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JOHN BALL ZOO

SOLAR INTEGRATION PROPOSAL

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Abstract

The goal of this project was to answer the question: *What would it take for John Ball Zoo to construct, own, operate, and maintain a solar photo-voltaic energy system?* A team of students from Calvin College analyzed the solar insolation of the JBZ campus and located areas and buildings most feasible for installation of a solar photo-voltaic energy system (solar PV system). The most feasible location for solar PV system integration is the roof of the Education Building and the roof of the Drop-Off Zone Canopies. The initial system cost is $791,539, with a payback period of 28 years. This system will be able to produce enough electricity to meet 100% of the Education Building's needs on an annual basis.

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Executive Summary

Introduction

The goal of this project was to answer the question: *What would it take for John Ball Zoo to construct, own, operate, and maintain a solar photo-voltaic energy system?* This coincides with John Ball Zoo's (JBZ's) mission statement which is, "John Ball Zoo inspires people to be active participants in the conservation of wildlife and our natural environment" [1]. A team of students from Calvin College analyzed the solar insolation of the JBZ campus and located areas and buildings most feasible for installation of a solar photo-voltaic energy system (solar PV system). This report details the steps that were taken to design multiple installation options for a solar PV system at JBZ.

Procedure

The first step in designing a solar PV system for JBZ was to learn more about the property and faculties available. This was done with the help of Allmon Forrester who is the operations manager at JBZ. He was very helpful in the describing the master plan for the zoo and sharing what the zoo is looking for in a solar PV system.

The first sites that were analyzed were existing facilities at the zoo that were suitable for solar PV panels. The aquarium and the veterinary building were the most suitable existing buildings for solar PV panels. However, they were still significantly covered by trees and did not provide enough area to warrant the installation of a solar PV system.

JBZ is currently redefining their master plan. As part of this the zoo is looking a building a new Educational Building as well as additional parking. These sites were analyzed to determine their feasibility for solar PV energy system installation. The possibility of integrating a solar PV into a new construction project is exciting because a large majority of the retrofit cost can be avoided and seamless integration is much more achievable.

Once the locations for the solar PV system were analyzed the optimal solar panel and inverter were selected. This was done by comparing a variety of makes and models and selecting the solar panels that were able to produce the maximum energy per unit area, and were competitively priced.

After the site and solar panels were selected, and the solar array was optimized a financial analysis was performed for the system. This involved creating a bill of materials for the project and calculating payback periods based upon the energy savings of the system.

In accordance with JBZ's master plan, educational resources were researched. These educational tools are to be used to inform the public about the solar PV systems that has been installed at the zoo. JBZs first priority is to educate the public about the environment and be a leader by example in conserving the environment and national resources.

Results

The location deemed most feasible for the implementation of solar panels was the education building and drop-off zone. Using these two locations will offset 100% of the buildings electricity use. The advised system would have a final cost of $784,128.42. This overall cost includes labor, material and 5 percent contingency. This system includes 583 LG 300N1C – B3 solar panels. This many solar panels produces 311 MWH/year and provides savings of $28,000 a year. The simple payback for the system will be 25.29 years.

Conclusion

The final recommendation to be implemented by JBZ is Option #2: Educational Building and Drop-Off Zones. This option involves the implementation of a solar PV energy system on the roof of the Educational Building as well as solar panels on the roof of any drop-off zones around the parking lot. This system will allow JBZ to produce enough electricity on site to cover the needs of the new Educational Building. This will allow the zoo to have a net-zero impact on electricity when the educational building is constructed. The implementation of option #2 has an initial investment of $791,539, this is a much more financially feasible option than the $6 million dollar parking canopy installation. Option #2 will allow the zoo to produce enough electricity for their new education building while still maintaining a reasonable budget. This will also provide JBZ with a great educational tool and reduce their dependence on fossil fuel, moving them one step closer to eliminating their need for fossil fuel consumption.

We would also like to strongly advise that the Zoo consider incorporating electric car charging stations into their new parking lot. Transportation accounts for over 25% of the US's energy use, and the sector runs almost exclusively on fossil fuels. When analyzed in 2012, the fossil fuel energy use of the US transportation sector exceeded the energy produced from all Solar, Nuclear, Hydro, Wind, and Geothermal installations in the country, combined [2]. In order for the US to switch over to renewable energies, it will have to first switch over its transportation infrastructure to run on electricity, rather than oil. The integration of electric car charging stations one of the first steps in the conversion of infrastructure.

How Solar Works

The Sun and Incident Sunlight

The Sunlight that hits the lower peninsula of Michigan carries 140 billion kW of Power. This power is what makes solar technologies possible. By capturing a fraction of this energy from the sun, we are able to generate enough energy to become independent of the grid.

Panels

Photovoltaic Panels contain components that allow for the harnessing of Solar Energy. These cells operate just like the batteries in your car. They have a positive and negative pole. When the sunlight hits the space between the positive and negative poles, the elements in the middle get excited and electricity is produced. When more PV panels are connected together, more electricity can be generated. However, as the panels age they start producing less and less energy every year.

Inverters

The Inverter takes DC (Direct Current), the type of current a battery emits, and converts it into AC (Alternating Current). Most household electronics and appliances require AC current. With the correct circuitry, the AC current can be turned into any voltage and frequency desired.

Measuring

Electric Meters measure the amount of electricity being generated by the solar panels. It also measures the amount of electricity that comes into a building not being generated by the solar panels.

JBZ Introduction

JBZ originally known as the Ball Forty was a piece of land that was donated by John Ball in his will in 1869 to be used for city park purposes. It was an informal picnic ground for the citizens of Grand Rapids for almost 20 years. It wasn't until May of 1890 that the city initiated the land as a city park. The zoo at the park started in 1890, with a pair of rabbits, and grew rapidly. By 1892 the zoo contained an eagle, owls, hawks, raccoons, squirrels, a woodchuck, deer, chickens, guinea fowls, and a pair of peacocks [3]. From there, the zoo began to grow into the large public attraction that it is today. Currently, the John Ball Zoo sees 470,000 visitor annually and is expecting to continue to grow. They have a passion for sharing nature with the public and have centered the zoo's focus on their mission statement.

"John Ball Zoo inspires people to be active participants in the conservation of wildlife and our natural environment" [1]

In 2015, JBZ is reviewing their master plan. As part of this plan, the zoo is looking into expanding their educational facilities as well as their parking structures. In accordance with their mission statement, JBZ is trying to conserve their natural environment. As a result, the zoo would like to reduce the environmental impacts of additional structures. Therefore, solar photovoltaic systems (PV) were investigated as possible methods by which to offset the electrical consumption of the zoo.

Introduction to solar insolation

The geography and layout of the zoo provides certain challenges to the installation of a PV system. Solar panels need direct sunlight in order to maximize their electrical output capability. However, most of the zoo is covered by forest. While this is great for the zoo experience and is helpful for visitor education and wildlife conservation, it is difficult to find direct solar insolation on the property. Most buildings are covered by trees and do not have the requirements necessary for the mounting of a solar PV system. Due to this, there was a very limited number of possible locations.

Of the buildings that are currently part of the JBZ campus, the Aquarium and the Veterinary hospital are the most likely candidates for a solar PV system installation. This is due to the fact that part of the roofs on these buildings receive direct solar radiation. A diagram of these buildings and exposed roofs can be viewed in Figure 1.

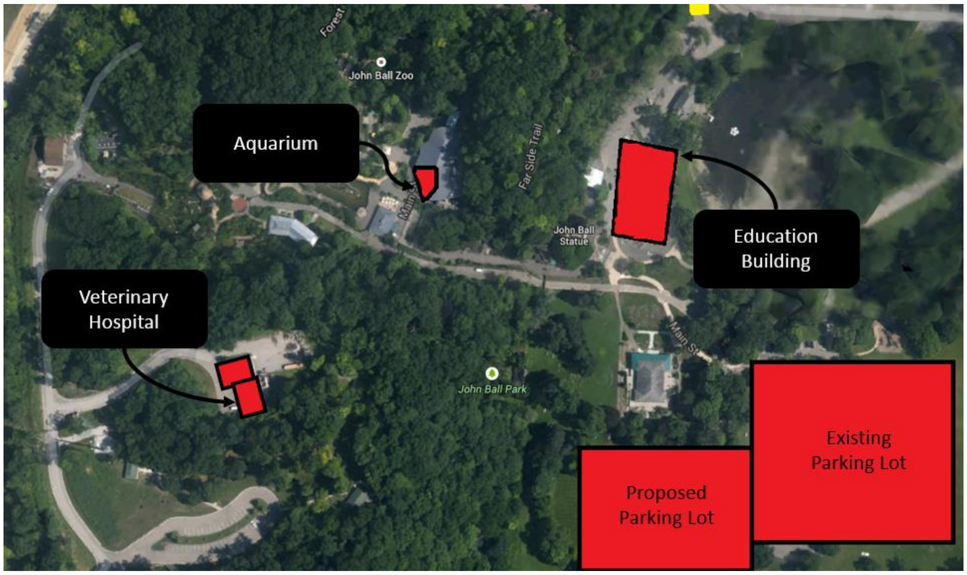


Figure 1: Proposed Future Building Projects

The Veterinary hospital roof was not considered for a solar PV system because it was not viewable by the general public. JBZ wants to showcase the solar PV system in order to inform the public about different ways to conserve natural resources. Due to this, the aquarium was a more suitable installation location. Unfortunately, the usable roof space of the aquarium is small due to shading from the trees. The roof is also highly sloped and curved. This makes installation and maintenance of a possible solar PV system dangerous and costly. The aquarium was deemed an unacceptable location for a solar PV system because it is small, has poor solar orientation, added installation costs, and additional safety concerns.

This eliminates all existing buildings on the JBZ campus for suitable locations for solar PV system installation. During their master planning process JBZ is evaluating adding an education building as well as auxiliary parking lots. These places provided much better solar insolation as they are not surrounded by woods. By integrating a solar PV system into a building during construction, costs can be saved that are typically incurred during a retrofit process. An overall image of the zoo property can be viewed in Figure 1. This figure shows the proposed location and size of the education building as well as the proposed parking lot.

The education building (Ed. building) was a great option for a solar PV system due to its size, orientation and lack of obstructions. The Ed. building is not designed yet, so all images and values are conceptual sketches and best guess estimations. However, the size of the building is estimated to be 38,000 ft^2 spread out over two stories. This provides a total roof space of 19,000 ft^2, this value was used to constrain the amount of space that was available for solar PV panels to be mounted. The Ed. building also provides a great way to educate the public about the solar PV panel system as well as showcase the system that was installed.

The new parking lots that are going to be constructed are very good candidates for a solar PV canopy system. The inspiration for this idea was the Cincinnati Zoo which recently installed a 4 megawatt solar PV canopy system. This system is able to generate enough power to meet 20 % of the Cincinnati Zoo's electrical needs on an annual basis and 100 % of their needs in April when heating and cooling loads are minimized. A picture of this canopy system can be viewed in Figure 2. With this in mind, the parking lot was selected to be an acceptable location for the installation of a solar PV canopy system. The parking lot provides a large area for the solar panels to be installed. The type of canopy that is used allows the panels to be installed at their optimal orientation. A solar PV canopy system also provides shading for cars as well as protection from rain and snow.

Figure 2: Cincinnati Zoo Solar PV Parking Canopy

Design Options

After identifying the ideal locations for solar panel arrays, three options for the zoo were developed. The purpose of these options is to make integration with the master plan easier. These options require different levels of financial and space commitments. They can also be implemented over time as more funds become available. Each of the options is based on theoretical structures using estimated values.

Option 1: Education Building

The new education building will be located next to the Zoo entrance where a small parking lot is currently located. This has decent sun exposure so there is potential for solar panels. The goal of this option was to generate 100% of the buildings electrical needs. This would be an excellent number for the zoo to advertise in order to collect donations and show the community the effectiveness of solar panels. These panels would also be of educational value which fits well with their mission statement. However, after initial analysis it was found that 100% of the electrical generation of the building could not be generated. This would still be a good option for solar panels and option 2 was created so the zoo still had the option of making the educational building net zero in electricity consumption.

Option 2: Education Building and Drop-off Zones

This option is similar to the first but it will include drop-off zones. Drop-off zones are areas located at the front of the parking lot designated for visitor arrival. The advantage of this option is that between the education building and the drop-off zones JBZ can produce enough energy to offset the electric needs of the education building with an extra 5% as well. Being able to completely eliminate the electric needs of a single building will be a great way to introduce solar energy to people as a great alternative energy source. The drop-off zones would be visible to the public and are of a scale to handle the needed number of panels.

Option 3: Parking Canopies

The final option presented will be to place a canopy with solar panels over the new parking lot that is included in the new master plan for the zoo. The new parking lot will be in a lot of open space so it is very good for solar panels. This option will produce a lot of energy due to the large scale and it will be very visible to visitors of the zoo. These solar panels would be the first things people would see when entering the zoo and it would give them an impression of what the zoo wants to do right from the beginning. This option, as well as the other two, fits in very well with JBZ's mission statement.

Building and Site Integration

Racking

Each site option has a need for racking integration of the solar panel arrays. This is how the panels will be mounted in each specified location. Racking needs are different according to the building design.

Option 1: Education Building Only

The Education Building's racking needs are fairly simple. The building at its current stage in the master plan is only conceptual. A flat roof is expected to be implemented in order to maximize solar panel array size and efficiency. The racking system chosen for this scenario is the EcoFoot 2+ found from Ecolibrium Solar. This is a ballasted roof mounting system. This racking system was chosen for various advantages reasons. The EcoFoot 2+ does not require any roof penetration points. This eliminates the need for weather proofing in case of damage including rain and snow. The EcoFoot 2+ requires little installation hours due to no roof penetration points as well. This racking system is ballasted with concrete blocks and can withstand wind speeds up to 150mph. This system will required 700 EcoFoot2+ and the required hardware. This will also necessitate 1400 bricks that are needed for ballasting the system. This will equate to a roof load of approximately 70,000 lbs total or 4 lbs per sq^2. The total cost of the feet, mounting hardware, and bricks required for ballast is $40,000 including labor and shipping costs. This was significantly less than other racking systems that were evaluated. Figure 3: EcoFoot 2+ Racking Equipment provides an image of the EcoFoot 2+ racking foot, Figure 4 provides a sample of a fully assembled solar PV array using the EcoFoot 2+ racking system.

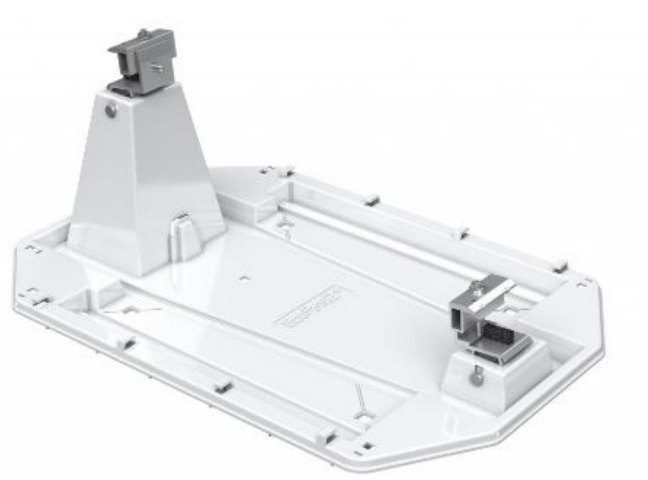


Figure 3: EcoFoot 2+ Racking Equipment [4]

Figure 4: Exemplary Solar PV System Using EcoFoot 2+ Racking System [4]

Option 2: Education Building and Drop-Off Zone

The following description for racking is for the Education Building and drop-off zones. Racking for the Education Building is the same as described in Option 1 above. Racking for the Drop-Off Zones requires a building in which to integrate the panels. Drop-Off Zones are locations at which visitors may be dropped off via tour buses, school buses, etc. The best fit structure for a solar array implementation into a drop-off zone is a canopy overhang. Below is a representation of an overhanging canopy.

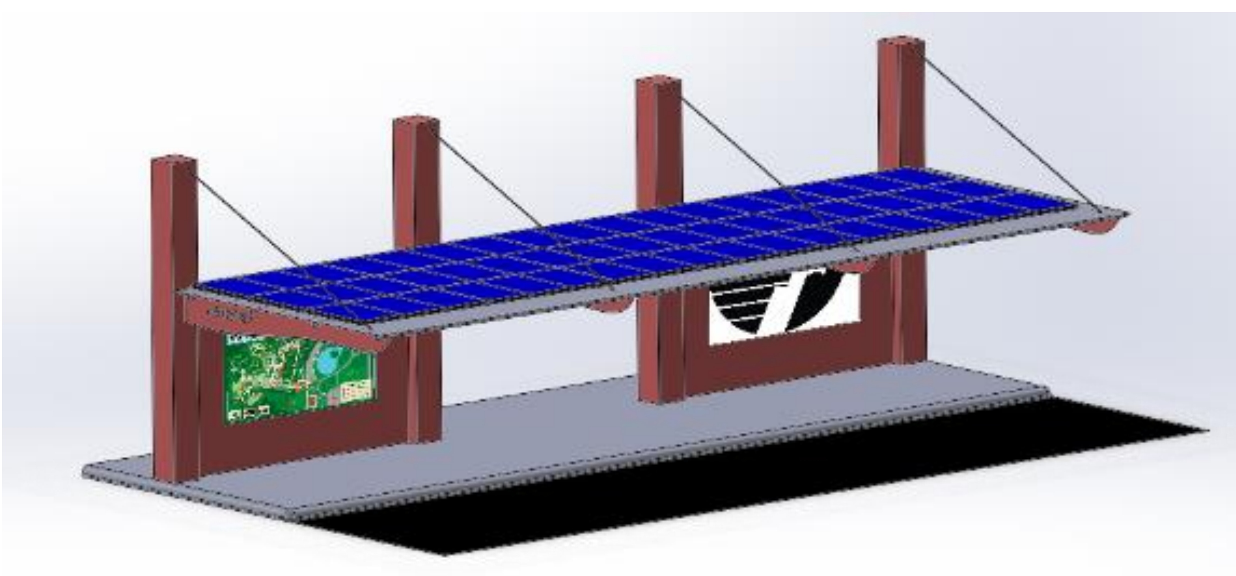


Figure 5: Conceptual Drop-Off Zone

The structure itself must be long enough to fit a standard tour bus underneath. This requires the canopy to extend approximately 60ft in length. The height of the canopy is most important so as to refrain from any interference with buses. The standard height of a coach bus is 11ft. In order to eliminate any possible collision, the canopy should be approximately 13ft in height. The canopy should have an overhang of 20ft in order to cover the width of the bus. The depth of the foundation pillars should be deep enough to compensate for the canopy weight distribution. The canopy itself will remain stable given steel wiring of at least 1-0" thick.

The solar array location recommendation is on top of the canopy overhang. The overhang will be flat in nature so that any change in orientation will not affect the output power of the array. The panels will have a 3 x 17 panel pattern on the canopy. Racking for the panels will be simple screw penetration through the metal canopy structure.

Option 3: Parking Lot Canopy

Racking options described below are based on one row of parking. Racking for the parking lot solar canopies includes full construction of the canopies. The canopies will have central foundations located at the front junction of parking stalls in a row. These foundations should be 20ft apart. The canopies themselves should over hang in each direction over a full parking stall. This requires the canopy to extend 20ft in each direction giving a total canopy width of 40ft. Under given specifications by the managers of JBZ, the parking lot should have room for approximately 370 parking stalls. Given this specification and limiting the parking lot to only 4 rows, each row should be 466ft in length. The canopy should extend this total length to give complete shade coverage over all parking stalls. The height of the parking canopy central foundations should extend to at least 14-1/2’. There should be a 5^{o} angle on the canopy to increase the amount of direct sunlight on the solar panels. This results in a height of 13-0’ for the low end of the canopy and a 16-0’ height at the high end. This is a recommended height for the canopy structure to eliminate any chance of vehicular collision with the canopy.

The racking for the parking lot canopy will extend the full length of one row of parking. The array size for each row will be 8 x 138 panels. Each panel will be fastened with flush margins, each panel is butted right up to the next. The panels will have screw-in penetration into the canopy structure. It is recommended that the canopy be reinforced with L-angled steel to act as the primary penetration points for the panels.

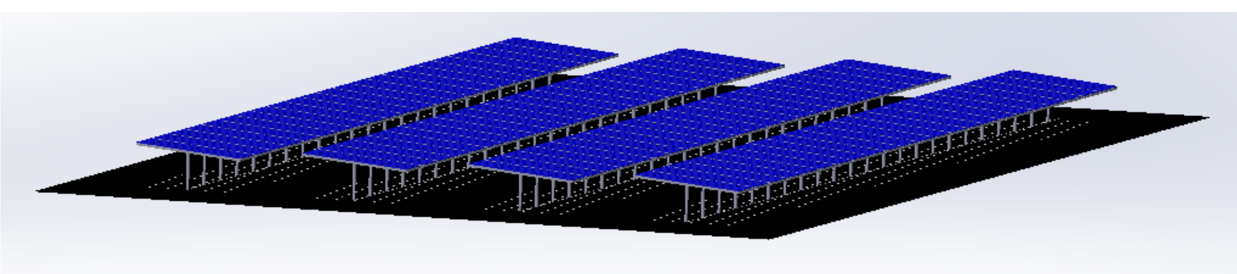


Figure 6. SolidWorks design of parking lot solar canopy

Electrical Integration and Wiring

Each option listed here will require unique wiring considerations in order to be successfully integrated into the JBZ's electrical infrastructure. This includes wire gauge, grid-tie locations, and transforming power.

Option 1: Education Building Only

This building will likely prove to be the easiest to integrate into the existing zoo infrastructure, largely due to the fact that the building does not yet exist. Rather than having to insert new hardware into an existing circuit, the Zoo and its partners will have a unique opportunity to design their new electrical setup around the planned solar array.

A few key things should be noted here. Regardless of location or size of the array, there will be power losses in the electrical lines due to natural resistance. In order to mitigate these line losses, it is prudent to plan on running your electrical wires at a high voltage, and low amperage, for as long as possible.

When constructing the new education building, it will be receiving its own tie-in to the JBZ power loop, as well as a dedicated transformer for the building. These will most likely be located on a fenced-in concrete pad, placed on the North side of the building in order to avoid the majority of direct sun exposure. It is also here that, most likely, the inverters for the solar array will be located. This makes sense not only from a maintenance stand-point, placing all the electrical hardware in a centralized location, but also from a power-loss standpoint. Placing the inverters near the grid-tie almost eliminates line losses between the two pieces of hardware, and allows us to maximize on the almost 1000VDC power coming off the solar arrays.

Also, it would be advised that the solar power supply line should feed directly to the grid, rather than to the building itself. This way, a dedicated transformer may be chosen for the building that could accurately handle the building's electrical needs. Solar power is notoriously intermittent, and pushing that power into the grid itself will enable the Zoo to effectively distribute it through its facilities. Tying directly to the building would require the installation of a reverse-feed compatible transformer of sufficient size to handle the sporadic loading which is characteristic of a Solar PV system, which would most likely prove to be inefficient and needlessly expensive. Despite the seeming waste of putting two transformers in the same general area, having two separate, dedicated transformers will most likely prove to be the most effective and efficient method of integration.

Due to the rather short distance from the Solar Array to the inverters and grid-tie, the gauge of the connecting wire will not have to be exorbitant. Even with all lines combined, 1AWG copper wire should be able to keep the voltage drop well below 2%, which is our design target.

Option 2: Education Building and Solar Drop-Off Zones

This option will incorporate all the recommendations stated in the previous section, while also incorporating new material for the Solar Drop-Off Zones. The design of this option calls for four of these structures, located near the new parking lot.

Once again, it would be prudent to run connecting wire from the arrays to the grid-tie at 1000VDC, reducing line losses and capital cost. However, the main question in this case is not necessarily *how* to tie into the grid, but rather where to do so.

There are three distinct options in this case. First, the zoo could plan to extend their electrical power loop out to the drop-off zones themselves, providing a near-by grid tie. Second, the Education Building's electrical hardware could be connected to the Drop-Off Zones via underground conduit. Finally, the Drop-Off Zones could be routed to the near-by gift shop, which presently has its own dedicated grid tie.

Each of these options provide unique advantages and disadvantages. Placing a grid tie near the Drop-Off Zones would greatly reduce line losses, but would also cost quite a bit to implement. Running conduit to the Education Building would allow the Drop-Off Zones to tie into the new system being installed there, perhaps reducing the cost of purchasing additional electrical hardware or retrofitting an existing connection. Additionally, it would allow for easy monitoring of total solar power production, which might be beneficial for financial or educational purposes. However, line losses and/or initial cost of wiring would drastically increase. Finally, tying into the Gift Shop would reduce line losses in the underground conduit. However, they would still be greater than if the Drop-Off Zones had a dedicated grid tie location, and retrofitting the existing connection could prove difficult in practice.

Considering the fact that the new transformer at the education building could be designed to handle both the Drop-Off Zones' and Education Building's power outputs, an analysis would have to be conducted weighing the costs and benefits of independent transformers and separate locations, versus additional line losses and a single, centralized transformer.

Option 3: Education Building, Drop-Off Zones, and Parking Canopies

Including parking canopies drastically increases the Zoo's possible power generation, but also greatly complicates the system's integration into the existing electrical infrastructure. It is unlikely that the majority of the power lines on campus, outside the main loop, are designed to handle such a large influx of power. Thus, before deciding to tie in at any specific location, it would be wise to verify the power carrying capacity of the electrical lines involved.

The parking canopies could be tied into the grid at the same three locations considered for the Drop-Off Zones, with much the same advantages and disadvantages. However, due to the sheer amount of power coming off the Parking Canopy arrays, the option of having a dedicated grid tie is much more appealing than in the previous option. Also, it would be completely infeasible for the Parking Canopies to tie into the same transformer as is used for the Education Building. The peak power rating for the Parking Canopies is more than four times greater than that of the Education Building.

For a dedicated grid tie, the line losses would once again be minimized as the inverters and transformers would have to be located near the grid tie, next to the parking lot. However, design optimization becomes more interesting when we look to tie in at either the new Education Building or the Gift Shop.

Line losses become a key concern when we are looking to transfer such a large amount of power more than 100 feet. In order to meet our design constraint of at most 2% voltage drop through the lines, we are restricted to using fairly large gauge wire. Additionally, we cannot combine each of the four canopy feeds until just before reaching the inverters.

Using the 1000VDC coming directly off the solar arrays, the 2% design constraint would require us to use 4/0AWG 1000V rated copper wire, one cable for each canopy. While somewhat rare when it comes to typical electrical applications, there are actually a number of solar parts suppliers who produce 1000V rated wire of such large sizes. An example of this would be SolarLink's 30401PV 4/0 insulated copper wire (RHW-2 rated) [5].

However, another option would be to run the Parking Canopies into two, industrial sized inverters placed immediately next to the parking lot. From there, the power would be transported in six cables (one cable per phase per inverter) to the appropriate transformer and grid tie. In order for this option to actually decrease line-losses, the inverter would have to output power at a Voltage greater than 670VAC. As there are inverters capable of output Voltages exceeding 800VAC, this option could be feasible.

If the cable feed to the Gift Shop is not rated to allow for such large power inputs, it would be most feasible to either give the Parking Canopies their own dedicated grid tie, or to tie into the Education Building's new infrastructure, which could be designed to accommodate the increased load. Giving the system a dedicated grid tie could also prove to be beneficial for the Drop-Off Zones, reducing line losses from that system as well.

Finally, placing a grid tie near the parking lots would allow for the eventual integration of electric car charging stations. Due to the intermittent nature of solar power, such charging stations could not simply be supplied from the solar arrays over the parking lot, they would need to be tied to the steady power available from the grid itself. Without a dedicated grid tie nearby, this would mean additional wiring cost and line losses.

Final Notes:

We would like to strongly advise that the Zoo consider incorporating electric car charging stations into their new parking lot. Transportation accounts for over 25% of the US's energy use, and the sector runs almost exclusively on fossil fuels. When analyzed in 2012, the fossil fuel energy use of the US transportation sector exceeded the energy produced from all Solar, Nuclear, Hydro, Wind, and Geothermal installations in the country, combined [2]. In order for the US to switch over to renewable energies, it will have to first switch over its transportation infrastructure to run on electricity, rather than oil.

One of the principle barriers to this switch is a distinct lack of infrastructure. There are not enough places where electric car owners are able to charge their vehicles, making them impractical for use in most regions of the US. If the JBZ seeks to inspire and empower people to be active participants in the conservation of our natural resources, the installation of electric vehicle charging stations would be one of the single most significant steps that could be taken in order to fulfill this aspect of its mission statement. Even if the charging stations see little use in the first few years; simply by installing these stations the Zoo would validate electric vehicles and electric transportation infrastructure in the minds of their visitors, generating opportunities to learn and discuss the topic in greater depth. Having both public and private institutions take the initiative in the establishment and validation of this infrastructure may prove absolutely essential as the US looks to go through a nationwide transition to sustainable and renewable energy.

Some additional recommendations were provided by Mark Fisher, a member of the Cincinnati Zoo's team that oversaw the design and now, the continued maintenance of, their parking lot solar array. He is the one who advised that the parking lot canopies not go below 13'-0'' in height, as they have had problems with some tall vehicles. Rather than having a designated large vehicle parking area and simply trusting all drivers to adhere to that rule, it is safer to design in a few additional feet of clearance. He is also the individual who stressed that the centerline or "backbone" of the rows of parking spaces should run east to west, so that the eventual canopies may face due south. Finally, Mark also pointed out a couple lurking costs in the implementation of Solar Canopies. The first is lighting, as lights will have to be placed under the canopies in order to serve visitors. Apparently, visitors actually like this arrangement, as the area under the canopies appears much brighter, especially if the undersides are painted white. The other cost he mentioned was security, as due to the valuable nature of the panels and their general size, placing and routing security cameras for the parking lot could prove to be very difficult, as it did in Cincinnati. Neither of these concerns were factored into this initial analysis, but ought to be considered in the event of later interest in a parking lot PV installation.

Safety

Each option listed has specific safety requirements. Below is an explanation of those safety requirements for each option and structures which are able to fulfill those requirements.

Option 1: Education Building Only

The main concern with the Education Building is the flat roof. This of course has obvious concerns implied, such as the possibility of workers falling off the side. To combat this concern is the most simple safety system. A safety railing is recommended for the flat roof area. The recommended safety railing is found from Simplified Safety and as a KeeGuard Rooftop Railing. This railing system is recommended because it does not require any penetration points. This allows for faster installation time and less maintenance overall. A secondary option was considered because safety railings are not always pleasing to the eye. The secondary option was to extend the walls of the building up another 3'. This system would require no maintenance. The downside to this system is that much of the incoming sunlight will be blocked by the solid wall. A railing system allows sunlight penetration. The recommended system is still the KeeGuard Rooftop Railing.

Figure 7. KeeGuard rooftop railing system [6]

Option 2: Education Building and Drop-Off Zones

Safety systems for the Educational Building are equivalent to what is mentioned in Option 1 above. The drop-off zones have minimal safety requirements for how they are designed. The only safety concerns would be for maintenance work after the drop-off zones have been built. The design of the zones eliminate any public safety hazards because the height of the canopy is 13-0'. Scissor-lifts are recommended for maintenance on the solar array. All maintenance can be done beneath the canopy. A secondary concern for the drop-off zones is vandalism. It is recommended that video surveillance be positioned both below and above the canopy.

Option 3: Parking Lot Canopy

Safety hazards for the parking lot canopies are similar to that of the drop-off zones. The safety hazard of vehicle collision with the canopy is eliminated because of the height the canopy is designed at, with the low end being a minimum of 13-0' above the ground. All maintenance on the solar array can be done from a scissor lift beneath the canopies. Video surveillance is, again, a secondary recommendation. This would require multiple surveillance cameras placed above and below the canopies spanning the entire parking lot. Video surveillance is recommended to eliminate liability on the zoo for any damage done to the canopies or the panels themselves.

Cleaning

Cleaning the solar panels on all three options of arrays will be necessary to maximize the power production. Michigan's common weather trends will reduce the amount of cleaning necessary on all panels. Standard solar panel cleaning is recommended four times annually. But because of Michigan's annual rain fall, the recommended number of cleanings per year should be once. This recommendation comes directly from MeLink Corporation. The Cincinnati Zoo's parking lot solar array was built and is maintained by MeLink who has cleaned the array two times over the past three years. The cleaning methods are consistent throughout all three options.

Panels and Inverters

Panel Selection

Nine different panels from three different manufacturers were evaluated based on aesthetics, capacity, cost, efficiency, degradation, warranty, and weight. Two panels obtained high scores in the decisions matrix, the X21-345 solar panel by SunPower and the LG300 N1C-B3 by LG [7]. The X21-345 obtained the higher score because of its larger generation capacity per area. This was ideal given the limited space on the roof of the education building.

Table 1: Solar Panel Decision Matrix

Decision Matrix	Scale is 1-5	5 best	1 worst							
Categories	Weight (per category)	CS6X-P	CS6P-P	CS6V-P	X21-345	SPR-333NE-WHT-D	SPR-327NE-WHT-D	SPR-E20-327	MONO GS-S-260-FAB5	LG 300N1C-B3
Aesthetics	0.05	3	3	3	4	4	4	4	4	4
Capacity [W]	0.2	3	2	2	5	4	4	4	2	3
Cost [$]	0.2	4	4	4	3	3	3	3	4	6
Degredation [%/yr]	0.15	4	4	4	5	4	4	5	4	3
Efficiency [%]	0.2	3	3	3	4	4	4	4	4	4
Warranty [yr]	0.1	4	4	4	5	5	5	5	5	5
Weight [kg]	0.1	3	4	4	4	4	4	4	4	4
TOTAL	1	3.45	3.35	3.35	4.25	3.9	3.9	4.05	3.7	4.15

After initial calculations had been run, it was determined that the education building rooftop could not hold enough panels to generate 100% of its electricity needs and the payback period of the panels would be longer than their warranty lifetime.

The calculations were then ran using the LG300 N1C-B3. It is less efficient in wattage per area, but it was one of the cheapest panels per watt at $1.44/Watt while many other panels were roughly around $2.00/watt. While less could be fit on the roof of the educational building, this lower cost allowed a better payback period and was more ideal for the parking canopies. The LG also is 3% more efficient than panels analyzed of similar or better cost.

Panel Array Design

Education Building

In order to perform an analysis, the layout given in the master plan was taken into mind as well as the given dimensions from the customer. The education building is 38,000 square feet. If this is changed, it will require minor alterations to the array setup. Panels on the education building were placed to provide maximum panels per area while still leaving lanes to walk for maintenance. Space was also left for the air pump that needs to be on the roof as seen in the model of the education building. The panels were oriented south in order to maximize solar flux.

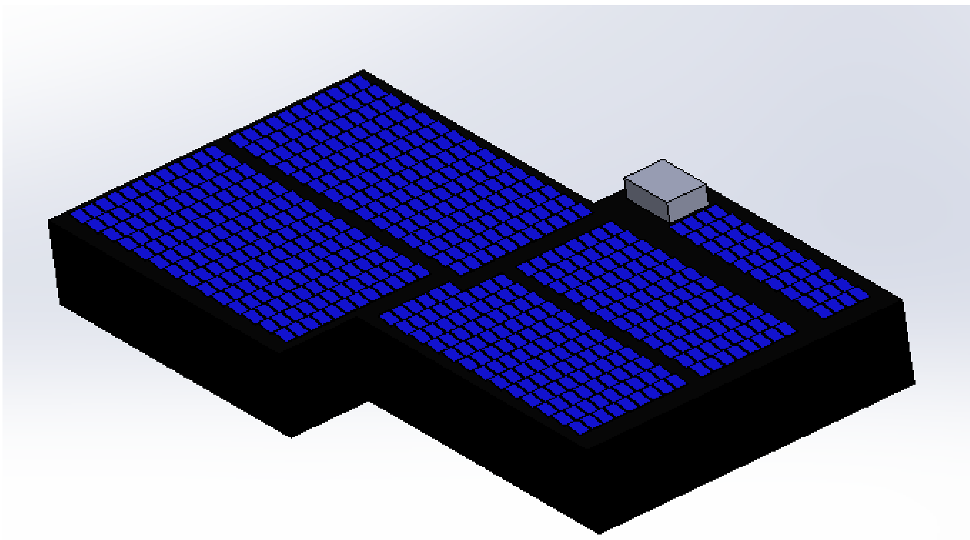


Figure 8: Education Building Panel Array Design

The following table shows the resulting values for the educational building array. It gives the type of panel, combiner boxes, and inverters selected along with the number used and the corresponding cost. The total material cost is reported at the bottom.

Table 2: Education Building Specifications

Option 1: Education Building							
	Panels	**Combiners**		**Inverters**			
	LG 300	*SCCB-12*	*SBCB-6*	*MLX 60*	*STP 24*	*STP 15*	*STP 12*
#	583	2	3	2	1	1	1
Cost [$]/unit	433	620.62	248.77	11,109	5,436	4,447	4,068
Cost [$]	252,439	1,241.24	746.31	22,218	5,436	4,447	4,068
Total Cost [$]	289,849.2						

The estimated yearly output of this array is 234,840 kWh/yr with a rated capacity of 177.8 kW. This number was found using the Sunny Design program. This accounts for 80% of the educational building's needs. The building was estimated to consume 295,108 kWh/yr including air conditioning.

Education Building and Drop-Off Zones

Drop-off zone panels were designed to provide maximum area coverage of panels for the desired size of the overhang. This design supports 51 panels per drop-off zone.

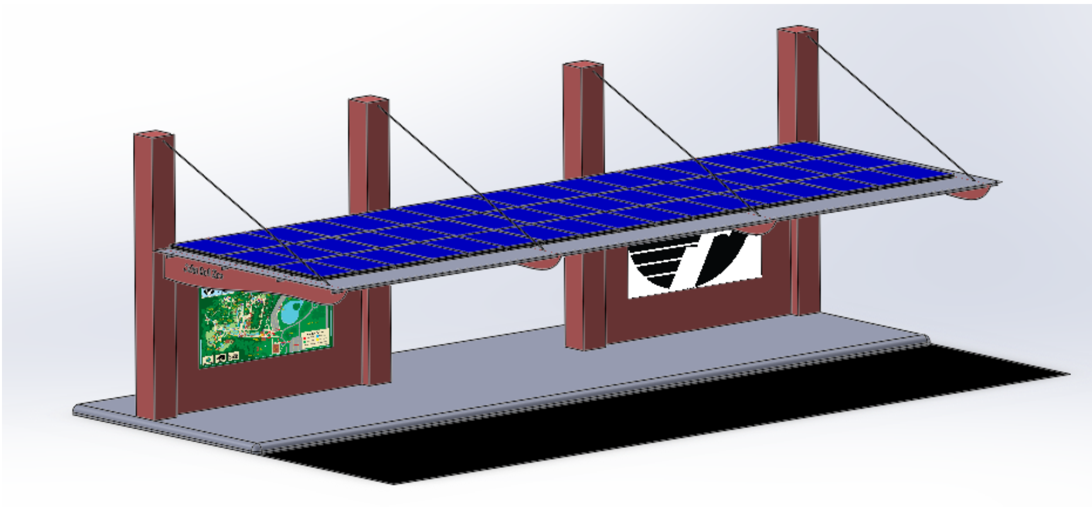


Figure 9: Drop-off Zone Panel Array

The following table details the components needed for a single drop-off zone.

Table 3: Drop-off Zone Specifications

Option 2a: Drop-Off Zones			
	Panels	**Combiners**	**Inverters**
	LG 300	*SBCB-6*	*STP 15*
#	204	1	1
Cost [$]/unit	433	248.44	4,447
Cost [$]	88,332	248.44	4,447
Total Cost [$]	93,027.44		

The following table lays out the costs of the education building and four drop-off zones together.

Table 4: Drop-off Zone and Education Building combined Costs Table

Option 2: Drop-Off & Ed. BLDG		
	Ed Bldg	**Drop-Off**
#	1	4
Cost [$]/project	289,849.2	93,027.44
Cost [$]	289,849.2	372,109.8
Total Cost [$]	661,959	

Using the education building roof and four drop-off zones, the zoo will be able to produce about 311,000 kWh/yr with a rated capacity of 240 kW. This accounts for 105% of the education building's electrical consumption.

Parking Canopies

The Parking canopies panel layout was also designed to provide maximum solar panel coverage for the desired area that would be covered by the structure. The size of the panels had an influence in the size of the canopies. This design includes 1,104 panels per row.

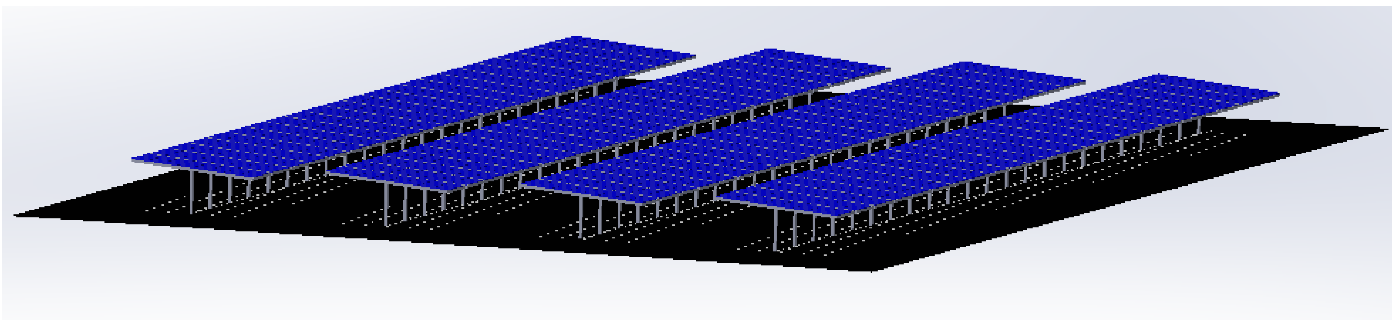


Figure 10: Parking Canopies Panel Arrays

The following table lists the components needed to cover the entire parking lot with solar canopies.

Table 5: Parking Canopies Specifications

Option 3: Canopies					
	Panels	**Combiner Boxes**		**Inverters**	
	LG 300	*SBCB-6*	*SCCB-12*	*MLX 60*	*STP 15*
#	4416	8	24	24	4
Cost [$]/unit	433	248.77	5,436	11,109	4,447
Cost [$]	1,912,128	1990.16	130,464	266,616	17,788
Total Cost [$]	2,328,986				

The parking lot is able to produce 1.7 M kWh/yr with a rated capacity of 1,346.9 kW. This would account for 63% of the zoo's electricity needs.

Inverter Selection

Inverters are necessary for solar panel arrays because the electricity coming from the panels is in DC. Typical power lines run AC so a device, an inverter, is needed to convert the electricity from DC to AC. The inverter selection process was highly dependent on the number of panels and the arrangement of the panels. From our panel array design, the team selected inverters to minimize the cost and create a simple wiring design. This final design included 5 inverters of 4 different kinds. Two 60 kW MLX 60 inverters were used to cover the main area of the solar panel arrays and 3 inverters, STP 12000TL-US-10, STP 15000TL-US-10, and STP 24000TL-US-10, of 12, 15, and 24 kW respectively were selected to cover the left over area of panels. These inverters provide a simple arrangement of panel coverage at a relatively low cost.

MLX 60 (UL) [2] STP 24000TL-US-10 [1] STP 15000TL-US-10 [2] STP 12000TL-US-10 [1]

- 60 kW
- $11,109
- Ed. Building

- 24 kW
- $5,436
- Ed. Building

- 15 kW
- $4,447
- Ed. Building & Drop-Off Zone

- 12 kW
- $4,068
- Ed. Building

Figure 11: Selected Inverters [8]

Combiner Boxes

Solar arrays are designed in several strings that connect each panel to each other. Strings can only handle a certain number of panels because of the amount of power running through the lines. This means that the strings will need to be combined into a single string later. Combiner boxes are used to take the power from several strings coming in and to output it in a single string. This is useful because it allows designs with fewer inverters and fewer line losses. The group looked at several combiner boxes that could handle the number of strings as designed in the solar panel array design section and will be using these. The selected combiner boxes are the SCCB-12, a 12 string box, and the SBCB-6, a 6 string box, as designed by SMA Solar Technology. There is very little variation between combiner boxes so it was not compared to other boxes. The education building will be using 5 of these boxes 2 of the 12 string boxes and 3 of the 6 string boxes. 4 boxes are required for the drop-off zones. 112 combiner boxes will be used for the parking canopies.

SCCB-12

- Up to 12 Strings
- $620.62
- (2) Ed. Building, (24) Canopy System

SBCB-6

- Up to 6 Strings
- $248.77
- (3) Ed. Building, (4) Drop-Off Zone, and (8) Canopy System

Figure 12: Selected Combiner Box [9]

Inverter Design

Education Building

Inverters for the education building will be placed according to the diagram below. The inverters can be placed on the roof near the panels that they will be converting for. This array was designed as such because of the limitations on string length and inverter power capability. This design gives a cheap and relatively simple design for inverter placement and wiring as mentioned in the inverter selection section.

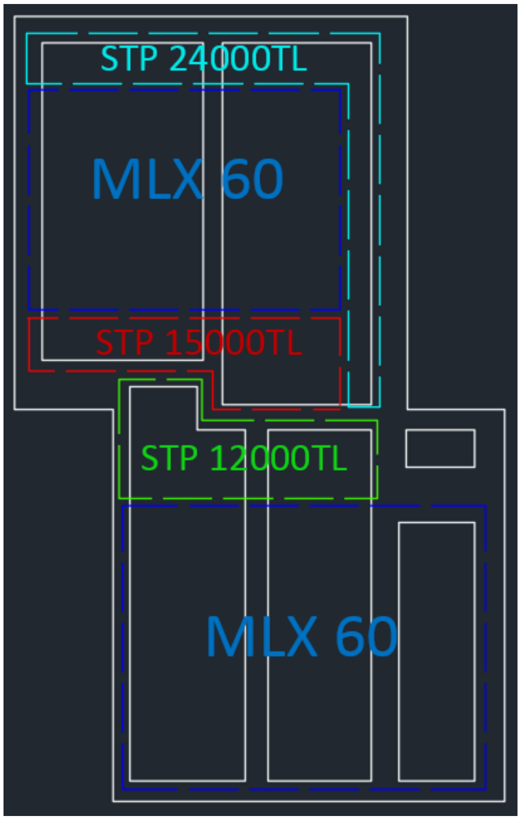


Figure 13: Inverter Array Diagram

Education Building and Drop-Off Zones

The inverter array design for the education building is the same as above. There will be one inverter on each of the drop-off zones. This inverter can be placed on the back of the drop-off zone structure.

Parking Canopies

The inverter design for the parking canopy arrays will consist of 6 MLX 60 inverters and 1 STP 15000TL-US-10 per canopy. These inverters can be placed on the structure, possibly bolted to the supports.

Marketing

One of the zoo's main goals in implementing a solar array is to use the project as a learning tool for the zoo's visitors. Unlike most things found in a zoo, the solar panels will not be easily visible to visitors. Therefore, a portion of this project explored ways to make the solar project accessible to visitors, allowing them to interact with and learn from the solar array. This will be done in two ways. First, a kiosk can be implemented which can incorporate live data from the solar panels with an interactive display. Secondly, simple comparisons and graphics can be used to portray different aspects of solar power.

Kiosk

The kiosk will provide an interactive way for visitors to learn about how solar panels work and how they are contributing to the zoo. This will be done by integrating a dashboard similar to the one seen in Figure 14.

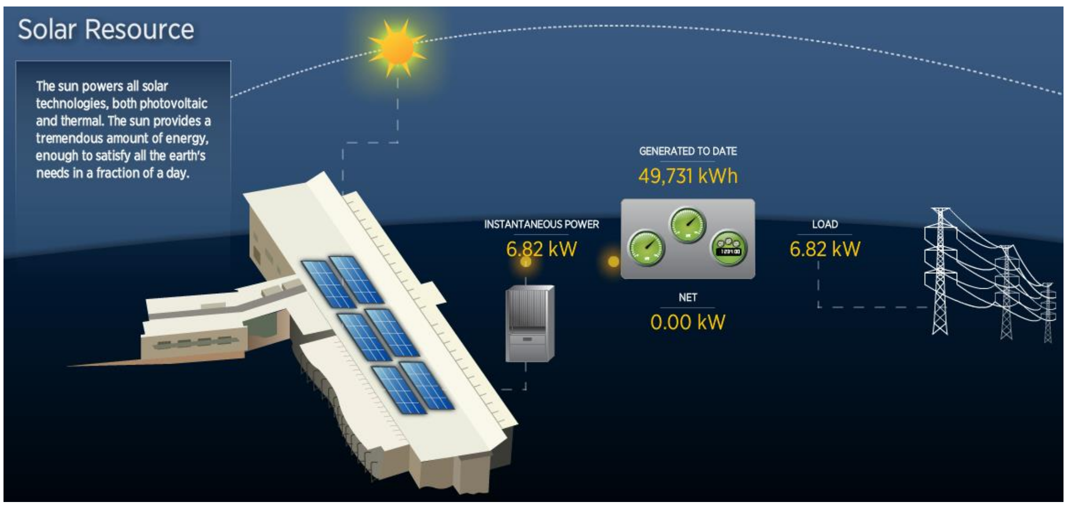


Figure 14: Dashboard [10]

The dashboard seen in this figure is one that was implemented at the St. Louis Zoo. This dashboard would not only be seen inside the kiosk but can also be viewed from any web browser. The marketing team recommends not only making this available in the kiosk found on the zoo grounds, but it should be integrated into the JBZ'sJohn Ball Zoo's website.

Supplier

There are two recommended suppliers. The first supplier is Locus Energy. Their dashboard is the same as the one displayed in Figure 14. This interface is easy to read and presents information in a relatively simple flow.

The Second recommended supplier is DECK Monitoring. A sample of their dashboard can be seen in Figure 15.

Figure 15: Deck Monitoring [11]

This dashboard does not flow as simply as the Locus Energy solution but still provides an ideal way of displaying relevant educational information to visitors.

Pricing

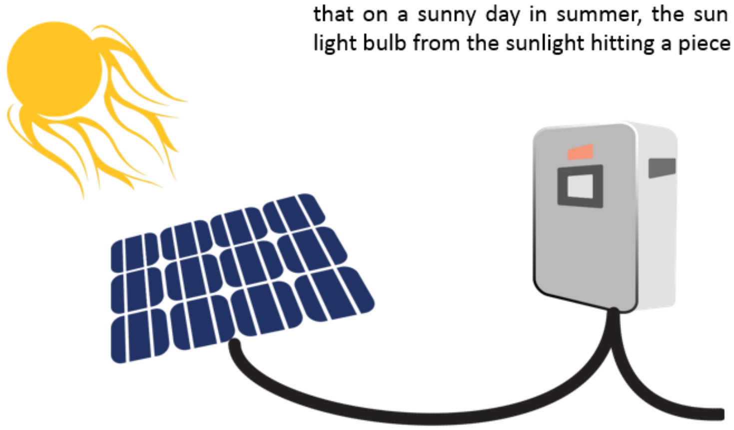
While an exact quote could not be obtained from either supplier, both the Cincinnati Zoo and Buyerzone.com estimated the cost of the kiosk, dashboard, installation, and measuring equipment to be around $5500. Since the Cincinnati zoo just recently implemented a solar system at their zoo, the marketing team finds this price to be a good representation of what to expect when actually obtaining quotes.

Graphics

Several graphics and facts have been compiled for this system to be used on posters or signs to help teach visitors about solar panels and to get visitors excited about helping out the environment. The final images had to be individually crafted to circumvent copyright infringements. The only exception is images which show maps. The maps used in the images were obtained via Bing's creative commons network, preventing any issues with copyright infringement.

The numbers shown with the graphics were generated using the Environmental Protection Agencies Greenhouse Gas Equivalency Calculator. The figures below are a sample of the educational fact potential for this project. See Appendices for more images.

The sunlight hitting the earth carries 1000 W/m^2 in energy. This means that on a sunny day in summer, the sun could power a standard 60 W light bulb from the sunlight hitting a piece of paper.



The Inverter turns the electricity produced by the Photovoltaic Panel and makes usable. The Photovoltaic panel produces Direct Current (DC) electricity, the type of current a battery emits. The Inverter turns this DC electricity and turns it into Alternating Current (AC) electricity. AC electricity is what comes out of the socket in your wall.

Photovoltaic Panels, also called Solar Panels, contain components that turn light into electricity. The contain two different substances, one with a positive charge and one with a negative charge. When the sunlight hits the space between these substances, electrons get excited, producing electricity. When more Photovoltaic panels are connected together, more electricity can be generated.

Figure 16: How Solar Works Info-graphic.

ACT!

Solar Panels are just one of many ways to save energy and help our environment. What else can you do?

Turn off electronics and lights at night.

Buy Locally.

Recycle when possible.

Keep your car and home well maintained.

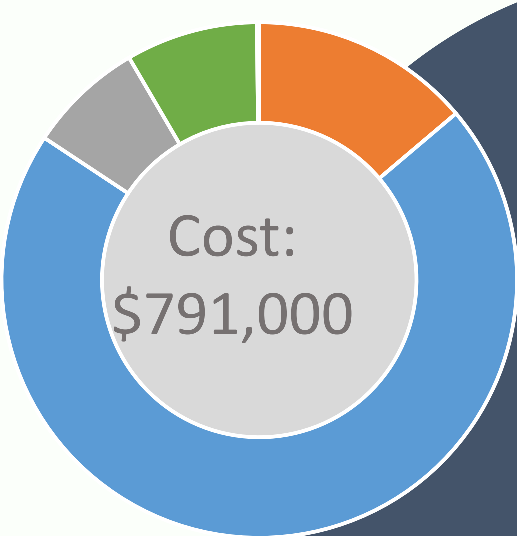
Figure 17: What you can do info-graphic.

Fact Sheet

A condensation of the final report was created in a fact sheet format. The sheet includes numbers and figures which represent the initial cost, total monetary savings along with CO_2 savings. The fact sheet also includes generated graphics that can be used by JBZ. John Ball Zoo.

Fact Sheet

BY THE NUMBERS



Savings:

$28,000 per year

311 $\frac{\text{MWh}}{\text{year}}$ electricity

This array could provide

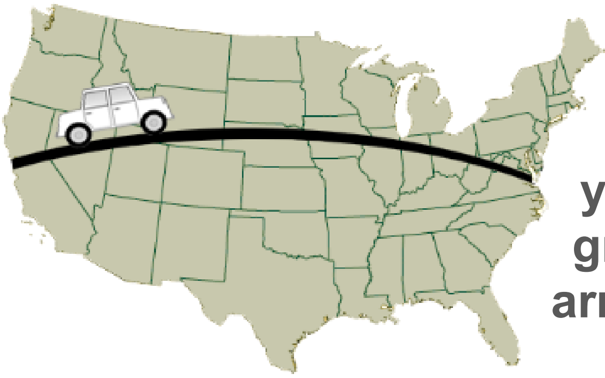
100%

of the new Educational Building's needs.

Covering the entire zoo with forest would only offset **80%** of the CO_2 that this array saves.

.

Many visitors will benefit from collected data.



This solar array produces so much clean energy that you would have to drive 130x across the United States every year to emit the amount of greenhouse gasses that this array saves.

These Photovoltaic Panels produce enough energy to power 29 homes.

These panels can provide substantial educational benefits for the zoo. They also prevent increased energy consumption by the proposed Educational Building.

Investment	Impact
$792,000	Purchases enough Panels and Equipment to power the entire proposed Educational Building. This includes panels on the roof of the proposed building as well as 4 drop-off zones.
$548,000	Purchases enough Panels and Equipment to power 80% of the proposed Educational Building. This includes panels on the roof of the proposed building.

Financial Analysis

Summary

Introduction

The financial team was responsible for providing the financing options for the solar system designed by the panels and site teams.

Procedure

The financial team for the JBZ project was comprised of three mechanical engineering students: Seth Koetje, Jack Kregel, and Josh Vanderbyl. Tasks were divided up between the teammates in order to efficiently provide financial information for the system. Seth was assigned the role as the primary creator of the financial team's spreadsheet as well as the primary person in charge of determining the necessary annual maintenance costs of the system. Jack was the team's primary researcher of the tax incentives, grants, and financing options. Josh was the primary loan investigator.

In addition to these roles, the team members were assigned broader responsibilities to make the team ensure steady progress on the project. Seth served are the primary coordinator, both with outside resources and inter-team communications. Jack as the primary data analyst. Josh served as the primary PowerPoint creator and therefore was responsible for providing the financial information gathered in a concise presentation. Both Jack and Josh served as the primary communicators between the other student teams working on this project.

Customer Contact

As previously mentioned, Seth was the primary coordinator between customers and accumulated resources. The financial team, in cooperation with the other JBZ PV project teams, communicated with Allmon Forrester, the end customer for this project at various points during the project. Allmon Forrester is the Director of Operations at JBZ, meaning the decision to ultimately move forward with the project was ultimately in his hands. The financial team desired to present him with the necessary financial information about the project so that he could make an informed decision. During the first meeting with Mr. Forrester, the team gathered valuable information about the needs of the zoo and the desires for this project. Mr. Forrester led the teams around the zoo in order to layout ideal positions for the solar arrays to be installed. This information helped the students determine the scope of the project. During the second meeting with Mr. Forrester, the teams had the opportunity to speak with Mark Fisher from the Cincinnati Zoo about their solar array installation. This meeting allowed the teams to find answers to several solar array related questions that had arose throughout the project. Additional meetings with Mr. Forrester allowed teams to address questions that had arose throughout the project. Additional communication was established with several other resources. The resources that were particularly helpful for the financial teams were the contacts with Cascade Renewable Energy and Full Spectrum Solar (a Sunpower solar array distributor).

Communication with Other Teams

As mentioned earlier, Jack and Josh served as the primary communication points between the teams working on the project. As part of this role, they worked closely with other groups to coordinate plans and convey valuable information among the teams.

Payment Options

Several different options were investigated and considered for paying for the system. In-depth discussion of the different options is given below.

Direct Financing

Direct financing is a payment method where JBZ would take on the entirety costs for the project. This would include the cost of the panels and racking, the installation, and maintenance. There are several advantages to direct financing. One advantage is that the zoo would have a huge amount of control over the financial decisions. Another advantage is that the direct financing method is the simplest way of financing any large purchase. One final advantage is that eventually the zoo would profit from installing solar panels, something that would not be possible with alternative payment methods. There are several disadvantages of this method. One disadvantage is that the zoo would not be able to take advantage of federal and state tax credits that sometimes take off up to 30% of overall costs. This is because the zoo is owned by the county. Another disadvantage is that the direct financing method can be more risky than other financing options, a risk the zoo might not want to undertake. Direct financing would cause the zoo to take out major loans to pay for the project

Fundraising

The fundraising method can be used with any other method, but most often used with the direct financing method. What happens during fundraising is that donors give money to the zoo and allow them to use the donations for the project. The main benefit for the fundraising method is that it eliminates loans, and also reduces the risk associated with the project. Another benefit is that the donors can get involved with the project, something that many donors desire.

Power Purchase Agreement

A power purchase agreement (PPA) is a contract signed with a larger company, in this case MeLink. What happens in a PPA is that the larger company purchases the solar panels, installs them for the other company (in this case the zoo). With this method, the zoo would pay MeLink for the power produced by the solar panels at a lower rate than what the zoo is currently paying. There are many advantages to this method. One is that the zoo would have no upfront costs and virtually no risk. This is because MeLink would own and maintain the solar panel. This results in another advantage. Because MeLink is a privately owned company, they can take advantage of tax incentives and renewable energy credits, resulting in lower overall costs for the implementation of the system. MeLink profits from this agreement by achieving low overall costs from the tax credits, selling electricity to the zoo and in addition to this, they sell renewable energy credits to utility companies. This makes a PPA a desirable because the zoo would save money on electricity, would have virtually no risk and MeLink would make good profits. There are several concerns with a PPA. One is that the agreement is contract based making it impossible to make changes to the panels. If the zoo for some reason decides that they want to eliminate the panels or make changes, they would have to go through MeLink, something that would be time consuming and possibly costly depending on the agreement. Another disadvantage is that the zoo would still be paying for electricity. This would prevent the zoo from profiting from this project in the future. As visual representation of savings from PPA is shown Figure 18.

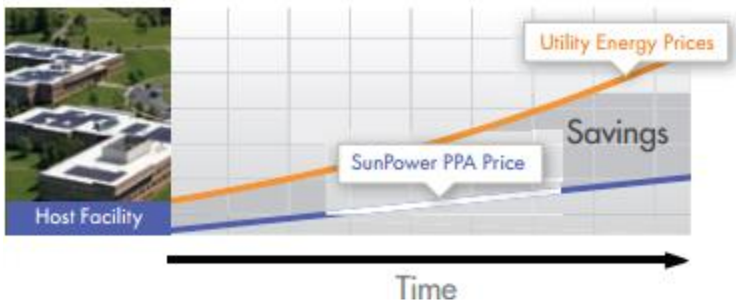


Figure 18. Example of PPA Savings

Solar Lease

A solar lease is a payment method that is very similar to a PPA. For a solar lease, JBZ would pay a company to rent the panels at a fixed rate. The advantage of using a solar lease as a payment method is that there is little to no initial capital investment, there is protection against volatile electricity prices and immediate savings on the electricity bill. Disadvantages of solar leases are that to get one, you have to sign a long term contract. Benefits of solar leasing are shown in Figure 19.

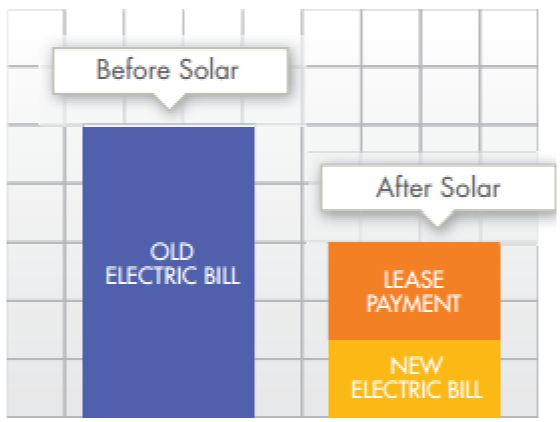


Figure 19. Benefits of Solar Leasing

Public Financing Options

Public financing is a payment method which enables public entities to take advantage of numerous financing options not available to corporate entities. These advantages include tax incentives, special leasing options and exclusive government subsidizes. This funding method is an advantageous method for the fact that extra incentives are available and great leasing options are available. It is also a collective ownership system which helps in the community aspect of solar power. Several disadvantages are that the public financing is a difficult process and takes extra work to ensure that you use your financing correctly. Flows of public financing is shown in Figure 20.

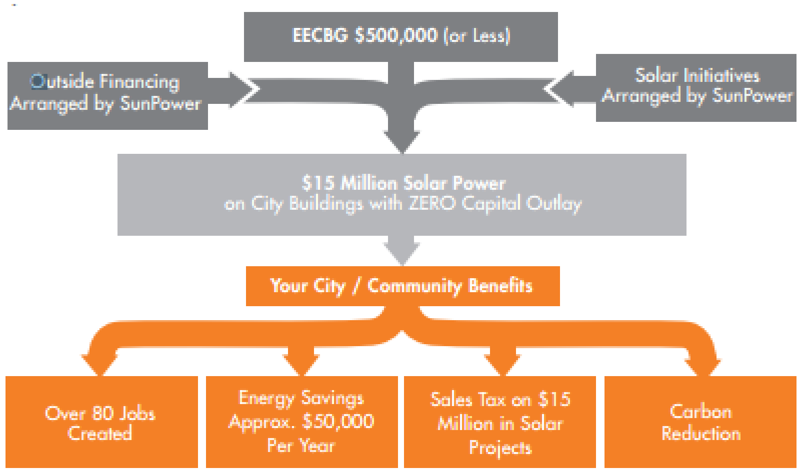


Figure 20. Public Financing Layout

Incentives and Grants

The finance team decided that researching grants and additional incentives would be very beneficial for the overall project. Even though the zoo will be funding the project via donations, any way to decrease overall costs would benefit the zoo. The team discussed grant opportunities with Chuck Holwerda and determined that the Database of State Incentives for Renewables and Efficiency (DSIRE) would be a great place to research grant and incentive opportunities for the zoo. DSIRE had information regarding both state and federal incentives. In addition to this, the team was in contact with Megan Berglund, the Director of Grants & Foundation Relations at Calvin College. In addition to using DSIRE, the team investigated grant opportunities through SPIN, a database provided by Calvin.

Federal

Based off of preliminary investigation the team determined that there would be no federal grants that JBZ could pursue. After more in-depth searching using the SPIN database, the team located a Department of Energy sponsored grant. The objective of the grant is to support the development of potentially disruptive new technologies across a wide range of energy applications. Ideal applicants are sought that address specific areas of the sponsors mission including solar PV. This grant would be attainable by JBZ because it is for use by non-profits, but it would require lots of work. Additional information will be forwarded to JBZ for their future investigation.

One federal option that is available is the use of Business Energy Investment Tax Credit (ITC). This is a tax credit that is available to businesses in the commercial sector. The only unfortunate thing about ITC is that it will not be useable by JBZ if they decide to use the direct financing method because they are a local government. The only way that JBZ will be able to take advantage of these tax credits is if they use an alternate financing method such as PPA or solar leasing.

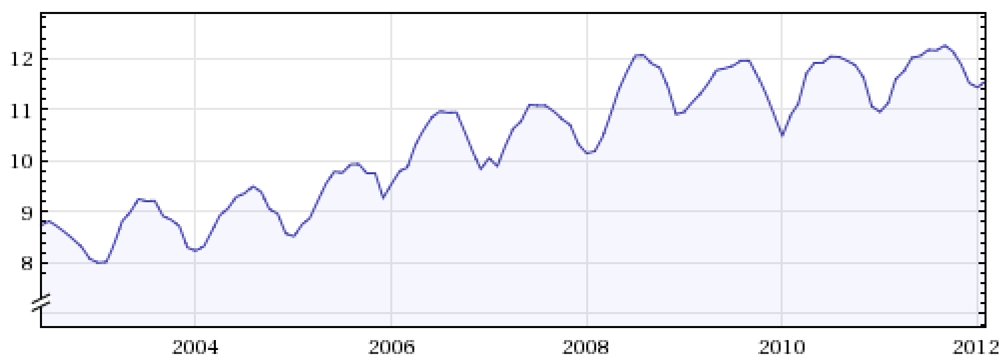
State

One possible grant opportunity that exists on a state level is from the Renewable Energy Program Grants found using DSIRE. This grant is given by the State of Michigan and includes grant opportunities for non-profits, schools, local governments, and state governments. In order to be eligible, the organization applying for the grant has to be pursuing either photovoltaic solar panels, wind, or biomass. Funding for this grant is given by the U.S. Department of Energy's State Energy Program (SEP).

Contact was made with Tania Howard, the Renewable Energy Program Coordinator from the Michigan Energy Office and more in-depth information regarding the grant opportunities available. Tania mentioned that currently their office is between funding cycles at the moment and that in general, the scope of solicitations vary quite a bit. Tania also mentioned that their plan for the upcoming year will begin this coming spring (2015). Tania was able to give some insight to approximate values for funding from these grants. Funding could vary from $40,000 to $100,000.

Rise of Electricity Rates

Michigan's current electricity rates are above the national average and are the highest in the Midwest. This is making it more difficult for businesses to compete as they are paying higher energy rates compared to competitors that have potentially lower rates.



(from Jun 2002 to Feb 2012) (in US cents per kilowatt hour)

Source Wolfram Alpha

Figure 21. Michigan Electricity Rate

As seen above in Figure 21, electricity rates have been on the rise since 2004 from about 8.5 [cents/kWh] to around 11.5 [cents/kWh] in 2012. According this data that would mean an increase in price of 3.2% per year. As the electricity rates rise it will cause payback periods for the solar projects to increase. As rates increase savings increase at the same rate due to the fact the zoo would be producing energy so the electricity price increases would be direct savings.

Cost Models & Forecasting

Creation and Assumptions

The team built an Excel spreadsheet modelling the financial story for each of the payment options. In the end, a financial payback period was determined for each of the payment options.

Rates

A number of assumptions went into these calculations and they are represented in Table 6.

Table 6: Annual Growth Rates

Annual Growth Rates (%)	
Cost of Electricity	3.50 %
Panel Degradation	0.70 %

The cost of electricity growth rate per year was estimated by Allmon Forrester and confirmed using historical data. More in depth analysis of this calculation can be seen in the Rise of Electricity Rates section. The panel degradation was determined from studies by LG and outside resources [7]. The team contemplated taking inflation into account, but based off of industry standards, it was determined that accurate values could be found without using inflation.

Cost Estimates

The following electricity costs were assumed along with the installation costs. Table 7 shows these assumptions.

Table 7: Cost Estimates

Cost Estimates ($/kWh)	
Current Electricity Cost	$ 0.09
PPA	$ 0.07
Cost Estimates ($/kW)	
Installation Costs	$ 800

The current electricity cost information was provided by Allmon Forrester. The PPA electricity costs were determined based on the rate the Cincinnati Zoo currently pays for their electricity produced by MeLink as part of their purchase power agreement. Based on interactions with Cascade Renewable Energy, installation costs per kW (which include panel wiring) were determined for the system.

Outputs

The estimated total costs and energy production of the system are shown in Table 8.

Table 8. Financing Options

	Education	Education + Drop-Off	Max Output
Number of panels	583	787	5090
Electricity Production	235 MWh/yr	311 MWh/yr	1960 MWh/yr
Peak Energy Production Rate	177.82 kW	240.04 kW	1586.93 kW
Education Buildings Need covered by Solar Production [%]	80%	105%	497%
Labor Costs [$]	$160,033	$216,031	$1,428,223
Material Costs [$]	$374,420	$568,260	$4,521,031
Total Cost [$]	$534,454	$784,238	$5,949,254
Savings [$/year]	$21,135	$27,990	$176,659
Payback	25.29 years	28.08 years	33.68 years

Results and Conclusion

As mentioned above, the finance team analyzed three different options for JBZ. Those options include maximum output for the zoo which includes putting panels on the education building, and drop-off zones. The second option includes putting panels on the education building and on drop-off zones. The third and final option include putting panels on the education building only. Shown below in Figure 22 is the payback chart for the direct financing method as discussed above.

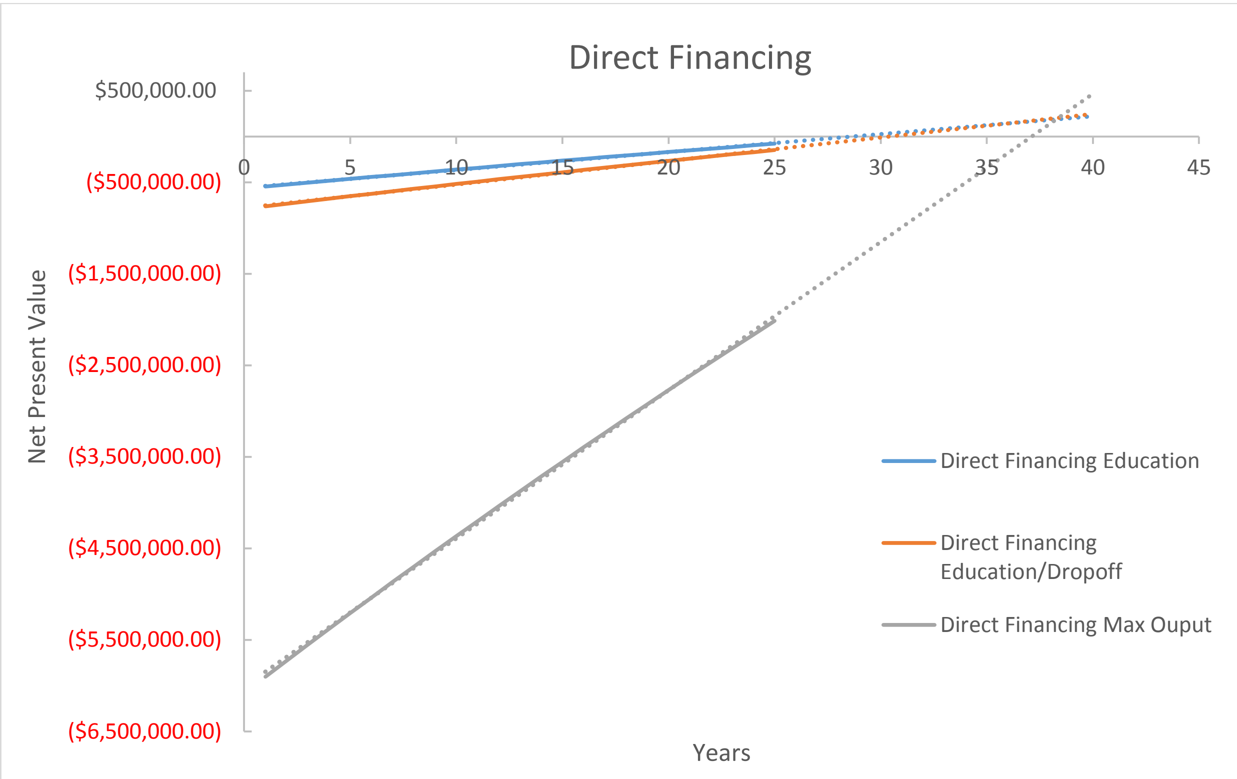


Figure 22. Direct Financing Payback

As shown above in Figure 22, you can see that none of the options pay back within the 25 year warranty. That being said, when the projected savings are extended out 15 years, the panels eventually break even and start binging profit to the zoo. Exact paybacks for this model are listed in Table 8.

The team decide that in order to better portray the payback of the two smaller scale projects, an additional figure, Figure 23, shows a more easily understandable view of payback options for the education building and for the education and drop-off zone proposal.

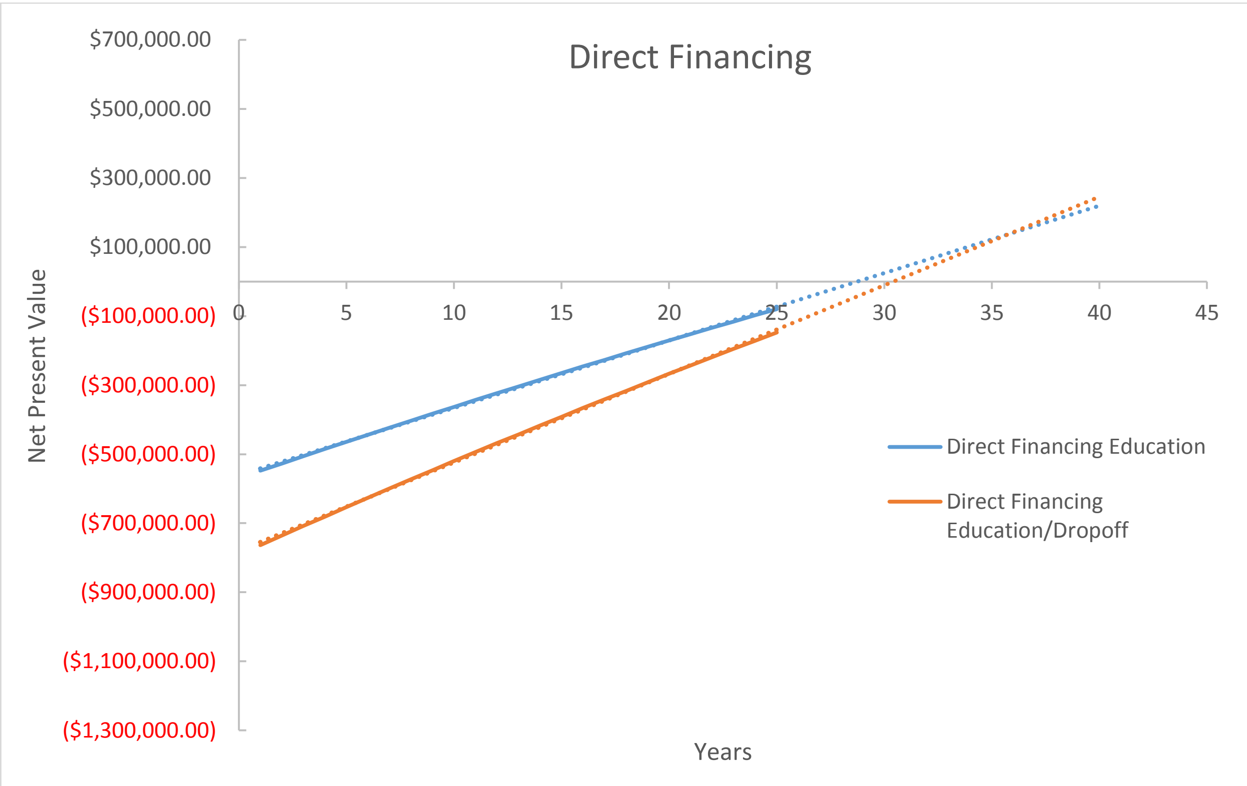


Figure 23. Direct Financing Small Scale

An additional option for the zoo would be to sign a power purchase agreement with another company. Figure 24 shown below presents the total savings for the three different designs. It can be seen that for the most savings, the zoo should try and install the largest system possible.

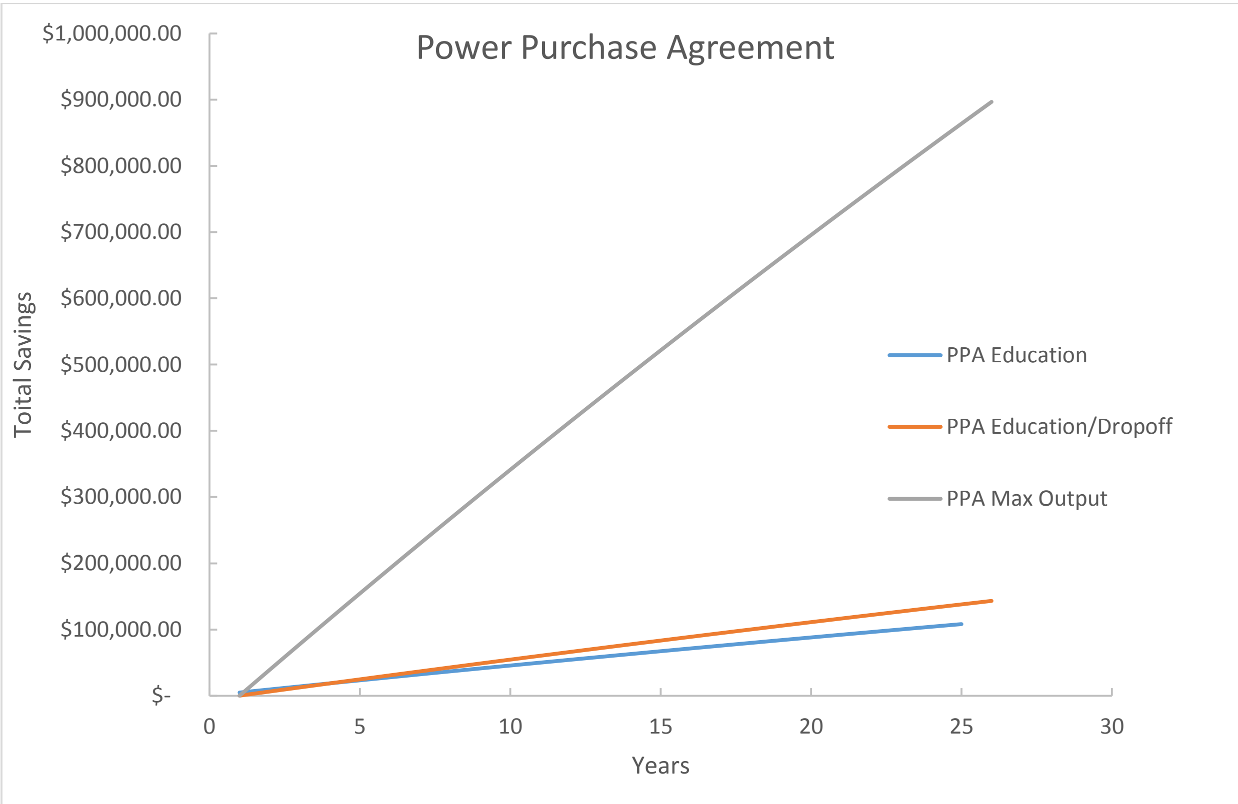


Figure 24. Power Purchase Agreement Payback

Shown below in Figure 25 is a payback graph for the two smaller scale options. This helps better demonstrate the differences between the education building and the education and drop-off zone.

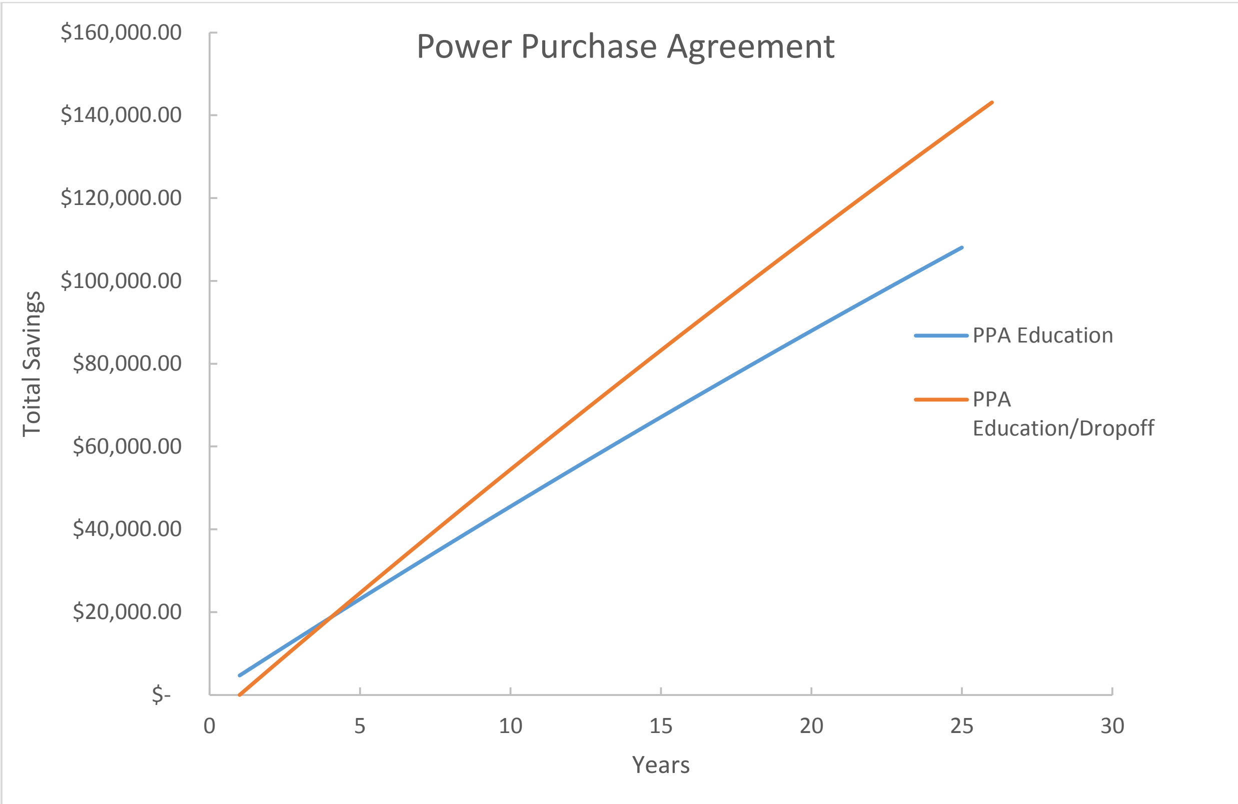


Figure 25. PPA Small Scale

The annual kWh cost per year may be seen below in Figure 26. The values for this figure were calculated by taking the initial investment cost required for each option and then dividing by the annual kWh capacity for the first year. This graphic helps give a better comparison of cost savings for the different systems. Please note that the right hand axis does not start at zero, and thus may be somewhat confusing at first glance. The bars thus are not to scale, but are useful for comparison between options.

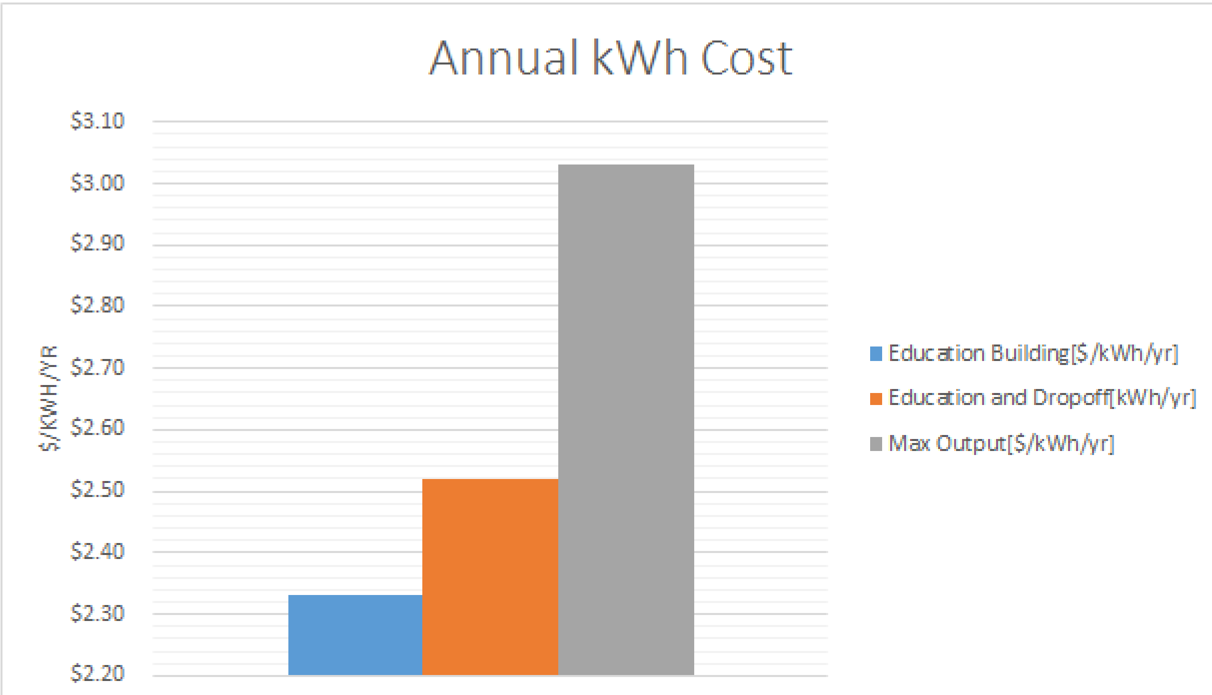


Figure 26. Annual kWh Cost

Another figure the team included in the analysis was savings that could be earned from selling renewable energy credits. This is shown in Figure 27. These credits, if sold by the zoo could net substantial savings. The team did not include these savings in the payback calculations because Michigan doesn't have a market for these credits and because the prices are so volatile. Because of this it is unlikely that they would be able to make much money from these credits, but if anything changes, it would be nice to understand potential savings.

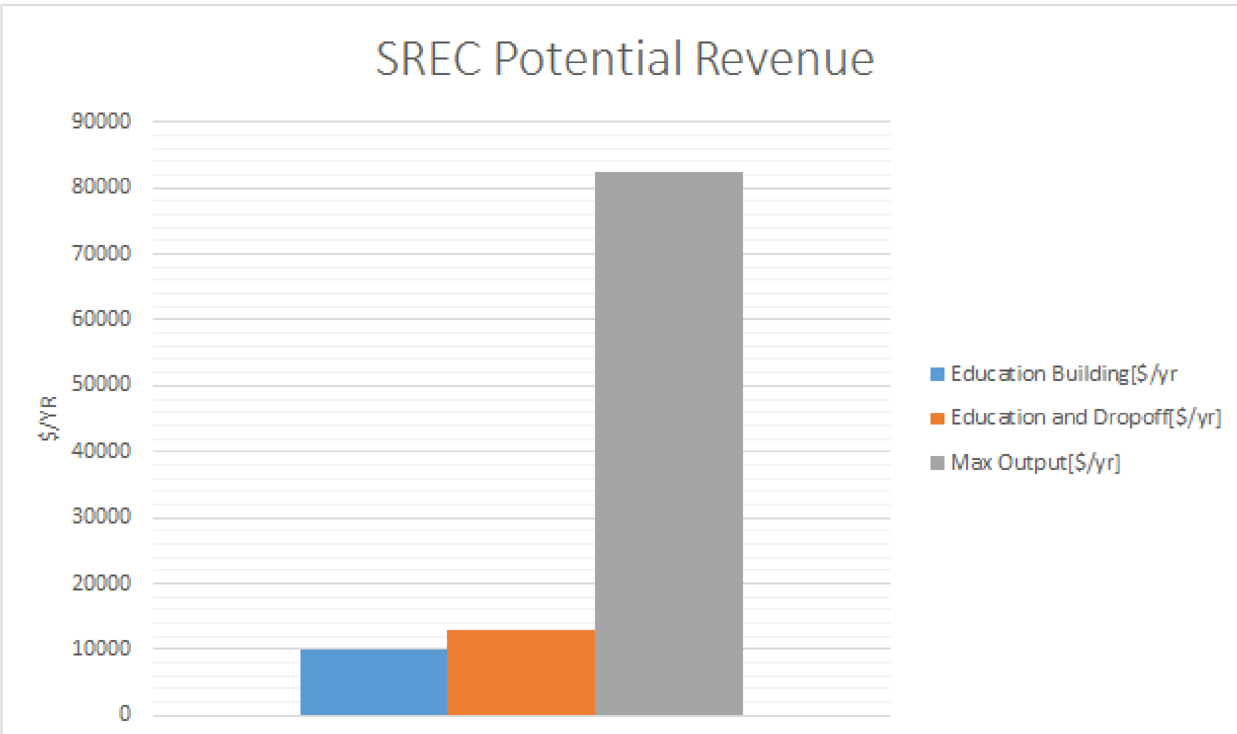


Figure 27. SREC Potential Revenue

For all of the above graphics, it was assumed that there was 0.4% degradation annually in panel performance. It was also assumed that there was no inflation and net present value of money was used. This was because of industry standards and the fact that most companies don't account for inflation or time value of money.

Appendices

Table 9: Summary of Financial Information

SUMMARY OF FINANCIAL INFORMATION					
Case: Max Output (Ed. Building and Canopy)					
Costs	**Amount [$]**	**% of Total**		**Savings [kWh/yr]**	**Amount [$/yr]**
Labor	$ 1,428,223.50	24.01%		1962880	$ 176,659.20
Material	$ 4,521,031.03	75.99%			
Total Installed	$ 5,949,254.53	100.00%			
Canopy System Alone	$ 4,630,561.94				
Simple Payback	33.68 yrs				
Case: Education Building					
Costs	**Amount [$]**	**% of Total**		**Savings [kWh/yr]**	**Amount [$/yr]**
Labor	$ 160,033.50	29.94%		234840	$ 21,135.60
Material	$ 374,420.67	70.06%			
Total Installed	$ 534,454.17	100.00%			
Simple Payback	25.29 yrs				
Case: Education Building and Drop Off Zone					
Costs	**Amount [$]**	**% of Total**		**Savings [kWh/yr]**	**Amount [$/yr]**
Labor	$ 216,031.50	27.55%		311000	$ 27,990.00
Material	$ 568,206.92	72.45%			
Total Installed	$ 784,238.42	100.00%			
Drop Off Zone Alone	$ 249,784.25				
Simple Payback	28.02 yrs				

Table 10: BOM: Educational Building

Bill of Materials: Ed. Building

Power Generation, Sunny Design (kWh/yr)	**234840**	**Supplied, Average [%]**	80%	**Degradation [%]**	**0.70%**
Power Generation, Bunker Data (kWh/yr)		**Capacity (Panels x kW/Panel) [kW]**	**177.82**	**Rated Power [W/unit]**	**305**

Description	Location	Sub-Assembly	Qty	Unit Price [$/Unit]	Subtotal
LG 300N1C - B3	Ed. Building	Panels	583	$ 433.00	$252,439.00
MLX 60	Ed. Building	Inverters	2	$11,109	$22,218.00
STP 15000TL-US-10	Ed. Building	Inverters	1	$4,781.83	$4,781.83
STP 24000TL-US-10	Ed. Building	Inverters	1	$5,436.00	$5,436.00
STP 12000TL-US-10	Ed. Building	Inverters	1	$4,068.00	$4,068.00
4/0 1kV Copper Wire: Off Ed. Building	Ed. Building	wiring	100	$ 10.00	$1,000.00
Boring and Conduit: Ed. Building to CSL meter	Ed. Building	Wiring	450	$ 6.20	$2,790.00
Input Transformer @ 75KVA: 480 => 208Y/120	Ed. Building	Wiring	1	$ 1,947.92	$1,947.92
Standard Safety Railings	Ed. Building	Safety	630	$ 65.00	$40,950.00
EcoFoot2+ Base	Ed. Building	Racking	667	$19.73	$13,159.91
EcoFoot2+ Clamp	Ed. Building	Racking	667	$ 15.73	$10,491.91
EcoFoot2+ Deflector	Ed. Building	Racking	556	$ 8.87	$4,931.72
4" x 8" x 16" Roof Paver (32 lbs)	Ed. Building	Racking	1334	$ 1.34	$1,787.56
SCCB-12 Combiner Box	Ed. Building	Wiring	2	$ 638.10	$1,276.20
SBCB-6 Combiner Box	Ed. Building	Wiring	6	$ 248.77	$1,492.62
Kiosk	Kiosk	Kiosk	1	$ 5,500.00	$5,500.00
Shipping			1	$ 150.00	$150.00
			Total		**$374,420.67**

Table 11: BOM: Ed. Bld. and Drop off

Bill of Materials: Ed. Bld. + Dropoff					
Power Generation, Sunny Design (kWh/yr)	**311000**	**Supplied, Average [%]**	105%	**Degradation [%/yr]**	**0.70%**
Power Generation, Bunker Data (kWh/yr)		**Capacity (Panels x kW/Panel) [kW]**	**240.04**	**Rated Power [W/unit]**	**305**
Description	**Location**	**Sub-Assembly**	**Qty**	**Unit Price [$/Unit]**	**Subtotal**
LG 300N1C - B3	Ed. Building	Panels	583	$ 433.00	$252,439.00
LG 300N1C - B3	DOZ	Panels	204	$ 433.00	$88,332.00
MLX 60	Ed. Building	Inverters	2	$11,109	$22,218.00
STP 24000TL-US-10	Ed. Building	Inverters	1	$5,436	$5,436.00
STP 15000TL-US-10	Ed. Building	Inverters	1	$4,447.00	$4,447.00
STP 12000TL-US-10	Ed. Building	Inverters	1	$4,068.00	$4,068.00
STP 15000TL-US-10	Drop Off	Inverters	4	$ 4,447.00	$17,788.00
4/0 1kV Copper Wire: Off Ed. Building	Ed. Building	wiring	100	$ 10.00	$1,000.00
4/0 1kV Copper Wire: Drop Off Zones to Ed E	DOZ	wiring	550	$ 10.00	$5,500.00
Input Transformer @ 75KVA: 480 => 208\	Ed. Building	Wiring	1	$ 1,947.92	$1,947.92
Boring and Conduit: DOZ to Ed. Building	Canopy	Wiring	550	$ 6.20	$3,410.00
Standard Safety Railings	Ed. Building	Safety	630	$ 65.00	$40,950.00
EcoFoot2+ Base	Ed. Building	Racking	667	$19.73	$13,159.91
EcoFoot2+ Clamp	Ed. Building	Racking	667	$ 15.73	$10,491.91
EcoFoot2+ Deflector	Ed. Building	Racking	556	$ 8.87	$4,931.72
4" x 8" x 16" Roof Paver (32 lbs)	Ed. Building	Racking	1334	$ 1.34	$1,787.56
SCCB-12 Combiner Box	Ed. Building	Wiring	2	$ 638.10	$1,276.20
SBCB-6 Combiner Box	Ed. Building	Wiring	6	$ 248.77	$1,492.62
SBCB-6 Combiner Box	Drop Off	Wiring	4	$ 248.77	$995.08
DOZ Structure	DOZ	Structure	62220	$ 1.30	$80,886.00
Kiosk	Kiosk	Kiosk	1	$ 5,500.00	$5,500.00
Shipping			1	$ 150.00	$150.00
			Total		**$ 568,206.92**

Table 12: BOM: Max Output

Bill of Materials: Max Output					2171221.95
Power Generation, Sunny Design (kWh/yr)	**1962880**	**Supplied, Average [%]**	497%	**Degradation [%/yr]**	**0.70%**
Power Generation, Bunker Data (kWh/yr)	**971905.582**	**Capacity (Panels x kW/Panel) [kW]**	**1586.915**	**Rated Power [W/unit]**	**305**
Description	**Location**	**Sub-Assembly**	**Qty**	**Unit Price [$/Unit]**	**Subtotal**
LG 300N1C - B3	Ed. Building	Panels	583	$ 433.00	$252,439.00
LG 300N1C - B3	Canopy	Panels	4416	$ 433.00	$1,912,128.00
MLX 60	Ed. Building	Inverters	2	$11,109	$22,218.00
STP 24000TL-US-10	Ed. Building	Inverters	1	$5,436	$5,436.00
STP 15000TL-US-10	Ed. Building	Inverters	1	$4,447.00	$4,447.00
STP 12000TL-US-10	Ed. Building	Inverters	1	$4,068.00	$4,068.00
MLX 60	Canopy	Inverters	24	$11,109	$266,616.00
STP 15000TL-US-10	Canopy	Inverters	4	$4,447.00	$17,788.00
4xs: 4/0 1kV Copper Wire: Canopies to Gift S	Canopy	wiring	1500	$ 10.00	$15,000.00
4/0 1kV Copper Wire: Off Ed. Building	Ed. Building	wiring	100	$ 10.00	$1,000.00
4/0 1kV Copper Wire: Drop Off Zones to Ed E	DOZ	wiring	550	$ 10.00	$5,500.00
Input Transformer @ 75KVA: 480 => 208\	Ed. Building	Wiring	1	$ 1,947.92	$1,947.92
Boring and Conduit: Canopies to Gift Sho	Canopy	Wiring	375	$ 6.20	$2,325.00
Boring and Conduit: DOZ to Ed Building	DOZ	Wiring	550	$ 6.20	$3,410.00
Standard Safety Railings	Ed. Building	Safety	630	$ 65.00	$40,950.00
EcoFoot2+ Base	Ed. Building	Racking	696	$19.73	$13,732.08
EcoFoot2+ Clamp	Ed. Building	Racking	696	$ 15.73	$10,948.08
EcoFoot2+ Deflector	Ed. Building	Racking	583	$ 8.87	$5,171.21
4" x 8" x 16" Roof Paver (32 lbs)	Ed. Building	Racking	1392	$ 1.34	$1,865.28
SCCB-12 Combiner Box	Ed. Building	Wiring	2	$ 638.10	$1,276.20
SBCB-6 Combiner Box	Ed. Building	Wiring	6	$ 248.77	$1,492.62
SCCB-12 Combiner Box	Canopy	Wiring	24	$ 638.10	$15,314.40
SBCB-6 Combiner Box	Canopy	Wiring	8	$ 248.77	$1,990.16
Canopy Structure	Canopy	Structure	1346880	$ 1.30	$1,750,944.00
Kiosk	Kiosk	Kiosk	1	$ 5,500.00	$5,500.00
LG 300N1C - B3	Drop Off	Panels	204	$ 433.00	$88,332.00
Drop Off Canopy Structure	Drop Off	Structure	31110	$ 1.30	$40,443.00
STP 15000TL-US-10	Drop Off	Inverters	4	$ 4,447.00	$17,788.00
SBCB-6 Combiner Box	Drop Off	Wiring	4	$ 248.77	$995.08
Electrical Vehicle Charging Stations	Parking	Wiring	8	$ 1,227.00	$9,816.00
Shipping			1	$ 150.00	$150.00
			Total		**$ 4,521,031.03**

Table 13: Labor Estimate Calculations

	Assumptions:				
	Labor	900	$/kW		
	C_electricity	0.09	$/kWh		
	Current Ed. B. Usage	295000	kWh		
	Elec. Conduit Bore	6.2	$/ft		
	Cost of Electricity Inflation	3.50%			
	MeLink				
	Cost / Watt Breakdown:			$/kW	
	solar panel	1	$/W	1000	
	canopy	1.3	$/W	1300	
	inverter	0.4	$/W	400	
	connection wires	0.15	$/W	150	
	electric/labor	0.65	$/W	650	
	Total	3.5	$/W	3500000	

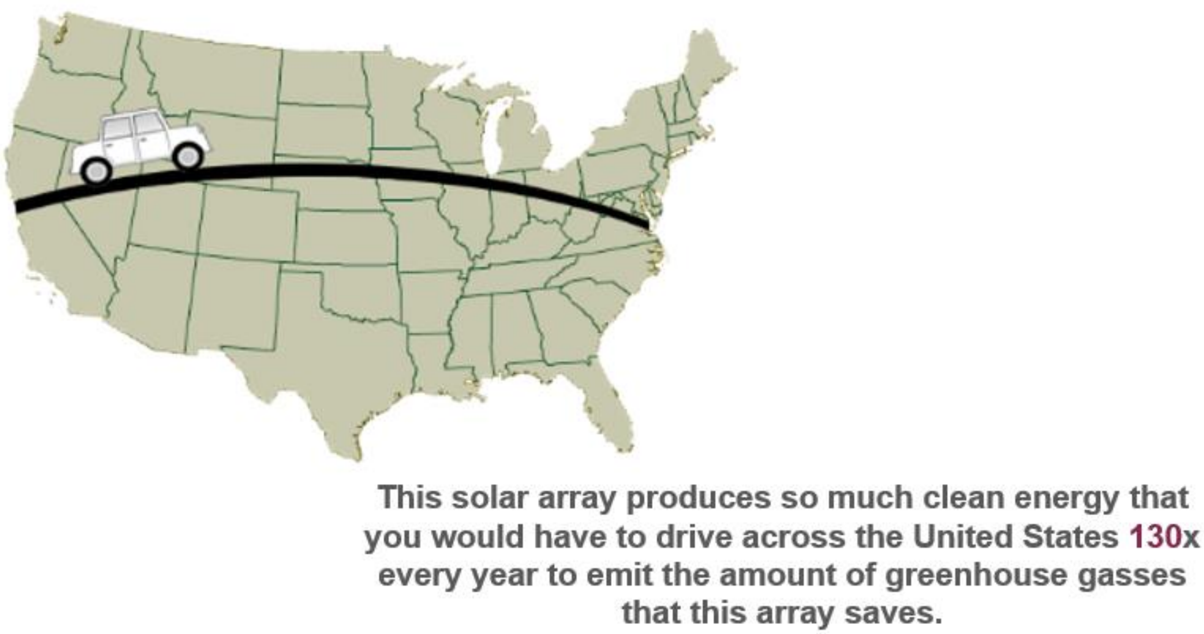


Figure 28: Info-graphic Number 1

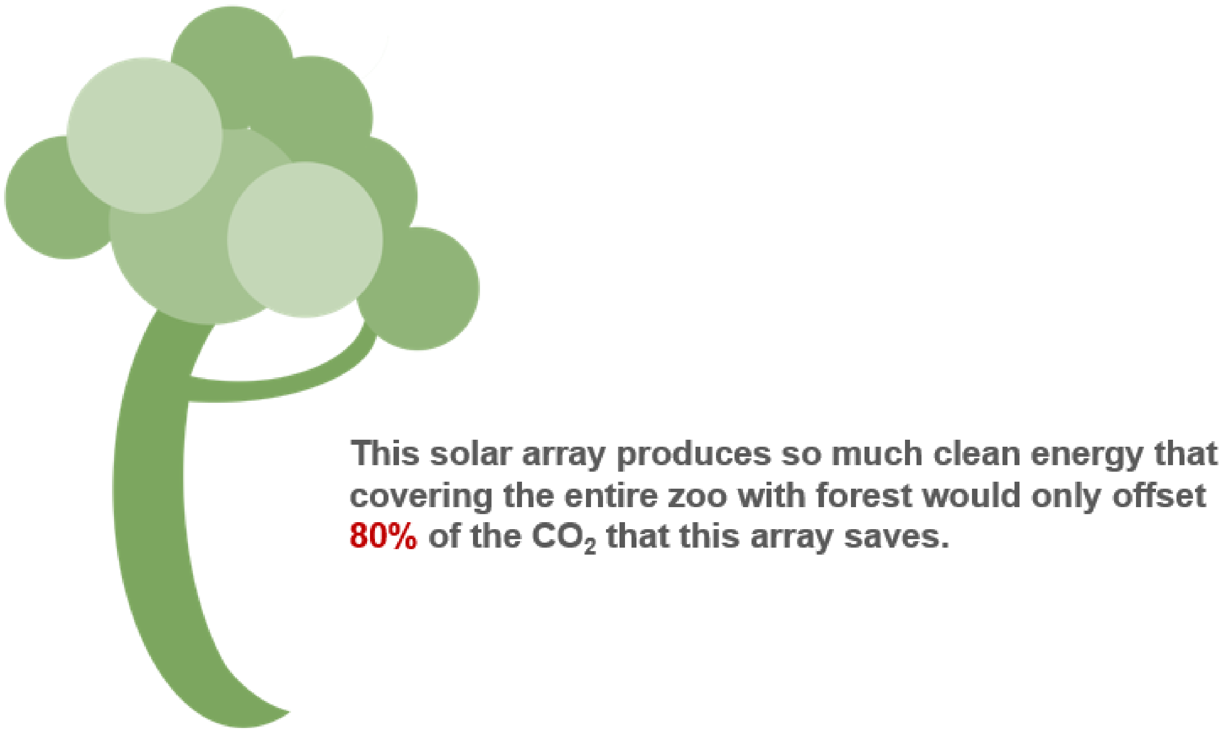


Figure 29: Info-graphic Number 2

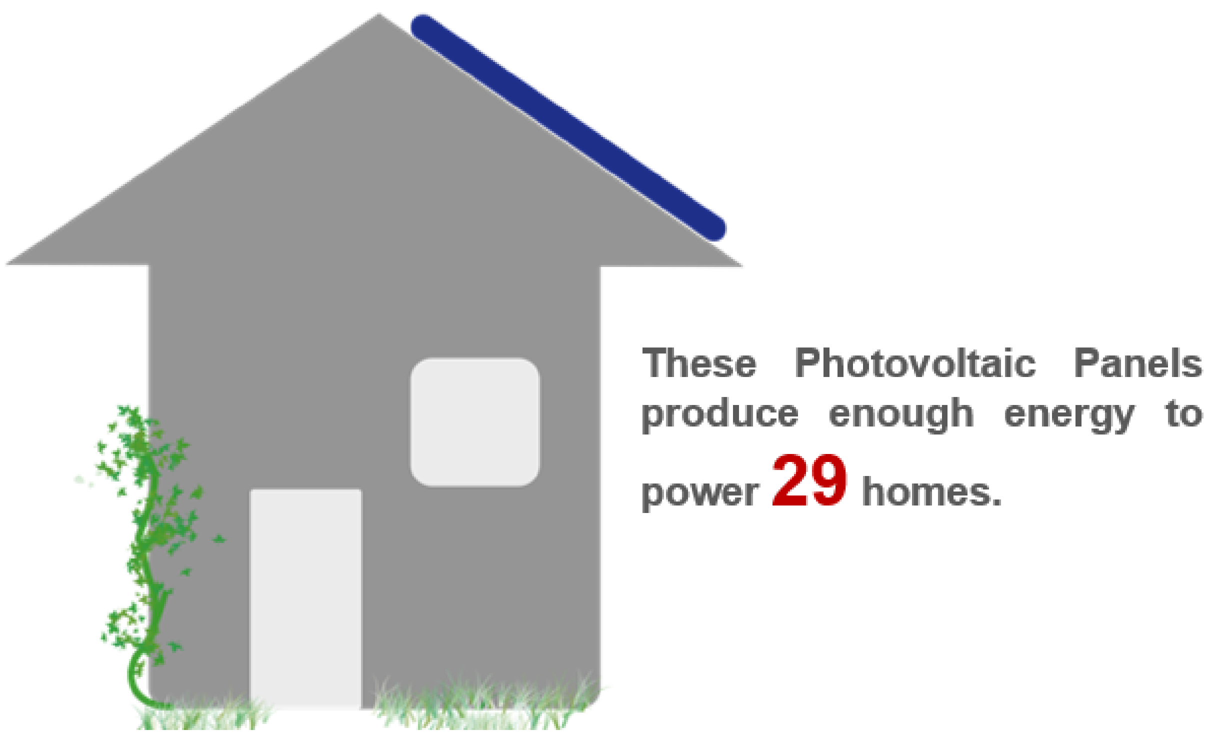


Figure 30: Info-graphic Number 3

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