CAL POLY

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Wind and Ventilation Turbine (WVT) Generator

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***Abstract*:**

This project aims to create a more compact and accessible renewable energy source using the Wind and Ventilation Turbine (WVT) Generator. The wind turbine provides ventilation while generating "clean" electricity using solar and kinetic energy. The electrical generation causes no functional losses to the ventilation as rising heat and passing wind turn the turbine, ventilating the house. Placing a generator beneath the spinning turbine allows for the transformation of mechanical motion into electrical energy. The system charges a battery, supplying recharging power into small standard electronics (i.e. cell phones, tablets, etc.) through a USB output.

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Chapter I - Introduction

The US Energy Information Association (EIA) defines fossil fuels as "An energy source formed in the Earth's crust from decayed organic material. The common fossil fuels are petroleum, coal, and natural gas." Using this definition, Figure 1-1 clearly displays that in 2012 the United States generated 68% of its energy from fossil fuels, while less than 12.5% was generated from clean energy sources (listed as hydropower, wind, and other renewables). Wind technology only generated one quarter of that energy, 3.5% of the total energy [1].

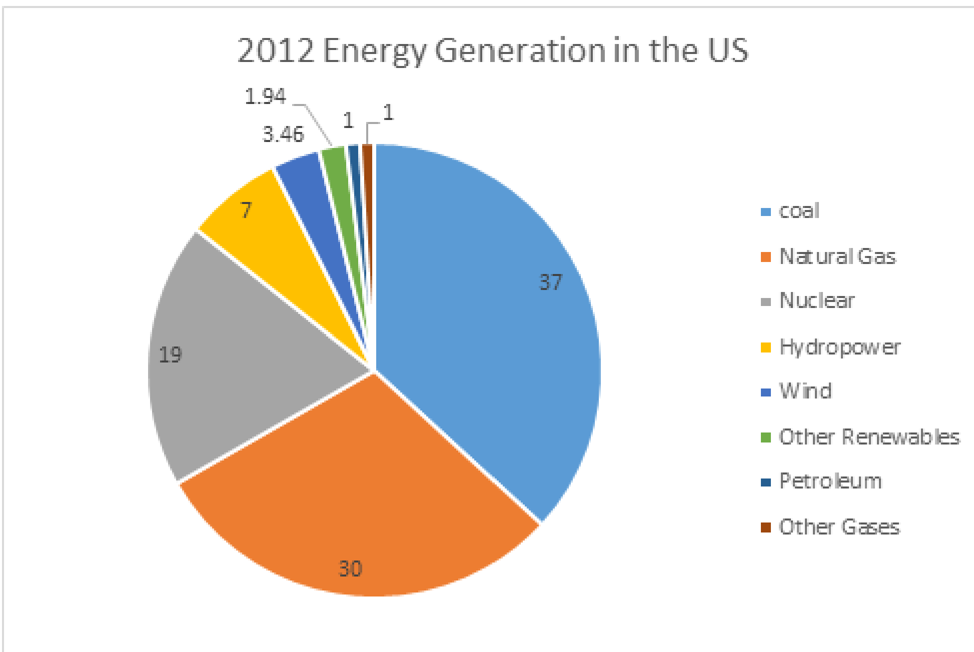

Figure 1-1: Sources of 2012 US Energy Generation

However, even at this low amount, the Global Wind Energy Council listed the United States' wind energy production as the second highest globally [2]. Fossil fuels, therefore, make up more than two-thirds of the world's energy supply; the other third is mostly nuclear generation. Burning fossil fuels and nuclear rods on this level contaminates the atmosphere with detrimental gases and pollutants and fills the land with radioactive waste. Reducing the fossil fuel and nuclear demand will reduce the pollutant level and preserve the natural greenhouse gas environment. If the greenhouse gas layer in the atmosphere gets any thicker, Earth's climate will be driven out of equilibrium and into the next Ice Age or into a climate similar to Venus'. As seen in Figure 1-2, the use of fossil fuels is continually rising; however, fossil fuels (by definition) have a limited supply and their availability is decreasing at the same rate they are used. Renewable energy must therefore become a more prominent source to maintain the Earth's energy demands and healthy climate. Cal Poly's DC house project takes necessary steps in the green movement by operating from self-generated, sustainable technology.

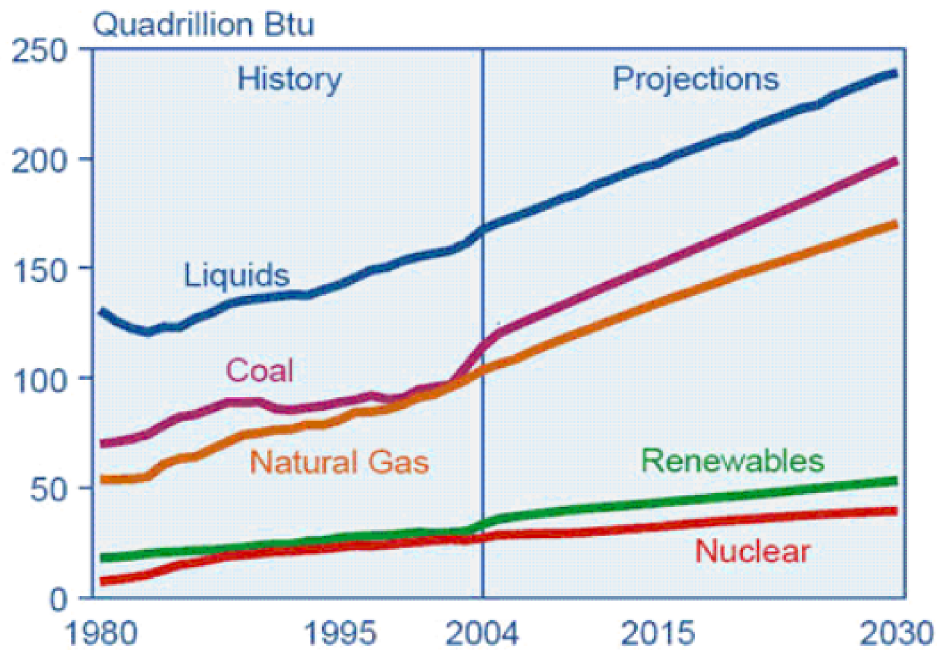

Figure 2 - Projected growth of energy generation

Fossil fuels (and particularly nuclear energy) lose their effectiveness in small scale developments. Producing energy on a need-by-need basis at the source of demand requires smaller energy generation and dramatically reduces loss over power lines. The DC house provides one implementation of this goal: the house permits the owner to add or remove the independent energy sources, minimizing over-production and the loss from it. Additionally, it allows rural communities, with no distribution access from near-by large scale power plants, to have electricity without the costly process of bringing power out to them.

Chapter II - Background

Reducing the amount of carbon emissions has been a rapidly growing goal of energy developers and governments worldwide for several years. One of the biggest problems towards moving away from fossil fuels is their very high energy density, which the renewable forms can't compete with. The Diablo Canyon nuclear power plant produces 2,300 MW on 545 acres [1], compared to the California Valley Solar Ranch project, which produces 250 MW on 4685 acres [2]. One solution to overcoming the land size barrier is local area production, which involves a household producing its own electricity needs on its own land. Achieving the local production goal requires the adaptation of houses and their appliances to more energy efficient (or energy producing) applications. The Wind Ventilation Turbine (WVT) project attempts to provide an answer to that requirement.

There are many examples of small-scale wind generation. *Popular Mechanics* listed an article in 2009 for a rooftop wind generator weighing 95lbs, capable of generating electricity in 2mph wind and producing over 2kWh per year. This generator provides a very useful solution to the problem of local generation, because it has a very wide capture range a low speed requirement; however it takes a lot of training to install [3]. Another invention uses four separate, independently turning turbines to capture energy from multiple directions; the multi-directional reduces the resistance of the turbine compared to single-direction turbines when wind goes against their angle [4]. Many yachts now come with wind turbines to provide electricity for their voyages; most of these are more traditional, horizontal-axis turbines however and can only be attached to towers [5].

Customers look for reliability in their purchases. Proving their effectiveness, ventilation turbines have been in production for decades, even dating back to 1924 [6]. The design simplicity keeps them in constant use: the blades catch passing wind, forcing that fresh air down into an attic, while pulling the warm, damp air up and out of the attic, providing needed ventilation. Since their invention, they have been constantly evolving to provide better air circulation and looser rotation. The WVT maintains the primary function of the ventilation turbine of sending fresh air into a room, but adds the ability to generate some house electricity.

The WVT will make use of a dynamo generator placed inside the turbine. Dynamos, commonly used on bikes to power the tail and headlights, provide friction-based energy generation by resting the shaft on the bike tire. Inside the ventilation turbine, the dynamos work off the same principle of transferring spin from one structure onto the generator shaft; instead of bike tires, the turbine shell spins the dynamo. This generator load prevents the turbine from spinning at low wind speeds under 10 mph, a much higher minimum wind speed than other turbines, such as the Honeywell wind turbine [4]. Although it takes about a 12 mph gust to begin spinning the turbine, it can maintain its motion down to 4 mph once it has begun spinning. In small buildings like the DC House, the WVT should fulfil complete ventilation needs without electricity while adding to the house's energy stores, which can be particularly useful in rural areas.

In rural areas where an electrical distribution system is not commonly available, satellite phones are very common. Keeping in contact with the outside world requires a charged phone (and satellite phones that are notorious for their low battery life), but without the grid these rural areas require some other source of power. The WVT is designed to allow customers to replace their existing turbine with the upgraded, energy generating system. The replacement keeps the house looking the same, provides electricity, and does not burden the house with size or weight, and does not disrupt the surrounding environment. The generated electricity feeds into a USB port, providing a practical use for the homeowners: a simple method to charge their phones or other small electronics.

This project aims to show that by making use of the small areas of wasted energy in the world, a large supply can be gathered. This project only supplies a small amount of that bonus energy, but it shows that it is possible to capture residual energy to enhance the quality of life.

Chapter III - Requirements and Specifications

The WVT's design allows customers to replace their existing turbine with the upgraded, energy generating, system capable of allocating charge via a USB output and via a rechargeable battery station. WVT enables homes to keep the same aesthetic feel without visually disturbing the neighbors or the surrounding environment. The elected design will maintain a small system size that will not burden the house.

The WVT generates electricity through a single Dynamo generators attached to the turbine shell interior. The generator's output passes through a full-wave rectifying circuit, converting the AC signal into fully positive signals before feeding into the LTC3108. The output is a 5V supply, which allocates the collected power into a USB port. This provides a practical use for the homeowners, giving them a simple method to charge their small electronics.

Customers look for the results of their purchases. The WVT adds electricity to the house, but its original function (ventilating the attic) should still work at a reasonable level. The generator load prevents the turbine from spinning at extremely low wind speed, but operating at a minimal 10 mph wind speed works well. High winds should not cause the product to fall apart either. The system should stay intact up to a 60 mph wind speed.

Table 3-1 lists the market requirements and engineering specifications for the Wind Ventilation Turbine (WVT). In-house installation stands for the replacement of an existing ventilation turbine and use wind induced rotation to generate torque or source of kinetic energy. The installation should be safe and the size of the product's weight cannot burden the house. The system charges electronic devices through USB ports from temporary supply. The turbine must still remain as a functioning ventilation system in the meantime. More specifically, the marketing requirements are listed below:

Marketing Requirements

1. The system provides an electrically practical use in houses.
2. The system replaces an existing system after an easy installation
3. The system produces cost-effective clean energy.
4. A small, clean energy system, non-intrusive to the house.
5. The system withstands extreme weather conditions.
6. The generator does not reduce the ventilation effectiveness, but remains powerful.
7. The system upgrade remains safe to install in the house.
8. The owner may know the available power.

Table 3-1: WVT Requirements and Specifications

Marketing Requirements	Engineering Specifications	Justification
1, 3	The system supplies power to three 5V, 500mA USB ports.	Many handheld electronics charge through USB cables. The ports allow the customer to power them using clean energy.
4, 5, 6	The turbine spins in a minimum wind speed range of 10mph-60mph.	The stand-alone turbine spins easily. The generator load cannot deprive the system of too much ventilation functionality. It also needs to withstand extreme weather.
2, 4	A turbine volume of no more than $20ft^3$.	The turbine should not create a major addition to the building's roof.
2, 4	A generator volume of no more than $30ft^3$.	The generator must fit inside an attic, supported by the house's framework.
3	The system costs no more than $750.	The generator requires a small frame and powerful, efficient energy transformation. This makes it more expensive than a more commercial generator.
1, 7	The system complies with the NEC and IEC requirements in all aspects.	Standard wire gauge, color, etc. ensures safe system installation and maintenance.

Functional Decomposition (Level 0 & 1)

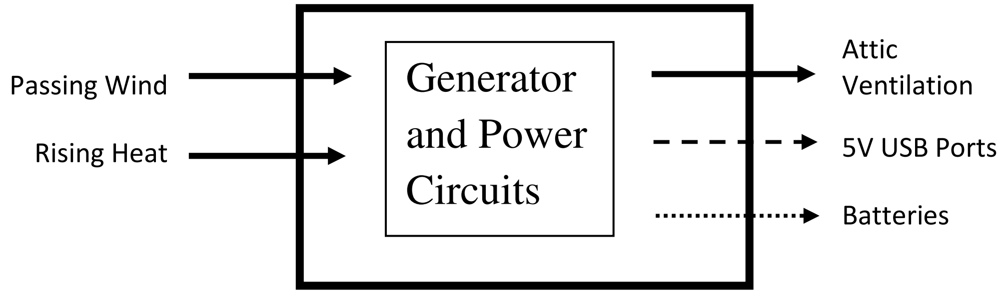

Figure 3-1: WVT Level 1 Diagram

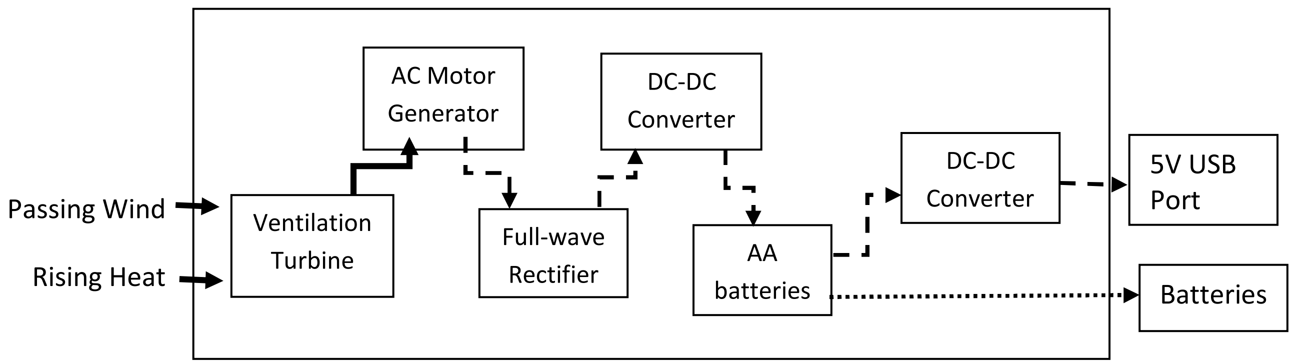

Figure 3-3: WVT Level 1 Block Diagram

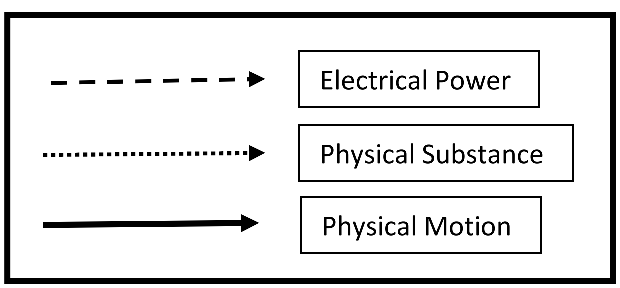

Figure 3- 4: Block Diagram Signal Legend

Chapter IV - Design

The main structure of the WVT comes from the ventilation turbine, as bought off the shelf. Fulfilling the goal of an easily installed system, the all modifications to the turbine are superficial to or surrounded by the visible exterior of the turbine (the shell). Keeping the electronics inside the shell provides natural weather protection, and requires only water proofing for complete protection. It also maintains the original appearance, visually helping to make it an acceptable addition to rooftops.

Housed by the shell, the generator system sits inside the vent of the turbine, just below the spinning blades. The blades serve as a glove by catching the wind. The interaction between, wind and metal, of the turbine blade, results in a net force in the horizontal direction toward the metal. This causes the turbine to rotate and the generator's magnets to produce eletricity. The system consists of a single Dynamo generators held in place by PVC piping. The PVC pipes are held in the center of the structure, sitting on top of a metal spacer, which sits on the turbine's own support beams, as shown in *Figure 4-1*. Extending from the center are three prongs, sitting 180^{o} apart; one of these prongs are attached to the generator, the second and third pipes rest on the shell's screw, adding support to the structure. The Dynamo generators are screwed into their respective PVC prongs and glued in place. Dynamo Generators were selected as the optimal generators due to the cheap price and the similar application on bicycles. Dynamo Generators use the rotation of a bicycle tire to light up the blinking LED light on bicycles commonly seen at night. A similar track was constructed of gardening water tubing on the inner-rim of the rotating turbine.

Figure 4-1: Center Structure supporting Dynamo Generators

Dynamo generators, regularly placed against bike tires, have a corrugated wheel at the shaft end, as shown in *Figure 4-2*. Setting the wheel against a rotating surface spins the wheel and shaft, rotating the internal polar magnetic field in proportion to the surface the generator is on. The rubber tubing has a firm; rough structure very successful applies the required friction to the corrugated wheel. Gluing two rows of the tubing onto the vent walls gives enough offset and surface area for the generator wheels to run on as the turbine spins. The PVC pipes also provide a protected path for the wires to travel along to the power circuitry. Prior to entering the batteries, the Dynamo's currents pass through a full wave rectifier (made of four diodes), allowing it to enter the step up circuit.

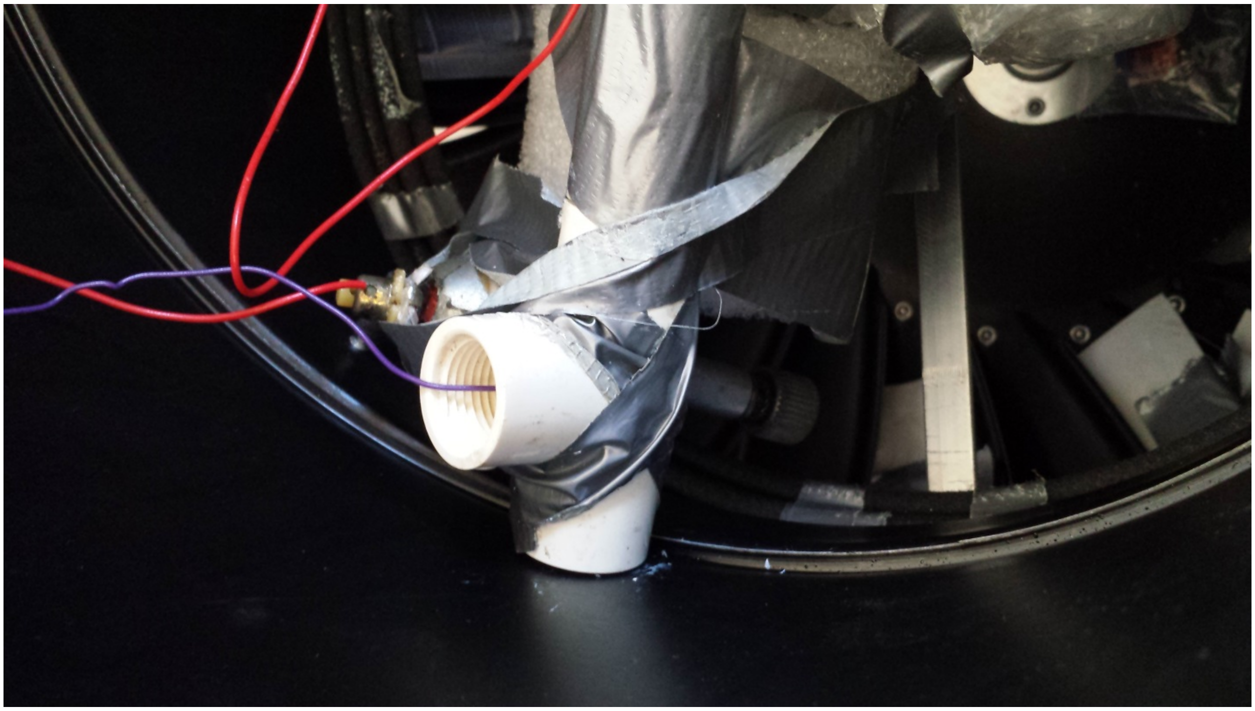

Figure 4-2: Individual Dynamo Generator on the conducting track

The now rectified current enters an LTC3108 IC, attached to the Energy Harvesting Module (EH1D) demo board, set to step the voltage up to 5V (1). This chip is an ultra-low power dc-dc converter, with an input range of 20mV-2V and a selectable output of 2.2V, 3.3V, 4.1V, or 5V (2). The original intention was to have this chip output 3.3V to charge two AA batteries before going to the USB. The batteries' 3V would then be stepped up to the USB's 5V port with a second dc-dc converter. However, the power lost across both step-ups was too inefficient, so the battery pack was removed from the final project. The EH1D was finally set to feed directly into the USB port.

The generators sitting on the turbine shell creates a great deal of friction. With both generators installed, the turbine cannot reach start spinning on its own for any wind less than 35 mph. With just one generator installed, only wind in excess of 24 mph has enough power to spin the turbine. Adding extensions onto the turbine's fins helps fix this issue by creating more surface area for the wind to catch. Six of these extra fins, which extend two inches beyond the normal blades, dramatically improve the performance, as described in *Table 4-1*. The additional fins attach to the surface of the turbine blades by gluing and screwing 1/3 of the panel onto the existing blade, as shown in *Figure 4-3*. This leaves about 2/3 of the panel available to catch more wind and provide more torque on the turbine.

Figure 4-3: Additional fin extensions attached to turbine blades

Table 4-1 - WVT wind speed test results under various structures

Turbine System		Test Results	
# of Generators	# of Fins	Wind Speed (mph) for sustained push start	Wind Speed (mph) for sustained own start
2	0	--	--
1	0	22	24.8
2	6	15.5	17.2
1	6	12.4	14.2
1	14	not tested	11.5

The final project uses fourteen fins and one generator. The single generator requires less wind speed for startup than two, and decreases the cost of the system. We had been considering using the second generator to help spin the turbine ("sustained push start" test), but this was dropped from the final design for a few reasons: 1, this takes power back out of the system to run the motor; 2, it takes more power to determine when to run the motor or when to turn it off; and 3, the start up speed drops low with one generator and full fins. We believe that this design simplifies the project enough to keep it within the scope and purpose of the DC House.

Chapter V – Testing

Testing the WVT requires a large source of constant wind that cannot be reliably found outside. The Electrical Engineering department's wind generator provided this needed wind supply. The generator can be adjusted from 0mph up to over 40mph, though our tests did not range beyond 35mph. Originally, flat 12" flexible solar panels (seen in *Figure 5-1*) were placed along four of the turbine blades. The panels are 197x98x0.8mm, with a P_{max}=1W, V_{oc}=2V, and I_{sc}=850mA. However, although initial testing showed the panels each provided about 0.8W in ambient light, they were ruled to be too expensive and unnecessary for the purpose of the DC House.

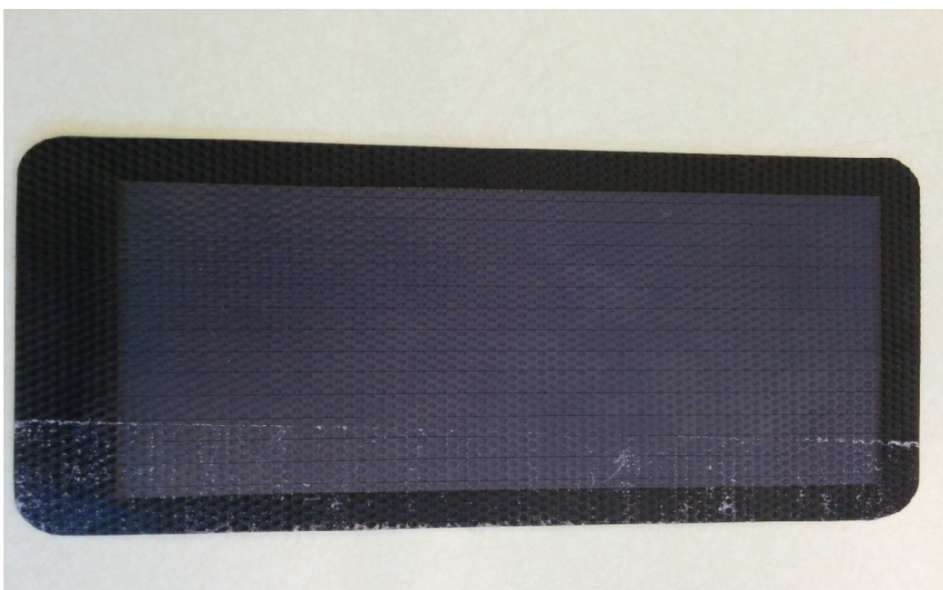

Figure 5-1: Original blades made of flat 12" flexible solar panels

During testing, the turbine was placed in the wind generated stream of air with a wind speedometer measuring the wind speed. The initial testing was performed on a standard ventilation turbine (see *Figure 2-1*), with no additions to the exterior, and two internal Dynamo generators attached. This design was quickly thrown out because it did not start spinning even at 35 mph; we did not determine what speed it would start at because even 35, let alone higher, is not a realistic speed for the scope of this project. We next tested the turbine with only one generator attached, which allowed it to begin moving at 24.8 mph, but that is still far beyond the 10 mph goal the project aims for. We determined to fix this problem by adding fins to the exterior of the turbine, as described in Chapter 4 and *Table 4-1*. First we taped the solar panels purchased previously onto the blades, because they were a firm, flexible option that was readily available. The additions of the fins were clearly a great help to the system, dropping the start up speed to about 18 mph. The performance boost gave us confidence to move forward with the solution.

The final fins are 12"x4" cuts of poster paper taped onto the turbine blades. Each fin is layered with two cuts for strength and completely covered in packing tape for weather-proofing. Before committing to this build, 6 fins were made for testing. A very large performance improvement was seen with the addition of those 6 fins, as the startup speed dropped by 7-10 mph, depending on the number of generators, and the 14 fins dropped it to 11.5 mph, closest to our goal.

Figure 5-2: WVT full fins, side view

Figure 5-3: WVT full fins, top view

During the 14 fin test, we first adjusted the wind speed to find start up wind speed. This is the speed necessary for the turbine to initially start rotating, and is found at 11.5 mph. At this speed, the generator outputs V_{max} of 400mV after rectification (see *Figure 5-4*). Next we scaled up the wind speed to see how much power could be drawn from this system, up to a maximum of 20 mph, which is a reasonable maximum for normal weather conditions. This produced our highest measured V_{out}=1.2V. *Table 5-1* shows more values from that same test. We also found that although it takes an 11.5 mph gust to start the spinning, once the standing friction is overcome the turbine is able to continue rotating down to 4.5 mph.

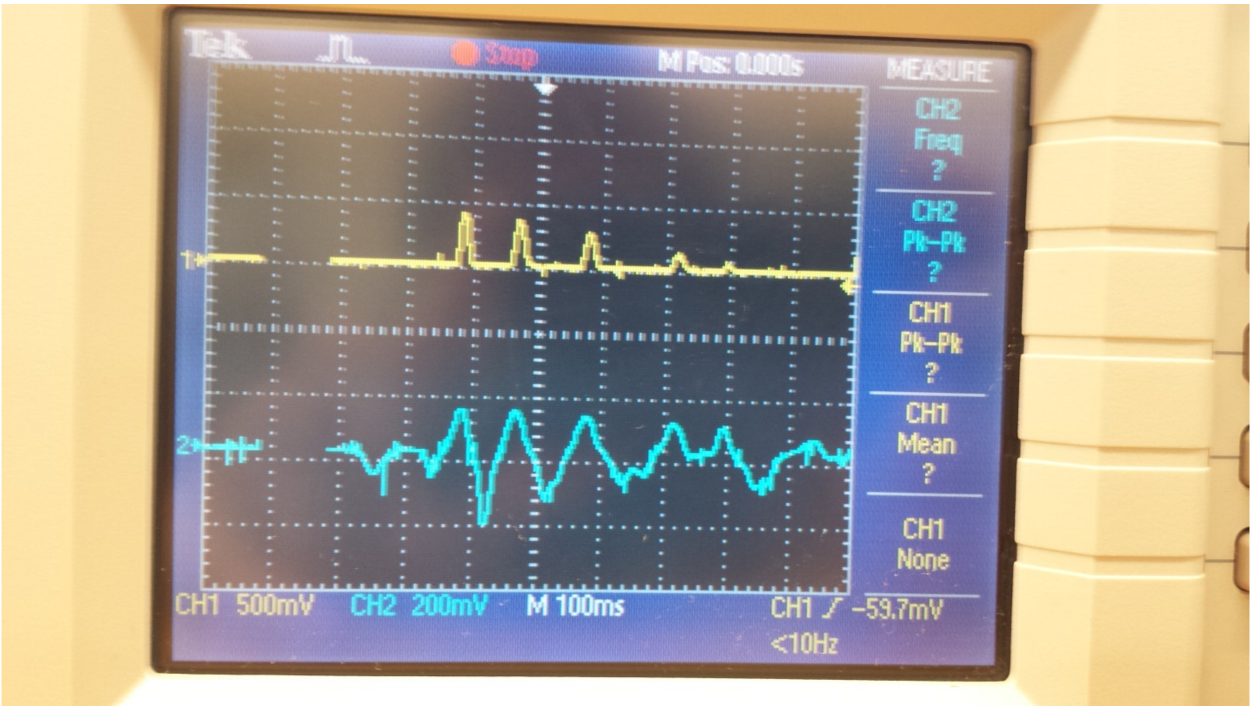

Figure 5-4: Test of generator outputs V_{max} of 400mV after rectification

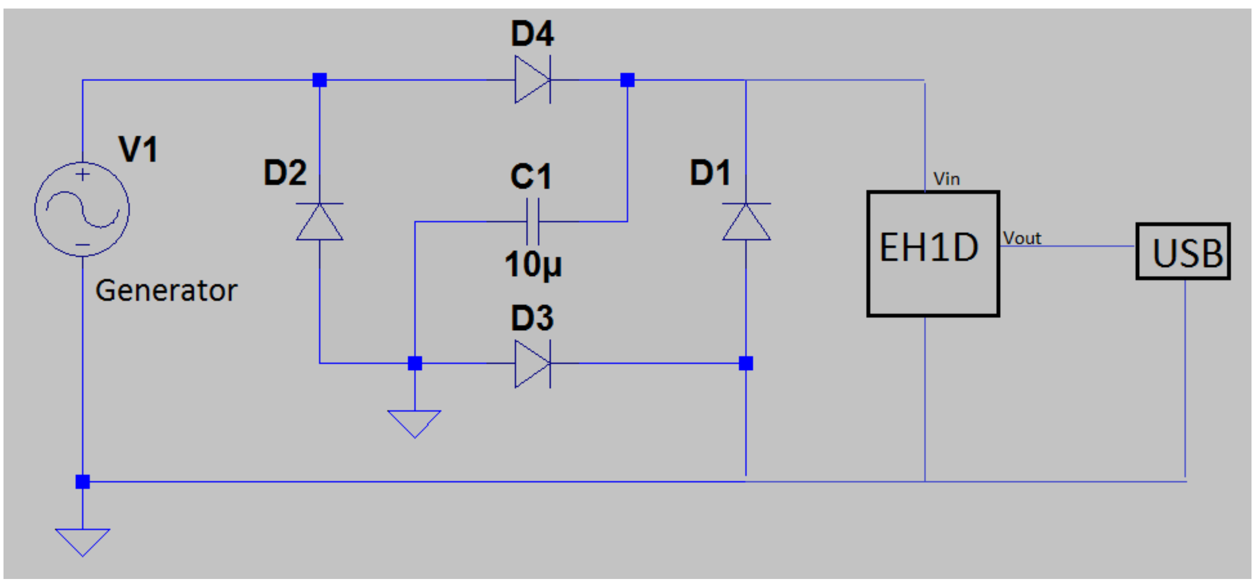

Figure 5-5: Test circuit for WVT output voltage

Table 5-1: Output ratings of WVT with 14 fins and 1 generator

Wind Speed (mph)	V_{out} (V)
11.5	0.4
13	0.47
17	0.96
20	1.2

The EH1D (*seen in Figure 5-6*) is a step-up dc-dc converter, 48mV to 5V see *Figure 5-7*, with a LTC3108 IC mounted on the board. Originally, the second step-up boost converter (seen in *Figure 5-8*), was set from 3V to 5V see *Figure 5-9*, with its output feeding the 5V USB output. However, it was ruled to be inefficient to have two step-ups back to back due to their loss of power. Instead, we adjusted the inputs into the EH1D so that the desired output of 5V would be met. The overall WVT test set up is shown in *Figure 5-10* its output waveform in *Figure 5-11*. *Figure 5-12* shows the loaded test of the project, with the USB port charging a battery. When the battery was plugged in, there was not enough current to maintain the charge and the voltage at the output of the EH1D dropped to about 200mV. The battery was not able to charge from the system, with a wind speed of 14mph.

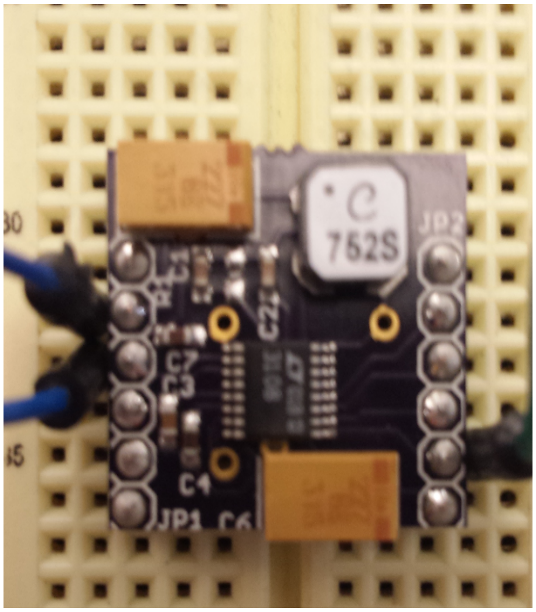

Figure 4-6: EH1D and demo board

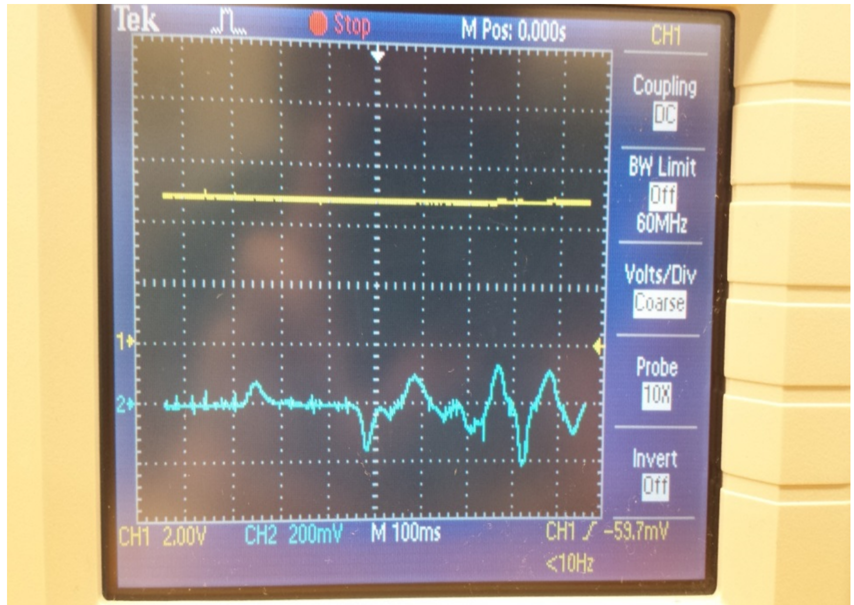

Figure 5-7: EH1D board Output Waveform (48mV to 5V)

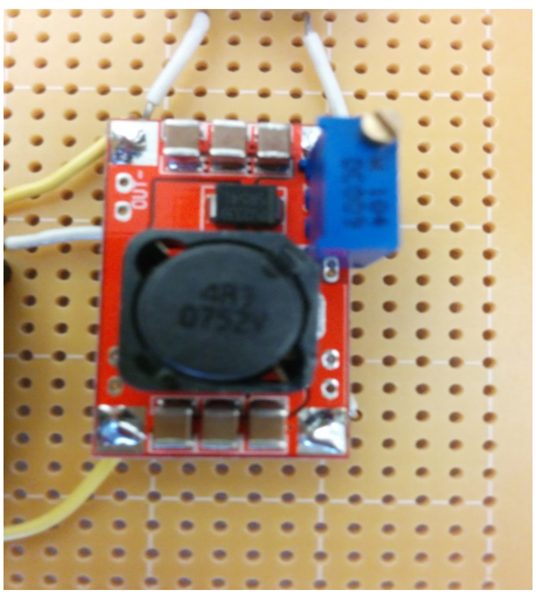

Figure 5-8: Unused step-up IC and demo board

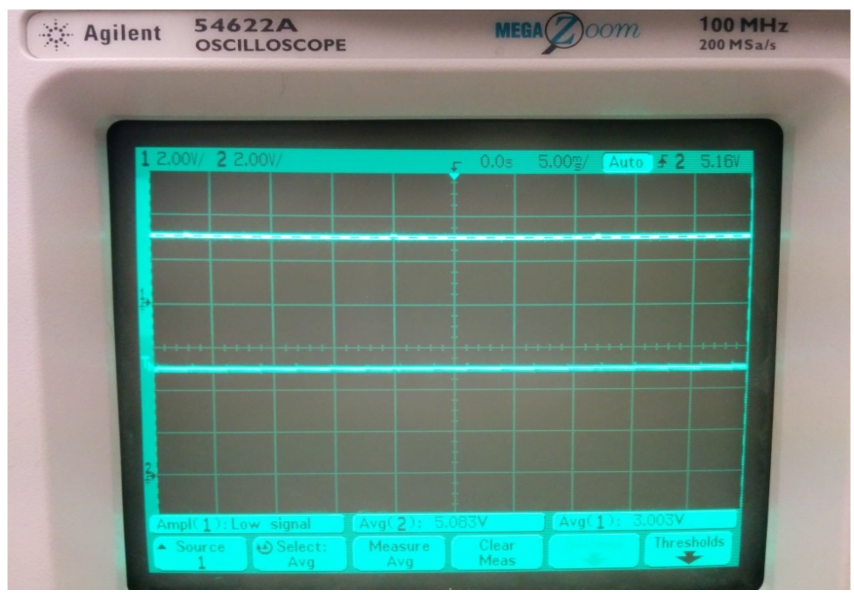

Figure 5-9: Unused Step-up IC Output Waveform (3V to 5V)

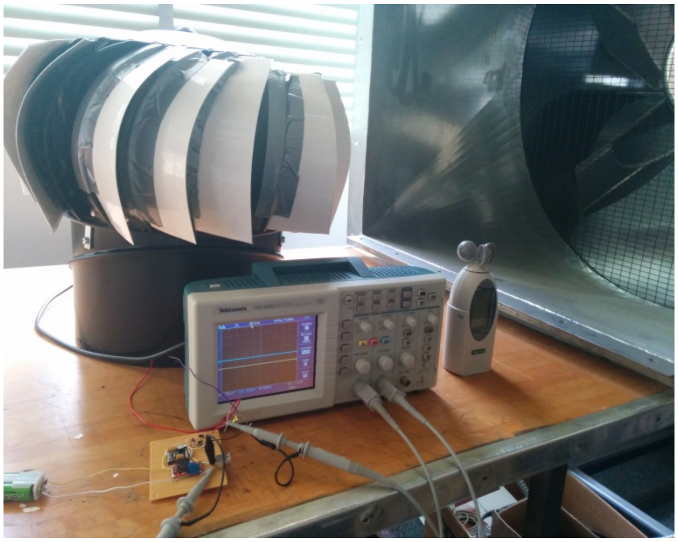

Figure 5-10: WVT Overall Test

Figure 5-11: WVT Overall Test waveform

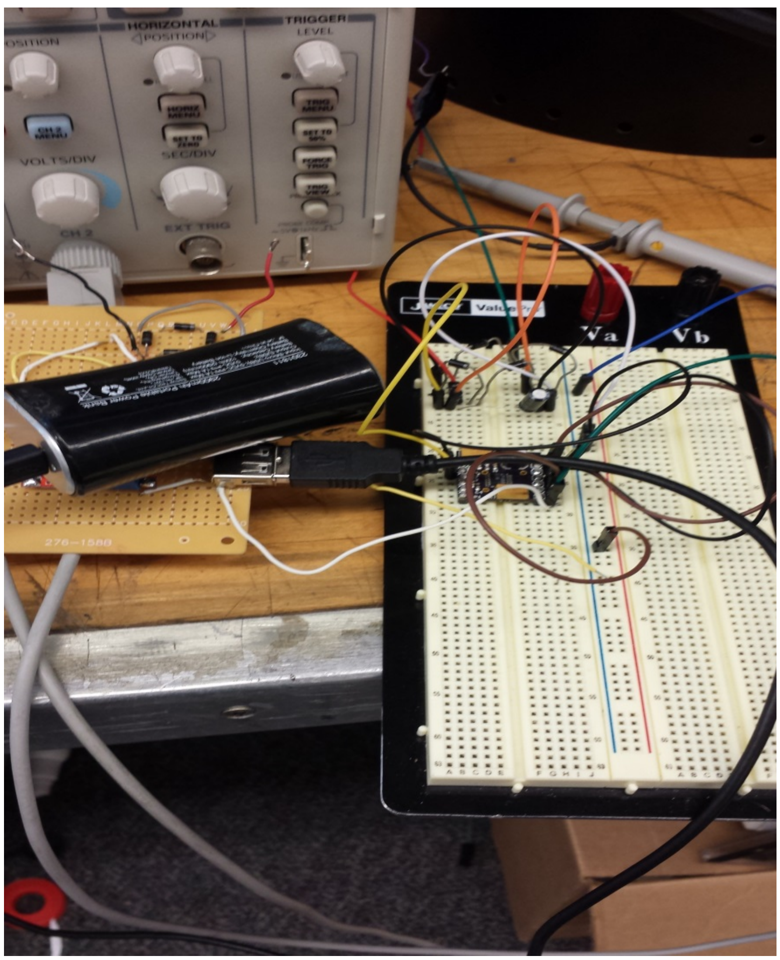

Figure 5-12: Charging an external battery

Chapter VI – Conclusion

The DC house is aimed for those lacking an electrical distribution system, while allowing for air to circulate through the house. The WVT has been shown to transform naturally supplied kinetic energy into electrical energy, and may potentially supply enough power to charge two AA batteries and a 5V USB port. This creates a very practical application for a developing or isolated community, common in "3rd World Countries," because they do not have an energy source or stored energy ready for purchase when they run out. As for the ventilation, the turbine begins rotating at 11.5 mph, which is close to our goal of a 10 mph minimum operating wind speed. Unexpectedly, once the turbine begins spinning, it is able to maintain that down to 4.5 mph. This means that although a fairly large gust is required for start up, the WVT operates within common wind speeds, fulfilling that requirement.

In this particular application on the DC House, this device would not be an ideal "DC add-on device" to a DC house as its cost heavily outweighs its production. The device in its entirety costs $140.00, including the turbine, the two step up circuits, the rectifying circuit, the USB port and rechargeable AA batteries. AA batteries are about $3.00 for a pair, so it would require over 40 battery charges to equalize that cost. On the other hand, common handheld devices, which are powered from a USB port (such as an iPad), require about 12kWh per year. Using a very conservative statement of energy cost of $0.50/kWh, that is only $6.00/year. With that, it would take 20 years to earn back the money spent on the system. To make any profit, the device would have to be sold for a higher value than $140.00, which would require more battery charges and an even longer payback time for the customer. This project serves as a proof of concept and would not be practical in the business world. However, it suffices as an adequate portrayal of our Electrical Engineering knowledge for an undergraduate degree.

If cost were not a constraint, larger turbines with less rotating friction would be the optimal platform for the device. The larger turbine would increase the ventilation capabilities. An AutoCAD designed structure would be ideal for mounting the Dynamo generators. The designed structure would be creating a better fit, increasing durability against destructive, vibrational disturbances caused by the rotating turbine. More modern Dynamo generators with a higher output magnitude would directly increase the amount of charge produced by the device. This would decrease the charging time of the AA batteries.

The single EH1D board does not produce enough current to charge a load. Further projects should aim at finding a way to increase the supplied current, so that the system can actually be used to charge a phone.

Appendix C

Summary of Functional Requirements

The Wind and Ventilation Turbine (WVT) operates as a standard rooftop ventilation turbine and as a wind turbine. The generation of energy happens as the turbine spins to circulate air through the room. It is low cost to allow developing and rural areas access to it, it is easily installed and operated, and it provides practical power applications in the form of battery and USB port charging.

Primary Constraints

The project was more difficult than anticipated because the only part of the system that moves is the exterior shell. This required us to totally redesign the project to have a side-attached Dynamo generator instead of a center-mounted generator. We also attached extensions to the blades of the turbine to increase the surface area and catch more wind; this allowed the turbine to spin, because the generator added too much friction and was preventing it from rotating. The generator was also unable to output much more than 1V after rectification, which made stepping it up to the 5V USB port very difficult. The standard USB port generally feeds 5V and 500mA to its load.

Economic

Table 3 – WVT Cost Estimate Table

Item Name	Price ($)			
	Optimistic	Realistic	Pessimistic	Calculated*
Turbine	40	60	100	63.33
Solar Cells	30	60	100	61.67
USB Female	0	10	20	10
Generator	200	300	450	308.33
12 V Battery	45	100	140	97.5
Industrial wiring	20	30	50	31.67
DC-DC mirco items	0	60	100	56.67
Total	$335	$620	$960	$629
	Optimistic	Realistic	Pessimistic	Calculated*
Labor (hours)	400	600	800	600
Labor Costs ($)	$800	$1200	$1600	$1200

*Calculated = $\frac{P_{opt}+4P_{real}+P_{pess}}{6}$

If manufactured on a commercial basis

We would intend to sell about 500 devices per year, with increasing numbers as the DC House grows in popularity for developing areas. We would charge about $250.00, which creates a profit $110.00 per unit, or $55,000 per year. Once the system is installed, it shouldn't require any service, unless a storm overloads the circuitry. If that happens, it would cost about $60.00 to repair. The Dynamo would wear out over time, which costs about $10-15 to replace. Over a 5 year period, it would cost an average of about $100 to upkeep.

Environmental

The WVT system reduces a home's environmental impact by decreasing their need for electricity taken from the grid. The generator uses a mechanical-electrical system, so there are no emissions of chemicals or noise. The batteries use some chemicals that are harmful to the environment, but because they are rechargeable instead of disposable, it helps reduce the toxic waste from throwing batteries away.

The system makes use of wind power to both generate home electricity and home ventilation. Because many homes have a similar ventilation turbine already, installing the system as a replacement causes little impact to the surrounding neighbors and would have no impact to animal or plant species around the house.

Manufacturability

The mass production of this product creates an issue in that houses are not all built the same, which means that the manufacturing a system for feeding the power from the generator down to the battery pack and USB port can be difficult.

Sustainability

The system's generator and batteries eventually require replacing as they wear out. Replacing them adds pollutants to the environment, even after recycling old equipment. The system reduces the need for generating electricity in large plants (most commonly coal, natural gas, or nuclear), which produce more pollutants than the WVT.

As technology advances, more advanced versions of the batteries, generator, or even turbine can replace the models used now. This ensures the product operates at its maximum potential.

Ethical

Might makes right – This product can further cause separation between classes of society. Customers who purchase it see themselves as and more righteous than those who cannot afford it or choose not to use it. Although intended to help humanity, it may result in dissension between groups.

Ethical Egoism – People look at this product and recognize a better way to charge their electronics. Growing and circulating information about pollution and clean causes people to want to do what's right for the environment and buy something that helps, even if it costs a little extra.

IEEE Code of Ethics – This product helps to promote the welfare of the environment by improving the understanding and use of technology. It promotes more efficient use of the world around us in creative ways. When trained professionals install the project, its prepared design keeps it save to have in the house.

Health and Safety

The possibility of electrical fires presents the system's largest safety concern. Damage to the wiring system could expose the wiring to the rest of the house and potentially start a fire. Production of the device might include an internal alarm system if a fire starts around it.

The weight of the generator is also a concern, because the house structure must be strong enough to support it. Weakened or improperly measured support beams may fail supporting the generator's weight and let it fall.

Social and Political

The WVT project steps in the direction of green energy. It appeals to green enthusiasts and homeowners looking to upgrade their houses; they receive nearly continual, clean electricity fed into their homes. Electrical Power companies would disapprove of the system, as another step of completely removing homes from the grid, reducing their customer base. The companies that manufacture the generators, batteries, circuit components, and turbines, benefit because people buy more their products.

Communities could feel an impact indirectly because of the disruption during installations that require professionals come their own trucks and equipment, adding traffic and noise the community. Companies that sell green technology would need to attain a more modern training. This would include the installation the system and therefore affecting the workers.

Development

Senior Project was approached using the SCAMPER method, introduced previously in EE 460, which has helped identify specifications and requirements the project. It helped the design of the project as we ran into obstacles, building and testing it. Oscilloscopes and function generators enables the testing of these circuits and step-up. This verified the intended function of the circuit being tested.

Task Name	Start	Finish	Duration
Research	28-Sep	13-Jun	8 Months
Order/ Shipping	31-Oct	30-Nov	30 Days
Construct/ Plan/ Reorg.	31-Oct	30-Nov	60 Days
Test Photo Cells	30-Nov	4-Dec	5 Days
DC-DC Circuitry Work	30-Nov	19-Jan	50 Days
Mount Cells on Vent	4-Dec	28-Dec	24 Days
Test DC-DC Interface	19-Jan	9-Feb	20 Days
DC-DC and Usb Interface	7-Feb	27-Feb	20 Days
Construct/Interface All	27-Feb	19-Mar	22 Days
Test	20-Mar	29-Mar	7 Days
Research	31-Mar	31-May	60 Days
Reconstruction	4-Apr	14-Apr	10 Days
Test with adjustments	3-Apr	29-Apr	26 Days
Reconstruction	19-Apr	29-Apr	10 Days
Test with final adjustments	30-Apr	31-May	30 Days
Final Report	1-Jun	10-Jun	9 Days

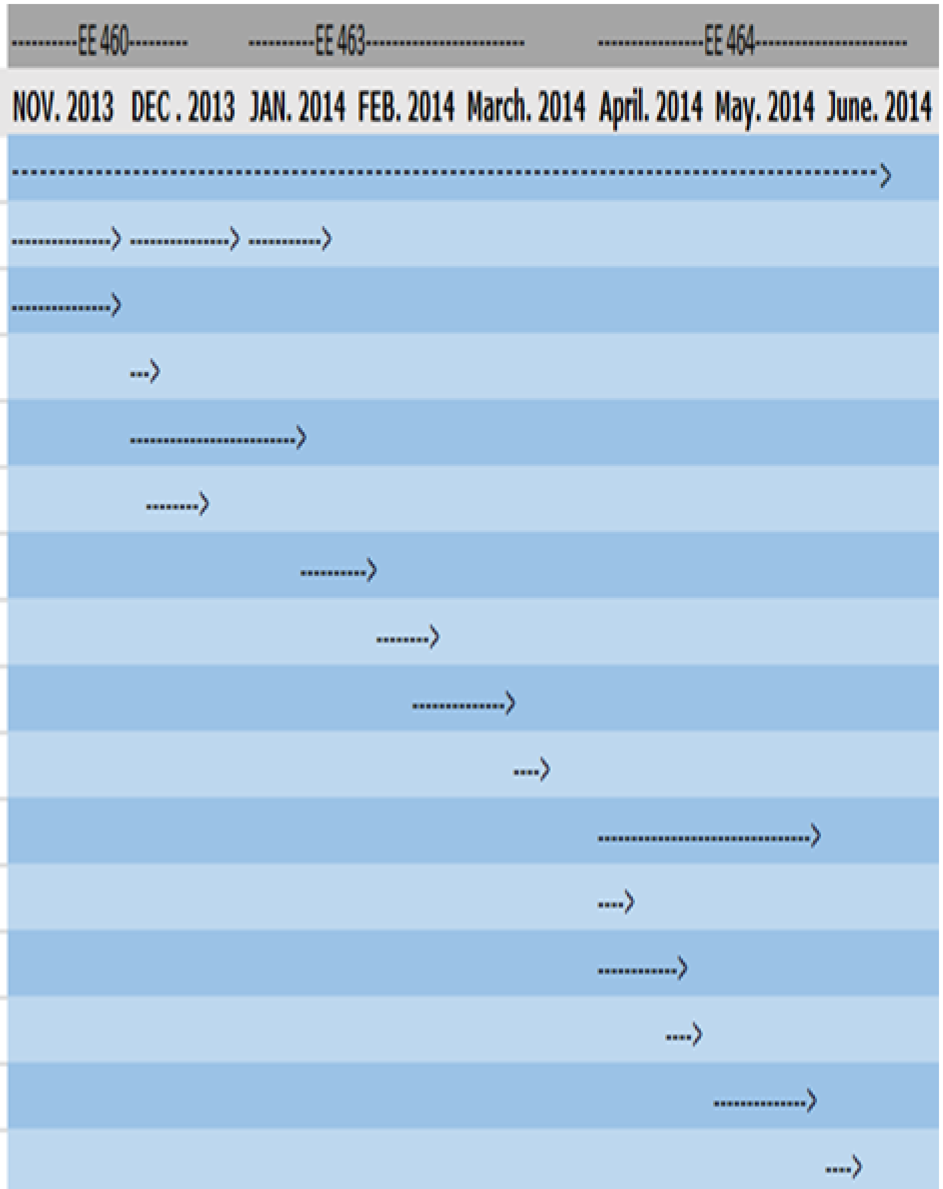

Figure C-1:- Gnatt Chart Original Time-line

Chapter VII - References

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