Small Scale Irradiance Device

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Concept Generation

Document

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Introduction

The small-scale solar irradiance project aims to create a device which may accurately model the irregularities of solar irradiance on COBar Ranch. Working with the Institute for Sustainable Energy Solutions (ISES) and Dr. Tom Acker at NAU, we strive to design a system that is compatible with the current site, while eliminating current problems. In doing so, many innovative solutions were determined. After evaluation of the potential ideas, we had to eliminate the less beneficial designs through a series of analysis and discussion.

Problem Statement

The current system is inefficient with its use of land, man hours, and produces poor data. The irradiance measuring system is large, semi-permanent, difficult to operate and maintain, and costly. Due to the large area of the current site, much time is required to set up the numerous pyranometers in the system and collect their data. This is an inconvenience for both the operators and land owners, as well as creates unnecessary expense. Our purpose is to design a more efficient system with respect to these issues. Presumably, we will be able to design a smaller scaled system which will collect data even more precisely. While striving to achieve our goal of designing a relatively small, portable solar irradiance measuring system that can accurately quantify variance in solar irradiance over a larger area, we generated various unique designs.

Concept Generation and Selection

Concept Evaluation Methodology:

Individual concepts must be evaluated before progressing through the design process. Providing criteria which either directly support the objectives or are the objectives themselves is the basis for our concept evaluation. Each of the criteria seen in Figure 1 represents a component that is instrumental to achieving our project goal and our determination of its importance represents the weight for that criteria. A few definitions of the criteria are:

- Technical adaptability- the ability of the system to accommodate additional pyranometers, varying their location, and the ease with which this can be accomplished.
- Environmental adaptability- the capability of the system to be assembled and operate as designed on ground surfaces which are uneven and whose soil composition varies from loose sand to dense rock.
- Wildlife- the ability of the system to remain unchanged when in the presence of large animals such as cows.

The criteria are rated on a scale of one to ten for each concept with the scoring system seen in Figure 2. The score received is multiplied by the weight for each criterion to determine the concept’s final score for each individual criterion. The final scores are then summed to achieve a total score which provides a basis to rank concepts.

Figure 1: Weighted Criteria for Concept Analysis.

Criteria	Weight
Technical Adaptability	5%
Setup 30%	
Time Required	7.5%
Tools Required	5%
Ease of Assembly	7.5%
Number of Pieces	2.5%
Environmental Adaptability	7.5%
Durability 15%	
Weather	7.5%
Wildlife	7.5%
Portability 10%	
Packed Size	5%
Weight	5%
Cost 40%	
Initial	24%
Setup	8%
Recurring	8%

Figure 2: Performance Levels for Concept Analysis

Performance Level	Score
Perfect	10
Excellent	9
Very Good	8
Good	7
Satisfactory	6
Adequate	5
Tolerable	4
Poor	3
Very Poor	2
Inadequate	1

Tripod

The tripod concept uses simple tripods with telescoping legs and brackets on the feet to support individual pyranometers in addition to a wireless transfer device. The telescoping legs allow the assembly to be set up level on nearly any reasonable gradient. Brackets on the feet provide a way to anchor the tripod to the earth by using heavy duty stakes in sand and soil, or bolt anchors in compact rock. A small solar panel would power a wireless data transfer device so that site data may be stored and collected on a single, centrally located, data acquisition center.

The tripod concept would be a good solution to the problem because it would be simple to physically add or remove pyranometers, and can set up quickly and easily on nearly any site. Furthermore, the tripod concept would not be a good solution to the problem because it is very expensive and has unique and difficult hardware and software integration issues. Some of these issues include:

- Reliable power is required for each transmission station to ensure data acquisition center receives proper data.
- Enough open channels of wireless transfer for the number of pyranometers is required.
- Accurate time keeping across an array of pyranometers is required.

These were the main benefits and drawbacks to this concept, though many more were considered during its evaluation. The final evaluation can be seen in Figure 3 below.

Figure 3: Tripod Concept Analysis

Criteria	Weight	Raw Score	Final Score
Technical Adaptability	5%	8	0.4
Setup 30%			
Time Required	7.5%	6	0.45
Tools Required	5%	5	0.25
Ease of Assembly	7.5%	7	0.525
Number of Pieces	2.5%	8	0.2
Environmental Adaptability	7.5%	8	0.6
Durability 15%			
Weather	7.5%	6	0.45
Wildlife	7.5%	6	0.45
Portability 10%			
Packed Size	5%	7	0.35
Weight	5%	8	0.4
Cost 40%			
Initial	24%	4	0.96
Setup	8%	6	0.48
Recurring	8%	6	0.48
	Total:	85	5.995

Umbrella

The Umbrella design is similar to a typical umbrella in that a collar slides up and down a main pole to raise and lower the arms. This collar is held by a pin that is placed by the operator. The pyranometers are located at the end of the telescoping arms. These arms are similar to a quick release bike post; lifting a lever will allow the arm to be extended to the desired length and locked in place. The data will be collected by one data acquisition system powered by a photovoltaic panel located on the main shaft. The entire array could be mounted on a tripod that will possibly be weighted or staked into the ground. If the ground conditions permit, the pole could be driven into the earth to provide a secure base.

The Umbrella design allows for reproducible pyranometer array setups despite ground conditions. Unfortunately, this design has limited pyranometer array options in both positioning and number of pyranometers. The telescoping arms have a bound on the maximum length. For instance, a 50 foot long telescoping arm is impractical. To add more pyranometer, the entire system would have to be redesigned to account for more arms. Figure 4 displays the evaluation of the Umbrella concept.

Figure 4: Umbrella Concept Analysis

Criteria	Weight	Raw Score	Final Score
Technical Adaptability	5%	5	.25
Setup 30%			
Time Required	7.5%	5	.375
Tools Required	5%	7	.35
Ease of Assembly	7.5%	6	.45
Number of Pieces	2.5%	7	.175
Environmental Adaptability	7.5%	9	.675
Durability 15%			
Weather	7.5%	5	.375
Wildlife	7.5%	7	.525
Portability 10%			
Packed Size	5%	6	.3
Weight	5%	6	.3
Cost 40%			
Initial	24%	5	1.2
Setup	8%	6	.48
Recurring	8%	8	.68
	Total:	82	6.095

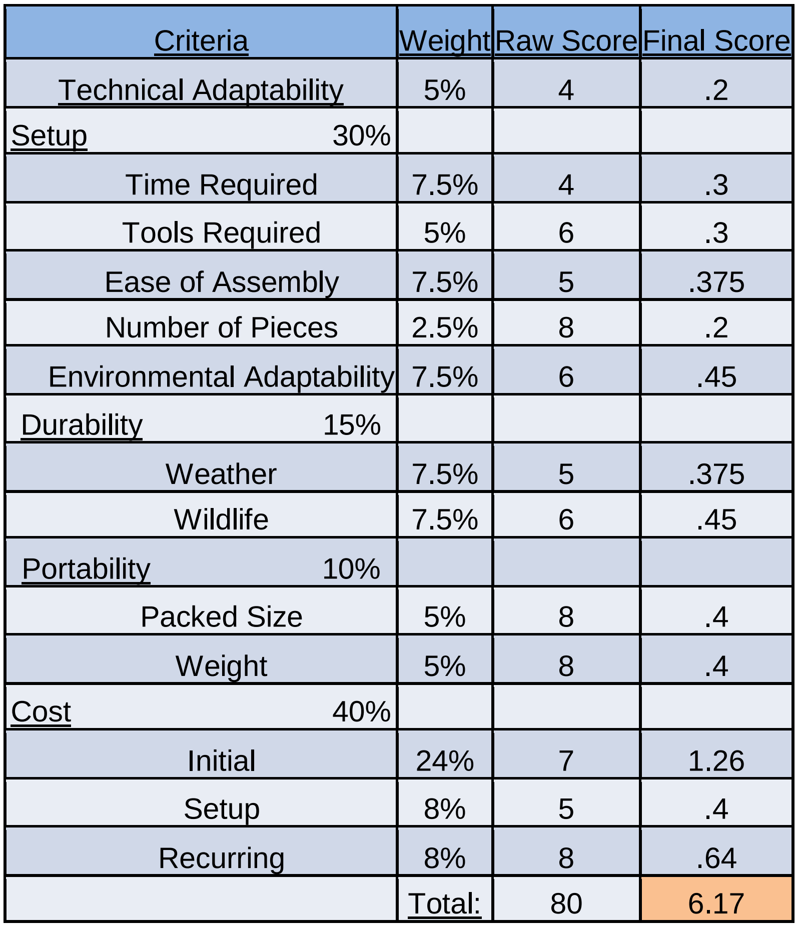
Sky Net

The Sky Net design consists of two poles supported by a tension system and a net with pyranometers attached. The design works by using the three way , or triangulated, tension system to position and hold each pole vertically, and to provide tension to steady the cables of net. The two poles will be separated by 25 feet. Each pole will be approximately eight feet tall.

This height will allow the system to minimize interactions with ground animals like cows that can be found on a site like CObar Ranch. The tensioning system will be anchored with large spikes, or expansion bolts placed in rock depending on the specific attributes of the ground. The tensioning system will be a basic pulley system of adequate reduction, as determined in our engineering analysis.

This system is complex and will require a large amount of time to setup, and will be greatly affected by weather, since regardless of the tension achieved in the system, the net will still move with the wind. Although the setup system will be large, the portability of the system is very high. All of the components such as the support poles, steaks, net, and the rest of the needed hardware and tools can easily be loaded into the bed of a full size pick-up truck. The aspects were evaluated and can be found in Figure 5.

Figure 5: Sky Net Concept Analysis



Criteria	Weight	Raw Score	Final Score
Technical Adaptability	5%	4	.2
Setup 30%			
Time Required	7.5%	4	.3
Tools Required	5%	6	.3
Ease of Assembly	7.5%	5	.375
Number of Pieces	2.5%	8	.2
Environmental Adaptability	7.5%	6	.45
Durability 15%			
Weather	7.5%	5	.375
Wildlife	7.5%	6	.45
Portability 10%			
Packed Size	5%	8	.4
Weight	5%	8	.4
Cost 40%			
Initial	24%	7	1.26
Setup	8%	5	.4
Recurring	8%	8	.64
	Total:	80	6.17

Bucket Post

The bucket post idea consists of a five gallon bucket filled with cement. A sleeve fitting for a tee post will be placed in the cement. This allows for insertion and removal of an approximately five foot tall tee oost. A pyranometer will be attached to the top of the tee post to measure solar irradiance. This design concept will allow for a singular data acquisition unit for multiple pyronometers, or having a data acquisition device for each pyronometer.

This design has several attributes that gave it high scores in the decision matrix. These implement attributes include simple set up with few pieces, and the design is inexpensive to implement. This design also has some negative attributes that gave it low scores in the decision matrix. These aspects include the weight and size of the design, in addition to poor environmental adaptability. For instance, the design is heavy, very large, and requires level ground for a proper set up. The full decision matrix is shown in Figure 6 below.

Figure 6: Bucket Post Concept Analysis

Criteria	Weight	Raw Score	Final Score
Technical Adaptability	5%	8	.4
Setup 30%			
Time Required	7.5%	4	.3
Tools Required	5%	8	.4
Ease of Assembly	7.5%	7	.525
Number of Pieces	2.5%	9	.225
Environmental Adaptability	7.5%	3	.225
Durability 15%			
Weather	7.5%	8	.6
Wildlife	7.5%	5	.375
Portability 10%			
Packed Size	5%	3	.15
Weight	5%	2	.1
Cost 40%			
Initial	24%	8	1.92
Setup	8%	6	.48
Recurring	8%	6	.48
	Total:	77	6.18

Conclusion

Final Concept Analysis:

For the concepts analyzed, the bucket post concept had the highest total score, though all four total scores were very similar. This indicates a deeper understanding of the intricacies of the project is required, in addition to adapting individual concept components where they will benefit the system. For the near future, all designs will be continually analyzed and modified for improvement towards the project goal until a clear winner is determined. Figure 7 below presents the final scores for each design.

Concept	**Tripod**	**Umbrella**	**Sky Net**	**Bucket Post**
Total Weighted Score	**5.995**	**6.095**	**6.17**	**6.18**

Figure 7: Concept total score comparison

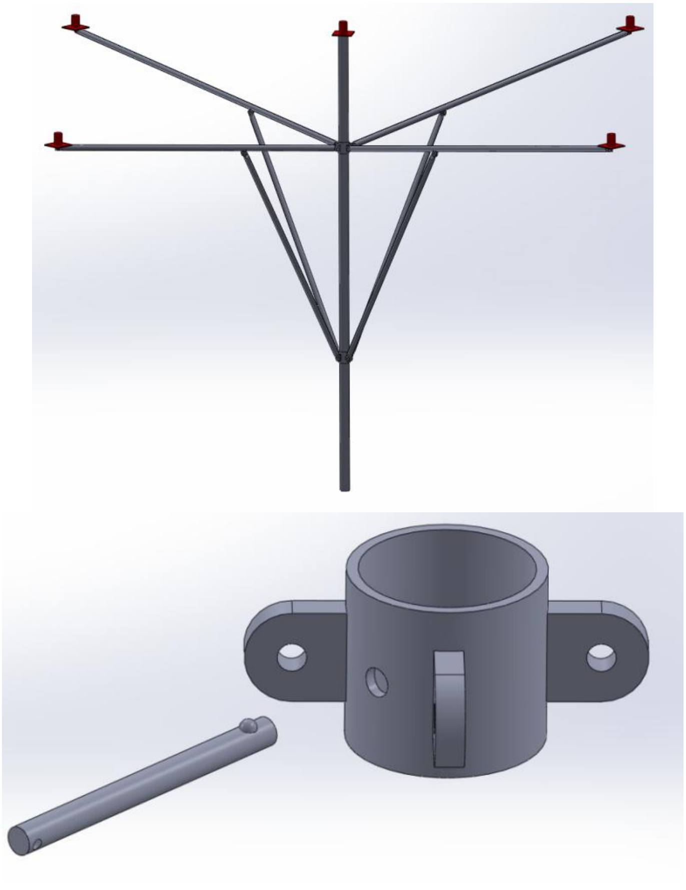
Next Step

In order to decide which design concept to go forward with, we must investigate further into the pyronometers and the data collected. Our final physical design will be very data driven; we will perform research to determine the optimal number and arrangement of pyranometers. Once a more strict land area is determined, our ultimate design can be chosen. A timeline of this plan can be found in Appendix B. In addition, schematics of the four concepts can be found in Appendix A.

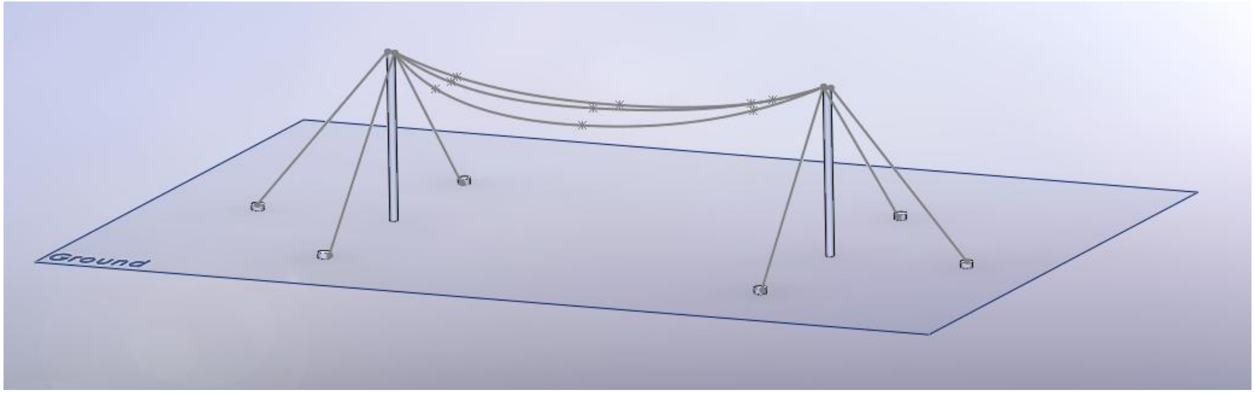
Appendix A: Design Diagrams

Tripod

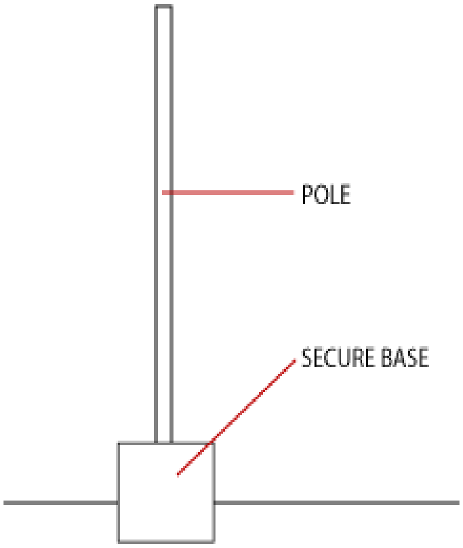
Umbrella



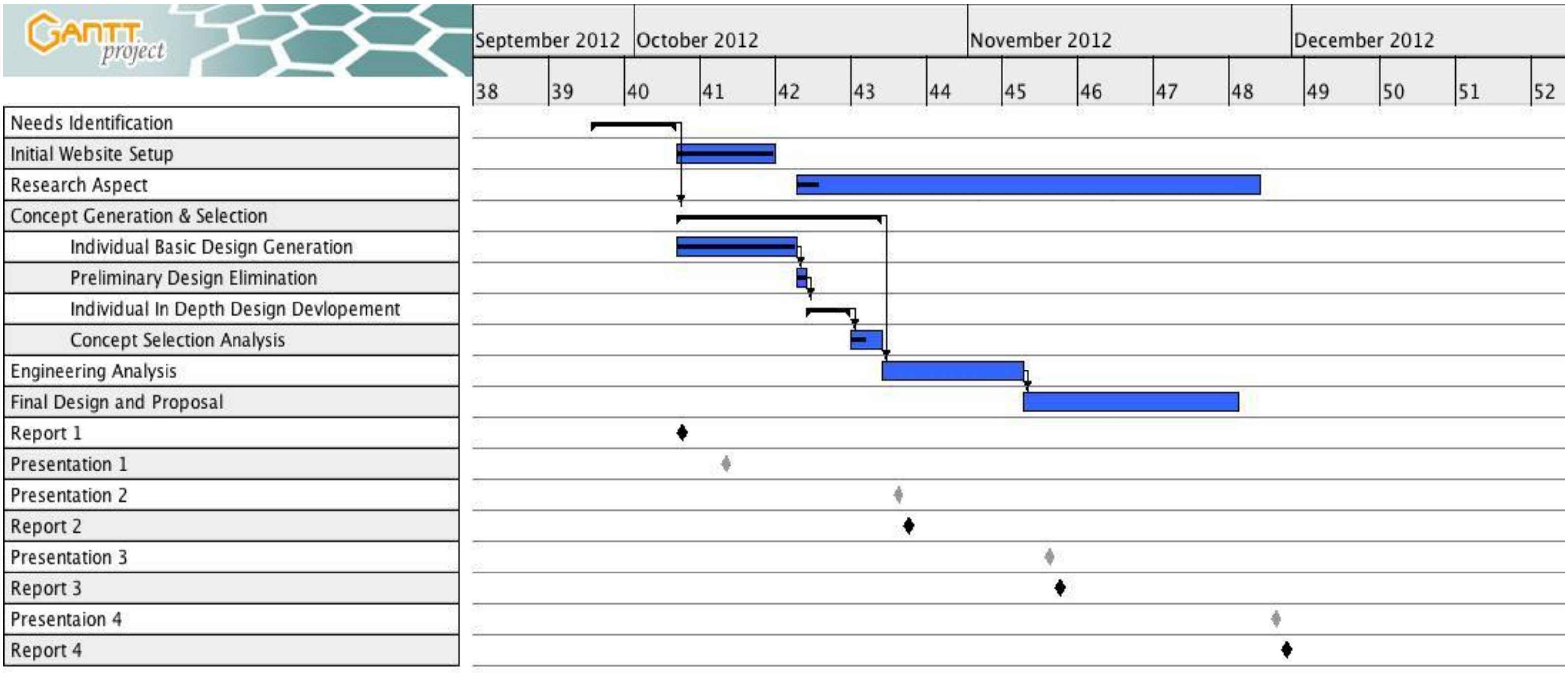
Sky Net



Bucket Post



Appendix B: Timeline (Gantt Chart)



Resources

1. Twidell, John, and Weir, Tony. *Renewable Energy Resources*. New York: Taylor and Francis Group, 2006.
2. www.envcoglobal.com/taxonomy/term/685/0
3. http://www.animatedlighting.com/learn/wiretree.asp