60Watt Embedded Solar Cell Umbrella

by

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Senior Project

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I would like to acknowledge my adviser for this project Pr. Dale Dolan who provided great help with troubleshooting various problems throughout the course of the project.

I would also like to thank Ron Murray inspiring me to pursue the idea of using solar energy to power electronic devices while outdoors.

Finally, I would like to thank Dan Malone for supplying two multimeters for this project. The multimeters provide for real time information on how effectively the panels are working and quantify to others how well the panels are charging the battery.
Abstract

The solar powered beach umbrella is designed to power the outdoor use of direct current ("DC") electronic devices where there are no electrical outlets available. It thereby replaces or augments the use of individual batters within those devices.

The project calls for the operation of a 60W (12V, 5A) appliance to run with minimal intermittence. The project involves attaching solar cells to an umbrella, and subsequently, it requires protecting the fragile solar cells from even slight impacts which would otherwise damage them.

The use of an umbrella as the base for the solar panels has several advantages: it is readily available for purchase; it provides ample surface area for mounting the panels, its design (and indeed its intended use) allows for easy exposure to sunlight, and it is conveniently portable. The solar powered umbrella has the ancillary benefit of providing shade for the user, making the outdoor experience more enjoyable while saving batteries.

Additional solar collection capacity may be added as the need arises and supplies are available. Extra capacity could be used to power more devices from the same umbrella or to make a panel to feed into a battery. The latter choice would more closely resemble a traditional use of solar panels.
I. Introduction

Solar power has become prevalent in modern power design as a form of renewable energy. With the global energy crisis, solar power and other forms of green energy will continue to be an ever more important area of electrical engineering. As a power engineer with a focus on sustainable design, I viewed this project as a way to gain practical experience with solar cells, while creating a product that can be useful and even fun.

The completion of this project required some construction skills as well. I was able to work alongside mechanical engineers while I was cutting protective backings and devising plexiglass covers for the solar panels. Mounting the DC electronics required additional work to ensure they are properly orientated and securely held in place.

Ultimately the goal of this project was to gain experience on a real-world project, while meeting deadlines and working through all phases of conception, design, acquisition of materials, production, testing and finally documenting the results.
II. Requirements

The embedded solar panels in the umbrella must charge a 12V battery when sun is available. The battery can then power any appliance (under 400W) via an inverter. The panels are to provide enough power to the battery to either charge the battery while in use or to prolong its longevity.

The solar panels must be removable and interchangeable in order to facilitate repairs. In addition, this allows the solar panels to be removed for long-term storage or to be used for other applications.

The panels must be mounted to the umbrella in a manner such that they do not fall off and break or cause injury to anyone under or nearby the umbrella.

The panels will incorporate multimeters which provide real time information about the amount of charge being generated by the panels, and discharged by the battery to the load(s).
III. Design

• Proposed Sub-assemblies

This section will provide a brief overview of requirements of each subassembly. Each subassembly has its own milestones and challenges. Integration of the subassemblies will have overlapping timelines which be visible in the attached calendar.

The proposed sub-assemblies can be divided into the following two categories:

• Fabricating protective solar backing and protective covering
• Embedding into the umbrella

• Fabricating protective solar backing

Creating the backing and protective covering for the solar panels is perhaps the most time consuming part of the project. The design calls for a 7-inch by 18-inch pegboard wood backing. The panels are to be wired using the pegboard then covered by a piece of Plexiglas of equal size. Cutting both the wood and Plexiglas requires a table saw, power drill, drill bits, screws and screwdriver. One significant obstacle was the limited availability (Saturday only) of the mechanical engineering facilities. The 7-inch by 18-inch boards hold 6 cells or 2.5 V, 9W rated.

The solar cells themselves are 3 inches by 5 inches.
Initially the panels were wired to fix 6 units per block, but this idea was later scrapped. Here are pictures from the first prototype.

Each square of graph paper represents a 1” by 1”. Cells are 3” by 5”. Wood pegboard is 7” by 18”. Panels are also covered by 7” by 18” Plexiglass.
Later a much improved 5 cell unit was implemented. The design is superior in durability, ease of use, and a better wiring scheme. (See Appendix D)

- **Embedding the solar panels into umbrella**

Embedding the solar panels into the umbrella presented several problems. The first of which was ensuring the panels would be hit by the sunlight with the maximum incident angle.

The plan was to purchase Velcro and glue it to the back of each panel. The other side to the Velcro had to be stitched into the fabric of the umbrella. Because the weight to surface area
of the panels is relatively light, the panels could be held in place, even while the umbrella was being opened and closed.

With an umbrella with a 10-foot diagonal measurement, there was enough room to comfortably accommodate the solar panels. Twenty of my designed panels (216 W rated) would cover half of the umbrella’s upper surface.

The Velcro strips were hand stitched to the fabric of the umbrella. The corresponding strips of Velcro were then the glued to the pegboard backing of the solar panels with a wood adhesive.
The umbrella is able to open and close while the panels are mounted on top without damaging the solar panels or impairing overall functionality. Disassembling the panels and removing them from the umbrella or reassembling the panels onto the umbrella requires about 3 to 5 minutes. If the umbrella is not being used on a daily basis, it is recommended that the panels be removed for secure storage.
IV. Development and Construction

After the general framework of the design was completed, the next step was to develop and construct the essential parts necessary for the project to generate solar energy successfully.

The development and construction procedures are broken down into the following categories:

- Creating detachable banana cables to connect panels together
- Selecting a charge controller
- Building a base to support the charge controller
- Securing the inverter
- Battery Protection

Creating detachable banana cables to connect panels together

The layout of the panels on the umbrella was orientated in such a way as to minimize wires running from panel to panel. The solar panels were arranged from positive to negative and wired together using fabricated banana leads.

Each of the solar panels has been soldered so that there are two tabs hanging from each end. The attached tabs were then soldered, crimped, and electrically taped to form a solid connection from the banana plug to the tabbing wire.
Selecting a charge controller

The Prostar-15 was purchased for this project because it has been successfully implemented on other Cal Poly projects. Built specifically for solar panels, the Prostar-15 will take input voltages from 12-24V and output 12V to charge the battery. In addition, the Prostar-15 charge controller has a built in load output designed to be wired to an inverter.

Building a base to support the charge controller

One of the requirements of the Prostar-15 charge controller is its need to be mounted vertically and securely. Therefore, the most obvious place to locate the charge controller was the base pole of the umbrella. The charge controller requires that the length of wire from the panels to the module must not exceed 15 feet. The location of the charge controller at the base of the umbrella pole easily met that requirement.

1) First, Velcro was zip-tied to the pole to allow for a long stable connection between the wood and the umbrella pole.

Figure 9: Umbrella pole with Velcro attached
2) Next the charge Controller was mounted to a pre-cut piece of wood, held together with wood screws.

![Figure 10: Umbrella pole with attached charge controller](image)

3) Finally the two are secured together. The photograph shows the close proximity to the battery and panels. The inverter will be mounted to the battery case and held with Velcro as showed.

**Securing the inverter**

With the charge controller feeding power to the battery, the inverter will be mounted to the battery case. This allows for alternating current ("AC") appliances or 12V DC appliances to be plugged into the same location. The advantage of plugging the appliance directly into the battery is increased efficiency. The inverter chosen for this project is a 400W two outlet design, with maximum power point tracking and built in safety fuses. While the inverter does have a maximum power point tracker, there are losses when converting from DC panels to AC inverter, then back to a DC electric motor.
Figure 11: Inverter mounted to battery

Battery protection

The most important safety aspect to the project is the protecting of the lead acid battery. Similar to a car battery, the battery is powerful and contains many harmful chemicals. A battery case was purchased to surround and protect the unit. The case also serves to protect against accidental shorts by the general user who may not understand the fundamentals of electricity. Holes were then drilled into the case to allow the wiring to and from the battery to go through the case while keeping the case securely closed.

Figure 12: Inside the battery case
V. Testing Procedures

Each of the individual panels was tested to produce a power curve. The power curve will be created using different resister value loads to find a maximum power point load. For a simulated short circuit, the following 5Amp shunt will be used.

![Figure 13: 5 Amp Shunt](image)

The significance of the 5 Amp Shunt is to provide a measureable short circuit. In other words the shunt is simply a 10mΩ resistor with a limit of 5 amps allowable. The solar cells are rated at 3.6 A rated short circuit.

This shunt was used instead of an ammeter for measuring the panel currents because of its small resistance. The ammeters available measured an internal resistance of approximately 2Ω. Because 2Ω is about equal the load resistance for maximum power draw, extremely inaccurate data would have resulted. Other measures were taken to improve the accuracy of measurements such as 4-wire resistance measuring and use of parallel leads.

After the power curve was recorded, the panels were then tested under no load conditions and under the 60W load to measure how quickly the battery would charge.
VI. Integration and Test Results

Each 5 panel array measures an Open circuit Voltage at 2.6 Volts.

With a 5 A shunt rated at 10mΩ, a short circuit current was measured to be the voltage across the panels divided by the 10mΩ resistance.

\[ I_{sc} = \frac{V_{sc}}{10m\Omega} = \frac{40mV}{10m\Omega} = 4A \]

This value was slightly higher than the rated short circuit current from the panel distributor.

With all 25 panels wired in series, the measured current delivered to the battery ranged from 1-1.5 Amps. At the 13 Volts the battery was stable and the power delivered to the battery while under a rated load of 60W is from 13 to 20 W.

That is, while the battery is driving a 60W load (cooler) is being charged at 13 to 20 W.

<table>
<thead>
<tr>
<th>Ω</th>
<th>V</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>15.7</td>
<td>0.02</td>
</tr>
<tr>
<td>100</td>
<td>15.7</td>
<td>0.16</td>
</tr>
<tr>
<td>50</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>14.4</td>
<td>1.44</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
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<td>5.6</td>
<td>3.2</td>
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<td>0.5</td>
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<tr>
<td>0.333</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>0.01</td>
<td>0.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Table 1: Voltage and Current characteristics under different loads per panel
While it was tough to obtain many reliable data points between .5 and 2 ohms for the power curve, it can be seen from the curve that the maximum power point is around 10 Volts. Although the battery remains at 12 Volts, this is sufficiently close to the optimal point for the given solar panels.

\[ V_{\text{panelOC}} = 2.6V \]

\[ V_{\text{totalpanel}} = 15.6V \]

\[ I_{\text{Panels}} = 2.1A \]

The current shown represents all the panels in series connected to the battery with no load on the battery.

The current is lower when 6 panels are connected in series than the current of each individual panel because the current is equal to that of the lowest panel output. For this reason, the system was designed so that all panels are located in a concentrated area and face the same direction in order to avoid shading. The panel outputting the lowest current will drag the other panels down to its lowest current output, thereby lowering the total power output.
\[ P_{\text{total panel}} = V_{\text{total panel}} \times I_{\text{panels}} = 32.8 \text{W} \]

Rated power of single cell = 1.8W

This value was obtained from the manufacturer

Total Rated power of panels = 54W

Efficiency of panels = 65%

The following numbers were calculated on a sunny 70° April day.

Flow of power and initial troubleshooting

In the first round of testing, the 5 solar panels were used which produced approximately 12V. The battery measured approximately 13 volts. When the two were connected via the charge controller a negative current was measured. This happened because the higher potential of the battery was actually supplying power to the solar panels, instead of the other way around.

The problem was corrected by adding panels to bump up the voltage to over 15 volts. This forces power to flow into the battery as planned. The charge controller supports voltages up to 24V, so that additional panels can be easily added, if needed. Should more than 24V of panels be required, the panels would have to be wired in parallel.

Longevity

The sealed lead-acid battery is rated to 35 Amp hours. This means that the cooler which draws 5 Amps should last for 7 hours before the battery is drained. Because the solar panels are continuously charging the battery as it is being drained the life of the battery is significantly prolonged.
According to the test results, the solar configuration as tested supplied around 32.8W of power. This meant that the battery would slowly drain because the panels did not keep up with the load. The battery should theoretically last 56% longer with the panels functioning properly, thus in effect increasing the battery life to 10.75 hours.
VII. Conclusion

The project was designed to provide power to different electronic devices in an outdoor setting in a reliable and safe manner. The following points summarize the design aspects of the project and the results that were achieved:

1) **Use of an umbrella for a base**

The choice of a large beach umbrella to support the solar panels was practical, efficient and worked well.

2) **Design and function of the protective covering for the solar cells**

The design of a rigid pegboard backing and Plexiglas protective covering secured by screws to encase the solar panels was time-consuming but that protective design measure was necessary to maintain the integrity of the extremely fragile solar panels. As designed the protective case kept the solar panels from breaking during the process of opening and closing the umbrella and other impacts.

3) **Attaching the solar panels to the umbrella**

As designed for the project, the use of Velcro strips to attach the solar panels to the umbrella was a relatively simple way of mounting the panels securely. The use of Velcro also permits the panels to be attached and removed separately. That greatly simplifies repairs and removal for long-term storage of the solar panels. The Velcro also made it possible to remove the solar panels for use in other potential applications. This is a significant advantage because of the relatively high cost of the panels. The ability to detach and use the panels for other purposes is one way to maximize the benefit of the most expensive parts of the solar umbrella.
4) **Wiring the solar panels**

The solar panels were designed to be wired so that they would be interchangeable in order to simplify repair and replacement. The cells themselves were self tabbed and soldered to make secure connections. The tabs were then fed into fabricated banana leads to allow standard equipment and meters to be used easily. The panels were wired to incorporate two ammeters which are easy to read and provide interesting and useful information about the panel for added flare.

5) **Connecting the components**

The block diagram used for the project can be viewed from Appendix F. The panels are wired in series and fed into a charge controller. The charge controller regulates the fluctuations from the panels and outputs a constant 12V to the battery. The battery is connected to an inverted where any subsequent devices can be powered (under 400W)

6) **To provide power to the battery to either charge the battery while in use or to prolong its longevity.**

From the equations provided, it is clear that at a 60% efficiency rating of the panels, the umbrella is unable to completely power a 60W appliance. It does however charge the battery when not in use and significantly prolongs the longevity of the battery when attached to a 60W load.

7) **The solar panels must be interchangeable to make any repairs simple. In addition, this allows the solar panels to be used in other situations allowing for more uses.**

By designing several smaller panels with interchangeable cables, held together by Velcro, the panels are completely independent of one another and allow for simple repairs. This was an extremely important goal because of the relatively high cost of the panels, the ability to use them in other services was paramount.
8) The panels will incorporate multimeters which will provide real time information about the amount of charge being generated by the panels, and dissipated by the battery to the load(s).

The two multimeters are secured from the panels to the charge controller and from the charge controller to the battery to provide real time information on the amount of current being supplied from the panels as well as the amount of current that is being sunk by the battery. The multimeters make it possible to explain how much energy was being generated and used, thereby making it possible to quantify and interpret the results and effectiveness of the solar panels. I was able to show that while the umbrella as configured could not completely generate enough power to run a 60W appliance (a cooler), it did deliver enough energy to the battery to significantly extend the longevity of the battery, powering the cooler for over 50% longer than the battery alone.

Closing thoughts

Working on this project by myself allowed for several lessons which made this project a valuable learning experience. Controlling costs and documenting the project were much easier as I was required to understand the project from every angle. This advantage is most helpful looking forward as I look to apply for jobs in the renewable energies sector of industry in understanding the value of making a GANTT chart and trying to stick to deadlines.

While I do feel I would be able to replicate this project in a tenth the time it took the first run through, the only way to reach that level of understanding is to physically do the work. I am content I was able to get the panels to successfully work and finally I am grateful for the experience of working on a large scale project and having to execute all aspects of the project from start to finish by myself.
VIII. References

Florida Solar Energy Center article on manufacturing solar panels. Site visited May 2011.

Knier, Gil.
Article on how solar cells work using the photoelectric effect. Site visited May 2011.

Article on how solar cells are made from silicon to mounted arrays. Site visited May 2011.

http://www.scu.edu/ethics/publications/ethicalperspectives/raphael.html
IX. Sustainability

The entire basis for my senior project and subsequently my college education is the proliferation of the study of sustainable energy. I feel that is incumbent upon ourselves as engineers to provide real solutions for global problems for the greater good.

Electric energy is undoubtedly one of the most useful tools society has in order to prosper. As technology continues to improve, the amount of energy used by the average person will continue to grow. This is great news for a number of reasons, but rather than dive into the benefits of electricity for people the discussion for engineers veers toward discovering ways to provide an increased amount of energy in a clean and affordable fashion.

Solar power is but the tip of the iceberg with regards to renewable energies. I chose this project because it provided me with experience from start to finish on the design and implementation of solar panels for a real world application. While many other solutions to the worlds energy crisis exist reducing emissions and dependencies on foreign countries are the two most important reasons.

The sun umbrella project taught me that producing power can have many complications. First, that in real life you will most likely not get the efficiency you seek from your products. Secondly, natural factors such as daylight hours, shading, solar angle, temperature of the panels, stability of connections, gauge of wire, differing power draw of loads all have significant impact on the power output of the system.

While solar power today does not provide a sizable portion of our nation’s energy it is part of the solution. The need to generate vast amounts of power will not have one solution but will require many and will have to adapt to the specific location of need. While this project is
rooted in idea of creating sustainable energy solutions, the knowledge obtained from the entirety of the project will hopefully lead to future sustainable efforts.
# Appendix A: Parts and Costs

<table>
<thead>
<tr>
<th>Part</th>
<th>Cost</th>
<th>Source</th>
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<tbody>
<tr>
<td>Sheet of pegboard wood</td>
<td>$16.45</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>36x48” sheet of Plexiglas</td>
<td>$32.25</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>Silicone Caulk as adhesive</td>
<td>$5.97</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>Screws</td>
<td>$3.00</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>108 solar cells (many left over)</td>
<td>$162.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>12V DC cooler</td>
<td>$50.65</td>
<td>(ebay)</td>
</tr>
<tr>
<td>Banana to grabber leads</td>
<td>$4.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>2” by 30’ Velcro</td>
<td>$12.00</td>
<td>(ebay)</td>
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<tr>
<td>10’ diameter umbrella</td>
<td>$60.00</td>
<td>(ebay)</td>
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<tr>
<td>Voltage Regulator</td>
<td>$9.99</td>
<td>(ebay)</td>
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<tr>
<td>14 gauge wire</td>
<td>$9.00</td>
<td>(ebay)</td>
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<tr>
<td>Umbrella base</td>
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<td>(Home Depot)</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$383.74</strong></td>
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## Additional costs for solar panel charger

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<thead>
<tr>
<th>Part</th>
<th>Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
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<td>Lead-Acid Battery</td>
<td>$86.00</td>
<td>(Battery Store SLO)</td>
</tr>
<tr>
<td>Charge Controller</td>
<td>$65.00</td>
<td>(Infinique)</td>
</tr>
<tr>
<td>300 W inverter</td>
<td>$30.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$181.00</strong></td>
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Appendix B: Schedule – Time Estimates

### Solar Umbrella GANTT chart

<table>
<thead>
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<th>Task</th>
<th>Start Date</th>
<th>Duration(days)</th>
<th>End Date</th>
</tr>
</thead>
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<td>Optimistic Final test date with VR</td>
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<td>1</td>
<td>3/19/2011</td>
</tr>
<tr>
<td>Go over required paperwork for SP</td>
<td>4/7/2011</td>
<td>5</td>
<td>4/12/2011</td>
</tr>
</tbody>
</table>

(Excell data used to make GANTT chart)
Appendix C: Wiring

- **Wiring the panels**

The design for wiring the panels is paramount. Wiring questions include what series parallel combination to use, as well as the physical wiring on the umbrella.

I have decided to wire all the panels in series and then send the total voltage into a voltage regulator. With the conservation of wattage, when 60 Watts of panels are wired up, the converter should still supply 60 watts of power.

The following pictures shows how the initial 6 cell panels were wired. Notice the unneeded complexity of the wiring scheme. This design was later scrapped for the more simpler 5 cell approach.

![Figure 14: Wiring of the 6 cell module in series.](image)

Notes on Figure 14:
- Birds eye view with solid black lines visible and dotted lines under cells
- Lines represent tabs on cell
- (* dots) represent start of tab (x) represents end
- Cells 1-6 measured in series in order
- Total voltage = tabs from 6 node to (x)’s under cell 1.

**Problems with initial wiring:**

The 6 cell panels were not a sufficient design for two main reasons. First, the half the panels were held together with a single tab while the other half were held together with 2 tabs from each
cell. Secondly, the terminal positive and negative leads were on opposite corners of the panel. This causes for uncomfortable wiring between cells when attached to the umbrella.

The improved and used schematic is as follows.

![Figure 15: Wiring for the 5 cell design](image)

The second design is much more stable and reliable. It is also more common in industry in solar panels today. The new panels have not experienced any contact issues to this date.
Appendix D: Hardware Configuration

Figure 16: Basic block diagram for the embedded panels

In addition to the inverter providing $120\text{V}_{\text{rms}}$, the battery can be directly connected to providing $13\text{V}_{\text{dc}}$.

In this schematic each of the panels as drawn consists of 5 cells which measure to approx. 2.6V. The panels are then all wired in series.
APPENDIX E:
ANALYSIS OF SENIOR PROJECT DESIGN

Please provide the following information regarding your Senior Project and submit to your advisor along with your final report. Attach additional sheets, for your response to the questions below.

**Project Title:**

**Student’s Name: Student’s Signature:**

**Advisor’s Name: Advisor’s Initials: Date:**

- **Summary of Functional Requirements**
  Describe the overall capabilities or functions of your project or design. Describe what your project does. (Do not describe how you designed it).

- **Primary Constraints**
  Describe significant challenges or difficulties associated with your project or implementation. For example, what were limiting factors, or other issues that impacted your approach? What made your project difficult? What parameters or specifications limited your options or directed your approach?

- **Economic**
  - Original estimated cost of component parts (as of the start of your project).
  - Actual final cost of component parts (at the end of your project)
  - *Attach a final bill of materials for all components.*
  - Additional equipment costs (any equipment needed for development?)
  - Original estimated development time (as of the start of your project)
  - Actual development time (at the end of your project)
  - If manufactured on a commercial basis:
    - Estimated number of devices to be sold per year
    - Estimated manufacturing cost for each device
    - Estimated purchase price for each device
    - Estimated profit per year
    - Estimated cost for user to operate device, per unit time (specify time interval)

- **Environmental**
  Describe any environmental impact associated with manufacturing or use.

- **Manufacturability**
  Describe any issues or challenges associated with manufacturing.

- **Sustainability**
  Describe any issues or challenges associated with maintaining the completed device, or system.
  - Describe how the project impacts the sustainable use of resources.
  - Describe any upgrades that would improve the design of the project.
  - Describe any issues or challenges associated with upgrading the design.

- **Ethical**
  - Describe ethical implications relating to the design, manufacture, use, or misuse of the project.

- **Health and Safety**
  - Describe any health and safety concerns associated with design, manufacture or use of the project.

- **Social and Political**
  - Describe any social and political concerns associated with design, manufacture or use.

- **Development**
  - Describe any new tools or techniques, used for either development or analysis that you learned independently during the course of your project.
Summary of Functional Requirements

The embedded solar cell umbrella will charge a 12V battery when no load is connected. When the battery has a 60W load attached to it, the solar cells will prolong the battery life by nearly 60% under standard operating conditions. The battery is wired to an inverter to allow the use for AC appliances as well.

Primary Constraints

The limiting factors to the project include the inefficiency of the purchased solar cells and the number of cells reasonably attached to the umbrella before overheating. The project was made difficult because of the inability to test during poor weather conditions. Many hours were also spent to wire the panels and construct the backing.

Economic

While the umbrella is not cheap or reasonable for the average person, it may be practical for hotel or beach resorts that would use the device on a daily basis.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet of pegboard wood:</td>
<td>$16.45</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>36x48&quot; sheet of Plexiglas:</td>
<td>$32.25</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>Silicone Caulk as adhesive:</td>
<td>$5.97</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>Screws:</td>
<td>$3.00</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td>108 solar cells (many left over)</td>
<td>$162.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>12V DC cooler</td>
<td>$50.65</td>
<td>(ebay)</td>
</tr>
<tr>
<td>Banana to grabber leads</td>
<td>$4.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>2&quot; by 30' Velcro</td>
<td>$12.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>10' diameter umbrella</td>
<td>$60.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>Voltage Regulator</td>
<td>$9.99</td>
<td>(ebay)</td>
</tr>
<tr>
<td>14 gauge wire</td>
<td>$9.00</td>
<td>(ebay)</td>
</tr>
<tr>
<td>Umbrella base</td>
<td>$18.43</td>
<td>(Home Depot)</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$383.74</strong></td>
<td></td>
</tr>
</tbody>
</table>
### Additional costs for solar panel charger

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead-Acid Battery</td>
<td>$86.00</td>
<td>(Battery Store SLO)</td>
</tr>
<tr>
<td>Charge Controller</td>
<td>$65.00</td>
<td>(Infinique)</td>
</tr>
<tr>
<td>300 W inverter</td>
<td>$30.00</td>
<td>(ebay)</td>
</tr>
</tbody>
</table>

**Subtotal** $181.00

The development of this project spanned over 4 months. The first month was primarily research and ordering parts. The second month was fabricating the cells. The third month was getting the panels to work. The final month was testing and improvements. The written report was done afterwards, but weekly progress reports were created throughout the course of the project and many pictures and data came from them.

**If manufactured on a commercial basis**

It is hard to estimate how many of the solar umbrellas would be created. The potential is for hundreds of thousands, but it ultimately depends on efficiency and cost of product.

Manufacturing the product can be made much cheaper because many of the part were left over, and all bought at retail price. Also, many of the products used can be applied for other applications. The umbrella itself can be used as a standalone and the panels can charge the battery anywhere. The battery is useful for thousands of applications and provides incredible mobility. Estimating profit per year is also to circumstantial, based on number of uses of the product, location of the owner, cost of electricity in location, cost of the umbrella, and longevity of the product.
Environmental

The environmental effects of using solar panels are under a lot of question. Many people argue that industrial panels can pay for themselves in a few years with nearly all panels come with over 20 year warranties. While saving money from using less grid energy is a benefit there are questions of how much energy they are actually saving.

Solar cells are fabricated by melting a very pure silicon. The silicon is processed from quartz and mined. The silicon is then doped and given an anti-reflective coating\(^1\). The question of how much energy is used in this process is highly debatable. While most people agree the process does require a lot of energy it is hard to quantify. While it is unclear if commercial cells net a gain in energy produced. The panels I have designed will not. The project I have designed is for recreational use and was not intended to alleviate grid pressure.

Manufacturability

The panels would have to hand soldered and would consume the most time. The stitching of Velcro into the umbrella can be done by sewing machine, as well as making appropriate wire lengths. The charge controller would have to be manufactured or purchased elsewhere.

Sustainability

The entire basis for my senior project and subsequently my college education is the proliferation of the study of sustainable energy. I feel that is incumbent upon ourselves as engineers to provide real solutions for global problems for the greater good.

\(^1\)http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/how_cells_made.htm

Florida Solar Energy Center article on manufacturing solar panels. Site visited May 2011.
Electric energy is undoubtedly one of the most useful tools society has in order to prosper. As technology continues to improve, the amount of energy used by the average person will continue to grow. This is great news for a number of reasons, but rather than dive into the benefits of electricity for people the discussion for engineers veers toward discovering ways to provide an increased amount of energy in a clean and affordable fashion.

Solar power is but the tip of the iceberg with regards to renewable energies. I chose this project because it provided me with experience from start to finish on the design and implementation of solar panels for a real world application. While many other solutions to the world’s energy crisis exist reducing emissions and dependencies on foreign countries are the two most important reasons.

The sun umbrella project taught me that producing power can have many complications. First, that in real life you will most likely not get the efficiency you seek from your products. Secondly, natural factors such as daylight hours, shading, solar angle, temperature of the panels, stability of connections, gauge of wire, differing power draw of loads all have significant impact on the power output of the system.

While solar power today does not provide a sizable portion of our nation’s energy it is part of the solution. The need to generate vast amounts of power will not have one solution but will require many and will have to adapt to the specific location of need. While this project is rooted in idea of creating sustainable energy solutions, the knowledge obtained from the entirety of the project will hopefully lead to future sustainable efforts.
Ethical

The ethical issues surrounding solar panels come from the production of the solar cells. Mining the silicon, chemically doping the wafers, and safely disposing of the chemicals are an issue where manufacturers need to be responsible of waste management.

All solar cells will eventually die and how they are disposed is an important issue. One way to dispose of this waste is to sell it to developing countries, who in turn try to harvest what materials they can. This is problematic because proper safety precautions are not observed and children usually end up working the dirty jobs. Underpaid workers, contaminating drinking water and exposure to toxic chemicals are the major issues when recycling any silicon project including solar panels.

Health and Safety

Safety concerns arise from the battery and the possibility of falling panels. The battery is secured with a case which helps keep bare wire covered and prevent people from accidentally shorting out the battery. The panels are held with Velcro and are very sturdy. The panels have remained waived during windy conditions and remain attached while the umbrella is opening or closing.

Social and Political

The project should be seen in an agreeable social light as the umbrella promotes a green energy solution. While the project may provide for lots of entertainment for the users, the political ramifications are negligible.

\[^2\text{http://www.scu.edu/ethics/publications/ethicalperspectives/raphael.html}\]

Development

During the development of the project, a wealth of experience came from working with solar cells. How to physically wire and tab cells, how they react under shading and the importance of making a GANTT chart. I feel the biggest advantage of working alone on a senior project is the ability to follow a project from start to finish and get exposure to all aspects of the development. Manufacturing the panels provided me experience with using a table saw. Wiring the cells was a unique skill set and previously did not know and writing the report was a major role in documenting the process.