MANAGEMENT FEASIBILITY OF SOLAR ENERGY CAPTURE SYSTEM IN A POULTRY PRODUCTION FACILITY

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ABSTRACT

This senior project involves designing a solar system for an agriculture entity and conducting a feasibility management study on the system. The feasibility study will look the initial cost, amount of energy generated, and estimated payback of the system. These factors will determine whether or not the Cal Poly poultry unit should ever implement solar into their operations. It will be ideal if the designed system can generate enough power to cover the electric usage associated. The system can be either photovoltaic or thermal and could either be a ground or roof mount system. The agriculture entity selected was the Cal Poly Poultry Unit and the solar company that has been selected for guidance is Pacific Energy. The design system must abide to Cal Fire building codes. The System must look professional, precise, uniform, and must be presentable.
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INTRODUCTION

The Cal Poly poultry unit has a total of 9 structures the major being chicken lay houses. Electric appliances in this lay house include fans, lights, sub pump, manure, egg conveyor, and feed motors. The poultry unit classroom and processing structure electric appliances includes incubations, the egg processing machines, cold storage motors, lights, offices and processing rooms. Due to increasing energy costs and deficits associated with Cal Poly, cheaper energy solutions are being looked at. The energy solution which is being considered is solar energy.

One solar energy method is a roof mounted photovoltaic system. This method involves installing solar by utilizing roof space. The following components which a photovoltaic roof mounted system requires are the modules, inverters, combiner boxes, and a mounting system. Other acquired costs, includes the cost of installation and cleaning the modules.

A roof mounted system has three major advantages. First, a roof mounted system would utilize empty roof space. Second, the chicken houses sloping gable roofs will be able to position the modules at a pitch to generate a good amount of energy. The lay houses have a pitch of fourteen degrees which is beneficial because the optimal module pitch for San Luis Obispo County is 11 degrees (http://www.csi-epbb.com/default.aspx). The third advantage is that the lay house’s roofs are oriented east to west. The west facing position of modules will receive a high amount of sunlight which will generate a substantial amount of energy.

A number of different solar designs were considered. In addition to those ideas collected from the literature review, the other solar systems considered were a photovoltaic ground mounted system, thermal parabolic trough system, power towering system, and solar dish engine system.

After considering all of the available options, it was decided that a roof mounted system would be the best option. Photovoltaic solar resources were readily available and after preliminary estimates indicated estimated that PV will be more financially feasible.

Pacific Energy’s John Ewan offered solar energy guidance through the duration for the management feasibility study. Dennis K Elliot Cal Poly’s assistance director of energy was the source behind the energy usage numbers for the Cal Poly poultry unit. Without electricity numbers, a management feasibility study couldn’t have been conducted.

The objective is to design a rooftop system for the Cal Poly poultry unit. This management feasibility study will focus on the cost of the components, total cost of the system and the system’s payback while consider the following constraints as outlined by John Ewan:

1. Abides by the Cal Fire Building Codes, which requires three feet of space between the modules and the edge of the rooftop.
2. Position modules facing the south and west for optimal efficiency and a greater payback.
4. Avoid using the classroom structure due to strict building codes for classrooms.
Photovoltaic (PV) Components

Figure 1 illustrates the components of a photovoltaic system.

Figure 1. Photovoltaic setup (how solar cell works).

Modules. A solar module is made up of several groups of solar cells. These cells are made out of semiconductor, which are used to conduct electricity by producing a current. The most commonly used semiconductor for solar is silicon diode. The initial light on the solar cell separates the electrons, which creates an electric current. The electrical current with the voltaic a positive and negative charge is transferred power through an electrical wire. The power unit used for solar is watts module wattage and is calculated by is multiplying the number of solar cells in the modules by the wattage per solar cell. The number of watts per system is determined by multiplying the watts per module by the number of modules. A glass cover is placed over the solar cells for protection and is the final component of a PV module.
Figure 2 shows 14 modules installed on a roof top.

![Figure 2. 14, 230 Watt (PV) photovoltaic modules.](image)

**Inverters.** An inverter is a photovoltaic component that converts the DC current into AC current. Solar modules produce DC current and the power grid only takes AC current. By converting the current allows the solar to be transferred to the grid. There can either be a central inverter or AC modules inverters can be built directly into the PV modules. Islanding is when a solar system delivers power to dead wires during a power outage. There are some inverters that are capable of preventing islanding from happening.

Figure 3 displays a residential solar inverter. Utility size inverters are much bigger in size.

![Figure 3. SMA 5000 USA inverter.](image)

**Combiner Box.** 12 to 14 modules make up a series (John Ewan Pacific Energy). Each series is hooked up to one of the combiner boxes fuse inlets. The combiner box is hooked up to one of the
inverters fuse inlets. The number of inlets a combiner box and invert has varies. The price of the unit will be affected when a combiner box with more fuse inlets is purchased.

Figure 4 displays a photovoltaic combiner box.

![Figure 4. PV combiner box.](image)

**Batteries.** Solar batteries are a form of energy storage and for systems that are connected to the grid. The issues that are created by storage batteries are that they are expensive and that they have a shorter life than the 30-year life span of PV modules. Another drawback of batteries is that they contain the chemical acidic electrolytes which is bad more the environment. Deep cycle discharge batteries offer a longer life while putting out more stored energy. The recent innovations in the electric car industry have brought many advancements in battery technology which can increase the affordability and dependable of a battery.
Figure 5 is an example of a battery used to store solar energy.

![Figure 5](image)

**Figure 5.** 8D gel solar battery.

**Mounting Systems.** PV modules can either be mounted on of a rooftop or can be installed at ground level. It makes sense to roof mount PV modules where the ground space is limited this is common to urban residential or cold storage facilities in agriculture. Figure 2, is an example of roof mounted system. Electrical production depends on the weather—the more sun light that the solar cells can observe the more power will be produced. The angle of inclination is the pitch a solar modules is position to receive the maximize amount of sunlight. Different regions have different angle of inclination depending on their longitude and latitude. In the northern hemisphere modules are position facing the south maximizing electrical output. Solar mounting systems can position modules at a desirable angle of inclination.

Figure 6 illustrates modules that are supported by a solar mounting system.

![Figure 6](image)

**Figure 6.** Example of solar mounting system.
Table 1 illustrates the slope angle of a roof associated to a particular pitch.

<table>
<thead>
<tr>
<th>Roof Pitch (Rise: Run)</th>
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<tr>
<td>2:12</td>
<td>9.5</td>
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<tr>
<td>3:12</td>
<td>14.0</td>
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<tr>
<td>4:12</td>
<td>18.4</td>
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<td>5:12</td>
<td>22.6</td>
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<td>6:12</td>
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<tr>
<td>11:12</td>
<td>42.5</td>
</tr>
<tr>
<td>12:12</td>
<td>45.0</td>
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**Factor Affecting Photovoltaic**

**Module Efficiency.** In 2009 solar modules averaged efficiency between 12 to 18 percent. The most efficient solar module efficiency was forty percent. The majority solar cells are a single crystal silicon cell. Makers have attempted to alter the traditional solar cells to increase module efficiency. An example of this is the type is the thin film solar cell, which has a lower efficiency initially but increases with age. Another example is multi junction solar cells which have multiple layers of different brand gaps which absorb the high energy protons to increase efficiency. In addition to solar cells mirrors and lenses have been implemented to collect light rays that missed initially absorbed by the solar cell.

**Solyndra.** Technology breakthroughs have allowed manufactures to produce solar modules with a greater efficiency. The issue is that high costs associated with high efficiency modules. Consumers would rather buy lower efficiency modules at a cheaper price module even if it meant purchasing additional modules. Solyndra a high efficiency module manufacture filed for bankruptcy in due 2011 because consumers weren’t will to pay a premium price for their modules.
**Thermal Solar Systems**

**Parabolic Trough System.** Parabolic systems are the most common type of thermal solar system. A signature component associated with parabolic systems is the parabolic trough. The parabolic trough rotates either north to south or east to west depending on the direction of the sun. The largest parabolic trough has up to 900 parabolic mirrors. The mirrors magnify the sunrays 30 to 100 times. The largest parabolic systems generates up to eighty MW of electricity. The parabolic system setup consists of the parabolic mirrors absorb energy from the sun. The energy is collected in the center of the folic point of the parabolic mirrors. Underneath the focal points there are receiver tubes, which hold the heat transfer fluids. The heat transfer fluids travel through tubes in a process called heat exchange. The steam is released and is fed into turbine generator the electricity is produced.

Figure 7 illustrates the layout of a thermal solar parabolic trough system.

![Figure 7. Example of a thermal solar parabolic trough system.](image)

**Solar Power Towering System.** The signature component in towering solar systems is heliostats. Heliostats are mirrors that rotate towards the sun's current position and there 1000s of these mirrors in towering system. Each towering systems will produce 200MW of power. Much like the parabolic system the towering system will concrete sun by as much 1500 times. Currently there isn’t large-scale towering system.
Figure 8 illustrates the layout of a solar power tower system.

**Solar Dish Engine.** A solar dish engine is a smaller thermal system that only generates 3 to 25 kilo-watts of power. Much like heliostats, the dish rotates towards the sun. The components include a dish receiver, tubes that carry heat-transfer fluids and the generator. A solar dish could be a good option in a smaller-scale setting.

Figure 9 illustrates the layout of a solar dish engine system.
**Residential Solar Example**

The residential solar example in figure 10 is a 5 DC KW photovoltaic system it generates enough power to cover 100 percent of the electrical usage of the residence. A water pump which is used for a well is also powered by this system. In this particular example are the utilities are covered with the exception of the landline. The electricity and water pump are powered by the system. There aren’t any costs for gas or sewer at this particular location. When the power generated from their system exceeds the energy that they used the homeowners receive an energy credit from PG&E. The monthly unused power is transferred through the grid to another PG&E user. The public utilities code 2887 says that the grid will act as storage for households who produce excess power during day and need power at night. (http://www.gosolarcalifornia.org/csi/step3.php).

Figure 10 shows a residential photovoltaic system that is located in Edna Valley. The homeowners of this solar system are Bob and Gay Spencer.

The picture above illustrates that the system is ground mounted. Ground mounted systems can be more attractive than roof mounted system when excess land is available. The ground mount system is attractive when a structure can’t support the dead load created by a modules. Also for aesthetic purpose homeowners may prefer a ground mounted system to keep modules hidden.
Figure 11 shows how the Spencer’s solar system is supported and is an example of ground mounted system.

This system was installed over a decade ago and its initial cost of this system was $17,000 after rebates. Today the same system cost will substantially lower and will offer a much quicker payback. This is because solar components dropped significantly due to increased competition from China, availability of silicon and increased wattage per module (beyondoilsolar.com). The one cost associated with solar that will never decline is labor. It is important to note that the homeowner of this system Mr. Spencer saved a lot of money cutting out the labor cost by installing the system.

**Agriculture Small Scale Examples**

In 2010 two Delano vineyards the Castle Rock Vineyard and VBZ Grapes invested two 1.1 MW systems. The two systems were ground mounted and covered an area of eight acres. These systems would cover 49 and 69 percent of the electricity usage required to run the vineyards. By combining lower utility bills and tax incentives after loan payments it was calculated that the vineyard would save 100,000 dollars annually and would expect to see greater savings after the loan was paid off (http://www.recsolar.com/business-government/market-served/agriculture-and-coldstorage). This is one of the biggest systems in the nation to date requiring 5,400 Kyocera 210 Watt modules.
Figure 12 displays a large agricultural system implemented at Castle Rock and VBZ Grape vineyards in Delano California.

Figure 12. Small-scale agriculture example solar example (rec solar).

J&L Wines in Paso Robles installed a roof mounted system that provides electricity for 28000 Sq. foot warehouse. The electricity is used for temperature control, electronic surveillance and computerized inventory management system. This system covers 70% of energy usage. It saves $12,000 annually and produces a total of 71000 kWh a year. The system components are (216) 215 watt PV modules, SolaRak PV mounting system and Six SMA SB7000US 7-KW commercial inverters.
Figure 13 displays an agriculture solar system which was implemented on J&L Wines in Paso Robles California.

![Agriculture small-scale example Paso Robles vineyard (rec solar)](image)

**Figure 13.** Agriculture small-scale example Paso Robles vineyard (rec solar).

**Large Scale Solar Projects**

**Carissa Plains.** Two large-scale solar farms are being implemented in Carissa Plains California. The first one is at High Plains Ranch, which owned by Sun Power and NRG Energy. This site will produce 250MW of power annually and the cost of the project is 1.6 Billion. Sun Power and NRG Energy will be receiving 1.237 billion in guarantee loans from to federal government. The High Plains is expected to be completed in 2013 and 360 workers were hired to help install the system. The project will cover an area of 1966 acres and will require 88,000 tracking devices that are used to track and absorb the sun rays.

The second solar farm is called Topaz Solar Farm it will generate 550MW electricity. This operation will cover an area of 9.5 square miles with an additional 640 acres. First Solar thin film module will be utilize and it is expected that this will be completed in 2015. First solar will receive 1.9 billion in guaranteed loans from the federal government. This solar farm will generate power to 160,000 homes and also include $417 Million in positive impacts for the local economy. The High Plains Ranch and Topaz Solar Farm after completion will be two of the biggest solar farms in the United States and are situated only 45 minutes away from Cal Poly.
Figure 14 displays a large scale solar system two in total that are being constructed in Carissa Plains California

![Large-scale photovoltaic solar system in Carissa Plains.](image)

**Solar Millennium.** Solar Millennium is located 8 miles west of Blythe an incorporate area in Riverside County. Solar Millennium would produce 1000MW of power from 4 different solar plants each generating 250 MW ([http://www.energy.ca.gov/siting/solar/index.html](http://www.energy.ca.gov/siting/solar/index.html)). The total area of Solar Millennium would cover an area of 7030 acres. This project plans on using parabolic trough thermal solar technology to generate electricity.

The Blythe Solar Plant developers are Solar Millennium, LLC, and Chevron. The estimated cost of the system was 2.8 Billion. The Blythe Solar Plant was offered 2.1 billion dollars in guarantee loans from the federal government. The federal government’s loan was turned down because one of the partners Solar Trust of America (LLC) filed for bankruptcy. Solar Trust of America cited thermal solar as their reasoning behind bankruptcy and is planning switch to photovoltaic. Solar Millennium would need some another sponsor to take LLC role for this project to get underway.
Figure 15 shows are row parabolic troughs and good illustration what solar thermal farm looks like when completed.

Figure 15. Thermal solar parabolic troughs.

**Government Incentives**

Governments make solar power more affordable for homeowners and businesses.

**Requirements to Receive Government Incentives.**

Requirements to be eligible for solar incentives:

1. Photovoltaic systems need to produce between 1KW to 5MW.
2. System must be connecting to the utility grid.
3. Solar components must be new.
4. Solar components must a minimum warrantee of 10 years.
5. Solar system must have a performance meter.
6. Systems must be incompliance with manufactures specifications, electrical, Cal Fire building codes.
7. Installer of system is required to have a A, B, C-10 or C-46 license.
8. Modules must be certified as UL 1703 and Inverter must be certified as UL 1741 which are based on performance and safety.

The components that are eligible for incentives are PV modules, inverters and meters (http://www.energy.ca.gov).

One requirement of the Cal Fire building codes is that roof system’s module must a distance of three feet away from edges of the roof top (osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf).
Figure 16 illustrates the Cal Fire 3 foot requirement when mandates 3 feet of open space above and on the side of the modules.

The Steps to Receive Solar Incentives

1. Conduct an energy audit to determine the size system needed
2. Find a solar qualified solar installer with A,B, C-10 C-46 license.
3. A certified installer will generate a bid which; include the peak power capacity, cost of hardware, installation, connection, permit and warranty.
4. Applying for California solar incentives is a lengthy process and may take up to 12 months to receive the rebates. Consumer must decide what rebate their eligible for.
5. (EPBB) is a lump sum incentive that is for smaller systems under 30KW. It is based by the amount of energy the system generates.
6. (PBI) is a monthly annuity payment that is good for 5 years which is for bigger systems. It based on the performance of the system.
7. When the system is installed the installer, local government inspectors and a utility representatives will inspect the systems energy output.
8. When finished the utility company will connect the system to the grid.
9. One completed state incentives will be received in the mail.
10. Federal government incentives are credited on the IRS 5696 form and often homeowners 30 percent rebate and businesses a 10 percent rebate on the system. Federal government will collected when the taxes are collected

**GreenWire Technology’s CEO’s Input on Solar Payback.** The two paragraphs listed below were written in an email from the CEO of Greenwire Technology Kevin Robertson. Kevin emphasized the importance of 30 percent federal tax credit. Kevin mentioned that a payback of 5 years or sooner will typical motivate business to pursue solar energy.

| ROI which stands for the return on the investment. Usually a 5 year payback will motivate a business to do the project. A job usually looks like this. A customer has an electrical bill of $10,000 per year. The solar system cost is $100,000 to install. The customer gets backs 30% the first year in a tax credit. The customer gets back another 30% in rebates and depreciation value. The customer avoids paying $10,000 per year in electricity cost every year for twenty years+.

As you can see the $100,000 is completely paid back in less than 5 years because of the tax credits, rebates and electricity cost avoidance. This is why a business is motivated to buy solar. The TAX consequences of a business drive their decision. The business MUST pay taxes anyway. Why not by solar with the tax money? (Kevin Robertson Greenwire). |
PROCEDURE AND METHODS

Poultry Unit Energy Usage

During the fiscal year of 2011-2012 the poultry unit used 290,535 kWh of electricity. Cal Poly is charged a utility rate of 10 cent per kWh. When looking at the fiscal year of 11-12 the average annual monthly cost was $2421, which is listed in Appendix B. The monthly electricity costs will be used as an input value when calculating the payback of the system later on in the report.

Designed System

After considering all of the constraints it was decided to design a roof mounted system which will utilize 7 chicken lay houses a, b, c, e, f, g, and h. The chicken houses are displayed below in figure 17.

Figure 17 displays the structure associated with the poultry unit.

![Figure 17. Cal Poly poultry unit from Google Earth](image)

150 Education Building, A-Caged Brooding House, B-Testing Brooding House
C-Equipment Maintenance & Quail house, D- Egg Packing Shed, E-Conventional lay house
F-High rise lay house, G-Project Breeding House
**Components.** After analyzing the poultry unit electricity numbers solar components were selected for the designed system. John Ewan of Pacific Energy recommended the following brands: Sun module, Soletria Renewables, Unirac. An 8 percent San Luis Obispo sales tax was factored into the cost of each solar component. The quantity of modules, inverters, combiners, wiring and piping required was calculated and is listed in Tyler Flavell’s report. The price quotes of the different solar components are listed in Appendix E of this report.

**Module Selected.** The Sun Module SW 275 mono model was selected because it is a high wattage module. A high wattage module was ideal because there was a limited amount of roof space available. The Sun Module SW 275 mono model helped to increase the size of the designed solar system. The dimensions of the module are 65.94inch x 39.41inch x 1.22inch located in Appendix C. The dimensions are important when calculating how many modules can be installed which directly affects the cost of the system.

The roof top dimensions were calculated with the assistant of the poultry unit floor plans located in Appendix D. It was determined that 468 modules could be installed. The Sun SW 275 mono modules were quoted by CED of San Luis Obispo. The shipping costs for the modules were quoted at $100 per set of 30 modules, and $150 dollars for sets with less than 30 modules. The cost for modules totaled to $146,306.93.

Cost of modules-

\[
(\text{Quantity} \times \text{unit price}) + \text{sales tax} = (468 \times 286.2) + 10,715.33 = 144,656.93
\]

Cost of shipping costs-

\[
\text{Quantity/30}=464/30=15.47 \quad 15 \times 100=1,500+150=1,650
\]

Total cost of modules-

\[
(\text{Cost of modules} + \text{shipping cost}) = 144,656.93 + 1,650=\text{146,306.93}
\]

**Inverter.** (2) Soletria Renewables 75 KW 480VAC central inverters were chosen. The Soletria Renewables 75KW inverter was quoted by Pacific Energy. There was a $1,750 shipping charge for the inverters and combiner boxes. The cost for inverters totaled to $76,062.23.

Cost of inverters-

\[
(\text{Quantity} \times \text{unit price}) + \text{shipping cost} + \text{sales tax} = (2 \times 32,797.5) + 1,750 + 5,247.6 = \text{76,062.23}
\]

**Combiner Box.** Each series of module requires one-fuse inlet connections The Soletria Renewables Diacom 4 combiner boxes with 8 and 10 fuse inlets were chosen. This was because the chicken lay houses required a maximum of 10 series of modules per lay house. After calculations were complete, (6) 8 fuse combiner boxes and (1) 10 fuse combiner box solar system were quoted by Pacific Energy. The total cost for combiner boxes totaled to $8,361.49.

Cost of 8 fuse combiner boxes-
(Quantity*unit price) + sales = (6*913.75)=5893.69+471.50=7,365.19

Cost of 10 fuse combiner box-

(Quantity*unit price) + sales tax = (1*922.5)+73.8=$996.3

Total cost of combiner boxes- 7,365.19+996.3= $8,361.49

Electrical Cost. Electrical wiring was needed to connect the different solar components together. 3,040 feet of 8 AWG wire was selected to connect the modules to their associated combiner box. 956 feet of 6 AWG wire was selected to connect the combiner boxes to their inverters. 502 feet of 2 AWG wire was selected to connect the inverters to the grid hookup control room. The type of wire used was determined with the help of the Soletria Renewables product specifications. Also by looking at max amperage wire chart, the specification and the wire chart are located in Appendix F. Further explanation of wire sizing can be found in Tyler Flavell’s report. The poultry unit floor plans listed in Appendix D was used to determine the total wiring length needed. The shipping costs are not included in the wiring estimates. The wiring cost totaled to $3,949.07.

8 AWG- Unit costs 500ft. = $239

(Quantity* unit cost) + sales tax = (7*239) + 133.84=$1,806.84

6 AWG- Unit costs 1000ft = $774.95

(Quantity* unit cost) + sales tax = (1* 774.95) + 62.00=$836.95

2 AWG- Unit costs 100ft = $186

(Quantity* unit cost) + sales tax = (6* 186) + 89.28=$1205.28

Total wiring costs- 1,806.84+836.95+1,205.28=$3,849.07

Piping Cost. Piping is used to protect the electric wires that run underground. 478 feet of 3/4 conduit is needed to cover the electrical cords that connect from the combiner box to the inverter. 250 feet of 1 inch conduit is needed to cover the electrical cords that connect the inverter to the grid control room. The size conduit needed was calculating by looking at the conduit selection table located in Tyler Flavell’s report. Flexible elbows were used to run the electric cords above and below the ground. Clamps were then used for securing the piping against the chicken lay houses while the cords travelled to their associated combiner boxes. The shipping costs are not included in the piping estimates. The conduits were quoted by Home Depot, with the exception of the 1 inch flexible elbow which was quoted by Summit Source. The piping cost totaled to $270.14.

3/4 piping- Unit costs 10ft. = $2.58
(Quantity* unit cost) + sales tax = (48*2.58) + 9.90=$133.74

3/4 flexible elbow-  Unit costs 1= $.79
(Quantity* unit cost) + sales tax = (20*.79) + 1.26=$17.06

3/4 clamp-  Unit costs 25 = $3.02
(Quantity* unit cost) + sales tax = (1*3.02) + .24=$3.26

1 piping-  Unit costs 10ft. = 3.79
(Quantity* unit cost) + sales tax = (26*3.79) + 7.88=$106.42

1 flexible elbow-  Unit costs 6 = $8.94
(Quantity* unit cost) + sales tax = (1*8.94) + .72=$9.66

Total piping cost-
  133.74+17.06+3.26+106.42+9.66=\textbf{$270.14$}

\textbf{Rac System Cost.} The Unirac solar mount racking was used for the designed system. The costs of the racking system were estimated using the Unirac design tool. Details on how the design is used are located in Appendix E. A Unirac parts list and quotes for the individual lay houses was generated and is also found in the Appendix E. The cost of the racking system totals to $44,114.28.

Calculations for the Unirac system-

\[
\text{building(a)+building(b)+building(c)+building(e)+building(f)+building(g)+building(h)} = 3,660.72+7,321.44+6,163.08+6,163.08+6,163.08+3,660.72+10,982.16 = \textbf{44,114.28}
\]

\textbf{Maintenance Cost.} The maintenance cost is the cost associated with cleaning the dust and other debris off of the solar modules. John Ewan recommended that solar modules should be cleaned up to 3 times a year. It is calculated that the annual maintenance cost is $720.

Maintenance Cost-

\[
(\text{# of cleanings} \times \text{# of employees} \times \text{hours} \times \text{pay rate} \times \text{years}) = (3\times2\times8\times15\times30) = \textbf{$720 \text{ per year, $21,600 over the 30 year period.}}
\]

\textbf{Cost of labor.} John Ewan from Pacific Energy mentioned that the average cost of labor could be calculated by multiplying the number of DC watts by $1.25. The DC wattage in our system
was computed by multiplying the number of modules by their wattage. The cost of labor is computed at $160,875.

Total wattage-
(# of modules* module wattage)= (468*275) = 128,700watts
Cost of labor-

\[
\text{DC wattage} \times \$1.25 = 128,700 \times \$1.25 = \$160,875
\]

**Management of the System**

A solar system is expected to have a life expectancy of 30 years. Throughout that time the solar system will require little to no maintenance. Any defective product will be fixed by the company who installed the system. The system is expected to survive harsh weather conditions with an exception of a natural disaster. One management cost associated with the system is the maintenance cleaning cost. This is the annual cost associated with cleaning the modules. Dust and other debris can prevent a module from working at its optimum output. The design system requires 3 cleanings a year recommended by John Ewan and it would take 2 employees 8 hours to clean 468 modules. It was calculated that the total management cost was $720 and $21,600 over the 30 year life of the system.
RESULTS

Total Cost of the System

Table 2 added up the cost of all the individual components and determined the total cost of the design system. The total cost of the system was $461,455.88 which was factored in the results to help determine the payback of the system.

Table 2. Total Cost of the system.

<table>
<thead>
<tr>
<th>Components</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>modules</td>
<td>$146,306.93</td>
</tr>
<tr>
<td>inverters</td>
<td>$76,062.23</td>
</tr>
<tr>
<td>combiner boxes</td>
<td>$8,361.49</td>
</tr>
<tr>
<td>electrical</td>
<td>$3,849.07</td>
</tr>
<tr>
<td>piping</td>
<td>$270.14</td>
</tr>
<tr>
<td>rac system</td>
<td>$44,114.28</td>
</tr>
<tr>
<td>maintenance</td>
<td>$21,600.00</td>
</tr>
<tr>
<td>labor</td>
<td>$160,875.00</td>
</tr>
<tr>
<td>total</td>
<td>$461,439.14</td>
</tr>
</tbody>
</table>

Size of the System

The size of the system had to be determined in order to calculate the payback of the system. Using the CSI EPBB (California Solar Initiative Expected Performance Based Buy down) solar calculator, the size of the design system was calculated on gosolarcalifornia.com. The calculator converted the DC watts produced by the modules into units of AC power to determine the size of the system.

In order for the calculation to be completed, a series of inputs had to be entered. The inputs included; the model and number of modules, model and number of inverters, the mounting method, shading, tilt of the modules, and their azimuth position. The mounting method was >6” because the racking system was positioned 6 inches above roof illustrated in Tyler Flavell’s Report. Module tilt was 14 degrees because all of the lay houses with the exception of one had a roof pitch of 14 degrees located in Appendix H. The azimuth position is 270 degrees because the modules are orientated to the west further explained in Tyler’s report.
Figure 18 displays the inputs that were entered into the CSI EPBB calculator to determine the size of the system.

![Figure 18. CSI calculator inputs.](image)

The inputs were entered and the CSI calculator determined that the size of the system would be 110 KW-AC units. The global positioning of the system, the system’s tilt, and azimuth positioning were key factors in determining the size of the system and they were compared to the optimal tilt and position for San Luis Obispo. The size of the system was recorded in the results section of the report, to help determine payback of the system and whether or not the system would cover the electric usage of the poultry unit.
Figure 19. illustrates the computed size of the system in AC power units.

![Table]

<table>
<thead>
<tr>
<th>Proposed</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual kWh</td>
<td>183,660 (a)</td>
</tr>
<tr>
<td>at optimal tilt</td>
<td>193,889 (b)</td>
</tr>
<tr>
<td>facing south at optimal tilt</td>
<td>205,065 (c)</td>
</tr>
<tr>
<td>Summer Months</td>
<td>May-October</td>
</tr>
<tr>
<td>Summer kWh</td>
<td>116,391 (e)</td>
</tr>
<tr>
<td>at optimal tilt</td>
<td>115,475 (f)</td>
</tr>
<tr>
<td>facing south at optimal tilt</td>
<td>120,153 (g)</td>
</tr>
<tr>
<td>CEC-AC Rating</td>
<td>110.394 kW</td>
</tr>
</tbody>
</table>

Systems greater than or equal to 30 kW (CEC-AC rating) are ineligible for EPBB incentives.

Cost Correction:

Design Correction² 99.927%
Geographic Correction³ 100.000%
Installation Correction⁴ 100.000%
Design Factor⁵ 99.927%

CSI Rating⁶ 110.313 kW

| Incentive Rate | $0.70/Watt |
| Incentive⁷ | $77,219 |
Report Generated on 5/31/2013 8:56:53 AM

Figure 19. CSI EPBB calculator size of system in AC power.

Cost KW-ac unit

The cost of the system per KW-ac unit will be used later results section to help determine the payback of the system. The cost of system per KW-ac unit was calculated to be $4,194 and was round up to $4,500.

Cost of the designed system per KW-ac unit-
Total costs of the system/size of the system= 461,439.14/110KW= $4,194 =4,500 per KW-ac unit
Payback on the Systems

The clean energy estimator calculated the annual kWh produced and number of years to payback the system. A number of inputs were entered in order to compute the estimated payback. This included; the size, total cost, maintenance cost, tilt, and orientation of the system. Additionally, inputs include the tax status, monthly energy cost associated with the poultry unit, utility escalation, and the system’s payment method. The listed inputs pertaining to the system were listed in the procedure and method section of report. The inputs regarding the Poultry Unit:

1. Poultry unit tax exempt because government agencies do not pay taxes.
2. Poultry unit electric bill was rounded down to $2000
3. Escalation was listed 4 percent because on average utility rate increase per year (John Ewan Pacific Energy).
4. The system is being paid with cash.

When all the inputs were factored in, the design system payback was computed to take 13.1 years. The annual projected kWh by the system was projected at 172,448 kWh. Which will be used later to help calculated the percentage of electric bill covered by the system.

Figure 20 illustrates the estimated payback and annual kWh generated annual by the system which outline in red. The inputs that were previously explained are outline in gray.

![Figure 20. Clean power estimator payback calculation.](image)
Percentage of the electric bill covered by the system

The percentage of the electric bill covered by the system was calculated. It was determined by taking the annual kWh generated by the system and dividing by the amount of kWh used by the poultry unit during the fiscal year of 2011-2012. The design system covered 59 percent of the electricity used by the poultry unit.

Percentage of the electric bill covered by the system-
kWh annually produced/ kWh used 2011-2012= 172,448/290,535= 59.4 percent
DISCUSSION

It was determined that the total cost of the system was $461,439.14. A 110 KW system was designed and covered 59 percent electrical usage at the poultry unit. The estimated years to pay off the system was 13.1 years. Kevin Robertson CEO at Greenwire Technology mentioned that businesses are typical consider solar power when it offers a payback of 5 years or less. It is clear that a majority of businesses wouldn’t implement a solar system that offered a 13 year payback. At this time it is not recommended to implement the design system.

A factor affecting the payback of the system was the current tax standing of the poultry unit. Cal Poly is a government entity whom is exempt from paying taxes and receiving solar tax breaks. The federal 5696 tax credit had offered homeowners 30 percent and businesses a 10 percent tax credit. Without the 5696 tax credit, entities would not have considered solar power. If the poultry unit was a taxable entity, it would have achieved a faster payback. Using the clean energy estimator, the system payback was calculated at 9.3 years by changing the tax standing to taxable listed in Appendix J. A 9.6 year payback doesn’t fall within 5 year window but it does make the system more enticing compared to the 13 year payback.

Another factor to the desirability of the system is the percentage of the electricity usage covered by the system. A system is more desirable if it can cover 100 percent of the electric bill. Homeowners and businesses love the idea of not paying an electric bill and image associated with using clean energy. Since the designed system would only cover 59 percent of the poultry unit electric usage, it was calculated that the poultry unit would need an 180KW system to cover the cost of its electric usage listed Appendix J. After looking at the estimated payback of the system and the electrical usage covered by the system, implementation is not recommended.
RECOMMENDATIONS

Whether or not to implement the system depends on the time it takes to pay off the system. Decreasing the cost of the system and increasing electricity produced would increase the payback.

The cost of the system could have been reduced by utilizing cheaper components. The module, inverters, combiner boxes and racking system were high end brands that required a steeper price. Picking low efficiency cheaper brands would have reduced the total cost of the system. The process entailed selecting a component, contacting a supplier and gathering a price quote without gathering additional price quotes. Gathering additional price quotes from a range of suppliers would have potentially lowered the component cost.

Designing a smaller system that produces the same amount of electricity output would have also increased the payback of the system by requiring fewer solar components. This could be achieved by positioning the model at the geographic optimal tilt. The optimal tilt for west orientated modules in San Luis Obispo County was 11 degrees compared to the 14 degrees and 26.6 degrees of the designed system listed in figure 38. Azimuth positioning of the modules will also increase the electrical output by a module. The designed system modules are oriented facing west instead of facing south. This would generate more electrical production due to more sunlight collection. Due to the roof tops east/west orientation, south facing roof mounted modules couldn’t be positioned properly. However, it is possible to have a south facing ground mounted system which would increase the payback.

Whether or not to implement the system can also depend on whether it covers the enterprise’s entire energy cost.

The designed system only covered 59 percent of the poultry unit annual electric costs. Hypothetically if the poultry unit required a system that fully covered the costs of their electric payments, this system could be implemented. Modules were positioned only facing the west because John Ewan mentioned that modules facing the west and south would receive more sunlight further explained in Tyler Flavell’s report. Hypothetically modules could also be placed on the east portion of chicken lay house and would end up covering the poultry unit’s electric usage.

Conclusion

The process to design a solar system was learned throughout the duration of this report. The clean energy estimator and CSI EPBB solar calculators were very useful tools in calculating solar energy payback. Even though the poultry unit system didn’t offer a five year payback, it doesn’t mean that solar cannot be implemented in the relative industry. Fosters Farms and Tyson Foods have not yet been implemented in solar and it would be expected that larger facilities with taxable tax standards would increase payback which would equate in increasing profits.
REFERENCES


14. President of GreenWire Technologies. 7 Mar. 2012. E-mail interview.


17. PVI 50KW/60KW/75KW/85KW/100KW Central Inverters. 2013. *Solectria Renewables.* Available at: http://www.solren.com/?page_id=1897


27. Unirac - Project Info SOLARMOUNT. 2013. Unirac - Project Info SOLARMOUNT.
APPENDICES
Appendix A: ASM Requirements
**Project Title:** Management Feasibility of Solar Energy Capture System in a Poultry Production Facility

**Background Information:** This senior project involves designing a solar system for an agriculture entity and conducting a feasibility management study on the system. The feasibility study will look the initial cost of the system, amount of energy generated, and estimated payback of the system. These factors will determine whether or not the Cal Poly Poultry Unit should ever implement solar into their operations. It will be ideal if the designed system can generate enough power to cover the electric usage associated. The system can be either photovoltaic or thermal and could either be a ground or roof mount system. The agriculture entity selected was the Cal Poly Poultry Unit and the solar company that has been selected for guidance is Pacific Energy. The design system must abide to Cal Fire building codes. The System must look professional, precise, uniform, and must be presentable.

**Statement of Work:** Determine the annual electricity usage of the electricity usage of the poultry unit. Select solar components and get quotes to determine the cost of each component. Determine the total cost of the system, size of the system percent covered by the system and calculate the estimated payback. Determine whether the poultry unit should or shouldn’t implement the designed system.

**How Project Meets Requirements for the BRAE Major**

**Major Design Experience** - The project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes the following fundamental elements. Explain how this project will address these issues. (Insert N/A for any item not applicable to this project.)

- Establishment of objectives and criteria
<table>
<thead>
<tr>
<th><strong>Synthesis and analysis</strong></th>
<th>The project will involve the application of renewable energy, the use of solar power in agricultural businesses and buildings.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction, testing and evaluation</strong></td>
<td>The project will involve skills in the areas of communicating between different businesses, cost analysis of solar power, what type of solar system to use.</td>
</tr>
<tr>
<td><strong>Incorporation of applicable engineering standards</strong></td>
<td>Quantitative problem solving will include the cost analysis of the project and energy calculations.</td>
</tr>
</tbody>
</table>

**Capstone Design Experience** - The engineering design project must be based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses).

**Incorporates knowledge/skills from earlier coursework**

**BRAE**
- 151 AutoCAD
- 324 Principles of Agricultural Electrification
- 348 Energy for a Sustainable Society
- 425 Computer Controls for Agriculture
- 432 Ag Buildings

**AGB**
- 202 Sales skills
- 212 Ag Economics
- 301 Food and Fiber Marketing
- 310 Ag Credit and Finance

**Design Parameters and Constraints** - The project should address a significant number of the categories of constraints listed below. (Insert N/A for any area not applicable to this project.)

- **Physical**
  - Contact a solar company who we will work with. We will be working with Pacific Energy who is based in San Luis Obispo California. Have Pacific Energy help us with additional references that might help us understand the concepts and industry better. In BRAE 462 Contact an agricultural company to design a solar for. The agriculture company that we are planning to work with is the Cal Poly Poultry Unit.

- **Economic**
  - Do a feasibility report calculating the costs of the system, cost of labor, estimated payback.

- **Environmental**
  - N/A

- **Sustainability**
  - Design a solar system that that big enough to efficiently power the
Design a system that is neat and ordinary that fits the allowable area.

Hopefully the company will consider implementing our system. Decide whether to use a roof or a grounded mounted system. For a ground mounted system compare the cost of solar per acre with the costs of producing field crops per ache.

<table>
<thead>
<tr>
<th>Health and Safety</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethical</td>
<td>N/A</td>
</tr>
<tr>
<td>Social</td>
<td>N/A</td>
</tr>
<tr>
<td>Political</td>
<td>Find out the amount of electricity that is needed to power that particular agriculture facility.</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>N/A</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: Poultry Unit Energy Usage
Table 3 displays the kWh electricity usage for the poultry unit for the fiscal year of 2011-2012. This data was provided by Dennis K Elliot through a personal email.

Table 3. Poultry unit electricity usage (Elliot, Dennis February 8, 2013).

<table>
<thead>
<tr>
<th>Bldg. #</th>
<th>Building Name</th>
<th>Units</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>Poultry Science</td>
<td>Electricity</td>
<td>7286</td>
<td>22656</td>
<td>22656</td>
<td>26680</td>
<td>24576</td>
<td>29568</td>
<td>22656</td>
<td>20736</td>
<td>23424</td>
<td>25344</td>
<td>25344</td>
<td>20736</td>
</tr>
</tbody>
</table>

Table 4 displays the total kWh and average monthly electricity cost associated with the poultry unit. The total kWh was calculated by finding the sum of the kWh generated monthly. The average cost per month was calculated by multiplying the total kWh hours by the utility rate, which was $.10 per kWh. The utility rate was provided by Dennis K Elliot through a personal email.

Table 4. Poultry unit electricity usage fiscal year 2011-2012.

<table>
<thead>
<tr>
<th>Bldg. #</th>
<th>Building Name</th>
<th>Units</th>
<th>Cal Poly rate</th>
<th>Fiscal Year 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>Poultry Science</td>
<td>kWh</td>
<td>$.10 per kWh</td>
<td>290534.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>29568.4</td>
<td>22656</td>
<td>22656</td>
<td>26680</td>
<td>24576</td>
<td>29568</td>
<td>22656</td>
<td>20736</td>
<td>23424</td>
<td>25344</td>
<td>25344</td>
<td>20736</td>
</tr>
</tbody>
</table>

Total kWh: 290534.4

AVG $ per Month: 2421.12
Appendix C: Module Dimensions
Figure 21 illustrates the Sun Module SW275 mono and displays the module dimensions, which were used to calculate the number of modules that could be implemented.
Appendix D: Poultry Unit Floor Plans and Roof Dimensions
Figure 22 displays the floor plans of the Cal Poly poultry unit. The floor plans were used to help calculate the roof top dimensions of the different chicken houses. The rooftop dimensions helped determine the number of modules that could be installed, the quantity of wires and piping needed.

![Floor plan of the Cal Poly poultry unit](image)

**Figure 22.** Poultry unit floor plan

Table 5 displays the calculated roof top dimensions for the different chicken lay houses at the poultry unit. These calculations were used to determine how many modules could be installed.
Table 5. Roof top dimensions.

<table>
<thead>
<tr>
<th>Buildings</th>
<th>Dimensions</th>
<th>Height of roof</th>
<th>Over hang Length</th>
<th>Room top dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>150-A</td>
<td>82ft x 26ft</td>
<td>3.25</td>
<td>1.5</td>
<td>14.9ft x 82ft</td>
</tr>
<tr>
<td>150-B</td>
<td>93ft x 40ft</td>
<td>5</td>
<td>1.5</td>
<td>22.1ft x 93ft</td>
</tr>
<tr>
<td>150-C</td>
<td>125ft x 26ft</td>
<td>3.25</td>
<td>1.5</td>
<td>14.9ft x 125ft</td>
</tr>
<tr>
<td>150-E</td>
<td>130ft x 26ft</td>
<td>3.25</td>
<td>1.5</td>
<td>14.9ft x 130ft</td>
</tr>
<tr>
<td>150-F</td>
<td>130ft x 26ft</td>
<td>6.5</td>
<td>1.5</td>
<td>16.0ft x 130ft</td>
</tr>
<tr>
<td>150-G</td>
<td>83ft x 32ft</td>
<td>4</td>
<td>1.5</td>
<td>18.0 x 83ft</td>
</tr>
<tr>
<td>150-H</td>
<td>148ft x 42ft</td>
<td>5.25</td>
<td>1.5</td>
<td>23.1ft x 149ft</td>
</tr>
</tbody>
</table>
Appendix E: Components Price Quotes
Figure 23 was a quote of Soletria Renewables’ inverter and combiner boxes. This quote was emailed by John Ewan of Pacific Energy.
Wiring Costs-

Figure 24 displays the price quote for 8AWG wire. There were 3,040 feet of AWG 8 wires required the unit price is $2.39 per 500 ft.

Figure 24. 8 AWG price quote.

Figure 25 displays the price quote for 6 AWG wire. There were 956 feet of 6 AWG wire required the unit price $774.95 per 1000 feet of wire.

Figure 25. 6 AWG price quote.

Figure 26 displays the price quote for 2 AWG wire. There were 502 feet of 2 AWG wire required the unit price $186 per 100ft.
Figure 26. 2 AWG price quote.
Piping costs-

Figure 27 displays the price quotes for 3/4 inch 40 PPC conduit, flexible elbows and conduit clamps. There is also a price estimate for 1 inch conduit price. The following piping and accessories were quoted by Home Depot.

![Figure 27. Price quote of the 3/4 and 1 inch piping and elbows.](image)

Figure 28 displays the price quote for 1 inch 40 PVC conduit piping which was quoted by Summit Source.

![Figure 28. Price quote for 1 inch conduit piping.](image)
Unirac Racking System-

Figure 29 displays the Unirac design tool which was used to calculate the cost of the racking system. The design tool determines the components of the racking system by considering the following: the size and number of modules, mounting method and the height of the racking system. After the inputs were entered the Unirac design tool generated a parts list with the computed cost of the system.

Figure 29. Unirac design tool.
Figure 30 displays the Unirac racking system price quote for chicken lay houses A and G. The buildings had 39 modules. Its components had a total price of $3660.72

![Table showing price quote for buildings A and G](image)

Figure 30. Unirac price quote for buildings a and g.

Figure 31 displays the Unirac racking system price quote chicken lay house B. This building had 78 modules. Its components had a total price of $7321.44

![Table showing price quote for building B](image)

Figure 31. Unirac price quote for building b.
Figure 32 displays the Unirac racking system price quote for chicken lay house c, e and f. The buildings had 65 modules. Its components had a total price of $6363.08

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PART TYPE</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>SUGGESTED QUANTITY</th>
<th>UNIT PRICE (USD)</th>
<th>TOTAL LIST PRICE (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>310168C</td>
<td>Rail</td>
<td>SM RAIL 168” CLR</td>
<td>24</td>
<td>24</td>
<td>92.00</td>
<td>2208.00</td>
</tr>
<tr>
<td>310240C</td>
<td>Rail</td>
<td>SM RAIL 240” CLR</td>
<td>6</td>
<td>6</td>
<td>132.00</td>
<td>792.00</td>
</tr>
<tr>
<td>303001C</td>
<td>Splice</td>
<td>SM SPLICE BAR SERRATED CLR</td>
<td>22</td>
<td>22</td>
<td>5.90</td>
<td>129.80</td>
</tr>
<tr>
<td>302002C</td>
<td>End Clamp</td>
<td>SM ENDCOMP B, WH/DW, CLR</td>
<td>32</td>
<td>32</td>
<td>2.22</td>
<td>71.04</td>
</tr>
<tr>
<td>302101C</td>
<td>Mid Clamp</td>
<td>SM MID CLAMP,ARBKD,HDW,CLR</td>
<td>114</td>
<td>114</td>
<td>2.48</td>
<td>282.72</td>
</tr>
<tr>
<td>004601G</td>
<td>Roof Attachment</td>
<td>STANDOFF 6” FLATTOP STL</td>
<td>66</td>
<td>66</td>
<td>19.69</td>
<td>1299.54</td>
</tr>
<tr>
<td>304000C</td>
<td>Roof Attachment</td>
<td>SM L-FOOT SERRATED WH/DW, CLR</td>
<td>66</td>
<td>66</td>
<td>4.34</td>
<td>286.44</td>
</tr>
<tr>
<td>004014C</td>
<td>Flashing</td>
<td>FLASHING OATEY 11840 GLYLIME</td>
<td>66</td>
<td>66</td>
<td>6.40</td>
<td>432.40</td>
</tr>
<tr>
<td>008002S</td>
<td>Grounding Lug</td>
<td>GROUND WEERLUG #1</td>
<td>52</td>
<td>52</td>
<td>10.00</td>
<td>520.00</td>
</tr>
<tr>
<td>308001S</td>
<td>UGC Clip</td>
<td>SM GROUND CLIP #1, UGC-1 SS</td>
<td>66</td>
<td>66</td>
<td>2.29</td>
<td>151.14</td>
</tr>
</tbody>
</table>

**BASE SYSTEM**
$3483.56
$0.21 per watt

**ACCESSORIES**
$2679.52
$0.16 per watt

**TOTAL PRICE**
$6163.08
$0.38 per watt

Figure 32. Unirac quote for buildings c, e, and f.

Figure 33 displays the Unirac racking system price quote for chicken lay house H. This building had 117 modules. Its components had a total price of $10982.16

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PART TYPE</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>SUGGESTED QUANTITY</th>
<th>UNIT PRICE (USD)</th>
<th>TOTAL LIST PRICE (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>310168C</td>
<td>Rail</td>
<td>SM RAIL 168” CLR</td>
<td>24</td>
<td>24</td>
<td>92.00</td>
<td>2208.00</td>
</tr>
<tr>
<td>310240C</td>
<td>Rail</td>
<td>SM RAIL 240” CLR</td>
<td>24</td>
<td>24</td>
<td>132.00</td>
<td>3368.00</td>
</tr>
<tr>
<td>303001C</td>
<td>Splice</td>
<td>SM SPLICE BAR SERRATED CLR</td>
<td>36</td>
<td>36</td>
<td>5.90</td>
<td>212.40</td>
</tr>
<tr>
<td>302002C</td>
<td>End Clamp</td>
<td>SM ENDCOMP B, WH/DW, CLR</td>
<td>48</td>
<td>48</td>
<td>2.22</td>
<td>106.56</td>
</tr>
<tr>
<td>302101C</td>
<td>Mid Clamp</td>
<td>SM MID CLAMP,ARBKD,HDW,CLR</td>
<td>210</td>
<td>210</td>
<td>2.48</td>
<td>520.80</td>
</tr>
<tr>
<td>004601G</td>
<td>Roof Attachment</td>
<td>STANDOFF 6” FLATTOP STL</td>
<td>120</td>
<td>120</td>
<td>19.69</td>
<td>2362.80</td>
</tr>
<tr>
<td>304000C</td>
<td>Roof Attachment</td>
<td>SM L-FOOT SERRATED WH/DW, CLR</td>
<td>120</td>
<td>120</td>
<td>4.34</td>
<td>520.80</td>
</tr>
<tr>
<td>004014C</td>
<td>Flashing</td>
<td>FLASHING OATEY 11840 GLYLIME</td>
<td>120</td>
<td>120</td>
<td>6.40</td>
<td>768.00</td>
</tr>
<tr>
<td>008002S</td>
<td>Grounding Lug</td>
<td>GROUND WEERLUG #1</td>
<td>84</td>
<td>84</td>
<td>10.00</td>
<td>840.00</td>
</tr>
<tr>
<td>508001S</td>
<td>UGC Clip</td>
<td>SM GROUND CLIP #1, UGC-1 SS</td>
<td>120</td>
<td>120</td>
<td>2.29</td>
<td>274.80</td>
</tr>
</tbody>
</table>

**BASE SYSTEM**
$6215.76
$0.22 per watt

**ACCESSORIES**
$4766.40
$0.16 per watt

**TOTAL PRICE**
$10982.16
$0.38 per watt

Figure 33. Unirac quote for building h.
Appendix F: Wire Size Calculations
Table 6 displays how the sizes of wires correspond to the different amps ranges. The different solar components max amperage was used to calculate the size of wire needed.

Table 6. Size of wires.

<table>
<thead>
<tr>
<th>Wire Use</th>
<th>Rated Amperity</th>
<th>Wire Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-voltage Lighting and Lamp Cords</td>
<td>10 Amps</td>
<td>18 Gauge</td>
</tr>
<tr>
<td>Extension Cords</td>
<td>13 Amps</td>
<td>16 Gauge</td>
</tr>
<tr>
<td>Light Fixtures, Lamps, Lighting Runs</td>
<td>15 Amps</td>
<td>14 Gauge</td>
</tr>
<tr>
<td>Receptacles, 110-volt Air Conditioners, Sump Pumps, Kitchen Appliances</td>
<td>20 Amps</td>
<td>12 Gauge</td>
</tr>
<tr>
<td>Electric Clothes Dryers, 220-volt Window Air Conditioners, Built-in Ovens, Electric Water Heaters</td>
<td>30 Amps</td>
<td>10 Gauge</td>
</tr>
<tr>
<td>Cook Taps</td>
<td>45 Amps</td>
<td>8 Gauge</td>
</tr>
<tr>
<td>Electric Furnaces, Large Electric Heaters</td>
<td>60 Amps</td>
<td>6 Gauge</td>
</tr>
<tr>
<td>Electric Furnaces, Large Electric Water Heaters, Sub Panels</td>
<td>80 Amps</td>
<td>4 Gauge</td>
</tr>
<tr>
<td>Service Panels, Sub Panels</td>
<td>100 Amps</td>
<td>2 Gauge</td>
</tr>
<tr>
<td>Service Entrance</td>
<td>150 Amps</td>
<td>1/0 Gauge</td>
</tr>
<tr>
<td>Service Entrance</td>
<td>200 Amps</td>
<td>2/0 Gauge</td>
</tr>
</tbody>
</table>

Table 7 shows that the max amperage of the Soletria Renewables 75KW 480 VAC inverter is 90 amps. The 2 AWG wire will support 90 amps and has been selected to connect the inverter to the grid control room.

Table 7. Soletria renewables amperage specifications inverter.

<table>
<thead>
<tr>
<th>Cont. Output Power (280/240/480/600)</th>
<th>50 kW</th>
<th>60 kW</th>
<th>75 kW</th>
<th>85 kW</th>
<th>100 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Output Current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(280 VAC)</td>
<td>139 A</td>
<td>167 A</td>
<td>208 A</td>
<td>236 A</td>
<td>278 A</td>
</tr>
<tr>
<td>(240 VAC)</td>
<td>120 A</td>
<td>145 A</td>
<td>180 A</td>
<td>205 A</td>
<td>241 A</td>
</tr>
<tr>
<td>(480 VAC)</td>
<td>60 A</td>
<td>72 A</td>
<td>90 A</td>
<td>102 A</td>
<td>120 A</td>
</tr>
<tr>
<td>(600 VAC)</td>
<td>48 A</td>
<td>58 A</td>
<td>72 A</td>
<td>82 A</td>
<td>96 A</td>
</tr>
</tbody>
</table>
Table 8 shows the max amperage of the Soletria Renewables Diacom 4 8 and 12 fuse combiner box. An 8 AWG wire was selected to connect the module to the combiner box because the input range was 14-6AWG. A 6 AWG wire was selected to hook up the combiner and the inverter because output wire required was a 6 AWG.

Table 8. Soletria renewables amperage specifications combiner.

<table>
<thead>
<tr>
<th>NUMBER OF FUSED INPUTS</th>
<th>8</th>
<th>12</th>
<th>15</th>
<th>20</th>
<th>24LT</th>
<th>24</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Wire Range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-6 AWG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Wire Range</td>
<td>6 AWG-350 kcmil</td>
<td>(2) 6 AWG-(2) 300 kcmil</td>
<td>(2) 4 AWG-(2) 600 kcmil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G: Roof Pitches
Figure 34 illustrates the pitch of the chicken lay houses A, B, C, E, G and H, which was 3/12. The degree pitch of a 3/12 roof is 14 degrees, which is shown in table 1 located in the literature review.

Figure 34. Pitch of chicken lay houses a, b, c, e, g and h.

Figure 35 illustrates the pitch of chicken lay house F which was 6/12. The degree pitch of a 6/12 roof is 26.6 degrees which is shown in table 1 located in the literature review.
Figure 35. Pitch of chicken house f.
Appendix H: Clean Energy Estimator Calculator Calculations
Figure 36 displays the estimated payback of the system for a taxable entity. Due to tax breaks, the payback of the system increased from 13.1 years to 9.3 years. The 9.3 year payback is outlined in red.
Figure 37 illustrates the size of the system needed to cover the entire electricity bill at the poultry unit. This system is an 180KW system and produces 282,187 annual kWh which is very close to the 290,535 kWh that the poultry unit used in 2011-2012. The size of the system is bordered in red along with the kWh produced.

Figure 37. Size of system needed to cover the poultry unit.
Appendix I: CSI EPBB Calculator Optimal Tilt Calculations
Figure 38 displays the optimal tilt for modules at the designed system proposed tilt which is 11 degrees. The CPI EPBB calculator determined the optimal tilt.