

FAMU-FSU College of Engineering

Department of Electrical and Computer Engineering

**Solar Thermal Generator**

Project Plan and Product Specification Report

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Table of Contents

[Table of Figures - 1 -](#_Toc465199557)

[Table of Tables - 2 -](#_Toc465199558)

[Abstract - 3 -](#_Toc465199559)

[Acknowledgments - 4 -](#_Toc465199560)

[1. Introduction - 5 -](#_Toc465199561)

[2. Background and Research - 6 -](#_Toc465199562)

[1.1 Scope - 7 -](#_Toc465199563)

[1.2 Needs Assessment - 8 -](#_Toc465199564)

[1.3 Project Constraints - 8 -](#_Toc465199565)

[3. Deliverables - 9 -](#_Toc465199566)

[1.1 Work Breakdown Structure - 9 -](#_Toc465199567)

[1.2 Gantt Chart - 11 -](#_Toc465199568)

[1.3 Assign Resources - 12 -](#_Toc465199569)

[4. Product Specifications - 13 -](#_Toc465199570)

[1.1 Design spec - 13 -](#_Toc465199571)

[1.2 Performance spec - 14 -](#_Toc465199572)

[1.3 Conceptual Design - 15 -](#_Toc465199573)

[5. Conclusion and Recommendations - 17 -](#_Toc465199574)

[References - 18 -](#_Toc465199575)

# Table of Figures

[Figure 1: Parabolic solar collector [3] - 6 -](#_Toc465195731)

[Figure 2: Thermoelectric generator composed of different semiconductors [6] - 7 -](#_Toc465195732)

[Figure 3: Research and Conceptual Design - 9 -](#_Toc465195733)

[Figure 4: Experimentation - 10 -](#_Toc465195734)

[Figure 5: Phase I Construction - 10 -](#_Toc465195735)

[Figure 6: Gantt Chart - 11 -](#_Toc465195736)

# Table of Tables

[Table 1: Needs and Wants - 8 -](#_Toc465191495)

# Abstract

The following project was proposed to The Department of Electrical & Computer Engineering at the FAMU-FSU College of Engineering by our designated team leader, Ernest Crabtree. The idea was conceived for the sole purpose of being able to generate electricity for the myriad of electronic devices used by an average camper aiming to be environmentally responsible. Although photo voltaic cells were initially considered for the design, a more interesting process involving thermoelectric power generation was sought as the more promising solution.

The concept transformed further with a trivial amount of experimentation using a small parabolic dish to concentrate the heat provided by the sun to a fixed point. The results of this small test yielded noteworthy temperatures which could effectively provide a framework for transferring heat into electrical energy using thermoelectric generators.

Ideally, the effective design must be simple to use for your average consumer. The system should run autonomously at the push of a button to intelligently track the sun, mechanically align itself and charge electric devices as well as the provided battery. Some additional concepts to explore would be developing a phone app to provide cellular data and provide frequent update messages for the status of the device.

# Acknowledgments

The members of team fourteen of this year’s senior design class would like to express their utmost appreciation to the FAMU-FSU College of Engineering for providing the necessary facilities and tools to both conceptualize and progress this undertaking. We would especially like to extend our gratitude to our faculty advisor, Dr Rajendra K. Arora, for providing excellent feedback with regards to the concept of our design as well as recommendations for alternative approaches to solving any existing dilemmas. We would also like to thank Dr Michael D. Devine for taking specific interest in our design and recommending we take this project further by entering the inNOLEvation challenge with FSU’s College of Business. Finally, we would like to sincerely acknowledge our esteemed instructor for the course, Dr Jerris W. Hooker, who both oversees the progress of our design and provides the essential materials in lecture to progress throughout the year.

# Introduction

This project is an entrepreneurial-based undertaking sponsored by FAMU-FSU College of Engineering, specifically through Dr. Michael D. Devine. Currently, there is no effective and simple way to generate power in remote locations, such as camp sites and national parks. In order to supply power to everyday electronic devices a gas generator is traditionally used. However, due to their tremendous weight, noise factor, and environmental impact, it has become increasingly problematic to use these generators responsibly in isolated locations.

While portable photo-voltaic technology is viewed as the current solution to this dilemma, it is important to recognize that there exist more promising alternatives, specifically in solar-thermal technology. Currently, photo-voltaic cells are only able to harness specific wavelengths within the spectrum of visible light to generate power. Additionally, if the sun were obscured by the geographic location or weather conditions, a photo voltaic cell would be unable to produce any energy. However, thermoelectric generators possess the capability to utilize the heat from the entire spectrum of visible light as well as UVA, UVB, and infrared rays. This allows the process of thermal-electric power generation to continue even while the sun is out of sight.

The overall goal for this project is to develop a convenient and portable device that transforms solar thermal energy into usable electricity. In order to for the device to be applicable as a charging station, it would be required to generate twenty watts of electricity. Other features include a convenient assembly and disassembly process as well as negligible negative environmental impact.

# Background and Research

The proposed design for the Solar Thermal Generator would ideally concentrate electromagnetic waves provided from the sun to create heat, where in turn that heat is utilized by the TEG (thermoelectric generator) to provide power. There are several ways to collect solar heat, the most popular method being parabolic dish collection. Parabolic solar dishes have been used in solar thermal power facilities for years around the world. The system design includes a parabolic shaped reflector which focuses the sun’s rays on a receiver pipe located at the focal point of the parabola. The collector would then tilt with the sun as it moves across the daytime sky from east to west during the day to ensure the sun is continuously focused on the receiver to maximize the potential heat output. To rotate the dish as well track the relative angles of the sun’s position, a microcontroller will be used in conjunction with several motors and a GPS unit. Because of dish’s parabolic shape, a trough can focus the sun from 30 times to 100 times its normal intensity (concentration ratio) on the receiver pipe located along the focal line of the trough, achieving operating temperatures higher than 750°F.

The heat energy collected will then be converted to electric energy with the help of a thermoelectric generator. A TEG is a solid-state device that converts the heat directly into electrical energy through a phenomenon called “The Seebeck effect”. 4

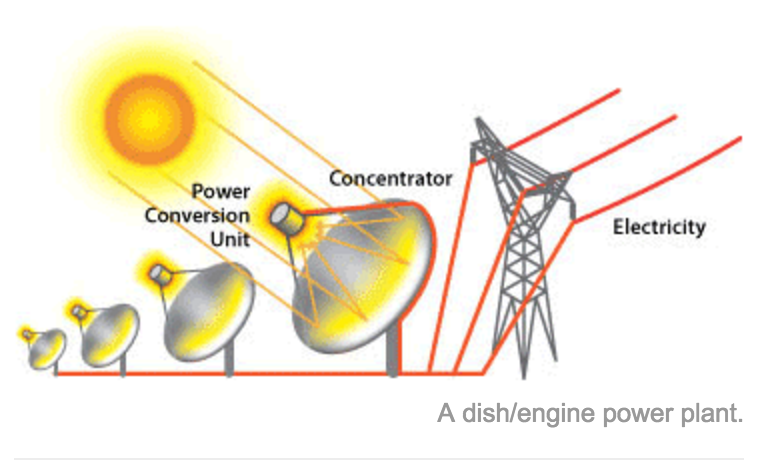


Figure : Parabolic solar collector [3]

In the early 19th century, Thomas Seebeck discovered that a thermal gradient between two dissimilar conductors or thermoelectric materials, where one side is significantly hotter in temperature than the other, can generate electricity. It was discovered that because a temperature gradient in conductive material produces heat, the flow of charge carriers between two regions effectively creates a voltage difference.

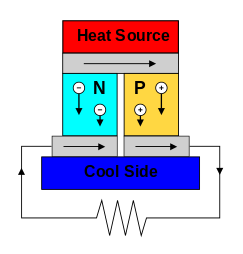


Figure : Thermoelectric generator composed of different semiconductors [6]

## Scope

In terms of the overall undertaking, the Solar Thermal Generator project will require knowledge within the fields of energy storage, voltage regulation, mechatronics, and computer programming. The following is a succinct list of the expected scope of the project.

* Solar or thermal heat collection
* Solar tracking program or algorithm
* Motion from a fixed mount
* TEG cooling or heat dissipation
* Energy storage and power output
* Scalability

## Needs Assessment

At the crux of this project, the simple problem we wish to address is this: people in remote locations do not have access to easily obtainable, inexpensive electricity for powering their electrical devices. Our proposed Solution is to provide electricity in remote locations using solar radiation, arguably the most abundant form of renewable energy on earth. Using a TEG installed in a mechanism for tracking the relative position of the sun and effectively storing energy will provide average consumers with a means of power generation in an environmentally safe way.

Table : Needs and Wants

|  |  |  |
| --- | --- | --- |
| *No.* | *Needs* | *Wants* |
| *1.* | *Generate 20W of power* | *Portability* |
| *2.* | *Energy Storage & efficiency* | *Low cost* |
| *3.* | *Solar tracking* | *User friendly* |
| *4.* | *Shock resistant* | *GPS modulator* |

## Project Constraints

To meet the specific needs illustrated above, the following limitations and constraints are addressed as follows

* Device weight must not exceed 50lbs
* The device itself must be compact (ideally less than 3ft3)
* The device should be resistant to corrosion and be waterproof
* Must operate in the confines of the designated budget
* Meet with all applicable safety and consumer standards
* Provide maximum standby time

# 3. Deliverables

## Work Breakdown Structure

Figure : Research and Conceptual Design

Figure : Experimentation

Figure : Phase I Construction

## Gantt Chart



Figure : Gantt Chart

## Assign Resources

**Financial Advisor: Ben Gallivan**

Manages the budget and maintains a record of all credits and debits to project account. Any product or expenditure requests must be presented to the advisor, whom is then responsible for reviewing and the analysis of equivalent/alternate solutions. They then relay the information to the team and if the request is granted, order the selection. A record of these analyses and budget adjustments must be kept.

**Software Engineers: Shazeen Tariq**

Responsible for developing code required for the scope of the project. Specifies required equipment including microcontrollers and servos and ergonomics / user interface.

**Software Engineers: Will Sidebottom**

Responsible for developing code required for the scope of the project. Also, responsible for data management and geo tracking.

**Electrical Engineer: Dylan Lee**

Responsible for energy storage and battery productivity / power management and drawing specifications.

**Electrical Engineer: Jason Galla**

Responsible for power management and controls within the system as well as chip placement and functionality.

**Electrical Engineer: Ernest Crabtree**

Responsible for chip cooling / heat sink design as well as drawing specifications and overall design.

**Note:** *All members of the team own an equal share of responsibility for developing a business model and competing in the InNOLEvation Challenge.*

# 4. Product Specifications

## Design spec

1. Weight and Spatial dimensions
   1. Relatively light weight, under 30 [lbs.]
   2. Compact – 3 [ft3]
2. Power
   1. Able to produce an average of 20 [watts] of power at any given time
3. Autonomous
   1. Able to track the relative position of the sun using a GPS module
   2. Able to control stepper or geared motors to position parabolic dish accordingly
4. Voltage Regulation
   1. Step up/down voltage levels at given gradients to avoid large heat dissipation
5. Cooling
   1. Regulate a low temperature for cool side of chip using little to no power
   2. Ideally have no moving parts
6. Power Storage
   1. Both charge and discharge nickel metal hydride battery

## Performance spec

1. Ranges of Operation
   1. Urban, rural and even remote areas
2. On Startup
   1. Establish a GPS connection to retrieve relative location based data
   2. [Manual Mode] Allow user to manually enter coordinates
   3. Input GPS data in solar tracking algorithm, retrieving Sun’s relative position
   4. Alter 3-dimensional position of parabolic dish to align with sun
3. Low Power Mode
   1. After establishing best dish angle with sun, sleep to consume little power from MCU
   2. Regulate average voltage generated from chip
   3. Cool chip using little to no power
4. Interrupt
   1. Alert user when provided battery is fully charged
   2. After given time period, re-align itself with sun
   3. After re-alignment, digitally display average power generated in time period
   4. Alert user when Sun is no longer available

## Conceptual Design

The overall design of this project includes a parabolic dish, which collects solar energy and concentrates it onto thermal electric generators, several TEG’s which will require cooling on one side in order to create the temperature gradient needed, a cooling system such as water cooling, air cooling and possible Ferro-fluid design that will utilize a combination of natural convection and electromagnetic convection to dissipate heat away from the chips. For the initial solar tracking component of the design, we will manually point the dish in a “known” position so the device can have a starting point. The dish will then use GPS to find the location of the sun and continue to follow. Later designs may include a feature that will automatically orient the dish to the required starting position (true north).

In order to aid the cooling of TEGs, we will start with an air cooled design. We expect this to be the least effective design but also the easiest. Multiple heatsinks will be used to effectively cool the chips.

Later designs will utilize either a water cooled system that will use natural flowing technique (i.e. a thermosiphon) or Ferro-fluid that will employ a magnetic liquid that will be attracted to a stationary magnet when cooled and will be repelled (less attracted) when hot (i.e. electro-magnetic convection). Both of these possible designs should allow the chips to cool more effectively while requiring less cooling components. These methods may also allow for a higher temperature gradient, thus maximizing power output.

In addition to possible differences in heat exchanger design, we have considered two different possibilities for chip placement. The chips will either be located directly above the dish near the focal point or will be located below the dish with an extra refraction mirror at the focal point of the dish in order direct the heat below the dish onto the TEGs. Mounting the chips below the dish will maximize the effective area of the dish, increasing collection of solar radiation. Additionally, this will allow us to more effectively implement more advanced cooling techniques.

Once the chips are placed and the best methods are found for cooling and solar tracking, energy storage will be implemented along with voltage regulation to achieve constant DC outputs. We will give two voltage outputs – 5 and 12 volts. These outputs will allow users to directly connect USB powered devices and any devices that may employ standard cigarette lighter connections. The batteries will most likely be arranged in arrays that allow them to be charged at either 5 volts or 12 volts.

The batteries must be protected and a safe circuit must be employed that will keep the batteries from being overcharged. These batteries will be used to help achieve power outputs necessary when the sun is not giving enough energy for the devices. In theory, the batteries will be constantly charging.

# 5. Conclusion and Recommendations

The assigned Senior Design Project relies on a sun’s heat energy to generate useable electrical energy. The finished product is ideally portable and will be used under such applications as lights and heaters in a relatively remote location where a power grid is unavailable or unreliable. Our research into solar thermal generators has shown an efficiency of about 80%, with power generation of above 20W. The Generators produce electricity through the use of Faraday’s principle of electromagnetic induction.This allows the generated mechanical power to be transformed into a higher quality and more useful electrical power. The design of our device should include a microcontroller, thermoelectric generator, anchor mount, and output ports as the main components. A new innovative set of prototype will be designed and tested in order to determine which is most efficient and practical. An established data is very helpful to calculate maximum efficiency and to determine the importance of functionality, durability, and price as the most important characteristics of our project.

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