

# Solar-Powered Carousel for Hands-On Teaching

by

Erin C. Shea

Submitted to the Department of Mechanical Engineering  
in Partial Fulfillment of the Requirements  
for the Degree of

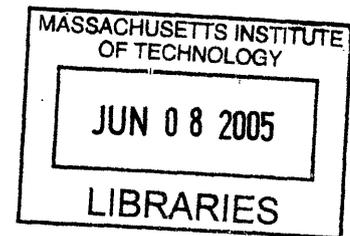
Bachelor of Science

at the

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## ABSTRACT

This thesis is the design of a solar-powered carousel that informs the public about the setup and capabilities of solar-powered systems. It is designed as a mobile tool that can be moved among college campuses, businesses, and residential neighborhoods to provide hands-on demonstrations about solar power. Users will sit on the carousel and feel the changes in speed of rotation of the platform as the insolation striking the solar panel or the torque/load fluctuates. A mini fan can be turned on as an extra electrical load on the system to explore how the solar power handles the additional loads, and meters will display the current and voltage levels. Through both the changes in speed and the metered displays, this carousel will enable the user to both physically and visually get a feel for solar power. The user will also be able to view the setup of the solar panel, batteries, and motor because the top of the carousel is removable. The hope in designing this carousel is that it can serve as a tool to educate the public, and that people will walk away with a better understanding of solar power, and, hopefully, more inclined to purchase and setup photovoltaics to power their home or workplace.

Thesis Supervisor: Louis L. Bucciarelli Jr.  
Title: Professor of Engineering

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## **1.0 Introduction**

This thesis presents a conceptual design of a solar-powered carousel intended to be used as a teaching aid. Photovoltaic (solar) systems were first utilized in space to provide a steady and reliable power source for equipment on spacecrafts. Today solar technology is used to supply electricity to homes and buildings, pump water for watering livestock, and power construction signs along highways—just to mention a few of many applications. More and more utilities offer green power options, and across the country local, state, and federal programs offer loan, rebate, and tax incentive programs for installing a photovoltaic system [1]. But before the public can purchase or even become interested in photovoltaics, they need to be educated in their performance, use, and probable cost.

This carousel consists of a removable platform supported by a shaft and base; the platform lifts off to display the batteries and motor mounted beneath, while a solar panel rests atop the platform. The rotation of the carousel is affected by both intensity of the sunlight and amount of electrical load. A small electric fan is included on the carousel and powered by the photovoltaic system. The fan's load on the system can be increased or decreased by the user-rider by controlling the speed of the fan. He or she can then observe how much the speed of the carousel decreases or increases with the changing electrical load on the system. After using this carousel, consumers will tangibly understand the makeup and capabilities, as well as limitations, of photovoltaic systems.

The carousel is designed to be a mobile display for experimentation at colleges, places of work, neighborhoods, and science museums or nature centers. Designing the structure of the carousel not too large and not fixed to the ground allows for people all over of all ages to experience this hands-on demonstration of solar power. After getting a feel for the capacity of photovoltaics as well as the setup and components that go with it, people will be more inclined to look into solar options available to them locally and from their power utility.

## **2.0 Background on Photovoltaics**

Renewable energies are being increasingly studied and utilized, yet the average citizen does not fully grasp the real domestic possibilities of such power. A Rocky Mountain Institute analysis found that average American home energy consumption rose 9% from 1987 to 2001 [2]; this increase was mainly due to lights and electrical appliances. Despite improvements in home insulation and efficiency, society is using more and more energy. To decrease dependence on fossil fuels, which not only pollute the atmosphere but are also rapidly disappearing, residential and commercial use of solar power, and other renewable resources, to supplement plant-generated power is necessary. Figure 1 below shows the breakdown of energy sources from the year 2003, and Figure 2 projects the growth of solar power production over the next 50 years.

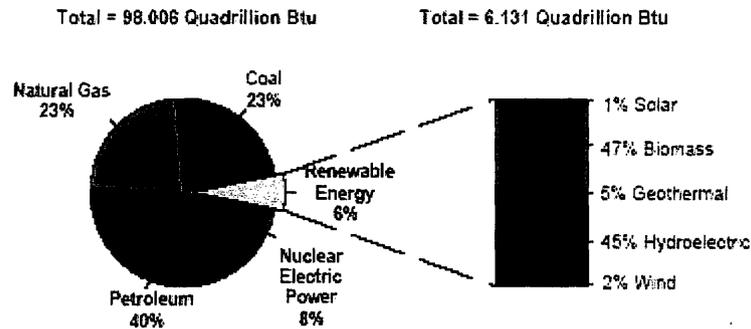


Figure 1: Breakdown of energy consumption in US in 2003, from the Energy Information Administration (EIA) of the Department of Energy [3].

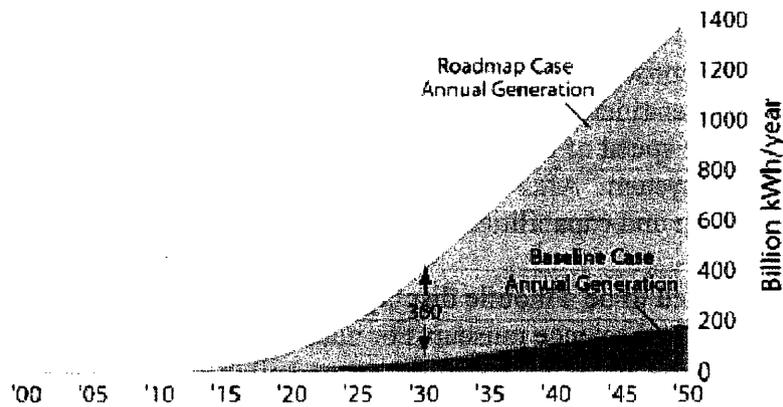


Figure 2: Projections for Solar Electricity Generation from 2000-2050; Baseline Case and Roadmap case, according to SEPA, Solar Electric Power Association [4].

Photovoltaic systems can be either stand-alone or grid-connected. Stand-alone systems are useful in isolated, remote areas, like rural homes and farms, or places without an existing power supplier, such as in developing countries. If these systems need to supply power 24 hours a day, a battery can be placed between the panels and the load. The battery is charged by the array during the day and can then supply the needed power at night and during cloudy periods. A charge controller is used to keep the battery from overcharging or discharging completely, increasing the longevity of the battery.

Grid-connected systems allow for generation of solar power with a back-up of grid-supplied electricity if needed. Another advantage to these systems is that many power suppliers offer a “buy-back” program, meaning the power company will buy any extra power generated by a personal solar system. For residential use, an inverter is necessary between the battery and the load to convert the DC power produced by the array into the AC power most commonly needed to run household appliances.

A photovoltaic system may be expensive at installation, but over its lifetime it will supply clean, free, quiet energy. As fossil fuel resources shrink, grid-electricity prices will increase, and as the use of solar energy increases, photovoltaic (pv) costs will continue to go down. Figure 3 below quantifies the downward trend the prices of solar cells and modules have seen over the past 10 years. Even as prices drop, though, few will make the decision to go solar without fully understanding it. Numbers on a page detailing power output and cost benefits do not talk as loudly as a hands-on demonstration, especially one designed to teach the public the setup and power available associated with a solar system. The use of this teaching carousel will open the eyes of consumers to the feasibility of photovoltaic systems, and raise interest in solar and other renewable energies.

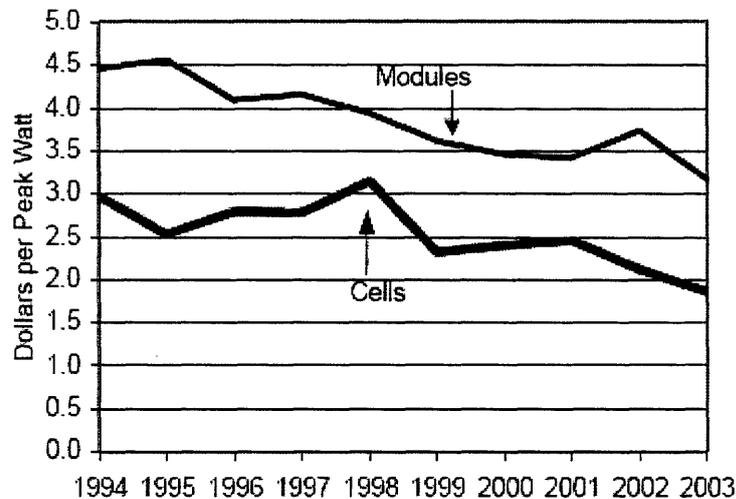


Figure 3: Average price of Photovoltaic cells and modules over time, from the EIA [5].

This carousel will be a stand-alone system, emulating the performance at a remote site, and therefore require a battery. The system will not need an inverter, however, since a DC motor and DC appliance will be used. A photovoltaic system installed in a home would be more complex than this carousel system, but this setup will still provide an educational introduction to solar-powered systems.

The photovoltaic module will sit fixed atop the carousel tilted at an angle of  $42.2^\circ$ , an angle equal to Boston's latitude [this carousel is designed specifically for the Boston area, but to maximize insolation wherever the carousel is transferred the module can simply be tilted at the angle of the new latitude]. The carousel will rotate at about 3.75 RPM, equivalent to roughly once every 16 seconds. The module will produce 60 W of power in full sun, but as the carousel rotates the module will be shaded when faced away from the sun, and therefore the output will vary between full (the "full" level dependent on weather conditions and time of day/position of sun) and near zero as the carousel spins. The loads on the solar panel will be the DC motor driving the carousel plus a DC fan. This fan will act as a variant load that can be turned on and cranked up to see how the extra power drain affects the solar module output and carousel speed.

### 3.0 Design Methods

This section describes the three main subsections of the carousel: motor and transmission, structure, and pv power supply.

#### 3.1 Motor and Transmission

In order to select a specific motor for the carousel, an estimate of the power and torque requirements is needed. The torque needed to overcome friction and handle the estimated load is calculated below.

To estimate the torque caused by friction in a machine comparable in both size and function, the technical specifications of a similar, existing carousel were considered. The Maxi Carousel, shown in Figure 4 below, is produced by British Turntable [6].

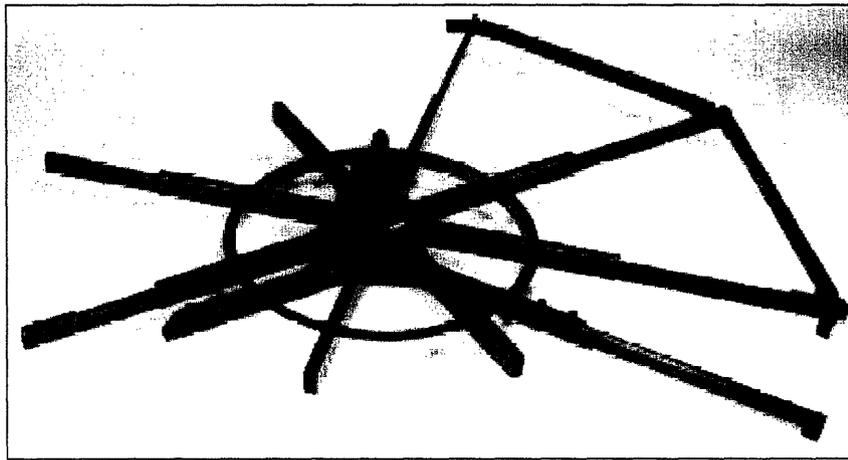


Figure 4: Maxi Carousel by British Turntable [6].

Table 1 below outlines the Maxi Carousel technical specifications.

Mass, $m_I$	73 kg
Max speed, $\omega_I$	1.1 rpm = 0.115 rad/sec
Max load, $L_I$	500 kg
Radius of steel ball bearing, $R_I$	4 inches = (0.1016 m)
Motor Power Rating	10 W

Table 1: British Turntable Maxi Carousel Specs [6].

Using the torque equation below, the torque,  $\tau_{friction}$ , needed to overcome friction is calculated, with the assumptions that 1/3 of the turntable mass is above the ball bearing, and the coefficient of rolling friction,  $\mu$ , of steel on steel is 0.005 [7]:

$$\tau_{friction} = \mu WR_I \quad (1)$$

$$(0.005)(9.8 \text{ m/s}^2)(500 \text{ kg} + (1/3)73 \text{ kg})(0.1016 \text{ m}) = 2.6 \text{ Nm.}$$

Using this  $\tau_{friction}$  and the maximum speed listed,  $\omega_1$ , for the turntable, the power needed to overcome friction,  $P_{friction}$ , for steady state rotation of the system can be calculated from the power-work equation.

$$P_{friction} = \tau_{friction} \omega_1 \quad (2)$$

$$(2.6 \text{ Nm})(0.115 \text{ rad/sec}) = 0.299 \text{ W.}$$

I will use the above friction estimates, and use load specifications for my carousel. Table 2 below lists the specifications for my carousel.

Mass, $m$	50 kg
Mass including max load, $m_2$	200 kg (carousel can accommodate 1-2 riders plus a bench or chair)
Max speed, $\omega$	3.75 rpm = 0.393 rad/sec
Radius of carousel top, $R$	1 m

Table 2: Specifications for my carousel.

The motor selected for the carousel is a 6 Nm, 10 W, 12V, DC geared motor out of the Crouzet catalogue. When we find where 2.6 Nm intersects on the 12V torque-speed curve in Figure 5 below, we see it corresponds to about 20 RPM. This speed is much faster than what we want the carousel to rotate at (riders need to be able to read meters and play with the fan and not be dizzy), so the speed will be geared down.

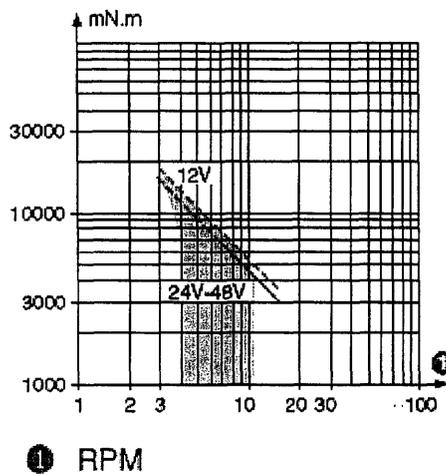


Figure 5: Torque-Speed Curve for selected motor [8].

A belt is used as means of transmission for the carousel. The motor (which is fixed beneath the carousel top) will be oriented vertically and the belt will run horizontally between the motor shaft and the shaft of the carousel. An idler will be positioned to keep the belt taut and prevent slippage. This configuration transmits power because the carousel shaft will be stationary (fixed to ground) while the motor runs and the belt causes the motor, its housing, the carousel top, and all components fixed to the top to

rotate. Figure 6 below shows a side view of the carousel with motor and transmission components.

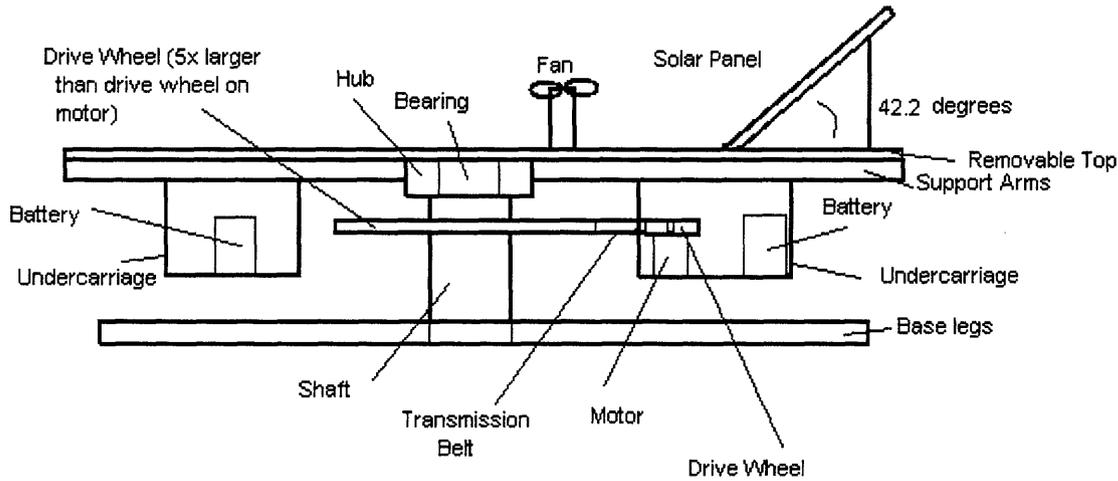


Figure 6: Side view of carousel and components.

Because we want to gear down the output speed of the motor, the diameter of the carousel shaft will have to be larger than the diameter of the drive wheel on the motor shaft. Structurally, the radius of the carousel shaft is 70.65 mm (as determined in Section 3.2.3), so a drive wheel of a certain radius will need to be fitted to the shaft. The diameter of the drive wheel on the motor shaft is 50 mm, to ensure the belt has an adequate radius. In order to produce a carousel speed of 3.75 RPM, the gear speed ratio below is used, where  $\omega$  is the speed of the carousel,  $R$  is the radius of the drive wheel on the carousel shaft,  $\omega_2$  is the output speed of the motor (at 2.6 Nm), and  $r$  is the radius of the drive wheel on the motor:

$$\begin{aligned} \omega R &= \omega_2 r. & (3) \\ R &= (\omega_2 r) / \omega = (20 \text{ RPM} * 50 \text{ mm}) / 3.75 \text{ RPM} \\ R &= 266.7 \text{ mm} \end{aligned}$$

From this relationship we found that the radius of the drive wheel on the carousel shaft needs to be 266.7 mm, or about 10.5 in, to achieve the desired rotational speed of the carousel; this equates to a gearing down of about 5:1. The output shaft of the motor is only 8 mm in diameter [8], so a gear with an outer radius of 46 mm and an inner radius of 4 mm must be attached to the motor output shaft. This configuration will achieve the transmission of the desired speed from the motor to the carousel.

The gearing down will change the torque-speed curve as seen below in Figure 7, in accordance with the 5:1 ratio. The stall torque increases and the no-load speed decreases. The initial stall torque will be sufficient to start and accelerate the carousel, and then the torque will decrease along the torque-speed curve to the correct speed corresponding to the steady state torque.

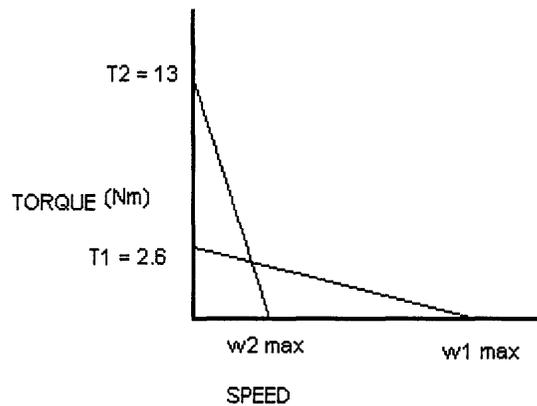


Figure 7: Adjusted torque-speed curve according to geared down ratio.

## 3.2 Carousel Structure

The carousel structure consists of four main components: the base, the support arms, the shaft, and the undercarriage. The following sections break down each component and detail the design parameters.

### 3.2.1 Base

Three legs splayed equally around the shaft make up the base of the carousel. Figure 8 below is an overhead view of the base legs. The main constraint on the legs is the length. The leg length was determined by assuming a point mass of the maximum advertised load of 200 kg at the end of the 1 m radius carousel top. A torque balance was used to find the minimum length of base leg needed to keep the carousel from tipping over when an assumed maximum force is applied. Figure 9 below shows a side view of the legs, shaft, and carousel top with described forces.

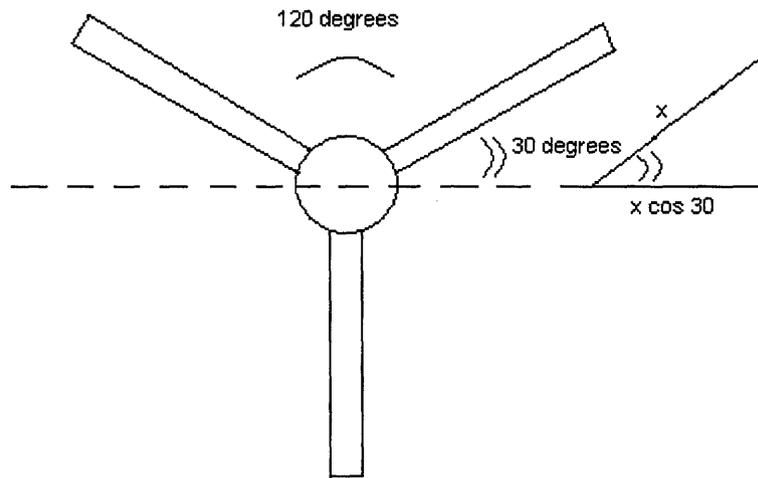


Figure 8: Overhead view of base legs with corresponding trigonometric calculations.

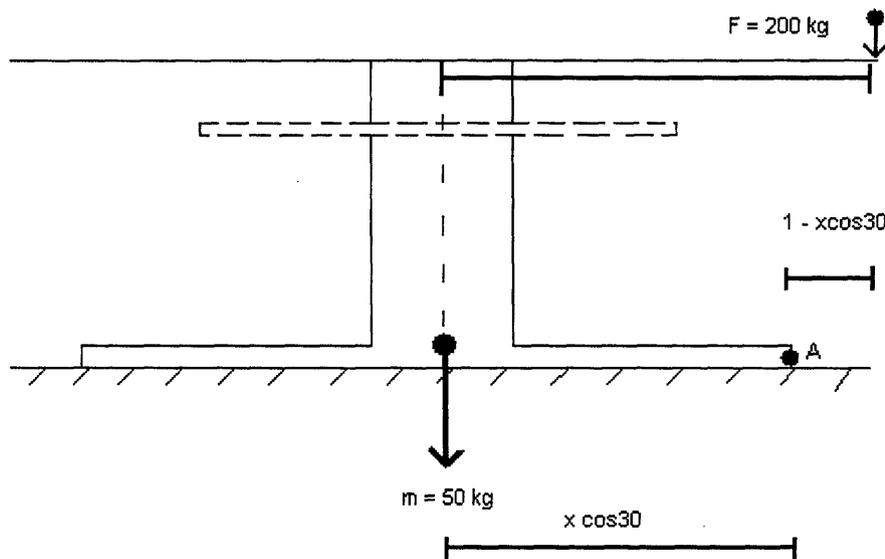


Figure 9: Side view of carousel with dimensions.

Using Point A as the outer tip of a base leg, Equation (4) below balances the forces about Point A to determine base leg length,  $x$ , that will ensure the carousel will not tip over even when the maximum load is applied at the radius. This equation assumes the center of mass of the carousel is its center point located in the middle of the shaft.

$$\begin{aligned}\tau_A &= F_1 r_1 - F_2 r_2 = 0 & (4) \\ F_1 r_1 &= F_2 r_2 \\ (200 \text{ kg})(9.8 \text{ m/s}^2)(1-x\cos 30) &= (50 \text{ kg})(9.8 \text{ m/s}^2)(x\cos 30) \\ x &> 0.924 \text{ m}\end{aligned}$$

The minimum leg length for the three legs composing the base of the carousel is 0.924 m to prevent tipping.

This carousel is designed assuming it will be placed on a hard, flat surface for use, such as a slab of concrete or wooden platform.

The cross-section of the steel bar used for the legs is the same as for the carousel arms, which is determined in Section 3.2.2.

### 3.2.2 Top Support Arms

The top of the carousel will be 2 meters in diameter; this area should allow sufficient room for the photovoltaic panel, a chair for subjects to sit in, and instrumentation, while keeping the carousel a manageable size for mobility. The top of the carousel itself will be a piece of plywood cut to the correct 2 m diameter circular dimensions, resting atop the support arms. This will enable the top to lift off easily for access to the components beneath it, allowing subjects to view all parts and the complete setup of the photovoltaic system. There will be six support arms for the top of the carousel, welded around the shaft. Figure 10 below is an overhead view of the six support arms.

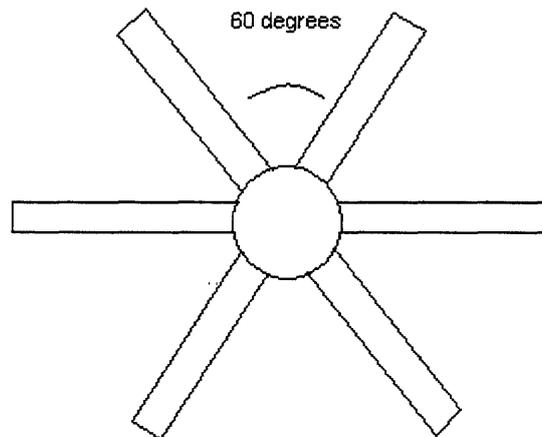


Figure 10: Overhead view of support arms.

The important calculations for the support arms are strength and displacement. The selected material for the support arms is 1020 HR (hot-rolled) steel. The yield stress,  $\sigma$ , of this type of steel is 262 MPa. From the relationship which determines the maximum stress due to bending in engineering beam theory, we can find  $S$ , the section modulus of the support arms, using  $M$ , is the applied moment:

$$\sigma = M / S. \quad (5)$$

Assuming the moment,  $M$ , is the maximum allowable load of 200 kg applied at the tip of the 1 m arms, the section modulus needs to be at least  $7.5 \times 10^3 \text{ mm}^3$  to keep the steel arms from yielding. Using the Steel Sections applet from the 1.050 course website [9], the cross-section with the required section modulus can be found. The arms will be made of S75x8 steel I-beam, with a moment of inertia,  $I_{xx}$ , of  $1.04 \times 10^6 \text{ mm}^4$ , and an  $S$  of  $2.74 \times 10^4 \text{ mm}^3$ . Figure 11 below depicts the cross-section of this S75x8 I-beam.

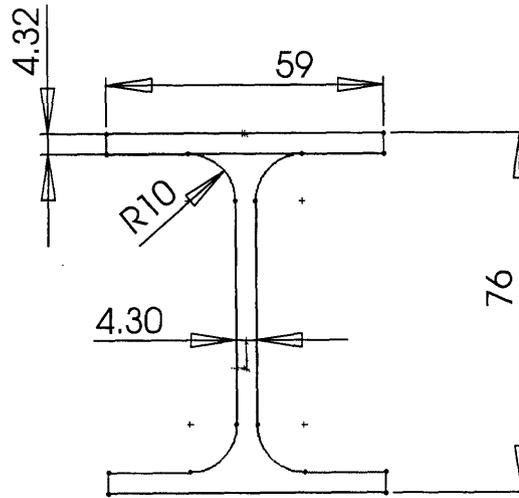


Figure 11: Cross-section view of S75x8 I-beam selected for arms and legs (dimensions are in mm).

The steel support arms will not break under the weight, but we also do not want them to displace noticeably. The Young's modulus,  $E$ , of steel is 195 GPa. The force,  $F$ , is the maximum allowable load applied at a length,  $l$ , equivalent to the top radius of 1 m, so the displacement,  $y$ , of the support arms with the given cross-section is found from the relationship for the tip deflection of an end-loaded cantilever from engineering beam theory—a conservative estimate:

$$y = Fl^3 / 3EI. \quad (6)$$

The displacement of the steel support arms under the maximum allowable load is 3.2 mm, which for this carousel is deemed acceptable.

### 3.2.3 Shaft

The shaft will be a hollow, steel cylinder. The shaft should be tall enough to allow ground clearance for the electrical components fixed below the carousel top, while keeping the carousel short enough for an easy step up for subjects. Assuming a shaft height of 35 cm, the dimensions of the steel cylinder need to be determined to keep the shaft from leaning. In Equation (7) below, 1 mm is the maximum allowable displacement,  $\delta$ . The moment,  $M$ , is again the maximum allowable load applied at a distance equal to the radius, and the length,  $L$ , equal to the height of the cylinder, 35 cm.  $E$  is still the Young's modulus of steel, and the equation is solved for the minimum  $I$ , moment of inertia, required for the given minimum displacement. Figure 12 below depicts the shaft and displacement configuration being calculated.

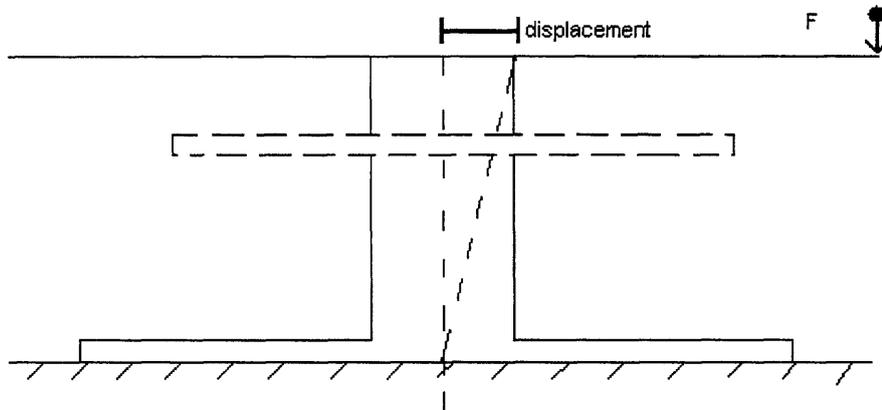


Figure 12: Side view of carousel showing shaft displacement.

$$\delta = \frac{ML^2}{2EI} \quad (7)$$

$$0.001 \text{ m} = \frac{[(200 \text{ kg})(9.8 \text{ m/s}^2)(1 \text{ m})(0.35 \text{ m})^2]}{[2(195 \times 10^9 \text{ Pa}) I]}$$

$$I = 6.16 \times 10^{-6} \text{ m}^4 = 6.16 \times 10^6 \text{ mm}^4$$

Using the Steel Sections Java applet [9], the dimensions of the hollow cylinder with the required moment of inertia can be found. The appropriate commercially-available steel section is the HS141x8.0 hollow steel cylinder, with a moment of inertia of  $7.43 \times 10^6 \text{ mm}^4$ . The cross section has an outer radius of 70.65 mm and a wall thickness of 7.95 mm.

At the top of this shaft is a 4 inch diameter steel ball bearing, about which the support arms and carousel top rotate. A three-inch thick steel hub is welded around this bearing, and the six support arms are welded to this hub.

### 3.2.4 Undercarriage

The batteries and motor need somewhere to be fastened, so beneath the plane of the support arms will be an undercarriage. It will be a piece of aluminum sheet metal riveted to two of the support arms and bent to form a flat-bottomed basket that hangs down and holds the components. The gel cell batteries weigh 3.8 lbs each, so the carousel has two undercarriage baskets opposite each other, one battery on each, for balance. The wires

strung between these two undercarriages can be fastened to the support arm in between them using plastic zipties to prevent sagging or tangling. Figure 13 is an overhead view of the undercarriage setup.

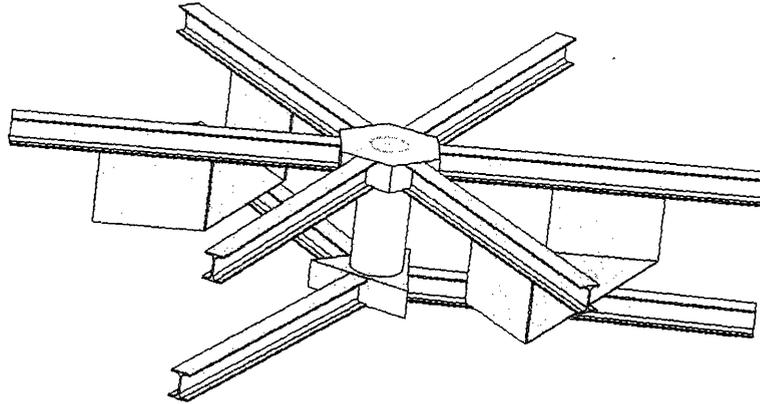


Figure 13: Views of undercarriages.

### 3.3 Photovoltaic Power Supply

Some areas of the United States receive more direct sun, and are therefore better suited for solar power. Boston is in the range of medium-low average annual insolation, as seen in Figure 14 below, and therefore is not the best of areas for photovoltaics, but can still make do.

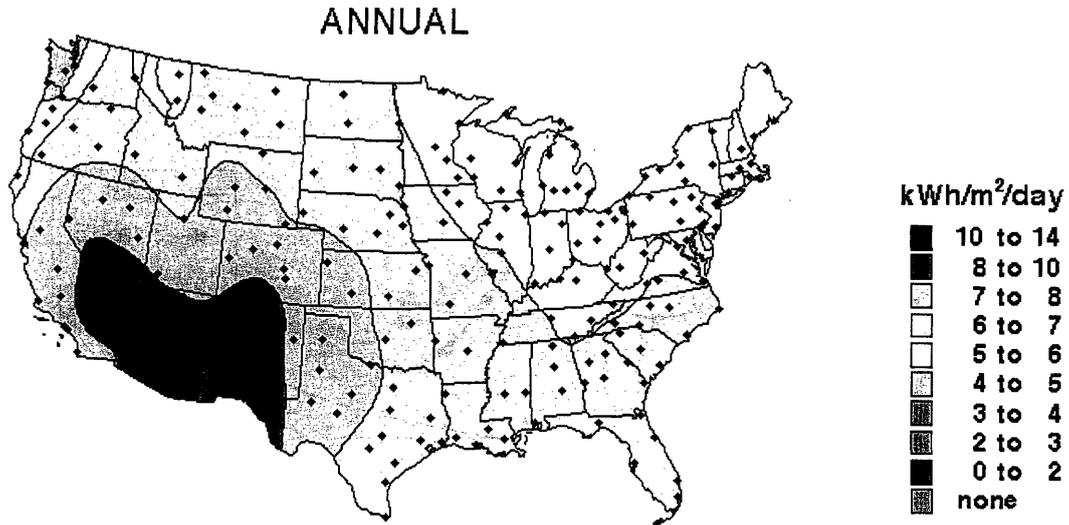


Figure 14: Map of Average Annual Insolation for contiguous US, for panels tilted at latitude; data from National Renewable Energy Laboratory (NREL) [10].

### 3.3.1 Solar Insolation

Solar panels can be fixed and tilted in a variety of ways. Flat-plate collectors are fixed facing solar south, and can be tilted horizontal, at latitude of the site, at latitude plus or minus  $15^\circ$ , or at a  $90^\circ$  angle. Flat-plate collectors do not have to be fixed in one position; they can also track the sun on 1 or 2 axes. These tracking collectors are often more expensive than they are worth, though, for the small amounts more of insolation collected than flat-plate collectors.

For this carousel a flat-plate collector will be used. Figure 15 below plots the differences in insolation over the year for panels in Boston tilted at  $0^\circ$ ,  $42.2^\circ$  (the latitude of Boston),  $42.2 \pm 15^\circ$ , and  $90^\circ$ .

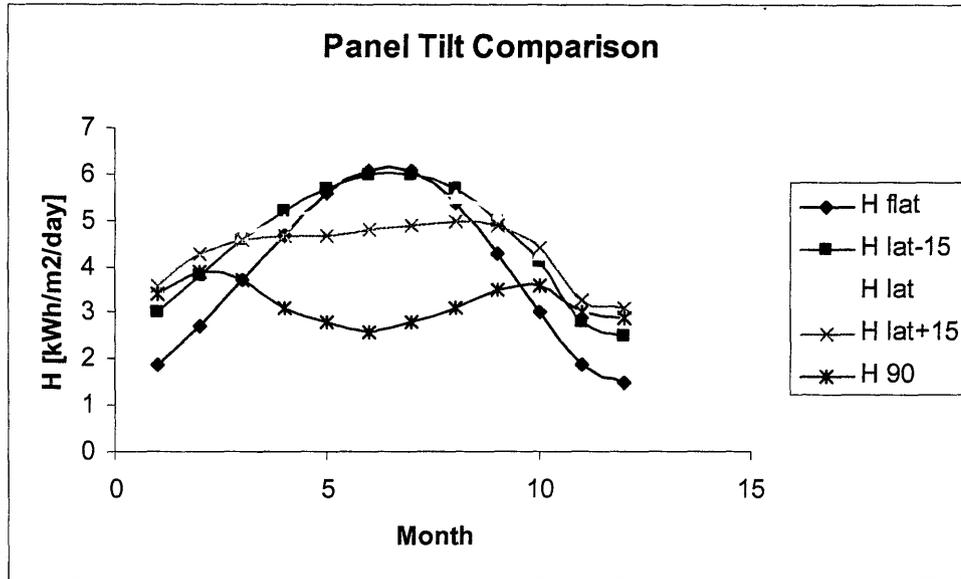


Figure 15: Comparison of different panel tilts; data are 30-year averages from Renewable Resource Data Center [11].

From this graph a tilt angle can be chosen. For this carousel, we want enough insolation throughout the year to power it during any month, and a roughly even distribution would be best. Obviously a tilt of  $90^\circ$  and  $0^\circ$  are too extreme, and  $\text{lat}+15^\circ$  is not optimal. Both tilts of  $\text{lat}$  and  $\text{lat}+15^\circ$  are fairly good, but I have selected a tilt at latitude because it receives more insolation during the winter months, which will be the time of year when all sun hours and insolation possible are necessary for enough power to run the carousel.

The average solar radiation over 30 years for Boston is given below in Table 3 (this is the same data as plotted above in Figure 15). The data is for solar panels at a tilt equal to Boston's latitude of  $42.2^\circ$ .

Month	Solar Insolation [kWh / m <sup>2</sup> / day]
January	3.4
February	4.2
March	4.7
April	5.0
May	5.3
June	5.5
July	5.6
August	5.5
September	5.1
October	4.3
November	3.1
December	2.9
<b>Yearly Average</b>	<b>4.6</b>

Table 3: Monthly Average Insolation for panel tilted at latitude in Boston [11].

The month with the least average insolation is December, so the carousel photovoltaic power supply will be tailored for the least sunny month to account for this worst case scenario.

### 3.3.2 Daily Load

If we assume the full 10 Watt rating of the motor is needed to run the carousel, and the carousel runs about six hours per day, the carousel requires 60 Whrs / day. Going back to what was established in Section 3.3.1, where the pv supply will accommodate the month of December, we can say that an insolation of 2.9 kWh/m<sup>2</sup>/day is equivalent to 1 kW/m<sup>2</sup> for 2.9 h/day. The following equation determines the module size needed to supply the required load, 60 Wh/day:

$$0.060 \text{ kWh/day} = x \text{ 2.9 h/day.} \quad (8)$$

Solving for module size,  $x$ , we get 0.021 kW = 21 W. One 60 W panel will more than suffice and provide enough power, even in December, because the panel rating, 60 W, is the power produced when the solar flux is equal to 1 kW/m<sup>2</sup> at 20° C and the power out is roughly proportional to the flux.

In summation, we will use one 12 Volt, 60 Watt module to power this carousel, and will tilt it at Boston's latitude of 42.2°. If we assume on average there are three hours of sun striking the 60 W module each day, that is 180 Whrs / day. The sun should provide plenty of power for the carousel, but if one day is cloudy and provides no sunlight or if the sun is not shining when the carousel is turned on, battery power is needed. This battery power will also supply required power as the carousel spins and the panel rotates out of the sun.

### 3.3.3 Battery Storage

For this application, a gel cell, or sealed lead acid, battery is appropriate. In a gel cell battery a gelling agent, typically silica, is added to the electrolyte to reduce movement, which reduces spills. These gel cell batteries must be charged at a lower voltage to prevent damage, but lead acid batteries do not develop "battery memory", so recharging can begin at any level of discharge without impairing battery life. The charge does need to be cut off when the battery is full to prevent overcharging, though. A solid-state automatic switch voltage controller for the batteries will be used to break the connection between the panel and the batteries when the batteries charge above 14.5 V and reconnect when the battery charges drop below 13 V.

We know that the carousel requires 60 W of power to run for one day, so if the battery is 12 V that is equivalent to 5 Amp hours of power. The website [www.zbattery.com](http://www.zbattery.com) sells 12 V, 5.5 AH gel cell batteries. One of these batteries supplies 66 Wh, or about one day's power requirement. Using 2 of these gel cell batteries will provide power for 2 full days.

## 4.0 System Behavior

The following figures are different views of a solid model of the carousel; note the three-legged base, shaft, six-armed support top, undercarriages for motor and batteries, and removable carousel cover.

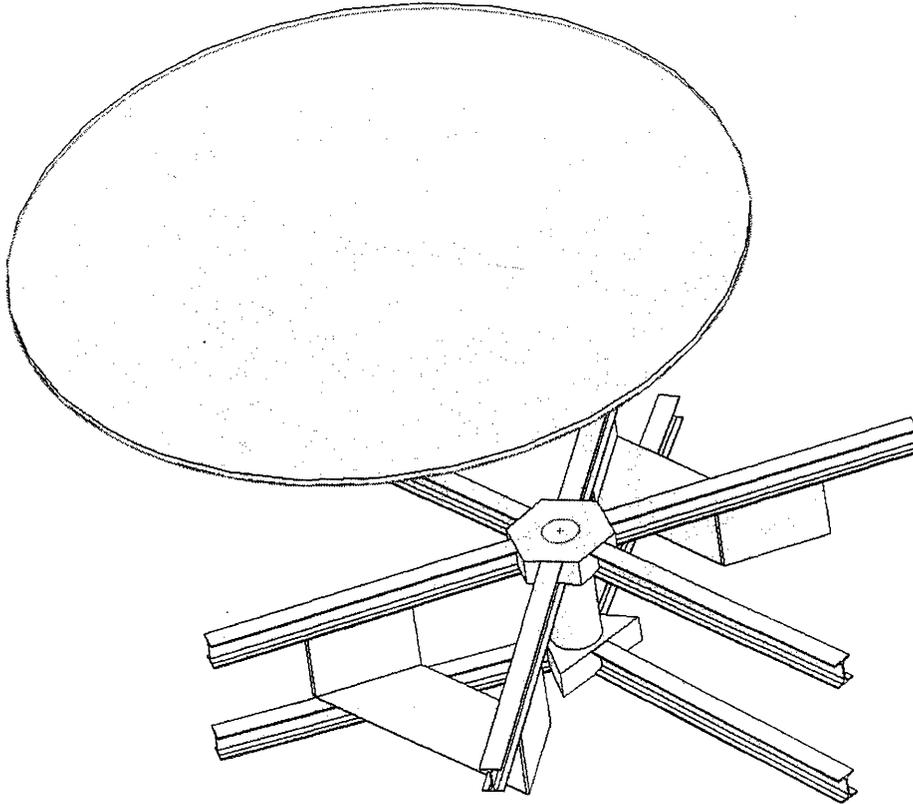


Figure 16: View of carousel with removable cover.

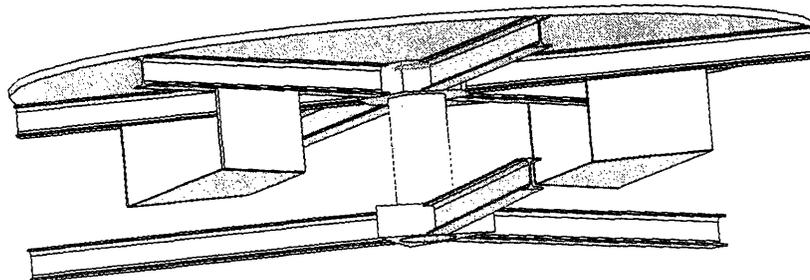


Figure 17: View looking up at an angle beneath the carousel.

Figure 18 below is a charge/discharge curve for one cell; ten of these cells in series would roughly equal a 12V battery, with behavior similar to the carousel batteries. When the photovoltaic module is in the sun and the batteries are charging, the bus voltage will be about 14.5V (the maximum before the connection is broken to prevent overcharging). But as the carousel rotates and the panel goes into the shade, or the mini fan is turned on and up, draining power, the battery jump from charge to discharge is about 10% over most of the states of charge, and the voltage will drop to around 12.5V. This voltage drop equates to a proportional decrease in speed, felt by the subject.

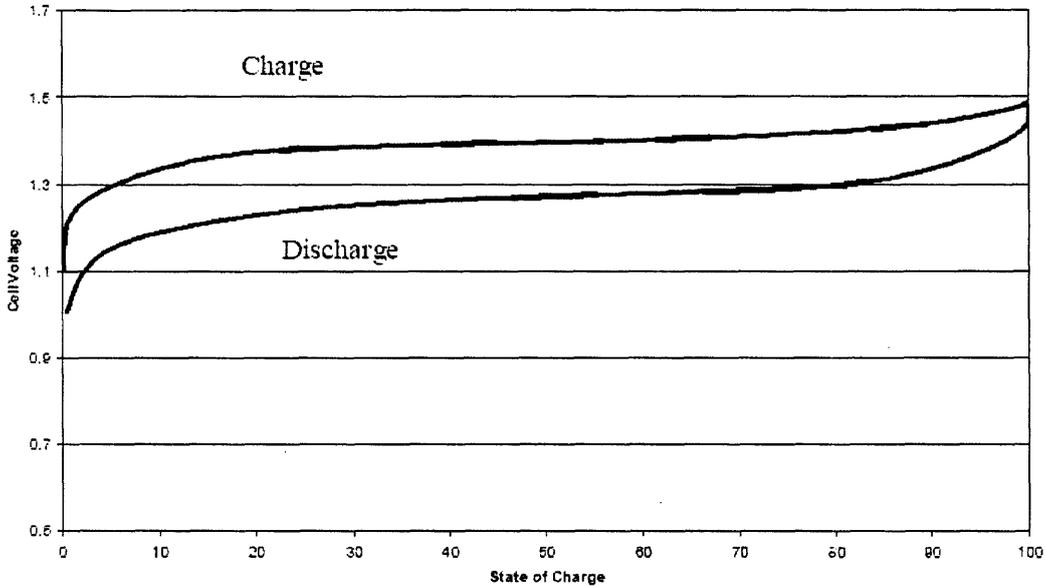


Figure 18: Charge/Discharge curves for a single cell in a battery [13].

An additional electrical load is added to the carousel setup to simulate added load on the system. A 12V, DC miniature fan with variable speeds will be in parallel with the batteries and motor. The fan will initially be off while the subject experiences the changes in speed based on insolation fluctuations alone, and then the fan can be turned on and up to different speeds to see how this extra load on the system affects the carousel speed. This fan consumes from 0.2-6.5 amps [12] (2.4-78 W). Because the fan can be turned up so high and consume a lot of power, as the batteries discharge, the bus voltage drops. This decrease in bus voltage will affect both appliances, and the subject will feel this decrease as the carousel speed slows down. Figure 19 below shows a circuit schematic, with the photovoltaics, batteries, fan, and motor in parallel.

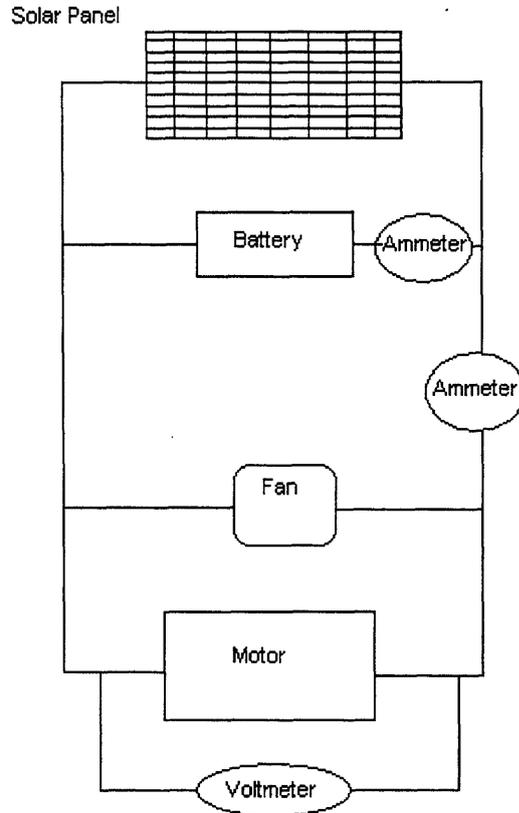


Figure 19: Carousel circuit diagram.

In Figure 19 above, an ammeter measures the charge/discharge current of the batteries, as well as the current to the loads, the motor plus the fan. A voltmeter measures the voltage across the motor, which is the bus voltage. These displays will give the subject a visual perspective for the power demands on the system in addition to the physical feeling they will gain from changes in speed. (The wires on the ammeters and voltmeter will run down through holes drilled in the plywood carousel top.)

## **5.0 Conclusion**

Users of this carousel will walk away having a better sense of the schematics and capabilities of solar power. They will have seen the setup of the solar panel, batteries, and loads; felt the changes in rotational speed of the carousel as the insolation striking the panel fluctuates and the speed on the mini fan is turned on and up; and observed the numerical differences in voltage and current as read off the meters. This hands-on carousel can be a powerful tool because it physically and visually teaches about solar power, and is mobile, so it can be introduced to people all over.

My hope is that a teaching carousel, like the one this thesis designs, will spread the knowledge and awareness necessary for society to move in the direction of green energy, such as solar. Right now this technology is not mainstream and relatively expensive, but in the future, at some point, it will become necessary as fossil fuels dwindle. A teaching tool such as this will ease the transition to photovoltaics for the public.

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