PV systems. This cost included the life cycle cost of the system and represents the total estimated financial investment required to convert the priority facilities into net-zero facilities. Since we were limited to the utility bills provided by the county, we were not be able to get real-time values of the energy profile at each facility. Typically to provide solar solutions for facilities with high energy consumption a detailed energy audit must be performed with the use of data loggers and professional energy auditors. The results from energy audits are useful in determining if it makes more financial sense to first invest in improving the energy efficiency of the facility which will then bring down the required cost for the required PV system.

Data Analysis

Key Energy metrics for each site obtained from the Florida Power and Light (FPL) utility bills over a 24-month period from 2017 to 2019. From this data, we arrived at the Baseline Energy Consumption, which is displayed in Table 10 below:

Location	Address	Baseline Energy *		
		kWh/yr.	kWh/Day	Cost of Electricity ($ /yr.)
Administration Building	1112 Manatee Ave West	1,647,840	4,520	$131,710.37
Public Safety Complex	2101 47th Terrace East	3,813,120	10,459	$247,633.60
Judicial Center	1051 Manatee Ave W	4,483,383	12,272	$425,842.73

Table 10: *This table represents the baseline energy consumption at the three locations and obtained by averaging the values obtained from the two years of FPL bills*

The most useful value to us at this point is the kWh/Day. The proposed PV system would have to be sized in order to meet the specific kWh/Day for each location. To help us derive at the size PV system required we first need to get an appreciation of the daily solar radiation per annum available at each location. This is obtained from the NREL's solar calculator "PV-Watts."

Once we have the solar radiation for each location, we can estimate the size of the PV system needed by dividing the daily kWh by the Average Solar Radiation. This represents the size needed if the system was 100% efficient, however a typical derating factor of 33% is used to make up for inefficiencies innate in the process of converting solar DC energy into AC energy.

Location	Average Solar Radiation*	Baseline Energy Consumption (kWh/Day)	Derated Factor	Required PV System (kW)
Administration Building	5.91	4,520	1.33	1,017
Public Safety Complex	5.77	10,459	1.33	2,411

Judicial Center	5.91	12,272	1.33	2,762

Table 11: *This table is showing the calculation of average solar radiation done on NREL using the PV-Watt calculator to give the required kW for each building (PVWatts Calculator, n.d.)*

According to the National Renewable Energy Labs (NREL) technical report entitled "US Solar Photovoltaic System Cost Benchmark: Q1 2018" the benchmark value in the United States to install commercial PV systems 10kW-2MW was found to be $1.83 Wdc (Fu, Feldman and Margolis, 2018). This cost is based on bottom-up modelling and includes all profits and soft costs including permits and engineering.

We can therefore use this factor of $1.83 Wdc to arrive at the total estimated cost for the required size PV system that will generate 100% of the annual energy at each site. We found it useful to also include the theoretical Return on Investment (ROI) using the simple payback calculation, which would be the cost of the system divided by the baseline cost of electricity.

Location	**PV System (MW)**	**Cost per MW ($/MW) ***	**Total Cost for System ($)**	**Cost of Electricity ($ /yr.)**	**Return on Investment (yrs.)**
Administration Building	1.02	1.83×10^6	$1,866,600.00	$131,710.37	14.17
Public Safety Complex	2.40	1.83×10^6	$4,392,000.00	$247,633.60	17.74
Judicial Center	2.80	1.83×10^6	$5,124,000.00	$425,842.73	12.03

Table 12: *This represents the cost of the system and the return on investment with the conversion from $/kW to $/MW*

Results and Data Interpretation

The estimated cost can only serve as a broad indicator of what it would look like financially to supply each location with enough energy from solar PV to become net-zero based on the current energy data available. In reality, energy efficiency measures can be carried out throughout each location and drastically reduce the size and cost of the PV system needed. In terms of financial feasibility, it can be noted that there exists great potential to decrease the ROI, however currently the ROI's are still much lower than the estimated 25 to 30-year life expectancy of PV systems. This means that the PV systems will pay for themselves well within their lifetime. With more detailed analysis into the energy profile of each building from energy audits the financial viability of incorporating other technologies such as battery backup and net-metering systems could be explored to reduce the ROI.

Future Possibilities and Challenges

Manatee County is held to high standards due to its achievements thus far, but this also opens up new resources. Resources only available to the highest achievers of "environmental pioneership". In business and government especially, more help is given to those who have proven themselves in the past. Manatee County has this advantage. The local government should always be looking out for its residents. In return, residents can choose to be a part of the community with pride. In the future, Manatee County can strive towards more than just government buildings being net-zero. A residential home with virtually no energy costs, low insurance rates, and still hurricane proof is what makes net-zero homes beneficial for a community.

According to the Organization for Economic Co-operation and Development (OECD), in 2018 only 23% of the population owned their home outright in the U.S. The leading countries in this category were Romania (95%), Croatia (84%) and Bulgaria (81%). While housing security may be threatened in the U.S., the data for Green Growth Indicators show much involvement in environmental pioneership (OECD, 2020). Local governments can help the cost of living decrease but utilizing sustainable housing. In return, the community can benefit from any excess energy produced from the optimal energy-efficient housing. Nearby Hillsborough County has displayed an act of pioneership when commissioners teamed up with Florida Home Partnership in Ruskin to build seven net-zero homes just this February (Glasser, 2020). Figure 32 shows how community-based solar can help benefit residents, businesses, and local government.

Fig. 32: Community Solar Model (Energy.gov, 2020)

The best way to create interest by the residents is to create visible installations, so citizens can see the solar energy being used effectively. These installations also offer educational opportunities to the community. The use of solar charging stations for electric county vehicles is a fantastic way to show off solar energy and its many uses. Solar phone charging stations are another great way to implement solar into the county. A strong showing by the county, will encourage residents to try out solar energy and establish solar energy systems in their homes.

Manatee County can also switch original public lighting fixtures including streetlights, traffic lights, and sign lights, to solar powered lighting fixtures. Solar streetlights can reduce operational costs, they require less maintenance, have a lower replacement cost, and the life expectancies are five times longer than the traditional lighting fixtures. Additionally, solar powered lightings are complete systems, which means they can be easily used in remote and rural areas, where access to the grid is difficult. This can be an efficient and handy solution to lighting problems in certain areas that have harder to access energy resources.

Different counties have different business needs and addressing these needs furthers the long-term sustainability of implementing solar. The county needs to encourage businesses to utilize solar energy as a means of electricity production. The county should incentivize solar power use and provide good press for businesses that install solar PV systems. Disney and Apple are companies that have used large amounts of solar, and therefore, have received praise from the public and their respective local governments. The creation of programs by local governments to incentivize solar implementation would be a great way to create solar power use by businesses in the county.

There are challenges and limitations to the proposed introduction of solar. One of the key issues is the damaging nature of solar panel production and construction. From the process of mining raw material, to chemicals used in extraction facilities, and waste produced in the manufacturing process, harm to local ecosystems occur. In addition, the process of solar thermal and PV solar recycling plants are still under-developed. Since the recycling process of solar panels is not efficient, it can cause a lot of waste if Manatee County invests in solar power in the long term.

Some of the other challenges for the implementation of solar energy in Manatee County would be the lack of education from the public and from government officials. The majority Republican Board of County Commissioners and population may make it more difficult to pass progressive environmental actions like solar energy. Innovative partnerships between solar power companies and private and public entities could help to provide educational opportunities for local citizens, while also powering local communities with clean renewable energy. The partnership of Florida Power & Light and Daytona International Speedway is a good example (Figure 33). They constructed more than 7000 solar panels on multiple canopy-like structures, on the roofs of the outside patios, and in parking lots. The electricity generated provides 2.1 megawatts of solar power in an hour for the racetrack, visitors, and FPL's 4.7 million customers via the grid (CISION PR Newswire, 2015).

Fig. 33: Daytona Speedway (Cision 2015)

The solar project prevented the emission of about 2,200 metric tons of carbon dioxide generated from the Speedway every year, which is equal to a car driving an average of 2 million laps around the iconic venue, and it also promotes green advertising to hundreds of thousands of visitors across the country every year (Florida Power & Light N.D.). Manatee County can emulate the approach by seeking solar power collaboration with its local sports, concert, and exhibition stadiums. This would allow the county to implement vertical solar installations and reduce the exploitation of untouched land. Showcasing their commitment of clean energy practices to local citizens, while also educating and advertising solar technology to local communities.

Another innovative program Manatee County can follow is the collaboration of Jack's Solar Garden, Xcel Energy company, and the local community (Figure 34). In 2016, Byron Kominek returned home to his family farm and saw the potential options of pairing solar panels with agriculture (Jack's Solar Garden, 2020). The plan is to turn the family hay farm into a community "agrivoltaic" farm, which can produce a variety of crops and solar energy. Five acres of the farm will be covered with an array of 3,000 six-foot long solar panels set in rows 17 feet apart. Crops will be cultivated underneath and around the panels with a drip irrigation system, which can protect them from hail and damaging winds, provide shade to keep moisture in the soil, regulate temperatures, and allow the vegetation below to flourish.


Fig. 34: Jacks Solar Garden (2017)

Solar panels can increase agricultural production on dry farmland that has not been irrigated, because the soil below the solar panels has higher levels of moisture than soil directly exposed to the sun. Also, in a recent test in Arizona, scientists found that total fruit production for red chiltepin peppers grown under solar panels was three times more than those grown in direct sunlight, and for cherry tomatoes production was two times more. Aside from a variety of crops underneath the solar panels, Jack's Solar Garden will also introduce a pollinator habitat for beehives on-site, install public art, collaborate with research efforts provide educational tours, and offer free energy to low-income households.

This program is a good example for Manatee County to consider for additional solar energy production. Agriculture and the services directly related to it are the second biggest economic drivers in Manatee County and bring in more than $2 billion dollars every year (Manatee County, 2018). Thousands of acres in Manatee are used for commercial vegetable production. This program can serve as a model for future consideration, to offset the demand needs rooftop solar does not meet in the county by combining solar power generation and agriculture.

Solar Fields in Manatee County

A solar field, also referred to as a solar farm, is an extensive solar project that generates electricity for communities on a massive scale. The benefits of having solar farms include energy security, job production, minimal installation cost, and no water usage or carbon emissions (Nelson, 2016). Challenges involved in constructing solar fields include project financing, location selection, high capital and battery cost, and intermittent energy performance (Nelson, 2016). The cost of electricity with natural gas costs more than switching to solar energy in the long run (Nelson, 2016). Solar farms will also improve air quality and decrease the impact humans are having on climate change by decreasing greenhouse gas emissions associated with fossil fuels. Investing in the transition towards renewable and clean energy may influence other nearby counties to follow suit. Having solar PV systems at many of the public schools will likely lead to further education and interests in the renewable energy field and sustainability.

The framework of this section is to identify the best instruments to build solar fields, carports, and rooftops in Manatee County starting with mounting systems including installation systems, photovoltaic panels companies, and inverters; then, make a preliminary cost study rely on the higher quality with reasonable prices. First, there are four basic installation systems to existing solar panels. In this research, we will compare between two systems which are Fixed-Tilt Solar Array system and Single Axis system (Table 13). We can use Fixed-Tilt Solar Array in both carports and rooftops, because it is considered the least expensive system (Fixed Tilt Non-Tracking Solar Panel, 2018). On the other hand, we can use the Single Axis system on the rooftops if we want to improve the efficiency of the solar system. However, it is considered more expensive due to the equipment seeking to upkeep or change some of the instruments (Zipp, K. 2020). The following table represent the differences between the types:

System Type	Life expediency	Annual Energy (kWh/kW)	Capacity factor	LCOE ($/kWh)
Fixed-Tilt Solar Array	25- 30 year	1,521	17.40%	0.0447
Single Axis	5-10 year	1,815	20.70%	0.0388

Table 13: *Comparison type of mounting system*

Based on the climate in Manatee the rate of radiation is high, because of their 249 sunny days throughout the year (Bradenton, Florida Climate. 2016). According to the table results the Fixed-Tilt Solar Array system is the best method to build a solar field or carport in Manatee County. Second, there are hundreds of companies and brands around the United States, so according to the site in Florida state, we will compare between photovoltaic panels companies in the state; however, this research will be limited by one type which is monocrystalline based on its high efficiency. The comparison will consider the panel cost, life expediency, efficiency, and guarantees. In our case, we will set in detail with three different models: the Suniva OPT340-72-4-100, the Hanwha Q CELLS Q.PEAK DUO-G5 325, and the REC Solar REC290TP2 (Table 14).

Company	Model	Nominal Power (W)	Efficiency (%)	Cost ($/W)
Suniva	OPT340-72-4-100	340W	17.43%	$0.42/W*
Hanwha Q CELLS	DUO-G5 325	325W	19.3%	$0.57/w*
REC Solar	REC290TP2	290W	17.4%	$0.44/w*

Table 14: *Comparison type of photovoltaic panels according to Sun Electronics*

The table above has shown that the costs are nearly similar to each other; this project should adopt the Q CELLS Q.PEAK DUO-G5 325, which is the monocrystalline-based panel with high efficiency and reasonable cost. Finally, one of the most crucial components for solar fields is the inverter. In the market, there are many brands of inverters; they come in two main types. In this paper, we will highlight on string inverters. The following table will present two different types of inverter. It was made by the same company SMA; the two types are SMA- SUNNY TRIPOWER CORE1/US and SMA-SC 1000CP XT.

Company- Model	Units	Power (kw)	Output Voltage	Efficiency (%)	Cost $/Unit	Total Cost $
SMA-SUNNY TRIPOWER CORE1/US	20	50	480	98	6426$	128,520$
SMA-SC 1000CP XT	1	1000	480	98.5	230,000$	230,000$

Table 15: *Comparison types of inverter*

According to Table 15, the types are nearly similar in efficiency, in this case the selection will be on lowest cost which is SMA- SUNNY TRIPOWER CORE1/US.

Since Manatee County already has a contract with Alternative Energy Services, Inc. (AES), which were installed two solar arrays installed at two different properties owned by the County (Robinson Preserve and Child Protection Services). This company has many advantages such as providing a product with a high quality, reasonable prices, and they provide free consultations. In addition, based upon the technologies that have been addressed above, which is utilizing carport solar panels to achieve the goals of Manatee County.

There are two companies specialized in installation of carport and rooftops solar panels, which are Orion Carport Systems and Construction Inc., and Schletter Solar Mounting Systems. The first company Orion Carport Systems and Construction Inc. (OCSC), is also expert in commercial installation of carport in three systems which are LETO (semi-cantilever), TITAN (T-cantilever), and custom carports. They have many projects across the U.S., including Legoland, FL, with a 1.8MW Custom system, and Northridge Mall, CA (Figure 35) (Orion Carport Systems & Construction, Inc. 2019).

Fig. 35: *An example of OCSC in Northridge Mall, CA*

The second company is Schletter Solar Mounting Systems (SSMS), which has several characteristics that make it distinct: they incorporate a device for charging electric vehicles, and they are made with a concrete ground collar for protection (Figure 36) (Schletter Solar Mounting Systems. 2020).

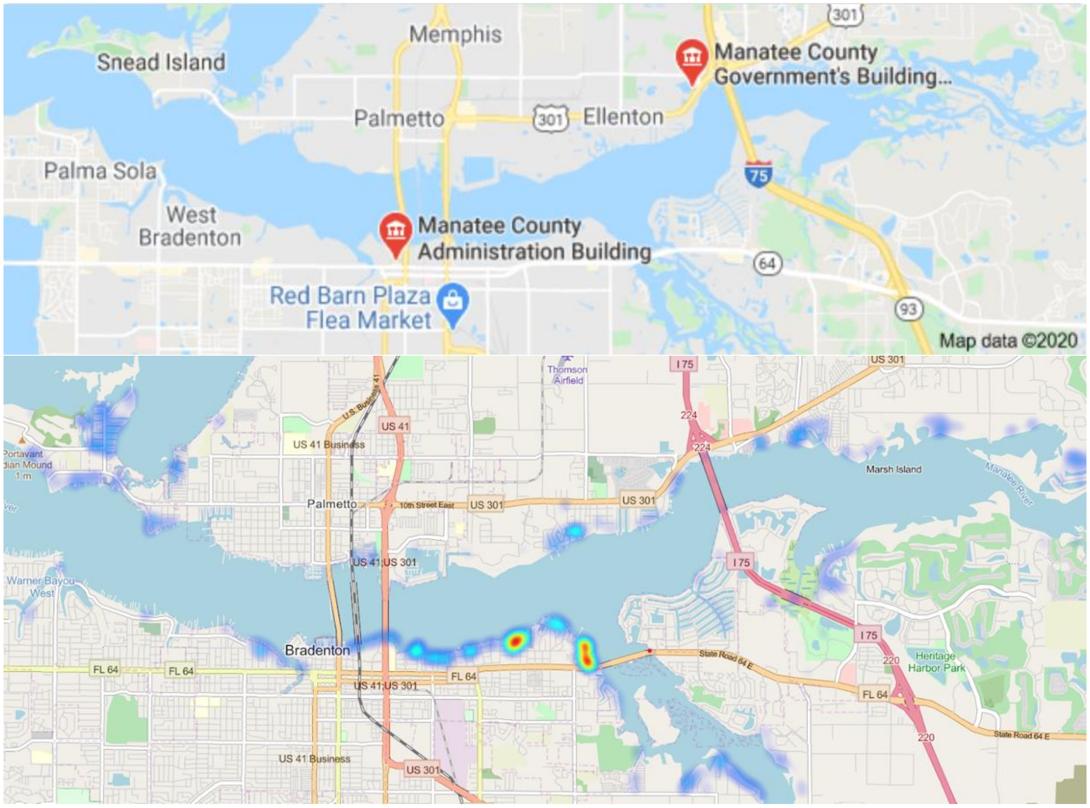
Fig. 36: *An example of SSMS in carport*

Some considerations that will need to be taken into account when determining locations for the solar power stations include; budgets, ideal locations with south-facing roofs or land surfaces, flood zones, evacuation routes, and projected areas that will experience sea-level rise. Solar power is intermittent without battery-backup, so fossil fuels may be needed for night-time energy or on cloudy days. Many of these departments do not run 24/7 so ideally, the ones that require round the clock energy will have a battery storage unit, which also requires special location planning for installation.

Other locations of interests such as hurricane evacuation routes and facilities of interest will need to be surveyed for the potential use of localized solar fields, photovoltaic roof panels, or solar carports. Given that Manatee County is particularly vulnerable to natural disasters, having a battery backup will allow for energy to be stored for the aftereffects of hurricanes, tropical storms, extreme flooding, etc. Many high priority buildings of interest such as schools that are heavily influenced by natural disasters and serve as hurricane shelters, may require more battery storage than those that shut down in such events.

Buildings that double as hurricane shelters or provide medical care will be rated higher due to its necessity in the event of a disaster or pandemic. The size of the roof and parking lot will be taken into consideration to better analyze energy capability. Environmental risks will provide insight to potential events that could take place based on geographical location and past natural disasters. Finally, recommended solar technology will be based on land/roof photos as well as topography (analyzed from GIS images) in the area. While many of the land features in Manatee County are considered marshes, swamps, or fall well below sea level which acts as a drainage area, it is still possible to build solar fields in these unpopulated spaces.

Before considering the feasibility of installing solar panels to power government buildings, an assessment of sea-level rise and flood zones must be surveyed. Both of Manatee Counties' administration buildings will likely be impacted by a two-foot increase in sea-level rise (Manatee GIS Portal, 2020). Preventing damage to the solar panels, would mean adding roof-top photovoltaic solar panels as opposed to solar fields. The public schools that will need roof-top photovoltaic systems installed will be based on geographic location and land availability. Specifically, solar satellites take up less space and provide a substantial amount of energy. Each school that installs PV panels will need to allocate a spot for the solar field. If land space is limited, roof-top photovoltaic is optimal. Carports are also efficient sources of energy that provide shade parking lots while also supplying plug-ins for electric vehicles.



Map 1 & 2: Above maps represent sea-level rise predictions in reference to government buildings. (Manatee GIS Portal, 2020).

The buildings with the highest priority for battery back-ups include Manatee County Public Health Clinic, MC Marine Rescue, MSO Marine Unit, MC EMS Station 5/16, Manatee County Utility Operations, Public Safety Complex, and the Lake Manatee Dam. Adding energy storage will ensure emergency back-up, power at night or on cloudy days, and maximize savings without having to sell energy back to the grid. Each battery unit will require a climate-controlled storage unit, in order to preserve the battery's life span and prevent deterioration.

Based on the maps below, a lot of the evacuation centers and schools in the area of concern to receive solar power are in low evacuation areas. Some of the buildings mentioned such as Manatee County Health department are in level A evacuation zones where it is not feasible to install any large ground based solar systems (Table 16). Other possibilities for zones A, B, and C that are heavily targeted by rising sea levels, hurricane flooding threats, and low elevation includes roof based solar panel systems, or battery backups.

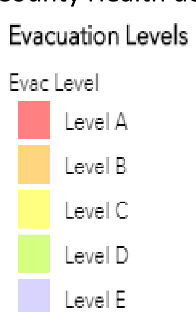
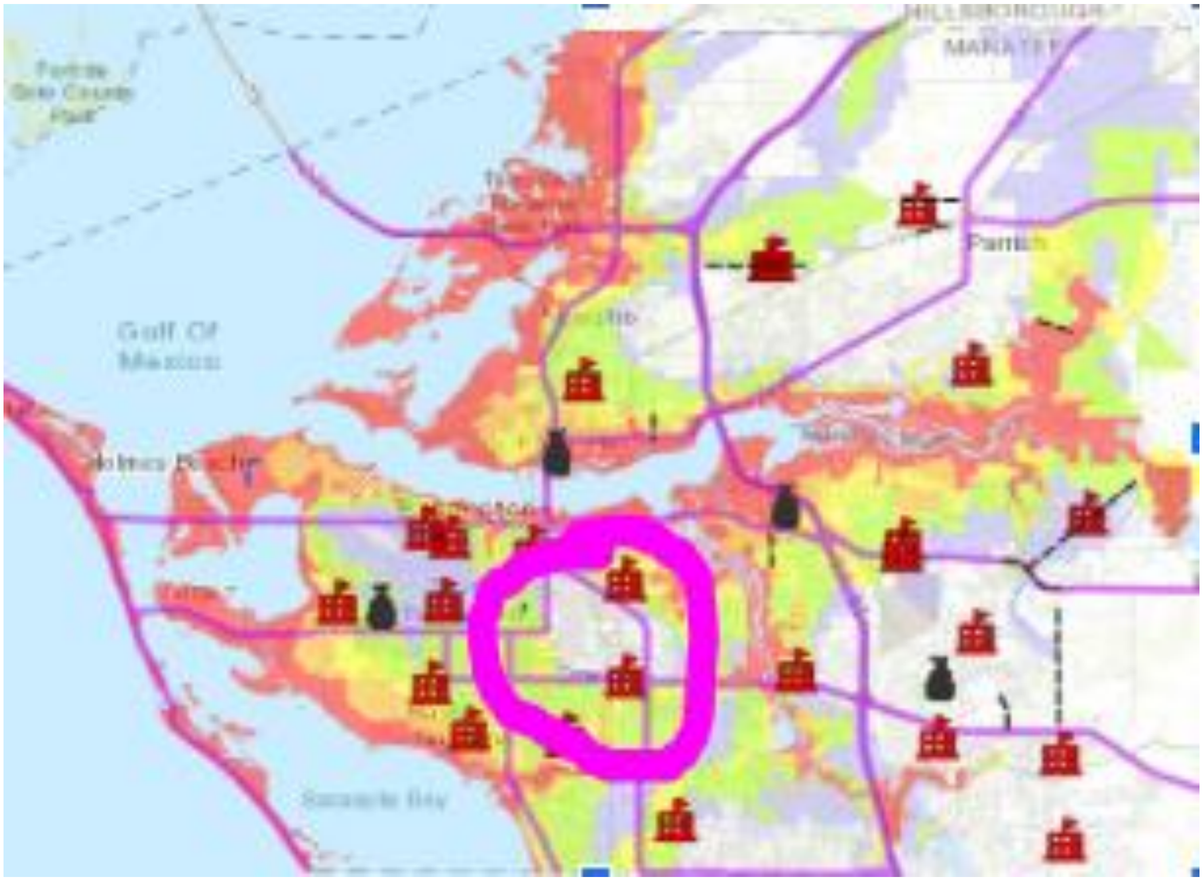


Table 16: *Evacuation Levels Color Legend*

Map 3: Evacuation Zones in Manatee County

When searching for the best areas to install large grid solar systems; school locations, public buildings recommended to us, all evacuation routes were considered and the best possible locations were targeted. The Bradenton, and West Samoset areas seem the most stable areas to install a solar farm system that has the lowest evacuation concern and the highest density for properties of interest. The only major evacuation route I-75 runs right in between those areas as well, which was prioritized in our decision. The highlighted circle below on the first image is the recommended area in the safest zone that serves three shelters with the highest elevation.

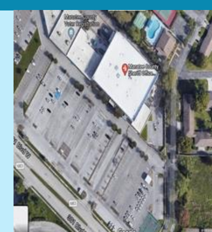
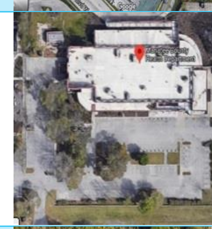
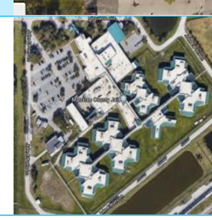


Map 4: Prime area to host solar farm along evacuation route (Manatee GIS Portal, 2020)

Results that could be concluding are as follows, if the building is high priority and in flood clearance zones it has the ability to support more than just PV roof panels. If the building is of high priority but is also in level A-C evacuation zones, then it may be limited to only panels and some small-scale panel parking covers. If an area has the land to host a solar farm operation, then land topography for water drainage, and past flooding history should be studied before implementation. There are limited options for high evacuation zones to host a variety of solar projects, even if many evacuation shelters, schools, and high priority buildings are close by. In their case, the most power they could generate would most likely be for that specific building itself. However, if the city is looking to generate solar power for surrounding buildings of interest, hybrid energy sources should be considered such as hydro energy or other means.

The prioritized buildings assigned to solar fields, PV roof panels, or carports are based on location, land space, and energy requirements. Buildings close to flood zones, or the Manatee River will require PV roof panels. Carports and solar fields will be designated for buildings at higher elevations more inland. Based on geographic location and land availability, some public schools will need roof-top photovoltaic systems installed. Because if land space is limited, roof-top photovoltaic is optimal. The following buildings; Manatee County Public Health Clinic, MC Marine Rescue, MSO Marine Unit, MC EMS Station 5/16, Manatee County Utility Operations, Public Safety Complex, and the Lake Manatee Dam should be with the highest priority for battery back-ups to ensure emergency back-up, power at night or on cloudy days, and maximize savings without having to sell energy back to the grid. For shade parking lots while also supplying plug-ins for electric vehicles, carports are efficient sources of energy to provide.

The recommendations presented below in Table 17 includes the level of importance, environmental risks with each location, suggested technologies, and aerial photos of each building:

Buildings	Level of Importance during pandemics, hurricanes, and other disasters	Environmental Risks	Recommend Solar Technology	Photo of Parking Lot or Roof (All photos are oriented based on compass positioning)
Manatee County Sheriff	**Medium**	**Located in safe zones – not high risk for storm surges**	**Carports**	
Manatee County Public Health Clinic	**High**	**Vulnerable to sea-level rise and storm surges**	**Roof-top PV Panels**	
Manatee County Utilities Operations WTP	**High**	**Not particularly vulnerable to storm surges or sea-level rise**	**Rooftop PV panels**	
MSO - Corrections Complex	**Medium**	**Vulnerable to sea-level rise and storm surges**	**Rooftop PV panels**	

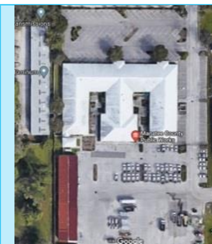
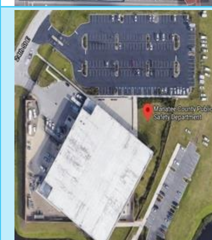
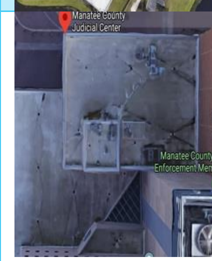
Public Works - Administration	**Medium**	**Located in safe zones – not high risk for storm surges**	**Carports**	
BOCC - Administration Building	**Medium**	**Highly vulnerable to floods and storm surges**	**Rooftop PV panels**	
Public Safety Complex	**High**	**Located in safe zones – not high risk for storm surges**	**Rooftop Panels or Carports**	
MSO - Judicial Center	**Medium**	**Highly vulnerable to floods and storm surges**	**Potentially rooftop panels, very intermittent sun potential in this area**	
MC EMS Station 16	**High**	**Vulnerable to sea-level rise and flooding**	**Rooftop PV panels**	

Table 17: *RPS Energy Types* (Wiser, Barbose and Holt, 2011)

Solar energy is the first step in helping the county become net zero. After this project is initiated, further investments in public transportation should be made to minimize fossil fuel emissions from vehicles. Town hall meetings centered on creating sustainable infrastructure in Manatee County should be made to include the community, various stakeholders, and other partners that should contribute to the plans suggested. Valuing the triple bottom line, or the three P's; people, planet, and profit, should also be taken into account when introducing a plan of action.

This project is not a one size fits all due to the nature of energy needs and geographical location. Each building will be a different case and require individual assessment to make appropriate decisions. Without energy bills, or estimated monthly kWh produced, predicting exact costs is challenging and virtually impossible. With the information collected, it was possible to predict the least expensive and most efficient technologies to purchase.

Final Recommendations

A "collaborative national effort to dramatically reduce the cost of solar energy" requires strategic plans. It is up to the "planners, local officials, and other community stakeholders'' to research and understand "the spatial, technological, economic, and political variables that constrain solar development before considering specific local policies or actions to promote solar energy use." (Morley, 2014). Figure 37, to the right, shows the **Municipal Solar Fundamentals** to lead municipalities to go solar (SOLAR INITIATIVE POLICY BRIEF). Manatee County should align with planning best practices to a development strategy that aims to mitigate the risk involved with high-cost projects by increasing ROI and EROI.

The goal of achieving net-zero for Manatee County government facilities can be achieved by examining the shortfall identified in the above analysis and implementing measures to overcome this shortfall. The goal of achieving net-zero for Manatee County facilities should begin with conservation. There are a number of measures that can be taken to reduce energy consumption:

MUNICIPAL SOLAR FUNDAMENTALS

- Set ambitious clean energy goals
- Evaluate and rank potential solar sites
- Determine project size and scope
- Consider financing options
- Select project developer
- Assess additional regulatory requirements
- Oversee installation
- Harness the benefits of solar power

SOURCE : SOLAR INITIATIVE POLICY BRIEF, SOLAR BEST PRACTICES FOR CITIES IN THE SOUTH

Energy Audit. Additional efficiency can be achieved by reducing energy usage. Every facility should be included in an energy audit. The data collected by the audit should identify potential means to save energy, such as insulation, energy-efficient windows, solar tubes to augment lighting, replace conventional fixtures with LED, and other sustainability measures. Any savings realized through these efforts means less energy will be required from solar arrays. The Department of Energy offers do-it-yourself audits and energy audit kits along with suggestions for improved energy efficiency. However, professional energy audits provide the most thorough assessment. ("Energy Audits", n.d.)

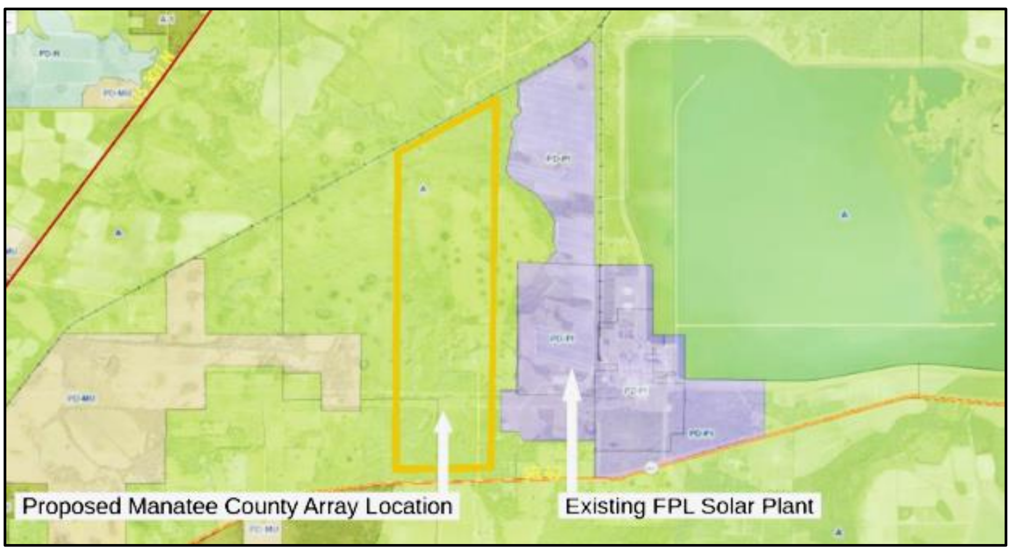
Public Education. Conservation can be promoted within the community. Educating the public may also contribute to the county's goal of net-zero. When people begin to understand the interrelated nature of sustainability, they modify their behavior, conserving natural resources, and using them in a more responsible way. Since the public uses county resources such as parks, recreation areas, and public buildings, education will pay dividends in additional energy savings.

Rooftop Photovoltaic Array. Facilities with large flat rooftops may be considered for grid-tied photovoltaic arrays with a net-metering agreement. This would help, but not alone achieve the goal of net-zero. Therefore, in addition to rooftop solar, parking shade structures and all unused county land should be considered for solar operational use.

Rooftop Solar Thermal. Buildings can be equipped with thermal collection solar technology and have the potential to substantially reduce the energy requirement. However, most industrial facilities use natural gas for hot water and heat, rather than electricity. Even though natural gas burns clean, it is by definition a non-renewable resource. Thermal Solar collection is more efficient than photovoltaic in terms of energy collected per square foot and will save money on the cost of gas.

Energy Storage. In buildings where floor space in a basement or utility room is available, it may be possible and advantageous to store energy. Energy can be stored as heat using hot water tanks. Existing heating and air conditioning systems can be retrofitted to exchange heat from storage tanks, saving energy in the form of natural gas. If solar photovoltaic arrays are installed, Lithium battery banks can store the energy generated. Potential uses for energy storage may be a building's emergency backup lighting, fire alarm, intrusion alarm system, or low-demand electrical circuits such as room lighting.

Land-based Solar Array. Installing a large grid-tied solar array will produce most of the power required to become net-zero. As pointed out previously, a 113-acre solar array is required. This could be done as concentrated solar or solar panel arrays. The recommended location for a large land-based array is based on the required acres and availability of the land for use as a solar farm. A location meeting these criteria was found and pictured below in Map 5. The area identified is about 1,000 acres, and it is located next to the existing Florida Power and Light solar farm.



Map 5. Manatee County Zoning Map 400.5 "A - Unclassified" undeveloped land adjacent to FPL solar plant. This is the proposed Solar Farm location. (Manatee County, 2020)

Funding and Installing a Large Land-based Solar Farm.

In all but four states two methods exist for large land-owners and government entities to use third party developers to create solar farms. They are the Community Solar farm, and the special contract called the Power Purchase Agreement (PPA). Unfortunately, at this time, Florida is one of the four states limiting the use of these avenues by third party developers. However, there is growing pressure to amend the State's Constitution allowing the sale of electrical power by third party developers. Community Solar and PPAs can be formed with a utility company. For example, as discussed in the next paragraph, three public schools have Community Solar agreements with FPL:

Community Solar. The legal vehicle to set up Community Solar is called a Special Purpose Entity (SPE) (Figure 38). Any group, corporation, or government entity can form a SPE. The group forming the SPE may but does not necessarily have to own the land and equipment. The land and hardware are owned and managed by the community, an electric utility company, or by a third party. The utility company enters into a net-metering agreement with the array owner. An agreement of this type is currently being implemented between Florida Power and LIght (FPL) and three schools in Manatee County. The schools are Carlos E Haile Middle School in Bradenton, Lincoln Middle School in Palmetto, and the Martha B King Middle School in Bradenton. (FPL, "Solar Education", n. d; EPA, 2018; "Community Solar", 2020)

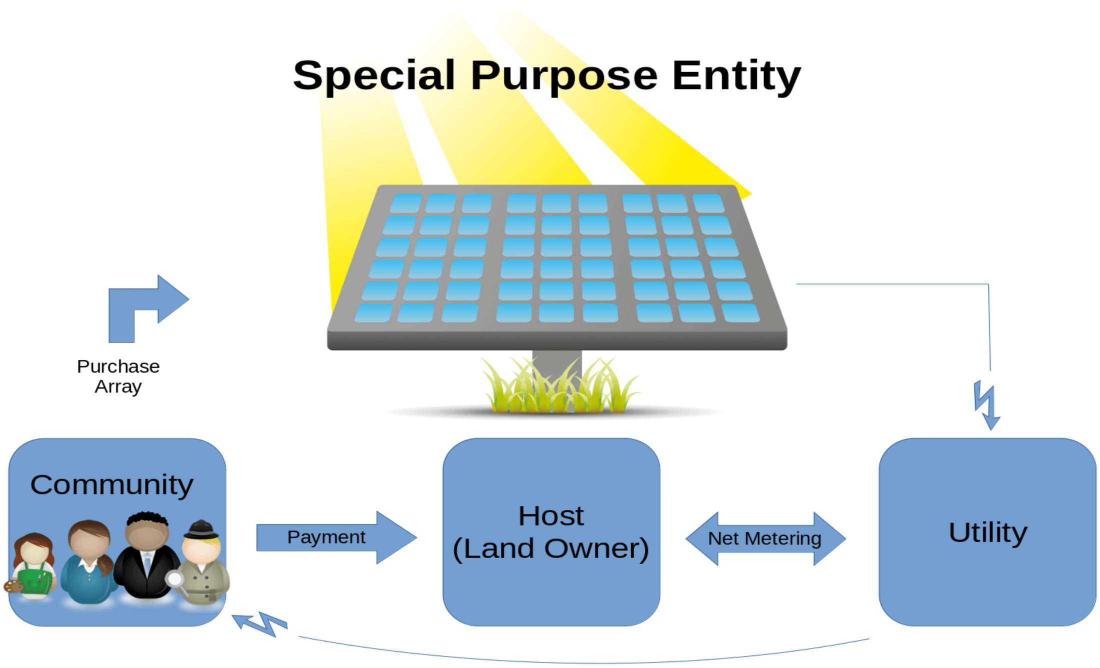


Fig. 38: The Special Purpose Entity is the legal vehicle used to set up Community Solar.

Solar Power Purchase Agreement. A Solar Power Purchase Agreement provides an avenue for a large energy user to install a solar farm at no cost (Figure 39). Using this type of agreement, the county could contract with its current solar service provider, Alternative Energy Services, Inc., and provide 100% of the energy needs for the county and greatly reduce energy costs. For this type of contract, the owner (Manatee County) offers the land to FPL at no cost. The solar service provider retains full ownership and responsibility for the equipment and is therefore entitled to government tax credits. The owner buys electricity from the solar service provider at an agreed-upon rate. ("Solar Power Purchase Agreements", 2019)

Using a Power Purchase Agreement, Manatee County can partner with FPL to create a large solar farm dedicated to its own power needs. The developer makes money by selling the power to the landowner, accomplished by virtual net-metering with the utility company. For large energy users, this is a better option than Community Solar.

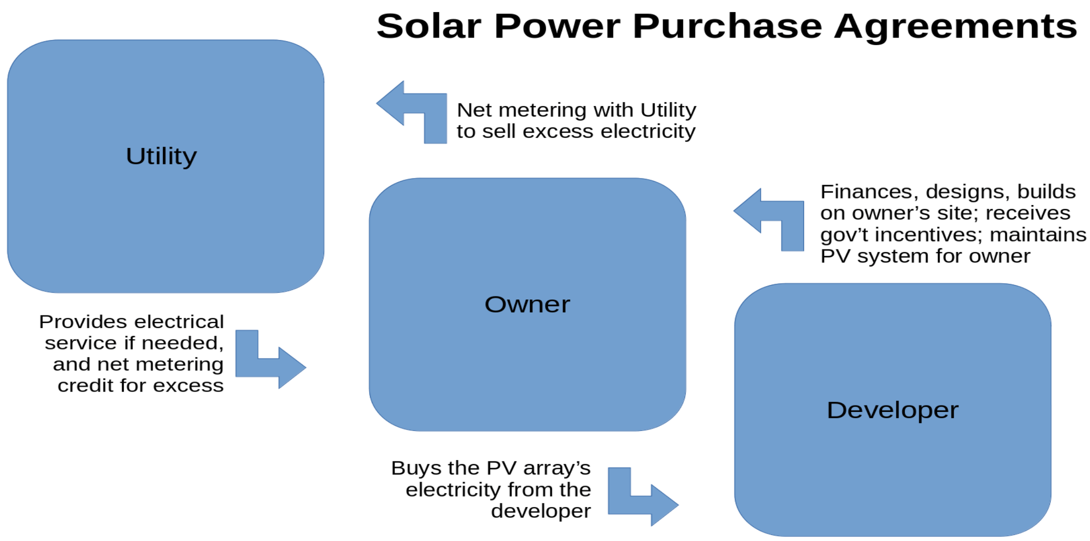


Fig. 39: Provides an avenue for a large energy user to install a solar farm at no cost.

Even though solar arrays can be created at no cost to the owner using Power Purchase Agreements (Figure 40), or through Community Solar, funding may still present a limitation. An energy audit should be completed for each facility. There will be a significant funding expense for this service. This will lead to remodeling and retrofitting facilities to achieve energy efficiency. If rooftop PV or thermal collection will be used there will be installation and maintenance costs. Building custodians may require training for operating and maintaining thermal collectors, and a service contract may be necessary for maintenance and cleaning of rooftop PV. Community education programs will likely incur a cost to implement.

Pictured left, (Figure 40) the Nellis AFB array provides 19-megawatts. It was created using the Solar Power Purchase Agreement with Nevada Energy at no cost to the government and provided 42% of the base's power requirement. This project has saved $1M per year in energy costs since 2007. (McCabe, 2014)

Figure 40: Nellis AFB Array. (Google Earth, 2020)

It is recommended that before any investment process, a team is established that will be the lead on this project. This team will be responsible for creating financial support, a budget and completing a full audit and calculation of return. To relieve any community hesitancy about this project it would be wise to create tax subsidies that reward energy generation (Stauffer, 2015) or the selling of electricity back to the grid. Retrofitting current buildings will address spatial concerns that the county may have.

By referencing Table 18 below, the overall savings in energy can be approximated before solar panel purchase or lease. Research on the type of solar panel installed will determine whether the overall direct savings on the cost of electricity generated from non-renewable resources will overcome and exceed the actual initial investment costs or not. A study of sun intensity would also be wise to conduct to ensure that the solar panels are placed in a manner that is expected to maximize efficiency and return.

	2019 Total kWh Consumption	**2019 Total Yearly Costs**	**2018 Total kWh Consumption**	**2018 Total Yearly Costs**	**Average kWh Consumption**	**Average Yearly Costs**
Manatee County Totals	67,951,282	$4,963,543.50	68,091,807	$5,092,026.10	68,021,545	$5,027,784.80

Table 18: *Sums and averages the kWh and yearly costs for Manatee County Municipal Buildings for 2019 and 2018.*

Limitations for this project include ensuring budgets are large enough to cover initial panel purchase, maintenance, and labor. Energy storage is also something that could limit smooth installation-especially when energy production exceeds usage. Another limitation would be the low conversion rate of the local manufacturers and determining if the investment would still be feasible.

Conclusions

Florida has a sub-tropical climate and sufficient sunlight to produce more renewable energy for those who visit and reside there. It is imperative that Manatee County, with all of its beautiful attractions, finds a way to be energy sustainable for the future. The development of sustainable solar energy operations is likely to help Manatee County's future economic development. With the constraints of the natural environment of Manatee County and the implications of harnessing an inexhaustible, long-term sustainable energy source, we must be better prepared for future scenarios. In terms of preparedness, this feasibility study analysis prioritized buildings of interest to citizens such as hurricane shelters, schools, and hospitals that would largely benefit from off-grid solar energy. This report discusses the development of solar energy in the region by examining the actual situation in Manatee County by assessing suitable installation locations, environmental risks, and capital costs.

There were some implications in the research project as it was affected by the COVID-19 pandemic. A tour of the high priority target buildings was planned for the class during the semester, but it was cancelled due to the coronavirus outbreak in both Manatee and Hillsborough county the week of the trip. The site visit was intended to give the students a deeper visual on-site connection, conduct more accurate measurements and close-up views for gauging solar panel potential, and get their questions answered in in person by the county officials. However, this crisis is the perfect example of why solar energy would be beneficial to build resiliency for future pandemics and catastrophic natural disasters.

During COVID-19 the influx of patients in hospitals was overwhelming to Manatee County and space and resources became scarce. If the hospitals were powered by solar energy, it could be used as either a stored battery back-up or provide a greener initiative for hospitals by powering it full time. Furthermore, in the case of a catastrophic event with a pandemic, power outages are the last thing anybody wants to deal with. Providing solar panels to hospitals and other important buildings is a win-win situation as it provides cleaner energy, and a back-up power plan.

Taking into account the overall environment, the development of solar energy fields in Manatee County will be influenced by the local politics, stakeholders, funding, and the natural environment. Further inspection of exact energy needs for priority buildings, estimated budget, and implementation of the project will need to be addressed. As climate change worsens, the development of solar fields in Manatee County will be of necessity as sustainability becomes a focal point in infrastructure planning. Furthermore, while it was not touched on much in this report, investing in hybrid energy sources such as a blend of wind and solar may be a good idea too. Limiting potential for resiliency to one source of alternative green energy would be unwise as Florida experiences hurricane seasons and high immigration rates. The cost effectiveness has been assessed and the group has concluded that it would be beneficial to invest in solar energy in Manatee County.

To conclude, it is recommended that the Manatee County administration continue their efforts in achieving Net-Zero buildings. Net-Zero building energy consumption must be considered an operational goal that requires planning, preparation, and performance testing. While achieving net-zero is a challenging task; structured planning and correct prioritization using a phased approach can help. To mitigate the risk from the high-cost investment, it is recommended to implement solar in phases based on the Hub Selection in *Appendix B*. The supplemental ROI Excel Tool enables the county to further its feasibility analysis and calculate the ROI for solar implementation on the Hubs identified or according to the country's interest. Furthermore, other initiatives must be incorporated into the strategic approach to reducing overall energy consumption. Thus, the current efficiency of each building must be analyzed and maximized to create a Net-Zero Energy Equilibrium. This equilibrium will only occur when energy consumed and energy produced are balanced, which requires on-site energy creation like solar as well as other building modifications.

Ultimately, maximizing the building efficiency to reduce energy consumption is crucial when implementing an on-site energy generation system like solar as it minimizes the energy demanded. Energy-saving measures include design functions that reduce demand-side loads such as sensors, LED lighting, AC modifications, and green roofs. Energy efficiency is usually a cost-effective strategy that offers a large ROI. By conducting this analysis, Manatee County has taken the first steps toward becoming a Solar Energy Leader. This document should be used to gain knowledge of energy best practices and draw recommendations towards achieving net-zero.

In order to accomplish the goal of net-zero, an 'all things considered' approach must be used. Resources from the community, public, and private sectors should be leveraged. An energy audit will lead to efficiency gains through remodeling and retrofitting. Energy-saving measures should be implemented. A public education program should be created to help strengthen understanding and participation in alternative energy, and energy-saving measures. Solar energy or thermal solar collection should be incorporated on public buildings where possible.

The feasibility of using rooftop solar arrays alone was analyzed by applying the current Manatee County electrical usage data to the amount of energy that could be captured from the facility rooftops (Table 18). The analysis showed that rooftop PV solar alone will only meet about 11% of the energy required to achieve net-zero. Nevertheless, in some cases, it may be useful to add either thermal or PV panels to large rooftops. For example, buildings with a very large unobstructed rooftop could have additional energy generating capability added. The choice to add either thermal or PV will depend on the specific conditions for each building. In general, however, thermal heat collection is approximately seven times more efficient in converting the energy received from the sun. Therefore, if all other factors are equal, thermal solar panels should be added. For large rooftops, it may be possible to add both thermal and PV.

Finally, a large land-based solar array should be constructed to provide the majority of the electrical power necessary to achieve net-zero. Construction of a large land-based array is essential to meet the remaining 89%. The Power Purchase Agreement is the recommended avenue to install a large 113-acre array. Through this agreement, the developer assumes responsibility for permits, approval, investors, funding, construction, and maintenance. The developer will sell power back to Manatee County presumably at a lower rate than the existing utility company, and the goal of achieving net-zero electrical usage will be met.

The main focus should be on direct ownership of solar modules for Manatee County. It does not only ensure energy resiliency for the county itself, but also creates clean energy jobs and boosts employment within the county. Purchasing PV systems requires high capital investments; therefore, tapping on grants and loans made available by the federal government is ideal. However, government policies are often not lasting as they have a certain period of validity. When the previous policy expires, a new policy will reappear. Although the conditions for obtaining government support are not demanding, all renewable energy projects are subjected to strict supervision. In addition, local government funds are limited, and high-level departments such as the Department of Energy control most of the funds. For solar financial feasibility, various sources of grants, funds, loans, and bonds can be used to aid project viability. It is important to identify and prioritize the application of financial support according to ease of access so as to obtain sufficient financial support within a manageable timeframe.

Project financing has presented feasibility and economic viability of transitioning public-owned government buildings in Manatee County to solar energy as a tactic to initiate net-zero. The established partnership gives added benefits of an outside perspective for financing and resiliency efforts. As a county with high susceptibility to climate change effects, Manatee faces severe challenges from growing economic, environmental, and social pressures. The caliber for sustainability and resiliency efforts needs to be continuously raised. The use of solar energy and innovative technology can be used in the mix for adaptation. Development and costs for new energy sources are highly dependent on supply and demand and market fluctuations.

Through statistical analysis, it has shown that high-energy consumption buildings and facilities in Manatee County coincide with the priority buildings identified by the county, illustrating the need to diversify energy sources and build energy resilience internally. Next, financing tools like Cost-Benefit Analysis and sustainability strategies such as LCCA were examined and could be delved further to evaluate the net profitability of equipping solar for specific buildings when the county engages third party solar installation partner(s) to manage the entire project.

Lastly, policy analyses were looked at to determine appropriate recommendations for creative and inexpensive ways to finance a solar project in terms of a local government's perspective. Due to a variety of funding opportunities available, identifying and prioritizing according to ease of access become the key to obtaining sufficient financing for solar development in the county. Seeking aid from the federal government is a major strategy for Manatee County to develop solar energy, i.e. grants and RE programs. Next, external investment sources such as loans are another type of funding option. Due to high capital and multi-stage processes needed for equipping facilities with solar energy from scratch, it is known that a long period of time is needed to reap the benefits of solar investment environmentally and economically. Therefore, finding suitable loans with low-interest rates is another important strategy. However, at times when government support and external funding sources are limited, funding via crowdsourcing or commercial activities might need to be applied. Due to difficulty to obtain a return in the early stages of solar construction, longer term bond issuance can assist with raising immediate funding from the crowd. To manage the end-to-end life cycle of solar as a product responsibly, it might also be crucial and interesting to look into recycling of PV panels after its end-of-life, or sourcing for recycled PV to reduce overall cost initially.

Renewable capacity increases will be needed to address climate change impacts and demand reduction of greenhouse gases. Future efforts will need to come from municipalities to initiate changes and address risk. As an initiative, solar power holds extensive benefits for the long-term to produce a more resilient community. Evidently, the role of a climate action plan along with setting specific, measurable, attainable goals would enable Manatee County to achieve sustainable goals.

Manatee County has a long timeline of history behind its emergence and has a great economic background in the development of the land. Although times have changed, the use of the land they live on is still a large contribution to its economy with tourism. As climate change continues to affect coastal cities, Manatee County will see large changes in the ecosystems that surround it causing them to see a decline in their economy. Manatee County wants to join in making a step toward solar energy in hopes to go net-zero in all public buildings. Going net-zero will allow Manatee County to control the way they get electricity to their public buildings and allow for them to make a more sustainable approach to climate change. The conversion of going net-zero in all public buildings will take a large amount of funding for the local government to establish.

By using the PV-Watt calculator from National Renewable Energy Labs we were able to calculate the estimated amount of energy needed for the high-priority buildings and allowed us to understand the total cost and the solar return on investment on these buildings. Most PV systems have a 25-30 year lifespan, but, on average, these buildings have a return on investment of less than 15 years. Allowing for these solar systems to pay for themselves in the relative near future will, over time, save Manatee County money. There are a handful of ways to finance the installation these systems such as pursuing green bonds, tax credits, budget surpluses, and even borrowing from investors. We can also approach going net-zero in myriad ways, but it must be seen as a necessary goal by local government.

This final report is an assessment of many of the technological, financial, and policy options available to the county. Hopefully, the research and recommendations put forward in this document will reinforce resilience initiatives already established by the county, create a feasible opportunity for renewable energy expansion, and provide economically viable solutions to solving ambient environmental problems. Based on the sustainability challenges ahead, there is no doubt that going solar to achieve net-zero carbon emissions county-wide is an innovative and responsible way to direct the energy future of Manatee County.

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Appendices

FOOTNOTES

[1] Calculations for comparison of efficiency between photovoltaic and thermal

Calculate photovoltaic output per square foot
A common size for a commercial photovoltaic panel is 77 inches by 39 inches, which is 20.8 square feet. The output for photovoltaic panels varies widely. For comparison purposes, an average value of 350 watts per hour will be used. ("Common Sizes of Solar Panels", 2017)
Converting to watts per square foot is done by dividing the output by the square feet of the panel: 350 ÷ 21 = 16.6 watts per square foot.

Calculate solar thermal output per square foot
In Tampa, Florida, one square meter generates about 2377.5 kWh per year. ("Undergraduate Journal of Mathematical Modeling: One + Two", 2014) The average clear sunshine for this area is 5.67 hours per day. ("Solar Electric System Sizing Step 4 - Determine the Sun Hours Available Per Day", 2016)

Converting to watts per square foot is done by multiplying by 1000 to convert from kilowatts to watts, then divide by the days in a year, by hours of sunshine per day, and by square feet per meter: 1000 × 2377.5 ÷ 365 ÷ 5.67 ÷ 10.2 = 112.6 watts per square foot.

Comparison of photovoltaic to thermal watts per square foot

- Photovoltaic panels produce 16.6 watts per square foot
- Thermal solar panels produce 112.6 watts per square foot

Therefore, thermal solar is 6.8 times more efficient than photovoltaic solar.

[2] Calculations for the size of a land-based array.

The formula for converting kilowatt-hours to watts is 1000 watts per kilowatt x daily usage (kWh) ÷ Avg. Sun-Hours per Day ÷ 0.8 loss from converting to AC = Minimum Solar Array Output Required. (Wholesale Solar, 2020)

Using this formula and the data from Table 1: 1000 x 186,106 ÷ 5.67 ÷ 0.8 = 41,028,659 watts required per day from solar panels. To convert this to the number of panels needed, divide by 350 watts per panel = 117,225 solar panels.

A solar panel is 21 square feet. Allowing 6 feet between rows for purposes of calculating the area needed, each panel requires 42 square feet.

Calculating the area needed: 136,762 x 42 = 4,923,450 sf. Converting to acres, divide the area value by 43,560 = 113 acres needed for a solar array that can provide power for all Manatee County government buildings.

TABLES

Table 19, page 1: Potential energy from rooftop photovoltaic arrays

Building name[1]	Avg. kWh / day[2]	# panels needed[3]	Sq ft useable roof area[4]	# panels that will fit on roof[5]
Manatee County Historic Courthouse	2,026	1,276	3,000	143
Carnegie Library	89	56	515	25
Judicial Center	12,191	7,679	4,681	223
Merrill Lynch	396	249	6,706	319
Central Records	374	236	3,176	151
Property Appraiser's Office	675	425	3,800	181
First Union Building	123	77	2,673	127
County Administration Building	4,587	2,889	5,776	275
Valentine House	74	47	0	0
Downtown Transit Restroom & Office	131	83	2,000	95
Central Energy Plant	2,550	1,606	0	0
Emerson Point (shop)	12	8	0	0
Emerson Point (office)	36	23	0	0
Utility Landfill	134	84	500	24
Bradenton River Park	585	368	825	39
GT Bray Gym	695	438	1,772	84
Bray Aquatic Center	1,348	849	0	0
Bray Administration	1,060	668	3,645	174
Buffalo Creek Maintenance	56	35	0	0
MPO	103	65	0	0
Island Library	127	80	4,333	206
EMS	52	33	0	0
Quattlebaum House	118	74	0	0
Lake Manatee and Dam	49,883	31,420	6,053	288
Manatee Beach Lifeguard Stand	31	20	0	0

Table 19, page 2: Potential energy from rooftop photovoltaic arrays

Building name[1]	Avg. kWh / day[2]	# panels needed[3]	Sq ft useable roof area[4]	# panels that will fit on roof[5]
John H Marble Park	9	6	0	0
John H Marble Park	637	401	2,654	126
East Bradenton Park	224	141	0	0
Agriculture Powell Cook Arena	49	31	0	0
ANR Fairgrounds	87	55	0	0
IFAS Kendrick Auditorium	173	109	0	0
Agriculture Administration	226	142	0	0
Utility	790	498	0	0
Utilities Maintenance Building	709	447	900	43
Fleet Services	236	149	5,162	246
Fleet Services	433	273	9,000	429
Administration Building	783	493	6,421	306
Fleet Wash	66	42	0	0
Traffic Control Sign Shop	102	64	0	0
Cabinet Shop	101	64	0	0
Central Stores	71	45	0	0
MTCE Office	69	43	0	0
Transit Admin	288	181	0	0
Palmetto MCAT	42	26	3,477	166
Central Jail Telecommunications Off.	141	89	3,375	161
Central Jail Classroom	562	354	0	0
Central Jail Sewing Room	171	108	0	0
Central Jail Greenhouses	192	121	0	0
Central Jail	16,804	10,585	17,472	832
MSO District Substation (Sheriff's)	146	92	5,118	244

Table 19, page 3: Potential energy from rooftop photovoltaic arrays

Building name[1]	Avg. kWh / day[2]	# panels needed[3]	Sq ft useable roof area[4]	# panels that will fit on roof[5]
MSO District Substation (Sheriff's)	539	340	0	0
Supervisor of Elections	610	384	7,410	353
MSO Desoto Ctr Property & Evidence	921	580	0	0
Desoto Tax Collector Main Office	1,425	898	13,076	623
Desoto Center	134	84	0	0
Desoto Center	6,420	4,044	7,117	339
Desoto Center	233	147	0	0
Juvenile Assessment Radio Shop	132	83	3,485	166
Bradenton Convention Center	8,850	5,574	12,959	617
Convention Center Sign	112	71	0	0
Offender Work Program	95	60	0	0
Health Department	1,753	1,104	6,000	286
South Manatee Library	412	260	2,893	138
BADS Annex Modular EMS	68	43	0	0
Powel Crowsley Carriage House	66	42	0	0
Powel Crowsley Estate	10	6	0	0
Powel Crowsley Estate 2	692	436	903	43
Animal Services Pound	639	402	0	0
Highway and Drainage	106	67	0	0
Palmeto Library	394	248	4,456	212
MSO South County Fleet	261	164	5,521	263
Employee Health Benefits	201	127	0	0
Bradenton River Branch Library	496	312	2,756	131
Public Safety Center	10,552	6,647	48,372	2,303
Rocky Bluff Library	292	184	2,879	137

Table 19, page 4: Potential energy from rooftop photovoltaic arrays

Building name[1]	Avg. kWh / day[2]	# panels needed[3]	Sq ft useable roof area[4]	# panels that will fit on roof[5]
Ellenton Tax Collector	168	106	1,659	79
SERWRF (wastewater treatment)	9,332	5,878	2,800	133
SERWRF Lab	2,417	1,522	0	0
SERWRF Admin	36,745	23,145	3,112	148
Parks and Ground Maintenance	91	57	12,744	607
Central Library	895	564	19,111	910
Account Analysis	308	194	0	0
Bradenton Beach Restrooms	3	2	0	0
TLE PLNT	44	28	0	0
ANIMAL CTR	8	5	0	0
MAINT TRLR	23	14	0	0
BADS North River	92	58	0	0
Totals	186,106	117,225	260,288	12,395
			% met:	**10.57%**

[1]from the provided Manatee County Utility data.

[2]from the Manatee County Utility data.

[3]derived using the formula (kWh ÷ 5.67 ÷ 0.8 ÷ 350 × 1000).

kWh is column one, 5.67 is the avg. sunlight hours per day in FL; 0.8 factors the loss from converting DC to AC; 350 is the wattage per panel; 1000 converts kWh to watts.

[4]area is taken from Google Earth using the area tool.

[5]derived using the formula (roof area ÷ 21).

A 350-watt panel is just under 21 square feet.

APPENDIX A

Table A1: Building Generation Estimate

Property Name	Public Safety Building	
Address	2101 47th Terrace E, Bradenton, FL 34203	
Actual Energy Meter Use (kWh) 2018	3,463,680	Imput Data
Actual Energy Cost 2018	$220,691.10	Imput Data (If data not provided, it can be calculate by the Energy use * Avarage Energy Cost)
Average Energy Rate ($kWh) 2018	$0.064	Imput Data
Roof DC System Size (kW) availability	770	PVWatts Estimate
Additional DC System Size (kW) availability	1456.1	PVWatts Estimate
Solar Panel UNInstalation Cost	$1,830.00	figure ES-1. NREL PV system cost
Roof Installation Cost Estimate	$1,409,100.00	
Additional Areas Installation Cost Estimate	$2,664,663.00	
Total Installation Cost Estimate	$4,073,763.00	
Solar Energy Roof Generation (Year estimate)	1,177,891	PVWatts Estimate
Solar Energy Additional structure Generation (Year estimate)	2,287,098	PVWatts Estimate
Total Solar Energy Potential Generation (Year estimate)	3,464,989	
Energy Cost Save (Year estimte)	$221,759.30	
Payback (Years)	18	
Financial Loan Period (Years)	30	Imput Data (Maturity of the financial loan)
ROI	63.31%	

Imput Data

PVWatts Estimate

APPENDIX B

Table B1: Hub Selection

Hub Selection

Meter Data from Jan - Nov 2018

Hub	Property Name	Street Address	Cost ($)	Usage/Quantity	Electricity Rate
Hub 1	PW - Water Treatment Plant Dam	17915 Waterline Rd	$1,659,582	17,040,000	0.10
	PS - MCEMS Station 5	1505 Dam Road	$1,403	13,940	0.10
	Total		**$1,660,985**	**17,053,940**	**0.10**
Hub 2	Clerk - Judicial Center	1051 Manatee Ave West	$341,600	3,817,920	0.09
	BOCC - Administration Building	1112 Manatee Ave. W-Bradenton	$132,003	1,688,880	0.08
	Total		**$473,603**	**5,506,800**	**0.08**
Hub 3	PS - PSC	2101 47th Terrace West	$220,691	3,463,680	0.06
	Total		**$220,691**	**3,463,680**	**0.06**
Hub 4	MSO - Desoto Center Operations	600 301 Blvd West Suite 202	$152,112	2,418,360	0.06
	MSO - Desoto Property and Evidence	600 301 Blvd West Suite # 112	$25,102	326,100	0.08
	Clerk - Supervisor of Elections	600 301 Blvd West #108	$21,549	242,400	0.09
	Total		**$198,764**	**2,986,860**	**0.08**
Hub 5	MSO - Central Jail A and B Buildings	14470 Harlee Road	$68,809	942,960	0.07
	MSO - Central Jail Telecommunication	14490 Harlee Rd	$4,666	49,113	0.10
	Total		**$73,475**	**992,073**	**0.08**
Hub 6	County Health Department	410 6th Ave E	$52,424	652,560	0.08
	CS - Health Dept Annex	216 6th Avenue East	$2,160	23,007	0.09
	Total		**$54,584**	**675,567**	**0.09**
Hub 7	PW - Administration	1022 26th Ave East	$21,725	258,720	0.08
	Total		**$21,725**	**258,720**	**0.08**
Hub 8	PS - Marine Rescue	2651 Gulf Drive South	$9,899	107,109	0.09
	Total		**$9,899**	**107,109**	**0.09**

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