

Solar Car Camping Kitchen

Senior Design submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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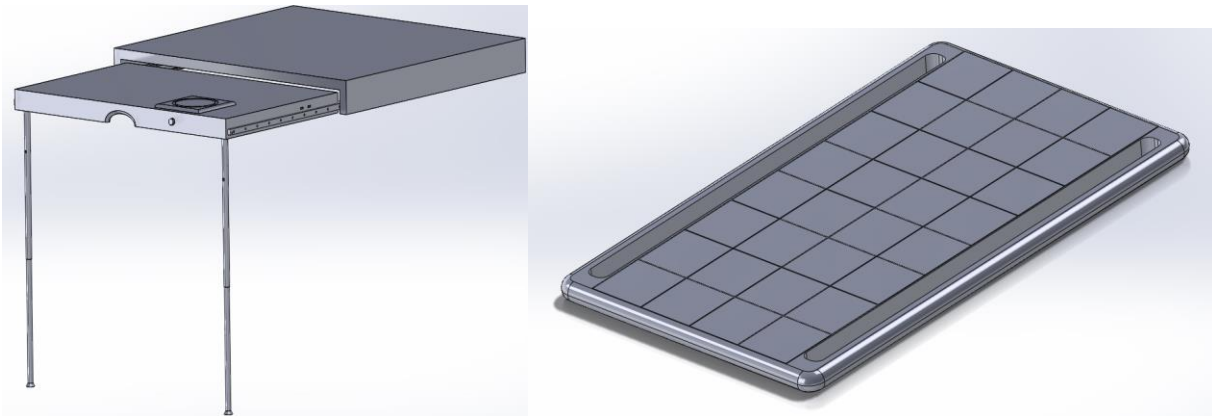
Thesis Advisor: Professor Ahmed Elgafy

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Problem Statement: While car camping it is difficult to prepare a limited selection of cooked meals without a proper kitchen area. Packing a table, stove, cooler, and other cooking accessories is cumbersome and takes up valuable space in the car that can be better used to store camping gear or additional passengers. Currently there are few options for a compactable car kitchen setup.

Proposal: My design proposal is a solar powered compactable kitchen area that can easily pull out from the back of a hatched car. The energy capture from the solar panels would be stored in batteries used to power a built-in water pump to be used for a water spout, a hot plate to cook simple meals, and LED lighting above and around the pull-out kitchen for night use. This also includes a small food prep surface.



Research:

Background of the problem

In the most recent “American Camper Report”, Sponsored through Coleman, (1) about 40.5 Million Americans or 13.7% of the population of the U.S over 6 years of age went camping at least once in 2017. On average each camper logged a total of 14.5 days camping per year. From the statistics about 9% of the total campers exclusively car camped. Those who long distance travel by car to escape to the wilderness understand that space within the car is crucial when packing essential items, especially when there is a larger number of passengers.

Because of this car camping is less than luxurious as certain camping items are left behind due to their size and utility. This is especially prevalent when preparing meals where stoves and fires are unavailable. This results in a large limitation on the variety of meals that can be created while car camping. Additional camp stoves can be packed, but they take up more space in the car and can be unsafe to store in a moving vehicle.

According to Alan Davidson, from altenergy.org, (2) The angle at which the solar panel is situated will maximize the amount of energy that it will absorb from the sun. This angle is very dependent on the time of year and the panel's location on earth. Since the panels are fixed it can only utilize the latitude of the Earth. In addition, because the panels will be attached to the top of a moving vehicle that changes direction, the panel will never be able to be facing the direction of the sun at all times. The Panel will have to absorb most of its energy during the peak hours of the

day, which is increased during the summer months. Since this product will be used primarily during warmer months it shouldn't be much of an issue during winter.

Current Technology: Currently, there are no commercial products available with the previously mentioned design features compacted into one product. Often Requiring long setup times, and providing little utility beyond storage and a work surface. The main Companies within the industry being: Cabela's, Bass Pro, and Coleman

Bass Pro: Deluxe Camp Kitchen

- **Heavy Duty Aluminum**
- **Weight: 36 lbs.**
- **Dimensions: 84"x19.75"x30"**
- **Weight Capacity: 90 lbs.**
- **Adjustable Stabilizers**
- **Cost \$144.99**



Overview: Provides a large lightweight platform to prep and cook food. Able to place on any flat surface. Requires assembly using multiple pieces that are stored in a travel case. Requires no power to use. Does not include stove, lights, refrigeration, or cooler.

Cabela's: Deluxe Camper's Kitchen

- **Heavy-Duty Steel Frame**
- **Weight: 57 lbs.**
- **Dimensions: 80"H x 88"W x 22"D**
- **Folded- 40.5"L x 26"W x 9.5"H**
- **Storage Compartments**
- **Cost \$140**



Overview: A strong platform with ample space to work with convenient storage compartments. Includes adjustable feet to be used anywhere that is semi-flat. Requires assembly using multiple pieces that are stored in a travel case. Requires no power to use. Does not include stove, lights, refrigeration, or cooler.

Key notes: All Commercial products designed for car camping provide limited uses beyond storage and work surfaces. Many use compressed fuels for cooking and don't have any electrical features. The most Common Materials used are Stainless steel and high strength aluminum.

Solar Panel: Peak Performance for solar panels occurs during the sun's highest point in the summer months. Energy absorption is dependent on the car's location in terms of the sun and cloud cover. Due to the panels fixed position on top of the car's roof, they won't always directly face the sun which will reduce the solar panels effectiveness.

Survey: I conducted a small survey to see what product features potential buyers would want. I sampled students from the University of Cincinnati Mountaineering club, an outdoors club on campus where camping and outdoors enthusiasts meet. Being knowledgeable about existing products, their input on my survey would be the most valuable.

Survey Results

How important is each feature in a car camping kitchen.

Feature	Low Importance: 1	2	3	4	High Importance: 5
Initial Investment Cost			3	3	2
Long Lasting Use			2	2	4
Durability			2	3	3
Compactable Size		3	1	2	2
Ease of Use		1	5	2	
Weight Capacity	1	3	1	2	1
Versatility				8	
Weight	3	3	1		1

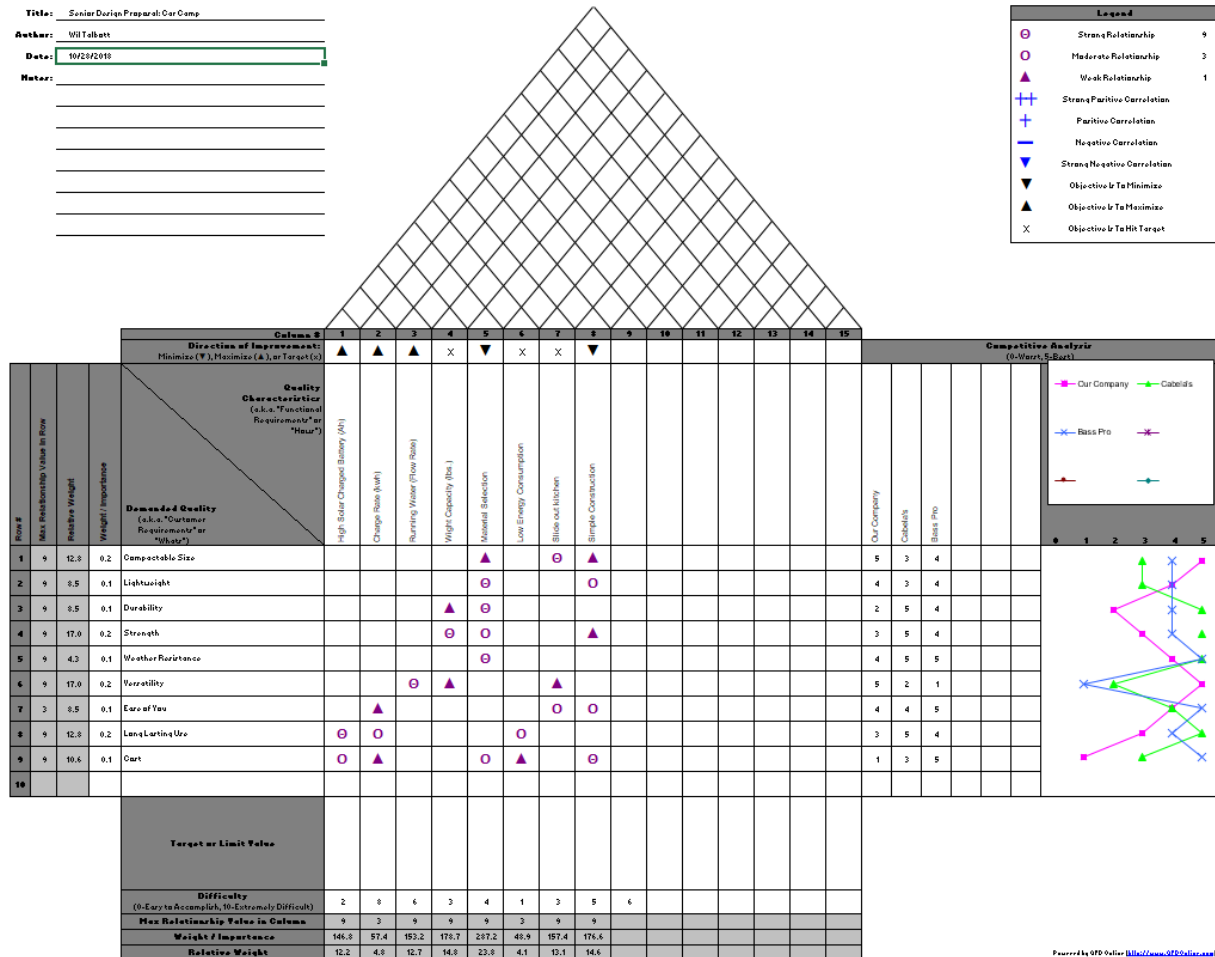
How satisfied are you with current Car camping equipment?

Feature	Low Importance: 1	2	3	4	High Importance: 5
Initial Investment Cost	1	1	3	3	
Long Lasting Use		1	4	2	1
Durability			2	2	4
Compactable Size		1	2	4	1
Ease of Use		1	2	4	1
Weight Capacity	2		4	2	
Versatility	3		4	1	
Weight	3	2	1	1	1

Above: The survey results showing the number of participants that answered their level of importance for each product feature. Some of the big take-aways from the survey were that customers valued versatility and long-lasting use, which current products did not meet their standards of satisfaction

QFD:

Title: Senior Design Proposal: Car Camp
 Author: Will Talbot
 Date: 10/24/2019
 Notes:



Customer Features:

Ease of use- Setup is quick and easy to understand: 0.1 importance

Compactable Size- The kitchen is able to collapse to a smaller size for better storage within the vehicle: 0.15 importance

Light weight- The product is low weight and easy to move: 0.1 importance

Durability- The kitchen can withstand wear and tear of multiple uses.: 0.1 importance

Long lasting use- All of the electrical components of the kitchen can run for a long period of time on a single day's worth of charging: 0.15 importance

Weather Resistance- The kitchen is able to withstand the elements of any climate without obtaining any defects such as rust: 0.05 importance

Strength- The table is able to handle larger than needed load sizes without deforming or breaking under stress: 0.1 importance

Versatility- The product provides multiple uses from the same power source.: 0.2 importance

Cost- The overall package is low cost: 0.05 importance

Engineering Characteristics

Slide out Kitchen – This design feature allows for an easy setup without having to remove any objects from the trunk compartment

Running water (flow rate) - The rate at which the water pump is able to flow water through the system, and provides a smooth laminar flow.

High capacity Solar charged Battery (Ah) - The battery is able to store a large amount of solar energy and is able to run all electrical components for an extended period of time on one charge.

Material Selection- The materials used to construct the product will determine its physical attributes, such as strength, weather resistance, and weight.

Weight Capacity (lbs.) - The maximum load both the table and its storage casing can hold without failure or deformation

Charge Rate (kwh) - The rate at which the roof solar panel will charge to devices

Low energy consumption (kwh) - The rate at which all the electrical components drain the battery while all are in use.

Simple construction- The product has an easy to understand construction for easy setup and deconstruction

Objectives:

- **A versatile design that allows for multiple uses and applications**
- **Takes up minimum space within the vehicle to make room for other luggage and gear.**
- **Quick easy to understand setup without having to move any gear packed into the back of the vehicle.**
- **Provides ample energy for all features from a fully charged battery**
- **Durable, weather resistant construction that provides customers with long lasting use.**
- **Strong material selection able to withstand moderate loads.**

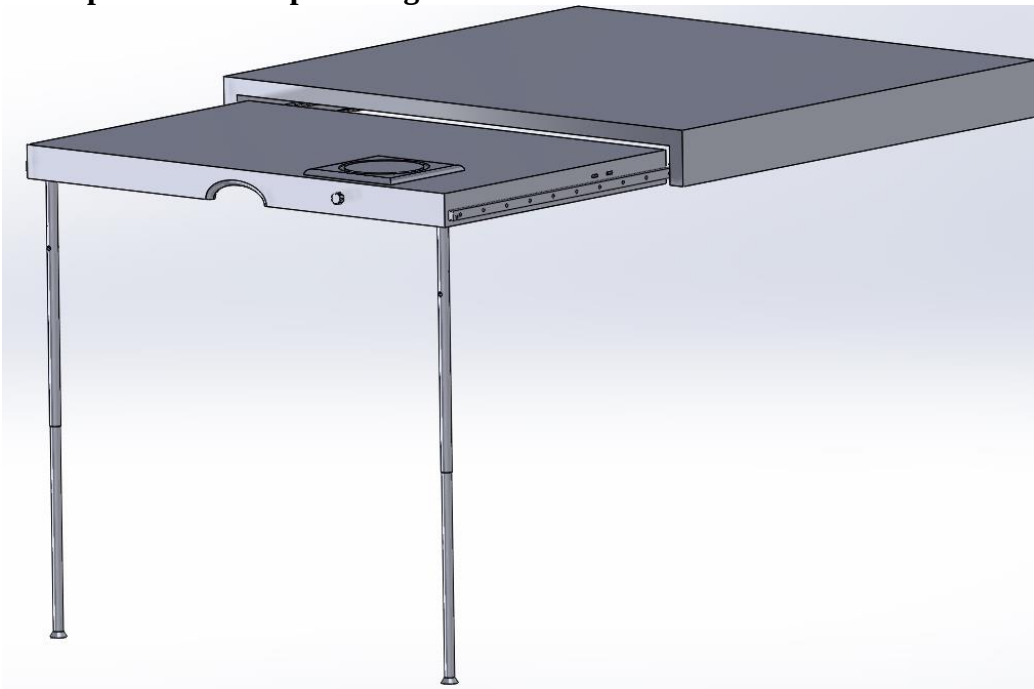
Design Analysis:

Pros:

- **Simple Construction**
- **Low profile in trunk**
- **Can be used without moving objects placed on top of it**
- **Provides multiple features and uses**
- **Easy Set up**

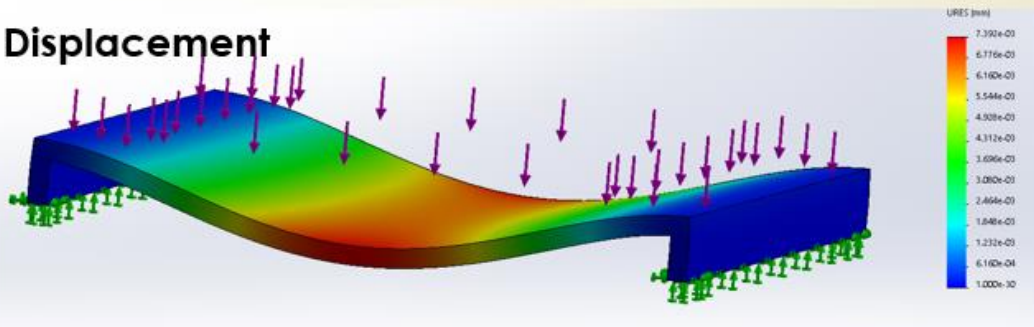
Cons:

- **Limited Vehicle Selection**
- **Dependent on ample sunlight**



Cover Top: 100 lb.F

Displacement



Stress

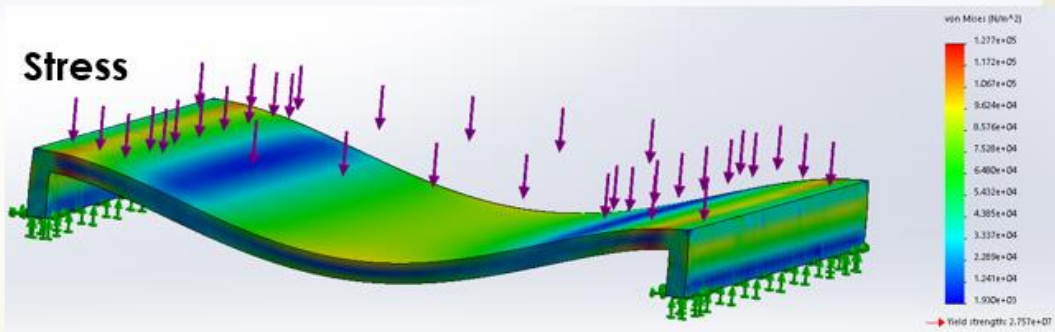
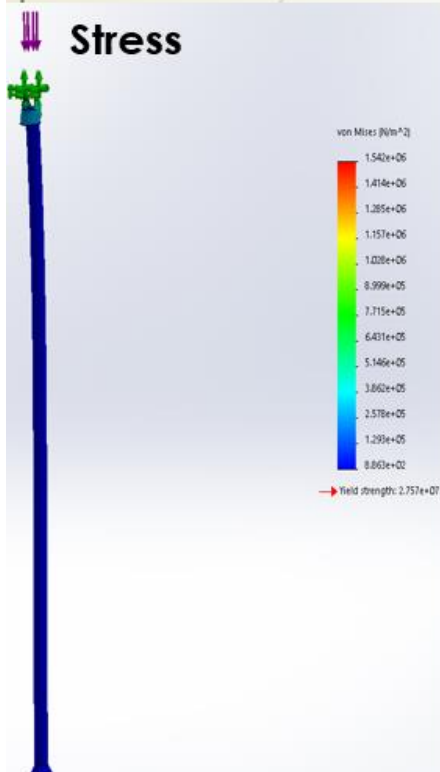
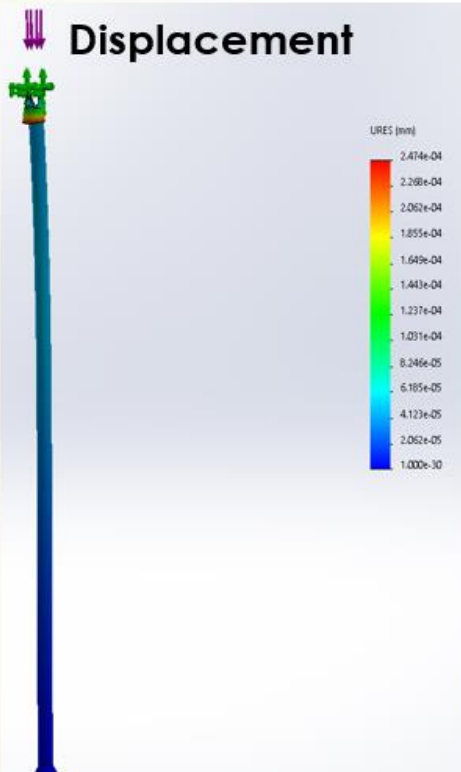


Table Legs: 25 lb.F

Stress

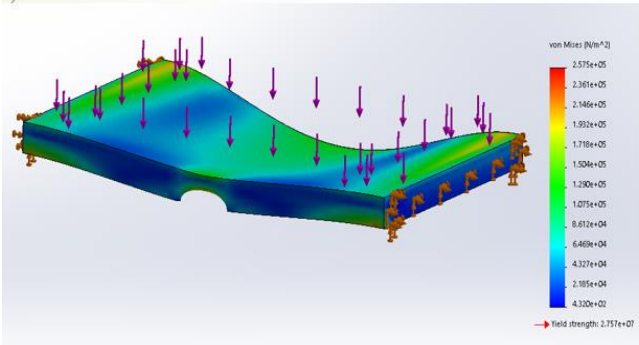


Displacement

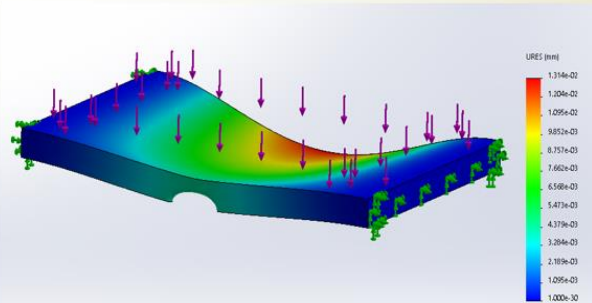


Counter Top: 50 lb.F

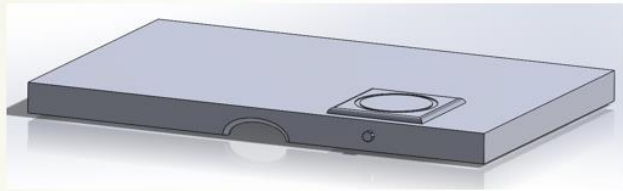
Stress



Displacement



Using Aluminum 1060 for the main body, it is clear in the simulation that the material will be able to hold the design loads expected with very little stress and displacement.



1060 Aluminum Alloy
Tensile Strength: 9,998.26 psi

Yield Strength: 3,999.3 psi



AISI 316 Stainless Steel
Tensile Strength: 84,121.89 psi

Yield Strength: 25,000 psi

Other Components:

- **Thunderbolt Magnum Solar Battery (12 Volt, 35 amp hours)**
- **LED Lights: 17.1 Watts**
- **Hot Plate: 120 W**
- **Phone Charger: 3.68W**
- **Water Pump: 4W**

Calculations:

Total wattage= $4+120+17.1+3.68= 144.78\text{Wh}$

Capacity= $144.78\text{Wh} / 12 \text{ volts}= 12.07 \text{ Amp hours}$

$C' = 12.07\text{Ah} / 0.8= 15.088\text{Ah}$

$C'' = 15.088\text{Ah} / .5= 30.175\text{Ah}$ (Designed battery capacity)

Solar Panel efficiency

$A = 1.5\text{m} \times .75\text{m}= 1.125\text{m}^2$

PR= 0.75 (Default performance ratio)

$r = 15\%$ (Panel efficiency)

$H = 700 \text{ Kwh/m}^2$ (average annual solar radiation in best conditions in the U.S)

$H = 200 \text{ Kwh/m}^2$ (average annual solar radiation for fixed non-tilted panels in the U.S)

Best Energy Output= $(1.125\text{m}^2) \times (0.75) \times (0.15) \times (700\text{Kwh})= 88.6 \text{ Kwh}$

Actual Energy Output= $(1.125\text{m}^2) \times (0.75) \times (0.15) \times (200\text{Kwh})= 25.31 \text{ Kwh}$

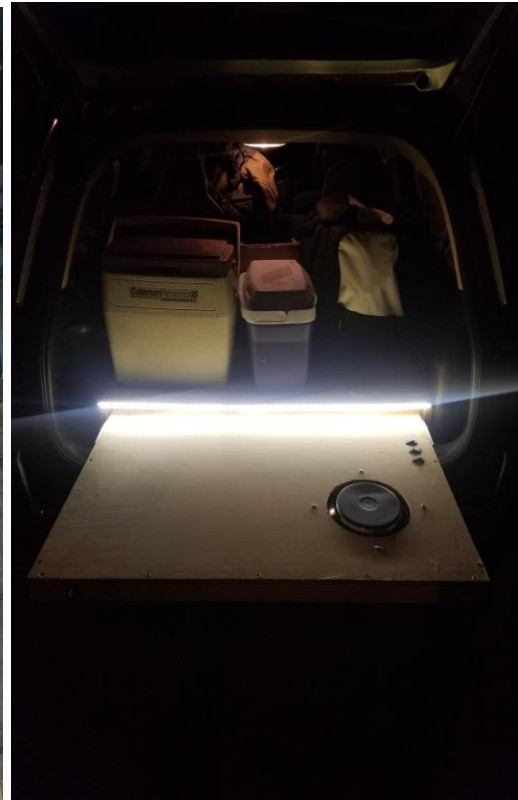
Battery Power= $35 \text{ Amps} \times 12 \text{ Volts}= 420 \text{ Watts}$ or .42Kw

Charge Time = $25.31 \text{ Kwh} / 0.42\text{K w}= 60.26 \text{ Hours}$

The Prototype: Due to budget limitations, the prototype was constructed using Oak wood boards for the main body and the PV Cell battery was replaced with a conventional 12 V battery in order to prove the concept.



Design Discussion: The Main body holds the work countertop that includes the Hot plate, water spout, LED Lights, and three switches used to control each feature. All electrical feature will only function when the countertop is fully extended using a simple pressure switch located at the end of the top cover. This safety feature prevents the user from forgetting to turn off any electrical components when putting it away. The table is held into the car via eye bolts connected to the wheel wells. A 5 gallon water reservoir is located underneath the back seat along with the water pump with a coiled tube extending out with the counter top to the spicket. All electrical components are located underneath the countertop and slide with the counter top.



Testing:

Tests conducted were a battery life time trial and load capacity on each major feature.

- The top cover was able to withstand a load of 200 lbs. and still function with the counter top.
- The counter top was able to withstand a load of 50 lbs. with only minor displacement, but was still able to function.

Time Trial:

Battery Life Time Trials

Trial #	Time (Minutes)
1	83.5
2	79.7
3	81.1
4	79.4

On average, with every electrical component in use the, the batteries provided power to all components on a full charge for 80 minutes. Using all components at once is an unrealistic use, but it shows the long-lasting use of the design. Unfortunately, the long time it takes the solar panel to obtain a fully charged battery limits the lasting ability of the design.



Budget:

Part	Link	Price	Qty	Total Price	Specs	Actual Price
Solar Panel	/express.g	\$127.99	1	\$127.99	36"x60"	N/A
Solar Battery	www.harb	\$69.99	1	\$69.99	12V/ 35Ah	\$200
Telescoping Slides	www.mcm	\$421.70	2	843.4		\$25.99
Water Pump	www.ama	\$10.34	1	\$10.34		\$9.99
5 Gallon Reservoir	https://www.ama	\$49.79	1	\$49.79		\$21
Hot Plate	www.lowe	\$16.76	1	\$16.76		\$16.76
Stock Aluminum		N/A	0		4x38x50	\$106
Strip (Aluminum)		N/A	0		2x40	N/A
Sheet Aluminum)		N/A	0		36x60	N/A
Tubing	www.web	\$7.90	2	\$15.80		\$12.55
Faucet	https://www.ama	\$8.98	1	\$8.98		\$5.29
Screws	https://www.ama	\$6.55	12	\$6.55		\$2.50
Bolts	https://www.ama	\$6.83	12	\$6.83		\$1.50
LED Lights	www.ama	\$15.99	1	\$15.99		\$15.99
USB Outlet	https://www.ama	\$38.18		\$38.18		N/A
				\$1,210.60		\$418

Schedule:

#	Task Name	Duration	Start Date	Finish Date
1	Senior Design: Solar Car Kitchen	179 days	8/20/2018	4/25/2019
2	Design 1 Formulation	34 days	8/20/2018	10/4/2018
3	Library Resources	3 days	Aug-18	8/22/2018
4	Binder Assembly	3 days	8/23/2018	8/27/2018
5	Background Research	4 days	8/28/2018	8/31/2018
6	End user	5 days	9/3/2018	9/7/2018
7	surveys	7 days	9/10/2018	9/18/2018
8	QFD	2 days	9/19/2018	9/20/2018
9	HoQ	3 days	9/21/2018	9/25/2018
10	Proposal/ research draft	7 days	9/26/2018	10/4/2018
11	submission of final proposal	0 days	10/4/2018	10/4/2018
12	Design 2 Design Development	42 days	10/8/2018	4/11/2019
13	Design decision	14 days	10/8/2018	10/25/2018
14	Calculations	14 days	2/5/2019	2/19/2019
15	final design and drawings	14 days	3/28/2019	4/11/2019
16	Design 3 Manufacturing	22 days	4/11/2019	4/25/2019
17	order materials	5 days	4/11/2019	4/16/2019
18	manufacture	14 days	4/13/2019	4/20/2019
19	Build	7 days	4/13/2019	4/20/2019
20	Test	3 days	4/20/2019	4/23/2019
21	Tech Expo	0 days	4/18/2019	4/18/2019
22	Final Presentation	4 days	4/22/2019	4/25/2019

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