# Green Energy Golf Cart: Project Based Learning for Innovation and Sustainability


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***Abstract* - The Raritan Valley Community College (RVCC) project-based Honors "Authentic Engineering Experience" tasks students to design, prototype, and make a real product in one semester. The product was a modified hand-pulled "Green Energy" golf cart that used the rotational motion of one of the golf cart wheels to rotate a DC motor to generate electricity to charge a cell phone and a solar panel to power a thermoelectric cooler to chill a beverage. A secondary objective of the course was to expose students, early in their careers and under "authentic engineering" conditions to skills used in industry that students can relate to potential internship and professional employers.**


## I. INTRODUCTION

A second-year Biology student, with a strong interest in sustainable "Green Energy", enrolled in a Raritan Valley Community College (RVCC) project-based Honors "Authentic Engineering Experience" course where students are tasked with making a real product in one semester. The student, also a Golfer, made innovative design changes to a hand-pulled golf-cart to solve the problems of her cell phone becoming discharged and the lack of a readily available cool beverage during the golf game. The resulting product used the rotational motion from one of the golf-cart wheels to turn a DC motor that performed as an electrical generator to charge the cell phone. The varying voltage generated as a function of walking speed was regulated for the cell phone to a constant five volts using a DC-DC Converter. Additionally, a solar panel was used to generate electricity to operate thermoelectric coolers that become cold on one side – to cool the beverage – and warm on the opposite side. A heat-sink and small fans were used to efficiently vent the excess heat back into the environment. The thermoelectric coolers were embedded in a custom designed and 3D Printed beverage holder and cooler (Figure 1).

A secondary goal of the project was to expose the student, early in her academic career and under "authentic engineering" conditions, to skills and practices used in industry. All project activity was hands-on and "live" – without classroom lectures or Labs. Principles and skills were experienced first-hand. The student was treated as a Professional Engineer in an Engineering-Solutions company – not as a student. The focus was for the student to learn by doing. The practical objective was to give the student authentic hands-on experience in rapid prototyping, project planning, project execution, and communication, to relate to potential internship interviewers and professional employers.

The spirit of this project is aligned with previous and on-going efforts to expose and engage students in "authentic" engineering experiences and environments through, for example, Hands-on projects and Project Based Learning [1-8] and Capstone projects [9].

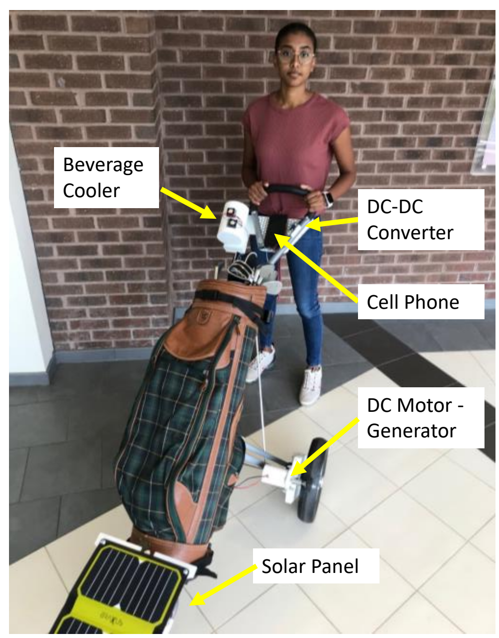


Fig 1: The Green Energy Golf Cart with DC motor/generator, solar panel, cell phone charging station, and beverage cooler identified

## II. CELL PHONE CHARGING

The first technical challenge was to provide sufficient electrical power to charge the cell phone battery within the timeframe of a game golf. The problem constraints were to match the charging requirements of most cell phones that are designed to use 2-8 watts of power, delivered at 5 volts DC, and charge in 1-2 hours [10].

As an initial step, a commercially available “hand-crank” battery-free flashlight was obtained, tested, and disassembled to investigate its “Green Energy” electrical generating mechanism and capability. The external hand-crank of the flashlight was attached to the shaft of a small DC motor (Figure 2). Rotating the hand-crank rotated the shaft of the motor and caused the wire coils wound around the shaft inside the motor housing to rotate. The rotating wire coils moved relative to fixed permanent magnets that surrounded the motor shaft.

Fig.2: DC motor: Top) Assembled, and Bottom) Disassembled showing the wire coil attached to the motor shaft and one of two permanent magnets surrounding the wire coil.

By Faraday’s Law of Induction (Equation 1), the relative motion of the wire coil moving through the magnetic field generated a voltage in the wire.

$$V = -N\frac{\Delta \Phi}{\Delta t} \qquad (1)$$

Where (V) is the induced voltage, (N) is the number of turns of wire in the wire coils, ($\Delta\Phi$) is change in the magnetic “flux” or number of magnetic field lines passing through the wire coil, and ($\Delta$t) is the change in time.

Further, by Ohm’s Law, the induced voltage resulted in an electrical current (Equation 2).

$$I = \frac{V}{R} \qquad (2)$$

Where (I) is the electrical current, (V) is the voltage, and (R) is the electrical resistance.

Therefore when the shaft was rotated the DC motor performed as an electrical generator.

The strategy was to use the rotational motion of one of the wheels of the golf cart to replace the hand-crank of the flashlight since the golf cart wheels are rotated as a matter of course throughout the golf game. The rotation rate of the golf cart wheel was measured to be about 60rpm at a normal walking pace and near 120rpm at a light jogging pace.

The low rotation rate of 60rpm produced only 0.20V, 0.03A, yielding less than 0.01W of electrical power using the hand-crank flashlight motor – far less than the 2-8W required for normal cell phone charging. An electric drill was used to rotate the motor shaft to experiment at higher rotating rates. Higher rotation rates increased the induced voltage by reducing the time per revolution and increasing the rate of change of the magnetic flux (Equation 1). However, these additional tests revealed the limitations of the flashlight motor capability to charge the cell phone battery as only 1.0W (2.4V, 0.4A) of electrical power was generated at 1000rpm. As a result, further work on the small flashlight motor was stopped and several larger motors were purchased and evaluated as well as ways to increase the motor shaft rotation rate were explored.

Larger motors have the advantage of using larger coils with more turns of wire (N) (Equation 1) to increase the induced voltage at lower motor revolution rates. Additionally, larger diameter wire is used in larger motors, resulting in lower electrical resistance (R) (Equation 2) and greater electrical current. Therefore larger motors produce greater electrical power compared to smaller motors at the same rotation rate.

The larger DC motors were evaluated by rotating the motor shafts using an electric drill and measuring the voltage and current as a function of drill rotation rate. The criteria were to identify a motor that yielded 5V and 5W (center of cell phone charging power range) at low motor shaft revolution rates. The chosen DC motor was rated at 24 volts at 2000rpm (Yae Tek 36W Model JK-0270). Figure 3 shows the chosen larger DC motor voltage, current, and electrical power as a function of the motor shaft revolution rate.

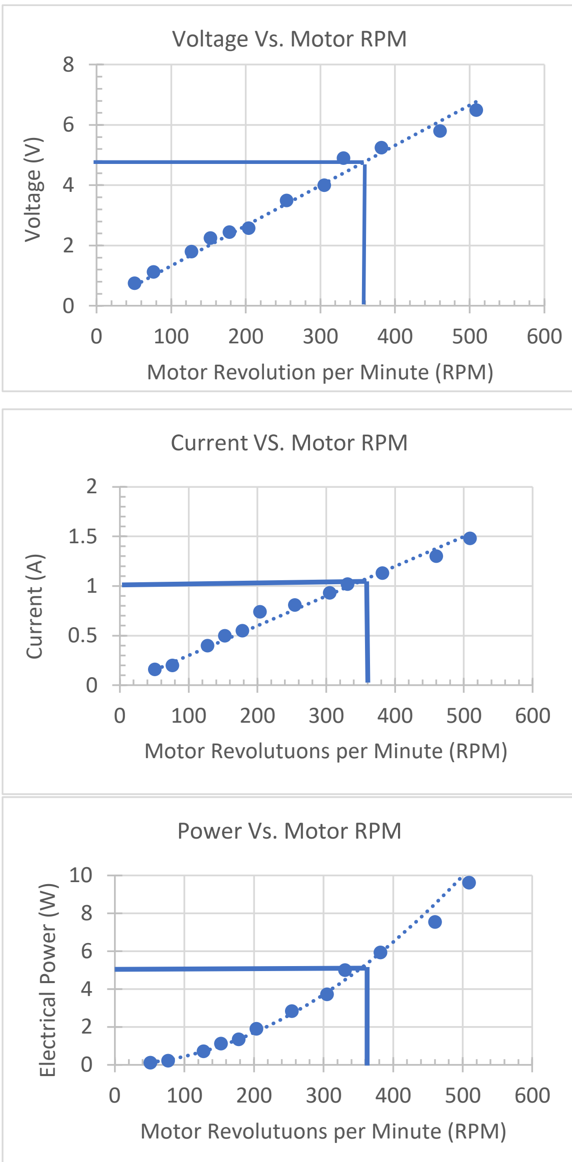


Fig. 3: Chosen DC Motor-generator A) Voltage, B) Current, and C) Electrical power as a function of the motor shaft rotation rate. The lines show the values at 360rpm.

The motor was selected because both the voltage and power achieved the target 5V and 5W, respectively, at about 360rpm. The rotation rate of 360rpm was only a factor of six greater than the 60rpm rotation rate of the golf cart wheel under conditions of normal walking speed. A simple “gear train” was constructed to amplify the 60rpm rotation rate of the golf cart wheel to the 360rpm motor shaft rotation rate (Figure 4). The gear train consisted of a small 2-inch diameter rubber wheel attached to the motor shaft and pressed against the surface of the 12-inch diameter golf cart wheel. The 12-inch to 2-inch diameter difference ratio resulted in the required factor of 6 increase in rotation rate to reach 360rpm for the motor shaft. Therefore the selected larger DC motor met the design targets for 5V and 5W at 360rpm that were achieved while pulling the golf cart under normal walking speed.

Fig 4: DC Motor “gear train” consisting of a small 2-inch diameter rubber wheel attached to the motor shaft and pressed against the surface of the 12-inch diameter golf cart wheel. The DC motor/generator is mounted behind the bracket.

While the selected DC motor met the design criteria of 5V and 5W at normal walking speed, increased walking speed resulted in higher voltages that could have damaged the cell phone electronics. For example, pulling the golf cart at the speed of a light jogging pace increased the voltage to the range of 8-10V. A DC-DC Converter was used to accept the varying input DC voltage from the motor and regulate the output to 5V (Figure 5) (Valefod, LM2596 3.0-40V Step-Down Converter)

A DC-DC Converter functions by changing the input DC voltage to a high frequency AC voltage. Then, the AC voltage is treated using inductors, transformers, and capacitors to produce a smooth output DC voltage. A "Step down" DC-DC Converter that reduces voltage was used in this project to ensure that voltages in excess of 5V were reduced to a constant 5V output to the cell phone.

Furthermore to provide a reservoir of ready-energy for the cell phone charging, the output of the DC-DC Converter was input to a cell phone battery charger unit mounted behind the golf cart handle. In this manner the battery charger was continually supplied with energy from the motion of the golf cart wheel/motor. The cell phone was connected to the battery charger when desired and the cell phone mounted to a front panel installed for this purpose on the golf cart handle (Figure 6). The panel was designed to functionally support the attachment of the cell phone using a magnetic mount and to be aesthetically pleasing by using a decorative screen as a background.

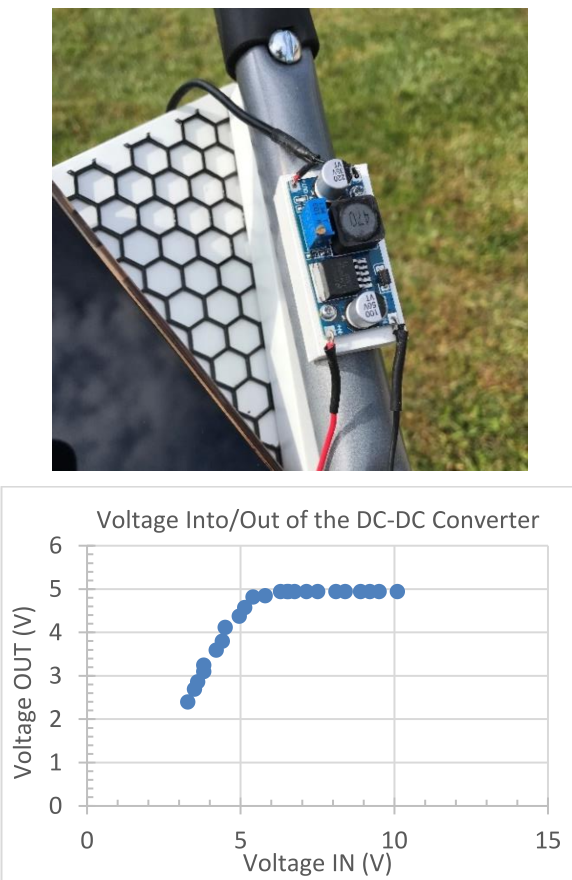


Fig 5: Top) The DC-DC Converter used in this project, and Bottom) The voltage into (x-axis) and out of (y-axis) the DC-DC converter showing the input voltage as high as 10V and the output voltage regulated to 5V.

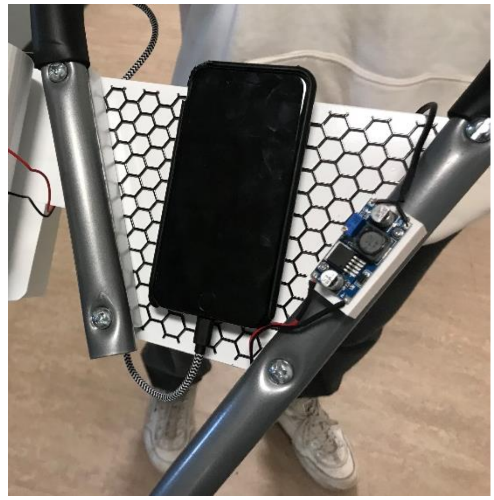

Fig 6: The cell phone mounted to the front of the golf cart panel. The panel was designed to be functional to support the attachment of the cell phone using a magnetic mount and to be aesthetically pleasing by using a decorative screen.

## III: SOLAR POWERED BEVERAGE COOLER

The second technical challenge was to cool a beverage during the golf game. A flexible and rugged solar panel (Braxus BXP-001) was used to generate 10W of electrical power at 5V and 2 amperes. The solar panel was mounted to the front of the cart on a custom made bracket (Figure 7).

Fig 7: A solar panel was mounted to the front of the cart on a custom bracket.

The beverage was cooled using Peltier thermoelectric coolers (Figure 8) (Adafruit 5V, 1A, Model 1331). The Peltier is a semiconductor device that becomes cool on one side and warm on the other when powered. To promote the cooling of the beverage a curved copper plate was machined that had the same radius of curvature of the beverage can. Copper was chosen because of its superior thermal conductivity. The curved copper plate was attached to the cool side of the Peltier device with thermally conductive adhesive. Contact between the curved copper plate and the beverage can resulted in more rapid cooling of the beverage. To further promote cooling, small finned heat sinks and small computer cooling fans, also powered by the solar panel, were mounted to the warm side of the Peltier device. The finned heat sink absorbed the heat from the Peltier device and the fans accelerated the removal of the heat into the environment. Two Peltier thermoelectric coolers were used to cool the beverage.

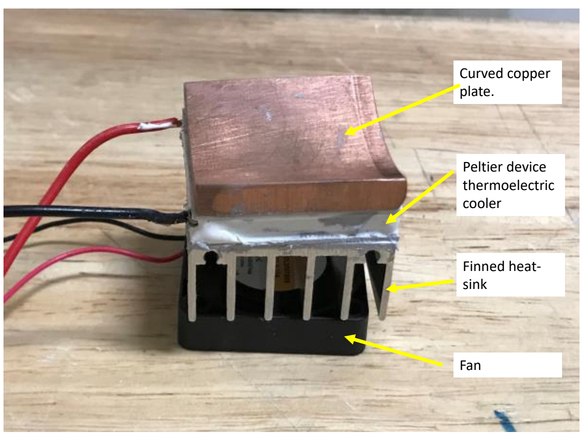


Fig 8: The Pelter thermoelectric cooler device with the curved copper plate that contacted the beverage and the finned heat sink and fan.

Additionally a beverage holder was designed using 3D design software and printed using a 3D printer. The beverage holder consisted of a two-wall design with thermal insulation between the walls (Figure 9). The Peltier thermoelectric coolers were inserted through the walls of the beverage holder to allow the curved copper plates to contact the beverage can walls. The beverage holder was mounted to the handle of the golf cart (Figure 10).

Fig 9: Top) The beverage holder showing the two wall design with thermal insulation between the walls. Also the curved copper plates are visible on the inside wall. Bottom) The two Peltier thermoelectric cooler assemblies viewed from outside the beverage holder.

Fig 10: The beverage cooler was mounted to the custom made bracket near the handle of the golf cart.

## IV: DESIGN FOR PORTABILITY

Throughout the design of the cell phone charger DC motor/generator and the solar powered beverage cooler, attention was paid to maintaining the easy portability of the golf cart. The position of each of the added components were carefully chosen to maintain the foldability of the golf cart for storage and transportation in the trunk of a car (Figure 11).

Fig 11: The golf cart was designed to maintain the easy foldability for transportation in an automobile trunk.

## V: HANDS-ON "AUTHENTIC" EXPERIENCE

A secondary goal of the project was to expose the student to methods and motivations used in industry. For example, the course of the project was guided using a project plan that was updated weekly. The concepts and practices of rapid-prototyping were used. The focus throughout the project was on the potential "Customer" with attention to both functionality to meet a potential Customer's requirements, but also the aesthetic attributes of the product. And the importance of building relationships with 3rd-party Suppliers was emphasized as support from the campus Advanced Manufacturing group was needed to machine the curved copper plate for the beverage cooler.

All project activity was hands-on and "live" – without classroom lectures or Labs. Principles and skills were experienced first-hand. The student was treated as a Professional Engineer in an Engineering-Solutions company – not as a student. The focus was for the student to learn by doing. The outcome was increased student confidence and capability.

Finally the project experience serves as an example for the student to relate to potential future internship employers and professional employers and positively differentiates the student.

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