Memo

To:	Marilla Lamb
From:	Rob Rosenberg, Kori Molever, Connor Kroneberger, Michael Klinefelter, Jon Jerome, Peet Dhillon, Rashed Alharbi, Alex Devine
Date:	April 18, 2014
Re:	Second Generation Bicycle Charging Station

After extensive research and testing, the Second Generation Bicycle Charging Station is almost to a state of completion. As per your request, the final design is easily transported and adjustable to provide a comfortable riding experience for various users. The final design includes a display that showcases information about power generation through graphical and numerical representation. Additionally, the station includes various chargers for small electronic devices and a three-prong AC outlet. The upright bicycle features multiple speeds and utilizes a chain driven generator to transfer the rotational energy of the rider's pedaling. The bicycle is fully functional, thus providing human powered mobility, and uses front and rear wheel stands that can be engaged for demonstration purposes and folded away for transportation purposes. Multiple electrical and mechanical prototypes were built to test various components on the charging station. These prototypes provided our team with valuable information about the system and allowed for changes in the design. Final testing is being completed this week and the charging station is scheduled to be finished and operational by Monday, April 21, 2014.

We look forward to presenting the final project and thank you for the opportunity to provide the community with an educational tool for demonstrating the effects of power generation.

Second Generation Bicycle Charging Station

By
Jon Jerome, Michael Klinefelter, Connor Kroneberger,
Kori Molever, Robert Rosenberg, Alex Devine, Peet Dhillon,
Rashed Alharbi
Team 22B

Final Report

Document
Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design II – Spring 2014

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

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1.0 Abstract

The purpose of this project is to design a second generation bicycle charging station that can accommodate for a wide range of users and provide educational value for students of all backgrounds. The second generation bicycle charging station must be easily transported and adjustable to provide a comfortable riding experience for various users. The final design includes a display that will showcase information about power generation through graphical and numerical outputs. Additionally, the station includes various chargers for small electronic devices and a three-prong AC outlet. The final design implements an upright, three speed bicycle that utilizes a chain driven generator to transfer the rotational energy of the rider's pedaling. The power generated is used to charge small electronic devices. The bicycle is fully functional, thus providing human powered mobility, and use a front and rear wheel stand that can be engaged for demonstration purposes and folded away for transportation purposes. Finally, the station must be built within the budget, granted through the NAU Green Fund, of $1600.00. This report outlines the process of identifying the problems associated with the first generation charging station and the design process that was taken while completing the second generation system.

2.0 Introduction

In 2012, a team of engineers designed and built a bicycle generator intended to power small electronics and educate the public about electrical power generation. The purpose of this project is to design a second generation of the Bicycle Generator in the Engineering Building at Northern Arizona University. The current design, located on the second floor of the Engineering building, is limited in both its power output and ability to address user needs. The Second Generation Bicycle Charging Station project team aims to redesign the charging station in a way that improves the portability, efficiency, usability, and versatility of the assembly to better aid in the design's overall purpose.

3.0 Problem Formulation

3.1 Identification of Need

The purpose of the bicycle charging station is to provide students with an avenue to understand and compare the amount of energy required to power and charge electronic electronic devices with the amount of energy produced by pedaling a bicycle in a controlled indoor setting. The first generation bike, however, does not meet all of the needs of the customer. The following are shortcomings identified within the first generation bike:

- The bike is not compatible with all major cell phones or laptops.
- The bike cannot readily be transported to different locations.
- The current display system is not user friendly and does not display adequate information.
- The bike is not comfortable or adjustable for the user.
- There is no consideration towards varying human power inputs (gearing and resistance).

3.2 Project Goal

Goals for this project is to "Provide students with a way to understand and compare the amount of energy required to power and charge electronic devices with the amount of energy produced by pedaling a bicycle."

3.3 Operating Environment

The second generation charging station will be used as an educational tool to teach about power generation. The station will potentially be used in both indoor and outdoor settings by users varying in age and body type.

3.4 Constraints

The second generation station must provide a wide variety of electronic chargers and a three-prong AC outlet allowing users to charge high wattage electronics such as a laptop. In addition, all parts and labor, between the mechanical and electrical teams, must fit within the allotted budget of the $1,600.00 granted through the Northern Arizona University Green Fund.

3.5 Objectives

In addition to the above constraints, the following objectives were deemed important to the completion of the project:

- adjustable seat height
- adjustable resistance/gearing
- successfully display of carbon offset and power generated
- portable design that allows for ease of transport

3.6 Quality Function Deployment

In preparation for concept generation and selection, a Quality Function Deployment (QFD) matrix was created to weigh the importance of the specifications to the objectives of the project defined by the clientele and problem needs. Within the QFD matrix, objectives and constraints are listed and weighted on a 1-10 scale of importance and then crossed with the specifications. The specification-objective scale relationship is a 1-3-9 scale with 9 being the most significant. The columns of specifications are then individually summed together to get a raw score and normalized against the highest raw score. The QFD, which can be seen below in Figure 1, shows these relationships for the second generation bicycle charging station.

		Specifications				
Objejctives	Weighted Importance	Weight	Power Output	Cost	Required Mantainence	Accuracy
Adjustable	7	1		1	1	1
Interactive display	10		9	9		9
Sufficient AC Power	10	1	9	3		3
Collapsible	4			3	3	
Geared	8	3		3	9	
Geometry	3	9		9		
Multiple Chargers	8		3	1		
AC plug for Laptop Charging	10		9	1		
Shows Power Generated	10		1			3
Shows Power Used	10		1			3
Shows Total Power Generated	9		1			3
Shows Total Number of Users	9		1			3
Carbon Offset	8		9			3
	Score	68	404	208	91	265
	Relative Weight	0.17	1.00	0.51	0.23	0.66
	Unit of Measure	lbs	Watt	$	Hours	*

* = relative error

Figure 1 - QFD Matrix showing constraints, specifications and their relationship

From the QFD, one can see that some of the more important factors are power output, accuracy in display and equipment cost. Weight and required maintenance were deemed to be less important, however they are not to be ignored altogether. The QFD matrix is vital to the decision making process and has a direct influence in the application of relative weights to criterion used to select concepts for the final design.

4.0 Final Design

4.1 Design Concepts

4.1.1 Mechanical

The final design features a chain driven generator for the purpose of limiting potential power loss while the system is in use. Gears allow the user to adjust to a speed and resistance that they find comfortable. An adjustable seat also promotes user comfort by accommodating a variety of user heights. A pivoting stand which can rotate about the axle and be secured above the rear wheel allows the bike to be transported with ease. To ensure the safety of users, finite element analysis was performed using Solidworks. A load of 1000 N was applied to the stand for computer aided analysis. The load case applied to the stand is a worst-case scenario, as the rider's weight is not fully resting on the stand. As shown below in Figure 2, the stand does not approach yielding or failure with normal loading.

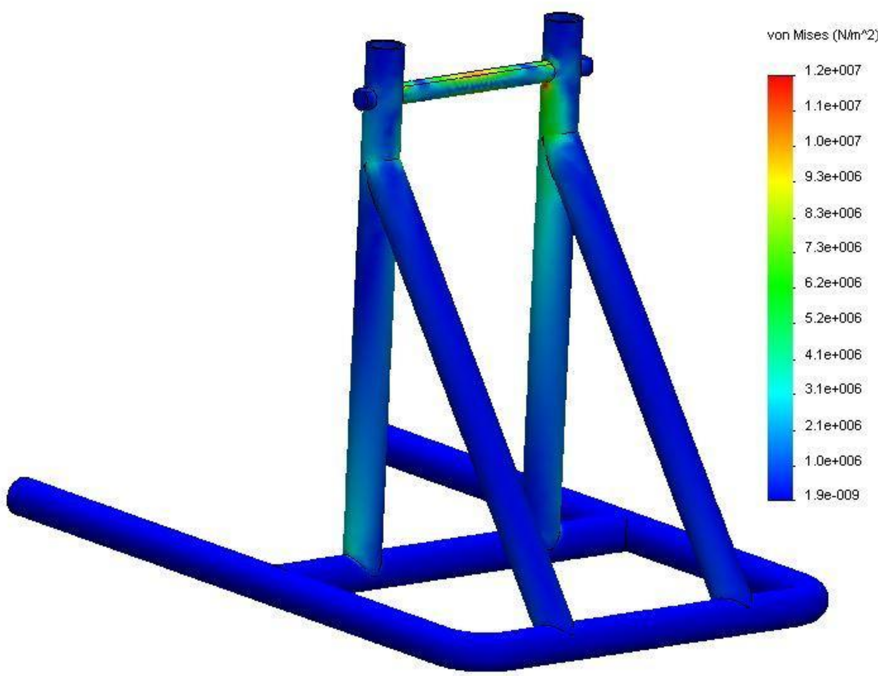

Figure 2 - Stress Analysis

The housing for electronics is transparent to show users the internal workings of the display and electrical components. This contributes to the educational value of the charging station. The final design can be seen in Figure 3.

Figure 3 - Final Design

4.1.2 Electrical

A purchased generator was considered to maximize efficiency and minimize cost. Purchased Generators are designed to use machined parts that fit together with minimal wasted space. By minimizing gap space, the generator achieves a higher flux density and a higher number of turns with the same materials. Figure 4 is the generator below that was used in this project.

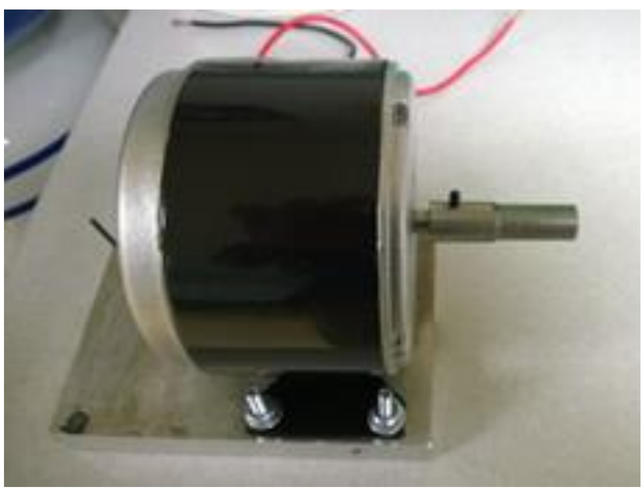

Figure 4 - Generator

According to Faraday's Law, higher flux density increases the induced electromotive force on the wire causing a larger current. The more turns of wire used in a generator multiplies the current generated due to Ampere's Law. From these two aspects we can see that a machined generator is very efficient. Table 1 below shows the specifications of the purchased generator in terms of voltage, current, and speed:

Table 1 - Generator Specifications

Voltage	24V DC
Rated Speed	2750 RPM
Rated Current	16.4 Amps
Output	300 W

The Raspberry Pi chipset has the ability of displaying an HD output due to its HDMI built-in ports. Furthermore, Raspberry Pi chipsets have expandable memory and can store very large amounts of data and build in a Linux operating system. Figure 5 below shows the Raspberry pi and its functionality.

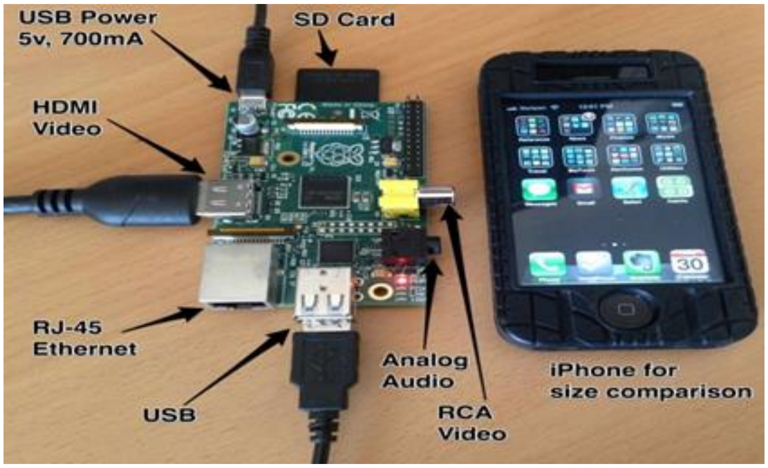

Figure 5 - Raspberry Pi Chipset

The Raspberry Pi can have multiple expansion ports that keep track of multiple sensors at once. The device also has the ability to use multiple video and audio input/outputs.Detailed specifications of the Raspberry Pi chipset are included in Table 2.

Table 2 - Raspberry Pi Specifications

Weight	0.126 pounds
Length	4.75 in
Width	3 in
Height	1 in
Power	3.5 Watts
Memory	512 MB
Storage	SD Card Slot
Graphics	Broadcom Video Core

The LCD screen that will be utilized for displaying information about power generation. This type of screen was chosen for its versatility and viewing pleasures when combined with the Raspberry Pi. Figure 6 represents the LCD below.

Figure 6 - LCD Display (7in)

As requested by the client, the display will show the power generated numerically and graphically. The display also uses frames as a tool to tell the user how much power was generated by activating one of the components of the frames (e.g. light bulbs).

Additionally, the display will show the power used to charge the user's device. The display will also show the energy produced over the lifetime of the charging station along with a small statistic calculator for the carbon offset of individual users and cumulatively over the lifetime of the charging station. Table 3 below shows the specification of the LCD screen display.

Table 3 - Touch Screen Specifications

Type	HDMI+VGA+2AV Controller Board
Size	7 in
Resolution	800 x 480 LCD

Another important electronic component is the power logger, which records power, current, and voltage in response to the program integrated into the Raspberry Pi. Figure 7 shows the detail of the power logger.

Figure 7 - Power Logger

The power logger was originally used for Macintosh and Windows operating system. After researching the potential for the power logger, a solution was devised to allow the component to run off the Linux based operating system found on the Raspberry Pi.

Since the output power from the generator will be in DC, a device to convert DC to AC is needed. A lightweight 200W inverter was chosen to accommodate. The purpose of this inverter is to convert the generated power to AC so it can charge devices such as Laptops. The inverter chosen will be able to take 12-16 V of DC power and will have a maximum current of 20 Amps. Figure 8 shows the inverter chosen.

Figure 8 - DC to AC Inverter

The second generation charging station will provide users with a variety of cables for common phone chargers. Additionally, the station will house a three-prong outlet for users who need an outlet for laptops and other miscellaneous chargers.

5.0 Prototype Fabrication

5.1 Prototype Fabrication

5.1.1 Mechanical

The NAU Green Fund requested a design that could be repeated without the need for specialty tools or machining equipment. Keeping this in mind, the bike stand was built using galvanized steel pipe fittings for emphasis on repeatability of assembly. The use of nonpermanent joints is also beneficial for maintenance. The final bike stand can be seen in Figure 9.

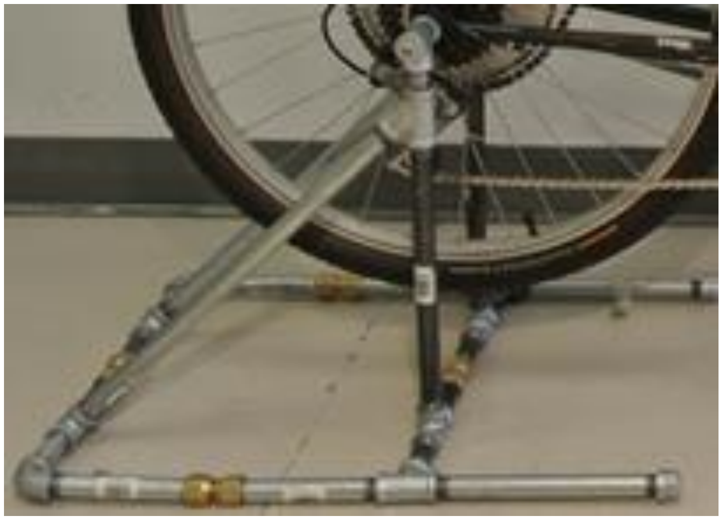

Figure 9 - Bike Stand

As seen in Figure 9, the stand is mounted directly to the axle. In order to attach the stand, a 300 mm solid axle was installed. The axle threads are protected from failure due to bearing stress by PVC pipe sleeves. The sleeves run through flare nuts which screw into the pipe tees. A washer and nut secure the tees and wheel to the rear dropouts of the bike frame. The golden pipe swivels allow the two stand halves to be assembled together around the rear wheel.

The generator was attached to the bicycle by means of 0.06 in. bent sheet metal plate. Figure 10 shows the location of the generator between the rear seat stay and the seat tube. The bent plate provides a stable attachment of the generator to the bike and allows for minute adjustments of angle for generator alignment.

Figure 10 - Generator Attachment

Power transmission to the rear tire was provided by fixing the fixing the front chain to a 53 tooth gear and keeping a rear 7-gear cassette. Power is then transmitted to the generator through a 56 tooth gear attached on the left side of the rear tire over a standard ANSI 41 chain to a 10 tooth gear coupled with the generator. The coupler was milled from a standard mild steel to accommodate the transition from a 9mm generator shaft to a ½ inch bore on the gear. Angular motion is secured by set screws.

5.1.2 Electrical

During the prototype phase, the generator was under a lot of stress during testing. The purpose of testing was to ensure proper readouts for the circuit making process. One of the tests was used to produce a range of user RPM's, which would provide the knowledge of how much voltage the generator could handle. During testing, the generator burned up and stopped functioning due to overloading. As a resolution, a new generator with similar attributes was purchased. Since the first generator stopped working due to high voltage, the team designed a circuit that would prevent any exceeding voltage issues.

Another issue that the team ran into was integrating the resistive touch screen display. Calibration was done to make the display work properly with a stylist, however it was determined that it would be better to have buttons instead of a stylist to switch between frames in the display. Push buttons, seen in Figure 11, were integrated into the design that function the movement of the frames from left to right or right to left.

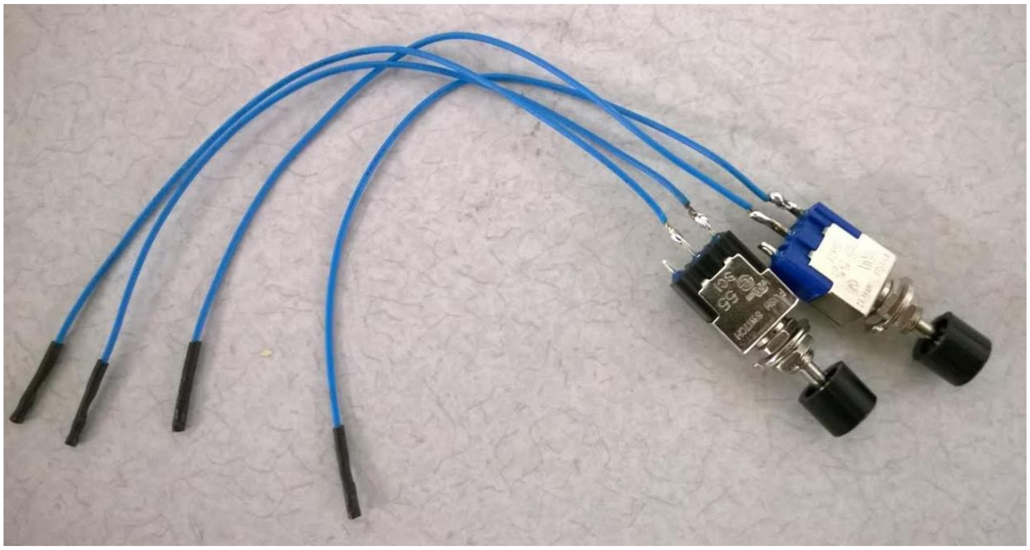

Figure 11 - Navigation Buttons

The power logger was used for operating systems such as windows and macintosh. Since the Raspberry Pi is a linux based operating system the software was not compatible. In order to fix this issue, the electrical team had to modify certain data structures on the power logger in order to make it compatible with the Raspberry Pi. After the power logger was incorporated into the programming, the device worked correctly on the linux system.

6.0 Testing and Results

6.1 Generator Testing

The generator was coupled with a motor and the output values at a known RPM were recorded. The relevant outputs for testing are voltage and current.

Since the supercapacitor's capacity will be determined by how much power, volts, and current the generator is outputting, a testing procedure had to be done. The mechanical team created a coupler to link the synchronous MotorSolver Dyno-Kit to the generator as seen in Figure 12. The coupler was then used for testing using the synchronous Motor, a dSPACE CP1104 connector / LED panel, and HiRel / Vishay electric drives inverter board. The team was able to get the generator up to a speed of 1000 RPM's. Unfortunately, the readings the team obtained were not enough to determine the size of the supercapacitor. The issue was that the readings of the voltage were not accurate enough when hitting the desired speed. The team was not able to attain the current readings because current is always measured in series and the board provided was in parallel. This made measuring the current impossible without a load (potentiometer).

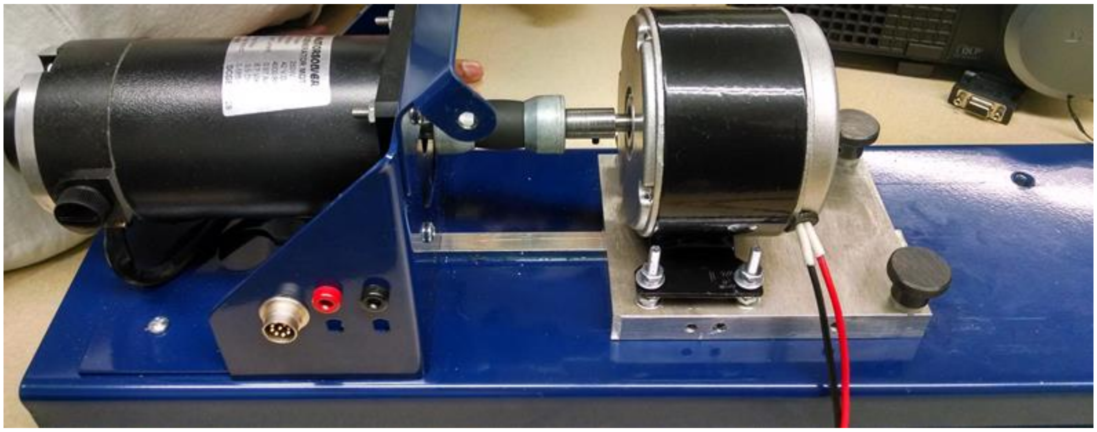

Figure 12 - Synchronous MotorSolver

Other tests were done to determine the output of the generator by neglecting the speed. The reason for neglecting the speed was the difficulty of finding the right potentiometer size for a reasonable price. The team did multiple tests to check the functionality of the generator to charge devices and get the voltage limits of turning the inverter on and off. As a result, the team was able to determine the exact amount of power/voltage needed for both the inverter and the device being charged. Below are the testing results:

- Inverter power output range: **12V-16V**
- Electrical devices charge at a rate of **5W**
- Laptops charge at 90W-100W

6.2 Gear Analysis

The purchased generator has a maximum operating speed of 2750 RPM at 24 volts. Testing of the generator with a load provided a short burst maximum input speed of 120 RPM. The maximum gear ratio at this maximum speed will provide a generator rotational speed of 2740 RPM. However, the voltage protection circuit will prevent a user from reaching the maximum voltage.

7.0 Cost Analysis

7.1 Bill of Materials

Tables 4 and 5 below contain a complete bill of materials with item cost in the production of the bike. Not included in the bill of materials is the bicycle itself and the butterfly handlebars, which were donated by AZ Bikes and Bike HUB respectively in Flagstaff, Arizona.

Table 4 - Mechanical Team Expenditures

Component	Price	Quantity	Total
Tires	$35.43	2	$70.86
Quill Stem	$16.20	1	$16.20
Handlebar Grips	$12.83	1	$12.83
Handlebar	$15.64	1	$15.64
Handlebar Tape	$15.00	1	$15.00
Crankset	$21.93	1	$21.93
Bottom Bracket Bearing	$23.71	1	$23.71
Brakes pads	$8.00	2	$16.00
V-brake calipers	$4.00	2	$8.00
Handlebar Shims	$9.31	1	$9.31
Handlebar Stem	$21.23	1	$21.23
Pedals	$19.80	1	$19.80
Indexing Chain	$15.50	1	$15.50
Multi-speed Chain	$11.00	1	$11.00
Generator Sprocket	$13.15	2	$26.30
Stand Components	$177.32	1	$177.32
Generator Mounting Hardware	$15.00	1	$15.00
187 mm Axle	$23.00	1	$23.00
300 mm Axle	$35.68	1	$35.68
ANSI 41 Chain	$18.00	1	$18.00
Chain tensioner	$7.00	1	$7.00
56 tooth gear	$25.00	1	$25.00
56 tooth gear adapter	$8.00	1	$8.00
Coupler	$8.00	1	$8.00
Assorted Nuts and Bolts	$31.32	1	$31.32
Housing Mounting Hardware	$71.96	1	$71.96
		Total	**$723.59**

Table 5 - Electrical Team Expenditures

Component	Price	Quantity	Total
Generator	$199.00	1	$199.00
Generator 2	$59.16	1	$59.16
Touch Screen	$89.00	1	$89.00
Power Inverter	$21.00	1	$21.00
Raspberry Pi	$35.00	1	$35.00
SD Card	$4.99	1	$4.99
Detector Plug	$4.33	1	$4.33
Cables	$59.61	1	$59.61
Push Buttons	$4.04	2	$8.08
12 Gauge Wire	$9.89	1	$9.89
Wire Nuts	$2.24	1	$2.24
Power Logger	$69.99	1	$69.99
Relays/ Circuit	$15.00	1	$15.00
		Total	**$577.29**

7.2 Production Cost

The project was given a budget of $1600 from the NAU Green Fund. Of that, $1301 was used in the production and testing of the bicycle station. Being under budget was made possible largely by donations from AZ Bikes, Bici Mundo, and Bike HUB.

8.0 Conclusion

After extensive research and testing, the Second Generation Bicycle Charging Station has been completed. With regards to constraints and client specifications, the charging station provides users with multiple options for charging electronics while providing educational information about user output. Additionally, the bicycle is adjustable to accommodate a variety of users and incorporates a geared system to give riders a range of comfort when pedaling. The entire charging station is portable thus allowing it to be set up quickly and easily at the given destination. Finally, the charging station was built within the allotted budget and is made with the intention of being repeated with ease.

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10.0 Acknowledgements

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AZ Bikes - Donation of the bicycle frame

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Bike HUB - Rubber inner tubes for wheels, handlebar end-bars, rear 7 speed gear cassette

NAU Green fund - Client and project funding