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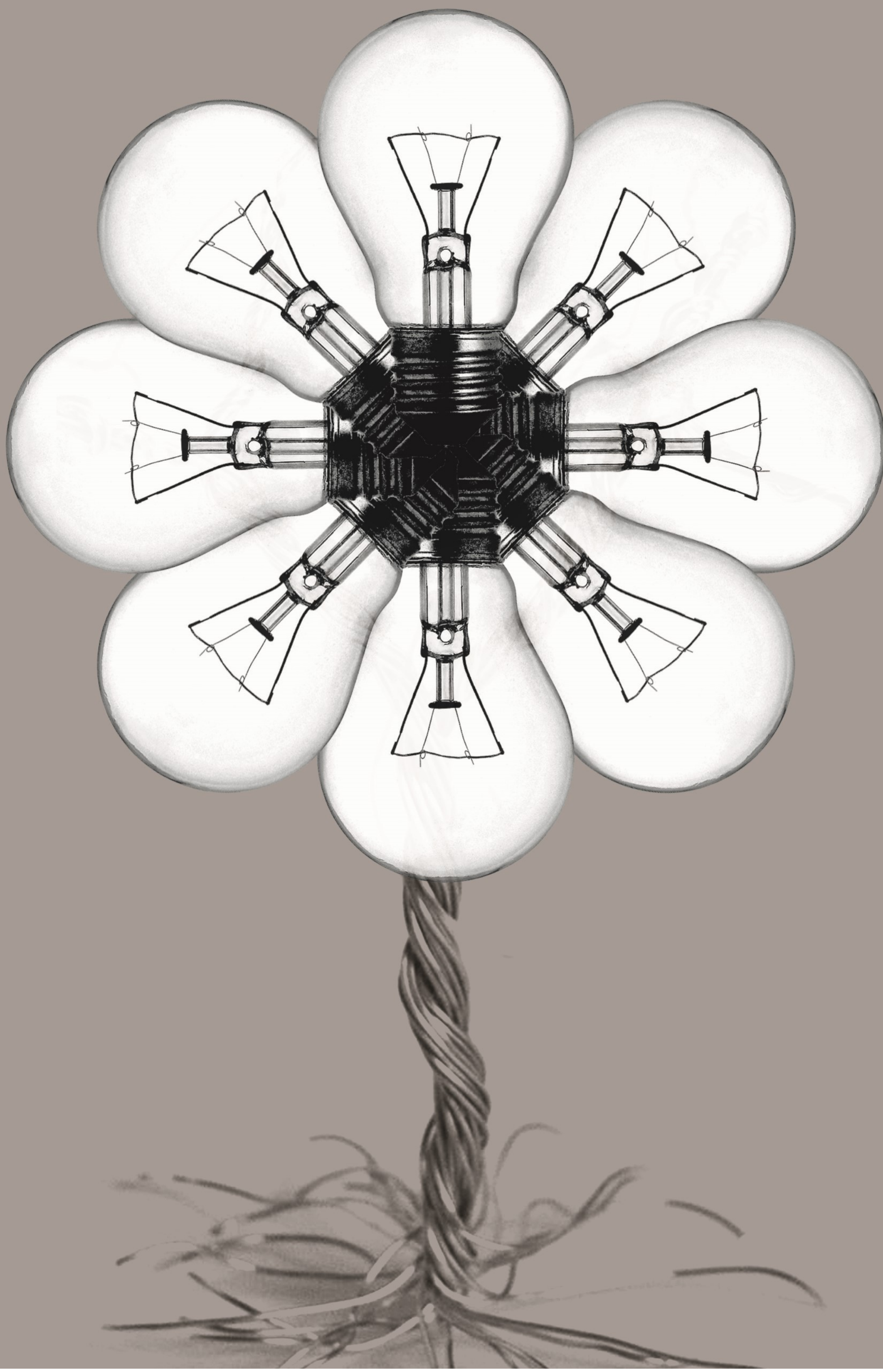

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Editor and Staff

Editor's Note

We are proud to present this third edition of our annual student research publication. The Nikola Tesla STEM Journal enables Tesla STEM High School students to share their research with the academic and business communities. The investigations included in this edition demonstrate both the increasing depth and diversity of our studies. In addition, we have included a list of the awards and honors earned by Tesla STEM students this year.

Students are encouraged to submit their work to thestemjournal@gmail.com, to be considered for next year's publication.

Many thanks to the dedicated journal staff, talented student researchers, and outstanding Tesla STEM faculty. Your long hours and hard work made this publication possible.

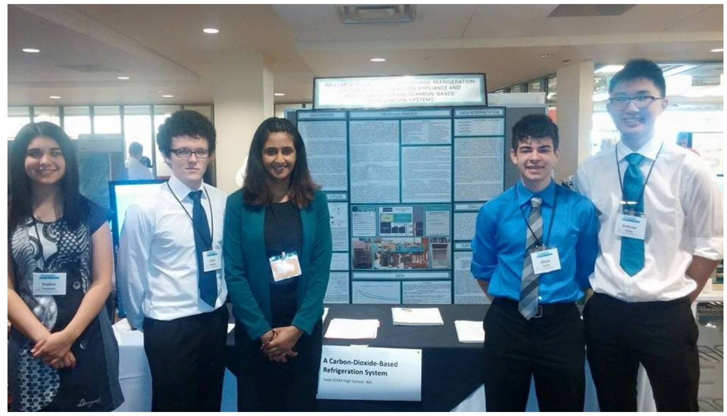
Editor-in-Chief,

Madison Minsk

2014-2015

Journal Staff

Implementation of a Carbon Dioxide Refrigeration System as a Cogeneration Appliance and Replacement for Halocarbon-Based Refrigeration Systems



Sophia Tevosyan, Oisin Doherty, Sonia Murthy, Ethan Perrin, Andrew Wang

ABSTRACT

This engineering project seeks to develop a novel refrigeration system implementing carbon dioxide (CO_2) as an alternative refrigerant to the hydrofluorocarbons (HFCs) currently in use in domestic settings. HFCs have increasingly gained notoriety for their high global warming potentials, which have been proven to contribute to global climate change. Utilizing a refrigerant with a much lower global warming potential, such as CO_2, would thereby reduce the significant greenhouse gas contributions of the refrigeration industry to this imminent global crisis. The engineering process began with the analysis of a current HFC refrigeration system in regards to power consumption, thermal performance, and environmental impact. Metrics gathered from an existing refrigeration unit and knowledge of the chemical properties of each refrigerant were then used to establish the design requirements for a comparable CO_2-based system. Performance data acquired from this working prototype led to repeatedly tuning and modifying the design to most closely achieve the performance of the existing HFC system. The prototype created has successfully achieved thermal performance of the pre-existing system in maintaining an internal temperature of 6 degrees Celsius, proving to be a viable refrigeration technology. In terms of power consumption, the prototype operates at a net 80 watts, lower than the 90 watts of the existing HFC system as a result of the cogeneration system which recovers lost energy to heat water. With regards to the environment, the global implementation of the much lower impact CO_2 refrigerant will reduce carbon dioxide equivalent emissions by more than 136 million metric tons.

BACKGROUND

The history of the refrigeration industry began in the early 1920s with the synthesis of chlorofluorocarbons (CFCs) when large American corporations began seeking less toxic alternatives to the ammonia (NH3), methyl chloride (CH_3Cl), and sulfur dioxide (SO_2) refrigerants that had been in use since the late 1800s. CFCs were quickly praised for their nontoxicity, and gained prominence in everyday households as they began being used as an inexpensive facilitator for cooling applications. In less than a century, the growth in CFC use peaked around the world with more than one million metric tons of the refrigerant being produced annually.

However, in 1974, scientists Frank Rowland and Mario Molina discovered the ozone-depleting effects of CFCs, leading to their phasing out by the Montreal Protocol. Implemented in 1989, this international agreement forced aerosol, refrigerator, and air conditioning companies to quickly begin looking for an alternative chemical to use in their products.

Although less energy efficient, HFCs became an increasingly feasible option. Unlike CFCs, HFCs lack the chlorine atom that catalyzes the harmful destruction of ozone, and generally remain in a nonreactive state in the troposphere. Still, HFCs have a crucial problem of their own: they are a very potent greenhouse gas and are being used on an increasingly global scale. According to current projections, HFCs could rise to 20% of total carbon dioxide equivalent emissions, resulting in the possible addition of 100 gigatons of carbon dioxide equivalent emissions and a 0.5 degree Celsius rise in global average temperature. Although seemingly insignificant, a 0.5 degree Celsius increase could greatly contribute to ocean acidification, sea level rise, and massive storm events, damaging marine life, agricultural productivity, and security on an international scale.

The implementation of carbon dioxide as a refrigerant provides an undeveloped solution to averting such detrimental crises. Not only does CO_2 have a global warming potential 0.025% that of HFCs, lower than the majority of other suggested refrigerants, it is nontoxic, nonflammable, and easy to obtain. While carbon dioxide is commonly utilized in large industrial cooling devices and factory-scale refrigerators, the residential refrigeration industry has yet to develop an appliance capable of using carbon dioxide on a domestic scale.

STATEMENT OF PURPOSE

The residential refrigeration industry is currently dominated by hydrofluorocarbon (HFC) based systems, which have long held commercial favor due to their nontoxicity, low flammability, and cost-efficient mass-production. However, the high global warming potentials (GWP) of these halocarbons (on average 1400 times that of carbon dioxide), have proven to be environmentally detrimental due to their propensity to contribute to global climate change and the associated environmental deterioration. The implementation of a carbon dioxide-based refrigeration system as an alternative to traditional HFC models would not only significantly reduce the negative effects of refrigerants on global climate health, but also the adverse implications associated with global warming. Moreover, the cogenerative functionality provided by the use of a water pump to cool the appliance would produce hot water without the consumption of additional energy. This would further reduce global warming as power plants operating on fossil fuels would lower their production rate and greenhouse gas emissions as a result of a lower electricity demand. Thus, engineering a novel carbon dioxide-based refrigeration system that acts as a cogeneration appliance has the potential to not only prevent the further degradation of global environmental health, but also to create energy-efficient and sustainable households.

Property Comparison of HFC-134a and CO_2

	Molar mass (g/mol)	Latent Heat of Vaporization (kJ/kg)	Specific Heat Capacity (J/°K/mol)	Boiling Point @ 1 bar (°C)	Melting Point @ 1 bar (°C)	Vapor Pressure @ 20°C (MPa)
HFC-134a	102.03	217.2	14.473	-26.3	-103.3	0.666
CO_2	44.01	574	37.135	-56.6	-78.0	5.73

DESIGN CONSIDERATIONS

Engineering Limitations: In order to create a refrigerator capable of operating on carbon dioxide, the appliance must be able to cool the hot supercritical CO_2 from the compressor to a liquid state at a safe temperature. Generally, the back of a refrigerator includes radiator tubing that cools the liquid refrigerant as it runs through the system. However, this is not powerful enough for CO_2, which can reach temperatures of up to 200 degrees Celsius. Furthermore, carbon dioxide requires higher pressures to condense than HFCs, necessitating different tubing and materials than those generally used in a refrigerator.

Engineering Goal: The goal of this engineering project is to design and construct a refrigerator capable of maintaining the high pressure and temperature conditions necessary to condense the carbon dioxide to usable levels as a refrigerant. Use of a CO_2-specific compressor and thick-walled tubing sustains the high pressures required for room-temperature phase changes, which are at the core of vapor-compression refrigeration. In addition, a water-based heat exchanger is capable of the thermal capacity required for rapidly cooling the hot supercritical CO_2 to a liquid state, concurrently cogenerating heated air and water to potentially reduce both domestic energy use and greenhouse gas emissions.

MATERIALS

- High pressure stainless steel tubing
- High pressure stainless steel Yor-Lok tube and pipe fittings
- Stainless steel pipe fittings
- High pressure ball and needle valves
- 1000 psi and 5000 psi pressure gauges
- SuperC CO_2
- Clear flexible PVC tubing and rigid pipe nipples
- Brass barb and water cooling fittings
- Arduino Leonardo and sensor interfaces
- Pressure and temperature sensors
- LCD display
- Power supply, prototype PCB, custom cables and connectors
- Water pump, radiator, and fans
- CO_2 Tank, hose, and fittings
- Rubber caster wheels and mounting hardware
- Mounting hardware, screws, bolts, etc. for each component

METHODS

1. Modify the compressor output so that it is able to function with CO_2-specific tubing. Create a plastic cover for the compressor.
2. Model the radiative tubing, (attached to the back of the fridge), and the evaporative tubing, (attached to the top of the metal heat sink), with wire. Bend the metal tubing based on the wire models.
3. Bend PVC tubing around the radiative tubing and secure with fittings, creating a small channel through which water can run through to cool the hot CO_2.
4. Attach the evaporative tubing onto the metal heat sink with aluminum tape, and bolt the heat sink to the inside of the fridge.
5. Bolt the plywood stand that will hold the compressor, water pump, and radiator on top of the fridge. Mount compressor, radiator, and water pump to the plywood.

6. Connect the water pump to the PVC tubing, and test the water loop.
7. If successful, connect all of the metal CO_2 tubing (radiative tubing on the back of the appliance and cooling heat sink tubing inside the appliance).
8. Attach the pressure and temperature sensors to measure the following locations:

    Hot water tube (temp)

    Cool water tube (temp)

    Throttle valve body (temp)

    Inside of the fridge (temp)

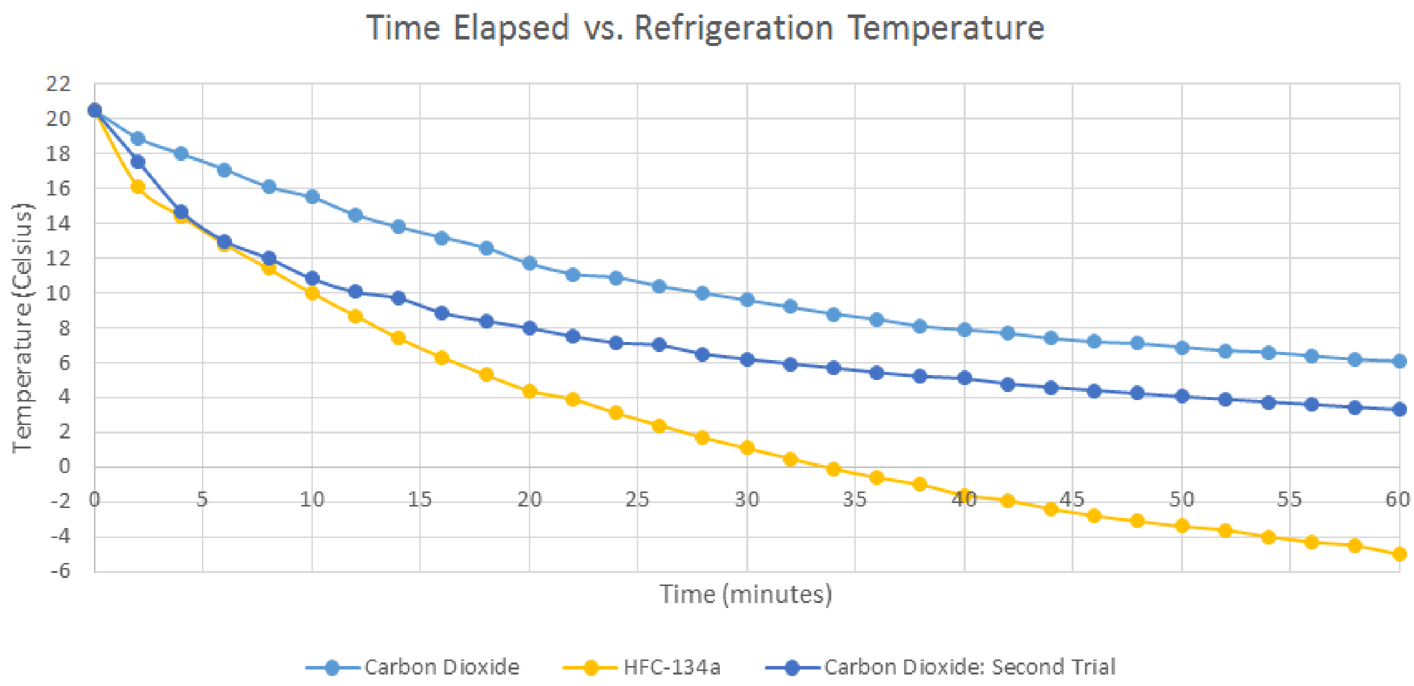
    CO_2 compressor output (temp)

    CO_2 compressor input (temp)

    Compressor input (pressure)

    Compressor output (pressure)
9. Assemble the Arduino circuit and create a program that reads, interprets, and displays the temperature and sensor data, as well as controls the speed at which the compressor and water pump operate.
10. Test the refrigerator with air, monitoring the pressure of the evaporated and condensed air.
11. Test the refrigerator with carbon dioxide, monitoring the pressure of the evaporated and condensed CO_2 as well as the inside of the refrigerator.

DATA



CALCULATIONS

The following calculations are based on the assumption that one kWh burns one pound of coal, an average household uses 3.74 million BTUs per year for space heating, refrigerators operate near full capacity for approximately 8 hours a day, and that approximately 500 million refrigerators are currently in use around the world. The "watts saved" calculations are based on a water flow rate of 120 gallons per hour and a rise in 0.4 C of the water.

Carbon Dioxide Refrigerator:

Watts Saved by Cogeneration: 120 gallons/hour (flow rate) = 454,249 grams/hour 454, 239 grams/hour * 0.4 C * 4.18 J/gC

= 759, 505 joules/hour = 210 watts

Contribution to Space Heating: 759, 505 J/h = 720 BTU/hour = 2,102,400 BTU/year

2,102,400 BTU/year / 37,350,000 BTU/year = 6% of yearly space heating

CO_2 Released from Power Consumption: 290 watts - 210 watts = 80 watts * 8 hours = 0.64 kWh per day = 233.6 kWh per year

233.6 * 500 million refrigerators globally = $1.17 * 10^{11}$ pounds of CO_2 = 53 million metric tons of CO_2 per year

Standard HFC Refrigerator:

CO_2 Released from Power Consumption:

90 watts * 8 hours = 0.72 kWh per day = 262.8 kWh yearly

262.8 * 500 million refrigerators globally = $1.31 * 10^{11}$ pounds of CO_2 = 59 million metric tons of CO_2 per year

CO_2 Saved by Carbon Dioxide Refrigerator:

59 million metric tons - 53 million metric tons = 6 million metric tons of CO_2 per year

130 million CO_2 equivalent metric tons of HFCs + 6 million = 136 million metric tons of CO_2 saved annually

INTERPRETATION OF DATA

The thermal performance of a typical refrigerator is higher than that of the CO_2-based prototype. The carbon dioxide-based refrigerator maintained a minimum temperature of only 6.1 degrees Celsius, while the conventional HFC refrigerator was able to attain temperatures as low as -5.0 degrees Celsius. Furthermore, the cooling speed of the HFC refrigerator is around 1.7 times faster than the CO_2 refrigerator, due to the lower thermal pumping capacity and efficiency of the prototype CO_2 system. However, 6.1 degrees is sufficient for the short-term refrigeration of many consumer products, and a second trial indicated the possibility of reaching temperatures as low as 3 degrees. The -4 degrees reached at the throttle valve indicates there is considerable potential for a further refined CO_2 system that reaches below the FDA minimum of 4 degrees.

The net power consumption of the carbon dioxide-based refrigerator, at 80 watts, is 10 watts less than the 90 watt power consumption of the HFC-based refrigerator. Without taking into account the cogeneration aspect of the refrigerator, it consumes 290 watts. This is mostly due to the compressor, which consumes more than half of the 290 watts when operating under a load. Since CO_2 requires a much higher pressure to condense, it consequently requires a much more powerful compressor. However, the prototype of the carbon dioxide-based refrigerator, due to its unoptimized nature, will inevitably use more electricity than the refined design of a mass-produced product. If implemented on a larger, commercial scale, the CO_2 refrigerator could be revised and improved to reach lower power consumption. Furthermore, even the prototype is able to save 210 of the 290 watts by using them to heat water, thus offsetting electrical consumption in other aspects of the domestic setting. Overall, through its cogeneration applications, the refrigerator is able to provide for 6% of annual space heating and has a net power consumption lower than that of the HFC refrigerator.

Due to its lower net power consumption and more eco-friendly refrigerant, the CO_2 refrigerator's environmental impact is much lower than that of its HFC counterpart. If implemented on a global scale, the CO_2 refrigerator would release around 136 million metric tons less of carbon dioxide equivalent emissions than the HFC refrigerators currently in use. This number was calculated based on the 80 watt power consumption of the prototype - if mass produced and improved to use less electricity, the decrease in greenhouse gas emissions could reach up to 150 million metric tons. Such a notable improvement to the negative contribution of the refrigeration industry to climate change could significantly help to lessen its environmental degradation.

CONCLUSION

Despite the lower thermal performance of the carbon dioxide-based refrigerator, its utilization of CO_2 as a replacement for HFCs is able to significantly reduce the negative impact of refrigerants on the environment. If implemented on a global scale, the CO_2 refrigerator could potentially reduce greenhouse gas emissions by more than 136 million metric tons. Furthermore, its functionality as a cogeneration appliance will reduce electricity use in other aspects of the domestic setting, providing for 6% of annual space heating demands. While the prototype of the refrigerator is unrefined and therefore does not operate at maximum efficiency, mass-production of the appliance with further design optimizations could both lower its power consumption and increase its thermal performance to better match that of current refrigerators. Thus, the carbon dioxide-based refrigerator is less detrimental to the environment, and has the potential to reach and even exceed the performance of current refrigerators as a growing technology.

FURTHER RESEARCH

The high power consumption and thermal inefficiencies of the carbon dioxide system leave room for significant design improvements over the initial prototype. The majority of improvements can be made in thermal design:

- Reduce losses in cooling power not contributing to the refrigeration cabinet
- Increase thermal efficiency of the supercritical CO2 heat exchanger
- Improve insulation of the refrigerator cabinet and reducing heat leaks

The existing prototype exhibits cold temperatures of about 8 degrees Celsius below room temperature on the gaseous CO_2 return tube after it exits the heatsink, indicating an uncapitalized opportunity to absorb more heat from the refrigeration cabinet. Increasing the size and surface area of the heatsink would improve thermal performance, as did increasing the expansion tube size to ¼" and extending it an additional 150% in length in our second prototype to offer a larger area for heat exchange. Heat leakage in the cabinet itself stemming from the inexpensive commercial construction contributes quite noticeably to thermal inefficiency - improving the construction and insulation quality would reduce the necessary cooling power and operating interval of the compressor, and gains in both power efficiency and thermal efficiency would result. Integrating the compressor's air-cooled pistons into the cogeneration system holds potential to recover an additional 30-50 watts of heated water from the compression process, as well as removing 20 watts of electrical consumption via eliminating the high-speed fan currently implemented.

On the compressor side, the high-speed fan cools the CO_2 pistons and the ½ HP motor, exhausting the energy as heated air. The motor only consumed 200W at peak load and 154W continuously in our design, while its maximum load specification details a 400W power draw. Utilization of a smaller, more appropriately sized or ¼ HP motor that operated in the ideal efficiency range would save 40-70 watts and eliminate the need for a dedicated cooling fan, further saving electricity and design complexity. Overall, the current configuration has provided substantial support for the viability of a

CO_2-based refrigeration system in domestic applications. There is significant room for improvement beyond the preliminary implementation that would narrow the performance gap between CO_2-based and existing HFC-based refrigeration systems.

Global Energy Plan

Dinesh Parimi, Ben Trowbridge, Teri Guo,
Udit Ranasaria, Suraj Buddhavarapu

PURPOSE

To determine which countries require the most financial aid in order to achieve sustainable industrial development and then design plans to show how these countries could benefit from the Green Fund/ to meet their growing energy demands over the next ten years.

PROJECT SUMMARY

The United Nations has proposed a solution to avoiding reaching the 500 parts per million carbon emission threshold imposed by the IPCC in the form of a U.N. accord. As part of the Copenhagen treaty the proposed "Green Fund" will delegate annually 100 billion dollars to countries in need of development so that they might develop cleanly with the money acquired through this accord. Taken from historic polluters, first world countries like the United States, England, and Germany would contribute to pool of donations whereas countries like Congo would benefit. Our project is creating a method of ranking countries in order to determine which countries are guilty of historic carbon emissions and which ones need more help to develop.

In essence we created an algorithm that accounts for a country's GDP, population, and historic carbon emissions resulting in a defining list of countries by developmental need. After this we chose 6 representative countries - China, India, Indonesia, Niger, Congo, and Brazil to analyze regional resources for the second half our project: implementing synergistic power plants to be built by the money gained through the Green Fund. Eventually our initial 6 countries whittled down to 3 countries with specific plans as to which form of renewable energy is used as well as how much money, terawatts of power, and carbon savings could be generated. Our plan cumulated in a business proposal modeled in the form of a U.N. treaty that we plan on delivering to the U.N. council gathered for the Climate Summit in hopes that our involvement and interest as students will convince their assembly and other students to sign onto our proposal.

WHAT IS THE GREEN FUND?

The Green Fund has been discussed as a possible part of the upcoming U.N. treaty on climate change. It involves all the first-world countries of the world sending a yearly fund of $100 billion to the third world, that those countries would then use to industrialize with renewable energy. One of the biggest problems with solving climate change today is that there is a huge existing dependency on fossil fuels in the first world, so if the third world were to industrialize greenly, this would not occur. This $100 billion fund would be based on historic carbon emission percentages, so countries that polluted more in the past would pay a greater percentage of the fund. In essence, the Green Fund is the first world's way of paying the third world for the damages fossil fuel-based industrialization has brought upon the world.

INTRODUCTION

The 15th Conference of the Parties (COP-15) in 2009 passed the Copenhagen Accord, which laid the groundwork of the Green Climate Fund. Working towards the goals of the United Nations Framework Convention on Climate Change (UNFCCC), the Fund "will promote the paradigm shift towards low-emission and climate-resilient development pathways by providing support to developing countries to limit or reduce their greenhouse gas emissions and to adapt to the impacts of climate change, taking into account the needs of those developing countries particularly vulnerable to the adverse effects of climate change." As of May 21, 2015, $10.2 billion has been pledged by U.N. members towards this goal. However, the fund hopes to ramp up to $100 billion of funding every year by 2020. In order to achieve this goal, there must be (a) an objective method of distributing funds, and (b) a way to predict and quantify the benefits of the fund.

MATERIALS AND METHODS

The countries most in need of financial aid from the United Nations are those that are rapidly industrializing. Nations like this are characterized by large populations, low GDPs per capita, and low (though increasing) carbon emissions per capita. These factors were used to determine a country's Environmental Development Index (EDI) rating:

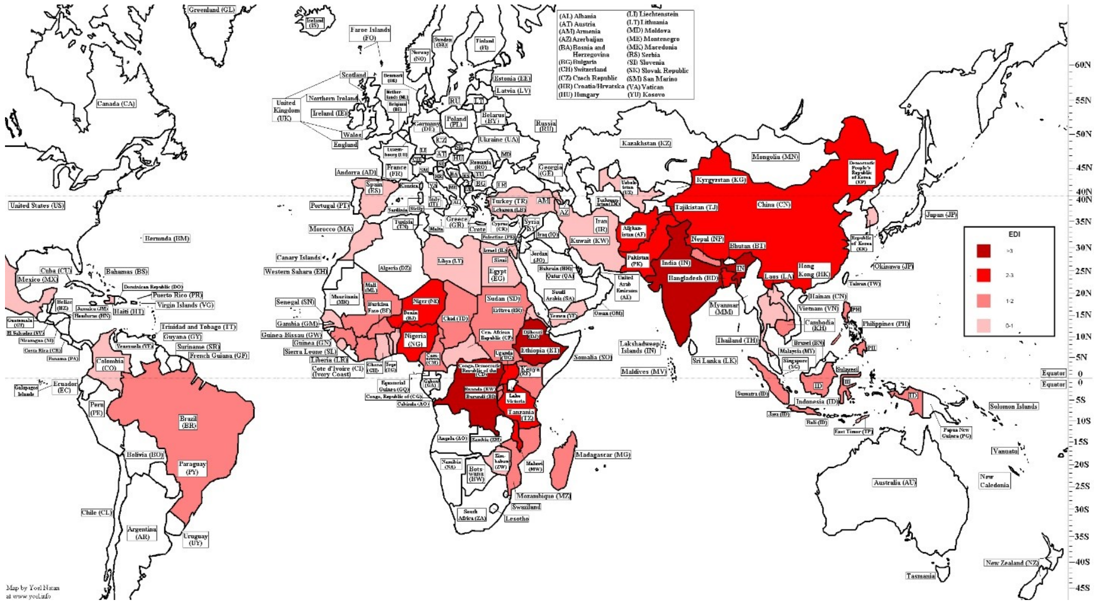
$$\log \frac{\frac{P^2}{G * F}}{\frac{{P_{usa}}^2}{G_{usa} * F_{usa}}}$$

This system gave the United States a rating of 0.00, and all other ratings were scaled relative to this. Countries rated above 1.00 are those which will likely be beneficiaries of the fund.

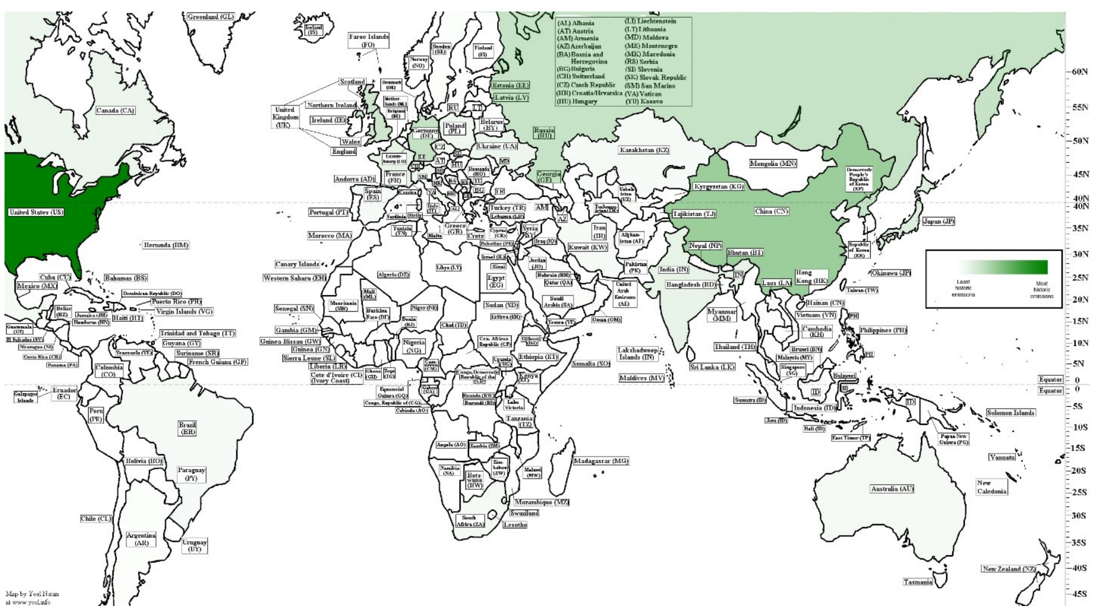
The highest rated countries were analyzed further to determine how U.N. funding could be most effectively used. A variety of factors, including topography, climate, and population density, were taken into account to determine the most effective renewable sources for a specific region. Given a portion of $1 trillion (spread over a decade), all countries were able to make significant strides towards sustainability.

Dinesh Parimi, Ben Trowbridge, Teri Guo, Udit Ranasaria, Suraj Buddhavarapu

RESULTS



EDI of every U.N. member country.



Amount each country will contribute to the fund, based on percent of historic global emissions.

EXPLANATION OF MATH

The idea of a “Green Fund”, by and for U.N. members, has been up in the air for several years. Naturally, the potential beneficiaries are eager about the idea, the potential funders less so. The Environmental Development Index (EDI) is a numerical index that quantifies the beneficiaries of this fund, effectively demonstrating which countries are in the most need of financial aid. The equation boils down to:

$$\log \frac{\frac{P^2}{G * F}}{\frac{{P_{usa}}^2}{G_{usa} * F_{usa}}}$$

where P is the total population of the country, G is the GDP per capita in USD, and F is the carbon footprint per capita in tons. Higher numbers correspond to developing nations – large and poor populations with comparatively high carbon emissions due to industrialization. The index is then divided by the numbers for the USA and log-scaled, so that the USA reads a 0 on the scale. Any number above 1 would be a potential beneficiary of the fund, as their developing status and large populations make them crucial in the fight against climate change.

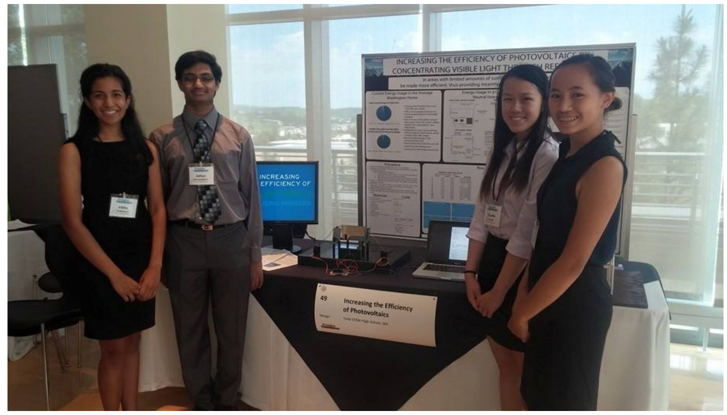
The contributors to the fund, on the other hand, will be determined strictly by their share of responsibility in how things stand right now – their historic carbon emissions. The USA is in the lead on this front, with 27.69% of emissions since 1850, corresponding to a $27.69 billion contribution to the fund.

WHY IS OUR PROJECT IMPORTANT?

One of the biggest obstacles to a successful green fund is the implementation of the funds. The first world is afraid the third world will misuse the funds given, as has occurred in the past. If a clear plan is put out, then the first world will know exactly where the money is going and will be more confident that what they are doing will make a difference. Another huge obstacle is determining which countries will receive the fund. By creating an index of the relative need of countries, the most problem areas will be isolated and can be given the greatest amount of money to either replace the fossil fuels they are currently using or develop renewable energy sources to base their economy on.

Increasing the Efficiency of Photovoltaics by Concentrating Visible Light through Reflection

Vibha Vadlamani, Aditya Ramanathan, Claudia Nguyen, Allison Tran, Grace Ren, Nick Bo



ABSTRACT

To maximize energy output for photovoltaics, solar industries use the system of Concentrated Solar Power (or CSP) to direct approximately 95% of the sun's rays which fall by using solar mirrors. Consumers are not able to utilize a similar technology due to the size of these industrial technologies. In places farther away from the equator, the earth's curvature limits the amount of concentrated sunlight which reaches the ground, decreasing the warmth of that area as well as the photons per square inch, which directly impacts the efficiency of a solar panel, and increases the payback time of the solar system. By introducing a system which utilizes solar mirrors on the edges of solar panels, the efficiency of these photovoltaics will increase due to the reflection of sunlight which would have previously not hit the panel, back to the photovoltaic, thus allowing for more sunlight to be converted into electrical energy. To test the effectiveness of this system, a control solar panel will be placed alongside a solar panel with this system attached. Each panel will be subjected under conditions of varying sunlight. To measure the sunlight levels, a flashlight with full batteries will be used to simulate the sun's rays. This flashlight will be placed at angles mimicking that of cities (Sammamish, Tucson, and Anchorage) at the respective city's winter and summer solstice. For the Winter Solstice in all places, the average value for the system with mirrors was 1.21 mVA and the average value without mirrors was 1.1 mVA. For the Summer Solstice, the system with mirrors had an average voltage value of 1.28 mVA while the average value for the system without mirrors was 1.2 mVA.

INTRODUCTION

In the year 2013, the Intergovernmental Panel of Climate Change deemed that at current rates of fossil fuel usage, our world will become uninhabitable by 2050. To ameliorate the imminent threat, scientists have urged countries to utilize renewable energies. Renewable energies are those which convert sustainable, omnipresent sources, such as wind, water, and heat into electrical energy, without releasing greenhouse gases. Renewable energies aren't a new invention; we have known about them for over 30 years. But we fail to utilize them in the manner in which they should be used, due to lack of economic feasibility- because of negligible return on original investment- in areas where these energies don't work at their maximum efficiencies. Therefore, in order to encourage the use of renewable energies to secure the future of planet Earth, we must start by making the most commonly known and used renewable energy efficient for all; we must make changes to the solar industry.

Solar panels or photovoltaics, were invented in the 1980s, and convert light energy into electrical energy through layered semiconductors. One silicon-based panel contains two semiconductors, the n-type and p-type, infused with boron and phosphorus, respectively. When light hits the solar panel, the photon dislodges an electron from the n-type semiconductor and when the electron passes through the p-type semiconductor, electrical energy is produced. The appeal of solar energy is that, as long as the sun exists, this method of harnessing energy is viable. In the past 13 years alone, the amount of gigawatt/hours produced by solar industries in the United States, has increased from 524 to 15,973, demonstrating the increasing popularity of this renewable resource. As for efficiency, current photovoltaic panels range between 10 and 20% in areas where 60% or more of sunlight reaches the ground. But due to the curvature of the earth's surface, and the diffusion of the sun's rays at higher latitudes, not every location receives over 60% of sunlight, thus reducing the efficiency of a solar panel in these areas significantly.

To increase energy output, solar industries in California, the Mojave Desert, and Nevada, utilize "solar mirrors". Solar mirrors use the reflective properties of normal mirrors to channel sunlight that otherwise wouldn't be converted into energy, onto a photovoltaic, in order to increase the efficiency and energy produced by that panel. But the drawback of these industrial mirrors, is stated in the name – they are only available for industrial purposes in places where sunlight is abundant. These 15 by 20 foot mirrors are stationary as well, and rather than adapting to the sun's position throughout the day, multiple mirrors are placed at varying angles to direct light to the solar panel. To secure renewable energy sources for the future, and to reduce dependence on fossil fuels around the world, solar mirrors should be introduced in a system which will increase the efficiency of photovoltaics in areas further from the equator.

Traditionally, the edges of solar panels have been left bare, allowing for the sun's rays which don't hit the photovoltaic, to escape. In areas near the equator, where sunlight is extremely concentrated, the decrease in efficiency is negligible, but in areas with less concentrated light, the loss of these rays dramatically decreases the efficiency of a photovoltaic. In addition to limited amounts of sunlight, the sun doesn't remain stationary due to the earth's rotation. Industries account for this "movement", by placing over 100 mirrors at numerous angles to capture the sun's rays, regardless of position. But in residential areas, the cost of the hundreds of mirrors industrial companies use to account for all those angles, would be extremely expensive, and would reduce the likelihood for people in colder environments to invest in solar technology.

By placing mirrors on the edges of the mirrors, sunlight that would normally not reach the panel will be reflected onto the photovoltaic, thus resulting in an increased efficiency and output of energy. In order to account for the various positions of the sun during the day, the mirrors should be constantly moving. By attaching servo motors, each mirror will be able to move from 0-180 degrees. Finally, to account for the sun's varying positions in different places around the world, GPS services with programs accounting for the various sun's angles at specific latitudes, will allow for the maximum amount of sunlight to be reflected back onto the solar panel.

BACKGROUND RESEARCH

Concentrated Solar Thermal (CST) is a method which utilizes mirrors to direct sunlight to a tube of oil which is then transported to a facility. In this facility, the hot oil is used to heat water which then turns a turbine to produce electrical energy. The mirrors used to heat the oil are parabolic troughs; energy collectors that functions with a combination of especially reflective parabolic/convex mirrors with a tube of oil placed in the center of each mirror in the trough. The mirrors are parabolic to account for the different angles of the sun and direct all the sunlight towards heating the oil in the tubes.

Another form of solar energy using mirrors is CLFR or Concentrating Linear Fresnel Reflectors. This method, similar to that of the parabolic trough, is different in that it uses Fresnel reflectors' lenses to increase the concentration of light being reflected by a factor of 30.

The final method is the Solar Power Tower (SPT). This method uses a large number of mirrors placed in a circular formation to direct sunlight from all angles of the sun to a central position of thermal fluid (liquid sodium) which is then used to boil water to drive steam engines.

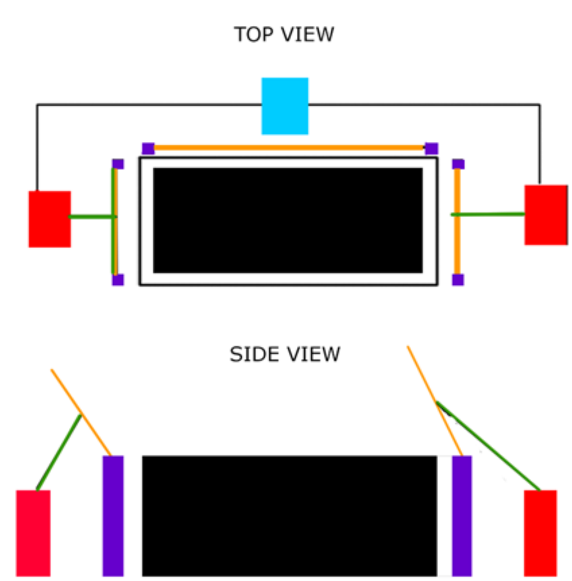
Though highly effective in that these different forms of solar technologies produce massive amounts of energy in a sustainable way, there are various limitations associated with these large scale production methods. First, companies primarily in California utilize these technologies due to the increased prevalence of the sun. This provides an incentive to invest in these technologies as the amount of energy produced is enormous. But in areas such as Washington or Maine, these systems aren't prevalent because of their costs. In addition, the electricity that is produced from these panels isn't directly connected to a house or a grid, and the transportation of the electricity produced has been known to produce resistance and back ups on the technology grid. Finally, the space required for these systems is large, due to the size of the mirrors and the quantity needed to produce adequate amounts of energy. And in cases of the Solar Tower, animals which fly through the area have been known to be burned alive due to the immense concentration of light being directed to a specific location.

METHODS

Materials:

- 2 Multimeters
- Potentiometers
- 2 9.0 V, 200 mVA solar panels
- Arduino
- Breadboard
- 2 inch tall mirrors
- 2 servo motors
- 2 Hangers

SCHEMATIC OF EXPERIMENTAL SYSTEM:

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#include <Servo.h>

Servo s1;
Servo s2;
int angle1 = 90;
int angle2 = 0;

void setup()
{
  s1.attach(9);
  s2.attach(10);
}

void loop()
{
  angle1 = changeServo(s1, angle1);
  angle2 = changeServo(s2, angle2);
  delay(200);
}

int changeServo(Servo s, int angle)
{
  s.write(angle);
  angle += 1;
  if (angle > 180)
    angle = 0;
  return angle;
}
```

Code used to power experimental system.

EXPERIMENTAL PROCEDURE

The angle of the sun changes throughout the day, and the length of the day depends on the location of the place due to latitudinal and longitudinal differences. By calculating the length of the day, we chose to use both Sammamish, Washington, Anchorage, Alaska, and Tuscon, Arizona as our different locations on the day of December 21, 2014 (the Winter Solstice) and June 21, 2014 (the Summer Solstice). To find the distance from the sun to the panel, we used an application which calculated the arc that the sun travels in and used a factor of 4 per centimeter to determine a constant length. Finally, to determine the angle at which the sun was placed at, we used the latitudes of each location and used a protractor to measure out the respective angles.

1. Gather two solar panels and place solar panels on a 4 cm foam board stand.
2. One of the solar panels will be the control, and will not have any mirrors attached on the edges of the panel.
3. The second solar panel will have three flat-surfaced mirrors attached to each edge.
4. Each mirror will be held up by an axle that will be attached to a motor by a hanger. The motor will be attached, along with a potentiometer, to an Arduino Uno board. The code provided will allow the potentiometer to move the mirrors to different positions depending on the angle of the sun.
5. Attach a multimeter to the wires of the solar panel, to record the amperage and voltage.
6. Place both solar panel systems in an inside location with similar temperature, humidity, and sunlight concentrations or conditions.
7. Use a flashlight to imitate the sun.
8. Test different angles of the day for Anchorage, Tucson and Sammamish for the Winter Solstice. (divide up the angle measures by

hours of the length of the day).

9. Repeat this step 8 for Summer solstice.
10. Record data in data table.

DATA COLLECTION

Data will be collected through the use of multimeters, which will record the voltage and amperage of each solar panel depending on the location of the sun. The higher the average voltage and amperage readings of a particular solar panel, the more efficient the solar panel is.

DATA ANALYSIS

The purpose of this experiment is to increase the efficiency of solar panels and to measure the increase in efficiency of the solar system, we will be placing multimeters on each solar panel during experimental the distinguished experimental timeframes.

The efficiency of the solar panel is dependent on the range in which the panel reaches the efficiency which the panel was meant to operate at.

The solar panels which were used in the experiment have a maximum voltage of 200 mVA and the higher the efficiency the closer the value will be to a 2.00 reading on the multimeter.

The more efficient panel will have a higher voltage overall and will determine the effectiveness of the mirror system used to concentrate the sunlight onto the solar panel.

RESULTS

The position values (1,2,3) correspond with the peak sun value (highest point of the day), the starting edge (east value), and the setting edge (west value).

Overall, the system with the mirrors displayed higher voltage values than the system without the mirrors.

CONCLUSION

By placing mirrors on the edge of solar panels, overall, the efficiency of the solar panel increased. By attaching Servo motors to the two mirrors and placing the back mirror at an angle which best reflected the most amount of sunlight, the position of the sun was accounted for and more light was reflected back onto the panel due to the increased sunlight hitting the photovoltaic. This system and design supports our design criteria in that the efficiency of the photovoltaic was increased, and also, the creation of the system was economically feasible, and would be able to provide a cost-effective addition to increasing residential PV systems. Overall, this project cost a little over $200, and on a larger scale, the motors used would have to be stronger, and the mirrors larger, which would reach an expected cost of approximately $500. But, the cost of the newly designed reflective system would be negligible compared to the cost of the PV system which can range from $10,000-$30,000. As for efficiency, during the Winter Solstice, the average value for the system with mirrors was 1.21 mVA and the average value without mirrors was 1.1 mVA. For the Summer Solstice, the system with mirrors had an average voltage value of 1.28 mVA while the average value for the system without mirrors was 1.2 mVA. One trend that was noticed was that when the values were tested for the start and end angles of the Summer Solstice, the average voltage value was much lower than that of the peak. This trend may have occurred due to the fact that the Summer Solstice angle measures were much greater than that of the angle measures in the Winter Solstice. This larger angle meas-

SAMMAMISH SUMMER SOLSTICE VALUES (VOLTAGE- mVA)		
POSITION NUMBER	WITH MIRRORS	WITHOUT MIRRORS
1	1.508	1.201
2	1.013	1.000
3	1.060	1.060
SAMMAMISH WINTER SOLSTICE VALUES (VOLTAGE- mVA)		
POSITION NUMBER	WITH MIRRORS	WITHOUT MIRRORS
1	1.207	1.036
2	1.264	1.169
3	1.246	1.031
ANCHORAGE WINTER SOLSTICE VALUES (VOLTAGE- mVA)		
POSITION NUMBER	WITH MIRRORS	WITHOUT MIRRORS
1	1.385	1.192
2	1.253	1.148
3	1.279	1.165
ANCHORAGE SUMMER SOLSTICE VALUES (VOLTAGE- mVA)		
POSITION NUMBER	WITH MIRRORS	WITHOUT MIRRORS
1	1.598	1.197
2	1.106	1.103
3	1.199	1.193
TUCSON WINTER SOLSTICE VALUES (VOLTAGE- mVA)		
POSITION NUMBER	WITH MIRRORS	WITHOUT MIRRORS
1	1.309	1.145
2	0.938	1.010
3	1.013	1.004
TUCSON SUMMER SOLSTICE VALUES (VOLTAGE- mVA)		
POSITION NUMBER	WITH MIRRORS	WITHOUT MIRRORS
1	1.985	1.239
2	1.211	0.936
3	0.968	0.942

ure led to sun positions which were behind the apparatus, thus resulting in a slight blockage of the sun due to the mirrors. One method to fix this is to collapse the mirrors at certain points of the day and cover them with black felt or fabric. The heat generated from that mirror would then be converted into electrical energy.

Overall, despite the increase in efficiency which resulted from the placement of mirrors, the average value was brought down significantly due to the sun's position during the Summer Solstice. This system could be implemented into modern residential settings where solar PV systems are utilized. The placement of this system will increase the efficiency of a photovoltaic by directing sunlight onto the solar panel, and this will increase payback time, thus resulting in an economic incentive for people to purchase solar technologies, thus securing our energy future.

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Creating an Inexpensive Development Platform as a Learning Tool to Improve Engineering Education

Udit Ranasaria, Nicholas Georgiou, Jeremy Chiu

ABSTRACT

Engineering is taught all around the world, from high school classrooms to graduate lectures, but much of this teaching is done with generalized notes and words, not in a meaningful manner in accordance to engineering ideals. For engineering to be taught in an effective way that will truly produce strong engineers, problem and product-based learning through development and products needs to be employed. The overarching goal of this project was to reform engineering in this way through the creation of a product that will provide a platform for students to learn how to drive varying display technologies through machine-level code in a fun, cheap, and informative way. Deciding that a game console would manifest this, significant research was done into the schematics for board design and technicalities in the code-interface process. Then, many prototypes and iterations were made until arriving at the final product, which was mass produced and assembled into kits to distributed to individual students at a final cost of under $15 per kit. The first set of students to be given these reported higher satisfaction as well as a 14% increase in test scores for this specific unit as compared to students from previous years. In conclusion, this device was quite successful in increasing learning and producing stronger engineering students but that said this kit has only been used in one university in one class for one unit and needs to promoted so that similar sort of systems are used in engineering education everywhere.

GOALS, OBJECTIVES, AND CRITERIA

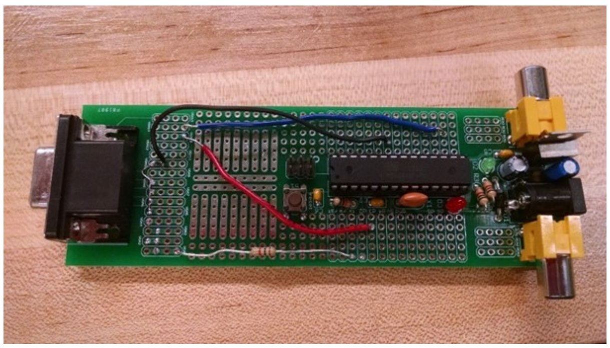
The requirement is to create some sort of a small, simple personal learning tool that will enable students to discover and explore the intricacies and basics of driving displays. A system will be developed that can implement multiple display technologies, while also create a platform on which students can be creative and develop further. To achieve this the objectives would be to, through research, test and understand the VGA Output already integrated into the Boarduino Derivative, figure out how to get TV Out through the RCA Jacks, see what possibilities RCA-Composite Output can create, and then lastly design a new system that makes the hardware as simple to use as possible, letting students focus on doing creative things with the software. The system should be within a university class budget, $25 per system, and should be deliverable as an easy to build kit to minimize time spent on and difficulty of hardware setup.

The decided means for the product after all this research was a game system/controller. It logically makes sense as it provides an interactive medium for human interaction but also a test platform for development. It would be a PCB that had all the Video Outputs that the Boarduino Derivative has in a compact system that includes peripherals (buttons, joysticks, etc.) for students to take advantage of. With these peripherals and the multiple of output options the students can truly make something creative and innovative.

RESEARCH

Boarduino Derivative

The Boarduino Derivative Kit, designed by John Sarik, was assembled with the aid of visual instructions from http://4193finalproject.weebly.com/1-assemble.html.

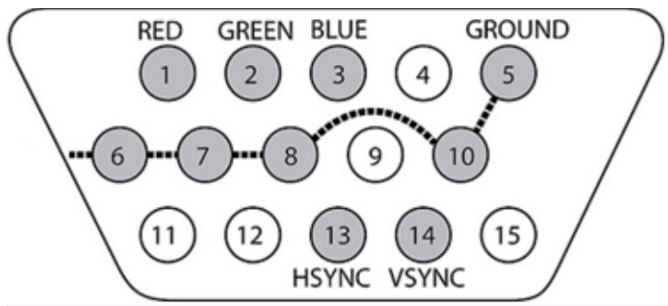


The first test at messing with code came with just tinkering with the basic example "Blink" program that is used to test if the board is functioning properly. Opened "Blink" via File Examples 01.Basics Blink. In "Blink" the amount of milliseconds, the turning on and off of the LED takes, can be altered by changing delay(1000) to either a longer or shorter delay. Half a second delay corresponds to delay(500) or a two second delay is delay(2000).

VGA Output: Hardware

VGA has 15 pins with the most common arrangement in 3 rows of 5 pins each (DE-15). Pin 1 displays red, Pin 2 displays green, and Pin 3 displays green, while Pins 5,6,7,8, and 10 are ground pins, which help regulate charge and are the zero. Pins 13 and 14 are HSYNC and VSYNC pins, meaning that they control both the horizontal and vertical refresh of display. In both cases, there is time needed to move the Electron Beam and there is wasted space called "porches".

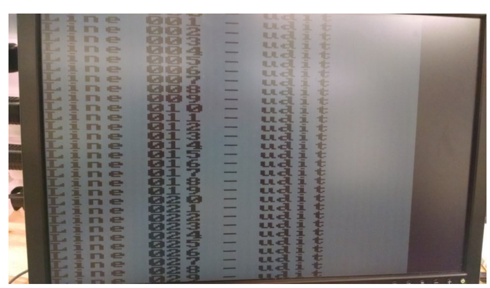
The code used (designed by Nick Gammon) is set up to output HSYNC on Digital 3 and VSYNC on D10. So those need to be connected to Pins 13 and 14 respectively. Also pins 5,6,7,8, and 10 need to be shorted together and connected to ground. For monochrome output the RGB pins must be connected by shorting together pins 1-3. Then, the TX line was connected to the RGB short.



Tinkering with Code: Monochrome

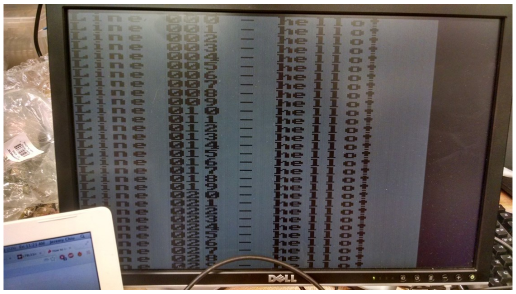
The VGA Out Code was downloaded from http://4193finalproject.weebly.com/3-vga-code.html. If the header files are in the same folder as the PDE then they should mount automatically and it should compile and upload.

Detailed description of how code works can be found on Nick Gammon's Website: http://www.gammon.com.au/forum/?id=11608

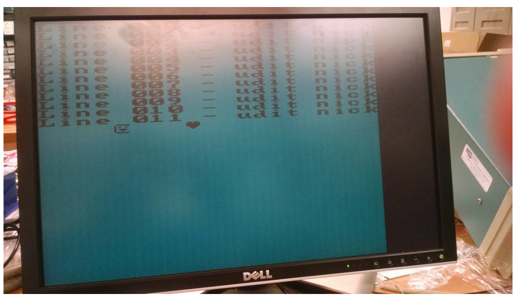


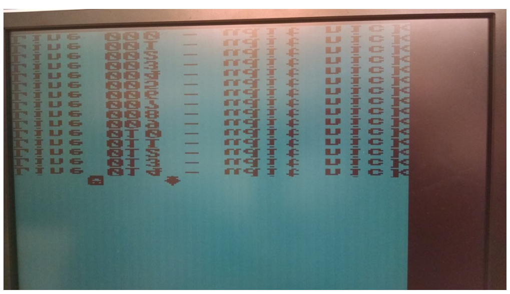
This code sets a default resolution of 160x480 and this is the highest horizontal resolution because even using SPI hardware to run the clock speed twice the speed at 125 ns, there is only enough time for 160 horizontal pixels.

Some basic modifications were done to get familiarized with the architecture.

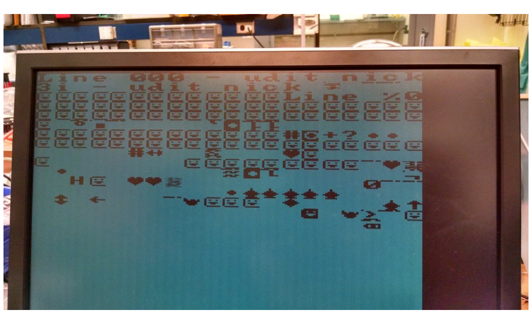


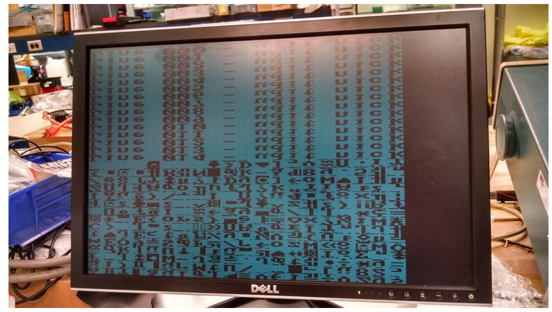
First just the value of the text was altered.





Line spacing, numbering, and text properties were all modified and tinkered with. Here is the first signs of the 9th bit problem start to show as can be seen with the vertical blank bars cutting off the signals.





After the character mapping and timing were changed significantly a possible shift in the reading caused all the characters to be misread into other characters. This creates the jumble of random symbols that are added as more obscure parts of the character map.

The 9th bit Problem

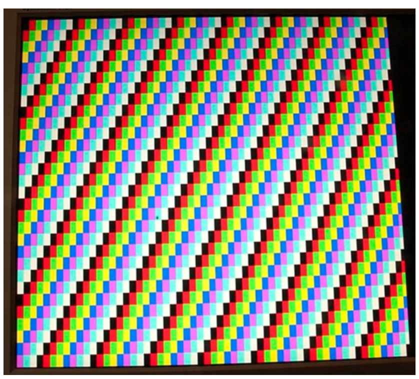
Outputting this code through VGA has a problem. The USART pin sends out one extra high-bit for every byte. This results in the black bars or spaces. Inverting the text mitigates this problem partly because the 9th bit bars get blended in with the spaces between letters but it is sometimes visible. This is best visualized with sending a signal of a plain white screen and the display shows the blanked bars at every 9th bit.

One unexplained observation is the lack in uniformity of the width of the bars.

Color Code

Incidentally, even with the RGB pins shorted together Blue and Purple screens were made just by replacing all the characters by 0x80 and 0xF8 respectively. It is unclear why this worked.

A more proper method would be what Nick Gammon has developed. His method of making color involves connecting each RGB to a separate pin on the Microcontroller so at least 3 pins are required; this won't use SPI and can only run it at the regular clock of 62.5 ns. Also storing the bitmap for the color information at a 160x480 resolution would take more memory than available. Therefore, resolution had to be lowered to 64x64 and we are outputting color pixels at 6 cycles per pixel.



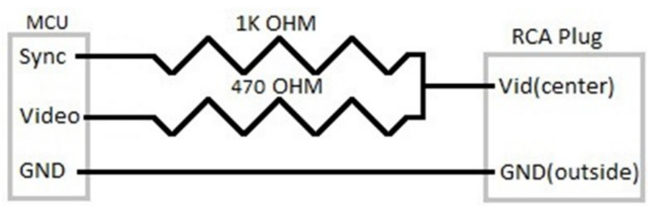
Notice that there is no sign of the 9th bit problem now. This is because of using multiple pins to output video information and not using SPI hardware.

RCA Output: Hardware

RCA has only 2 conductors: Center which passes the signal and Outside for ground. An RCA Jack can be used to either transmit Audio or Video, but not both. While RCA output is not of high quality resolution or has color it uses less memory, takes less time to output, conserves a pin on the microcontroller compared to VGA Output. For these reasons, it might be a better option than VGA.

RCA connections were completed using diagrams from http://playground.arduino.cc/Main/TVout designed by Miles Mentzler. A 2 Conductor-3 Contact RCA Jack is used and a multi-meter was used to test which contacts were connected to signal and ground. Ground is the outside of the RCA jack with one pin, and the center is signal with two pins. One RCA jack was wired for audio output while the other was wired for video output.

Arduino	SYNC	VIDEO	AUDIO
NG,Decimila,UNO	9	7	11



So a 1K Ohm resistor mused be connected from D9 and a 470 Ohm Resistor from D7 to the Center of the RCA Jack. Also, GND connected to the outside of the RCA. This should cover video. Audio is simpler with just a wire from D11 to Center and then GND to the outside.

Video Code

First, the example Demo NTSC was tested. Download the TV Out Beta Zip file from http://code.google.com/p/arduino-tvout/downloads/detail?name=TVoutBeta1.zip.

Extract all 3 files (TVout, TVoutfonts, and pollserial) into the Libraries Folder inside the Arduino Program Files (In windows via My Computer/This PC Windows Program Files (x86) Arduino Libraries). On the first attempt, the screens worked but the cube rotation was failing to display properly and some text was wavering. The 470 Ohm resistor with a 330 Ohm Resistor as seen in a schematic by Nootropic Design and the problems vanished. Otherwise video out worked fairly well, but sometimes due to poor connections and other issues, the signal was shaky and disrupted.

Audio Code

An RCA Jack was soldered to a small speaker with 2 wires and tested. Inside the existing code, just the audio commands were introduced.

TV.tone(frequency, duration);.

"TV.tone(500,1000);" yields a 500 Hertz noise for 1000 milliseconds or 1 second. The RCA Audio pin (D11) shares a pin with the VGA but that is not an issue since the Arduino won't be sending signals to both outputs at any time.

PROTOTYPE DEVELOPMENT

NicholUditv1.0

This attempt was unsuccessful due to design flaws when created in EAGLE CAD.

Has all necessary components: Buttons, RCA, VGA, Power, etc.. RCA is not connected within the board but there is proto-typing space. All the components are scattered somewhat randomly throughout the board.

Each button was connected to a different pin on the microcontroller and ground. Each button also had a place for a 10K resistor as a pull-up, if the internal ones in the microcontroller failed. On the board they were each arranged in 2 groups of 4 resembling a D-Pad and the ABXY buttons found on an Xbox.

Board size: 4.0x1.5

There was a big error in the schematic and many of the pins were not properly connected to the MCU. So this board was a fail.

NicholUditv2.0

This was a much needed working version of the board. Everything on the schematic was connected now. The board was organized in sections now and looks much more coherent. There is also a modified star arrangement to tie back ground lines.

It works. VGA works and RCA video/audio works.

NicholUdit3.0

This design was focused on removing prototype spaces, tweaking the schematic and reducing size.

The buttons on the schematic to be compatible with the Hackvision system layout. This caused some of the pins to be shared with the VGA Output, but the buttons are going to be used with RCA output so it should not matter.

After getting rid of the pull up resistor and prototyping space, it made most sense to turn the processor sideways. It seems to be more ergonomic while holding a controller as well. 2 diodes were added to the RCA lines to test and a large ground plain on the bottom of the board.

NicholUdit4.0

One more decoupling capacitor that connects Ground to +5V was added to improve stability. There was more descriptive silkscreen added and minor routing improvements. The diodes were removed because they caused more disruptions in the signals due to lack of voltage.

NicholUdit5.0

This was the final version and the first that would be fully fabricated instead of just a prototype board. The power supply was redesigned and the Hackvision power supply was used as a reference. Holes were added on the corners of the board so it can be mounted on a piece of plastic for comfort and protection while using the device.

RESULTS

The final prototype, Version 5.0, embodied all the design criteria that were decided at the beginning of the project. The final size was 1.5 inches by 3.5 inches or 5.25 inches squared which equates to approximately $5 per board, as each square inch costs $1 for board fabrication. The components when bought in bulk the components (excluding cabling) costs another $9 which makes for a total just around $15. Then if the cables and programmers (which most people already should have) are included, the cost increases by $16. The total, without cables, is around the $25 goal that was designated. The boards are using both the display technologies, VGA with Nick Gammon's libraries, and then RCA/Composite Audio and Video using Miles Metzler's Libraries. As for as a game console, the system has 8 fully programmable buttons, each hooked up to a different digital pin for use. Furthermore it uses an Arduino based processor that lets students employ the familiar Arduino IDE to program their games.

The systems were then provided these systems to a class for the display out education. Students reported much higher satisfaction with their learning and there was a decrease in drop-outs. The game system was used and the students used the console in the most creative of purposes and there were games developed from Mario to Worm. The test scores at the end of the unit showed an increase in 14% over the previous tests units, and since that group of students showed similar overall results in other units, this shows a definite net increase on the total understanding and comprehension of this unit's data.

It truly is possible to inexpensively improve the quality of engineering education. That said, this console was only effective in improving 1 unit for 1 class at 1 university and much needs to be done to implement such education in many more areas.

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VGA Out Code and Documentation: http://www.gammon.com.au/forum/?id=11608

TV Out Code, Resources, and Wiki: https://code.google.com/p/arduino-tvout/downloads/detail?name=TVoutBeta1.zip

EAGLE Tutorials: https://learn.sparkfun.com/tutorials/using-eagle-schematic/all

Lady Ada Boarduino Walk-Through and Documentation: https://learn.adafruit.com/boarduino-kits

Nootropic Design Hackvision Files, Games, and Forums: http://nootropicdesign.com/hackvision/

Per Unit Calculations				
Quantity	**Catalog/Part Number**	**Unit Price**	**Total Cost**	**Item or Cart Description or Quote Number**
1	ATMEGA328P-PU-ND	3.0044	3.0044	Unprogrammed Amtel Atmega 328p-PU microcontroller
1	3M5480-ND	0.576	0.576	28-pin socket
1	X908-ND	0.4	0.4	16.00 MHz ceramic oscillator
1	CP-202A-ND	0.4371	0.4371	2.1mm Power Jack
1	1N4001FSCT-ND	0.1094	0.1094	1N4001 diode
1	MC7805CT-BPMS-ND	0.3	0.3	5V regulator 7805 TO-220 package
2	399-4266-ND	0.095	0.19	Bypass capacitor 0.1uF ceramic
1	P812-ND	0.0802	0.0802	Electrolytic capacitor 47uF / 25V
1	P803-ND	0.0889	0.0889	100uF/6.3V capacitor
9	10KQBK-ND	0.0247	0.2223	10K ohm 1/4W 5% resistor
3	1.0KQBK-ND	0.0247	0.0741	1.0K 1/4W 5% resistor
1	754-1606-ND	0.0715	0.0715	3mm red LED
1	754-1603-ND	0.0715	0.0715	3mm green LED
9	450-1650-ND	0.05618	0.50562	6mm tact switch button
1	3M9459-ND	0.299	0.299	6 pin header, 0.1"x0.1" spacing
2	PJRAN1X1U04X-ND	0.5665	1.133	2 conductors 3 contact RCA Jack
1	S9581-ND	0.708	0.708	3 Row VGA connector
1	PGM-09825	13.46	13.46	AVR Pocket Programmer
1	6360	3.03	3.03	VGA Cable
1	107	0.74	0.74	USB to Mini USB Cable
	TOTAL		**25.50102**	

Ozonation Water Tri-Filtration System for Future Implementation in Developing Countries

Neha Hulkund, Anne Lee, Suchi Sridhar, Isaac Perrin

ABSTRACT

Water is a necessity of human survival, the one vital element we cannot live without. Unfortunately, 750 million humans around the world, approximately one in nine people cannot access this vitality. That's over twice of the United States' population that lacks the key to survival. Almost a million people die of water-related diseases each year because they have no resources to acquire purified drinking water. The system we developed utilizes ozonation technology to effectively filter drinking water in a cost-efficient manner to be implemented in developing countries. The portable water filtration system we conceived consists of three stages: a sand/charcoal filter, ozone chamber, and another sand/charcoal filter. Through conducting research and trials, we discovered that by the end of the system, water is purified and drinkable, proving this innovative technology could possibly save millions of lives in the future.

INTRODUCTION

The need for a powerful and cost-effective purification system is obvious. Millions of lives could be saved and improved each year. However, the pressing question we needed to address and research is, "What type of filtration is the most efficient, cost-effective, and convenient?" Many different systems exist today, such as chlorine, chloramine, chlorine dioxide, reverse osmosis, ozonation, and solar filtration.

Chlorination is the most common water filtration system today. Disadvantages include the bitter taste, the long reaction time, and the high toxicity. Furthermore, chlorine refills have be to be bought often, and are very expensive over time. The most serious concern with using chlorination is the serious health risk. Chlorine can be ineffective and does not always kill all the bacteria and organic compounds. And worst of all, when the chlorine reacts with naturally occurring organic matter in water, the reaction produces disinfection byproducts including trihalomethanes and haloacetic acids, which are highly carcinogenic. According to the U.S. Council of Environmental Quality, the cancer risk for people who drink chlorinated water is 93 percent higher than those who don't.

Chloramine is a combination of the chemicals chlorine and ammonia. It also produces potentially carcinogenic disinfectant byproducts, formed when a disinfectant combines with organic matter. The byproducts of chloramine are known to be more toxic than other filtration systems like chlorine, yet chloramine is not as effective as chlorine. Chloramine is very expensive compared to chlorine and is also toxic to the environment and human health. When filtering with chloramine, a separate filter is necessary to take out the chloramine in the water.

Reverse Osmosis is a water purification technology that uses filters to get small and potentially harmful particles out of the water. The particles are left on the other side of the filter while the water goes through it. This method is often used in combination with other filtration systems, such as chloramine, and is sometimes used for purifying salt water. However, this method is often costly and does not decontaminate the water well enough to drink by itself.

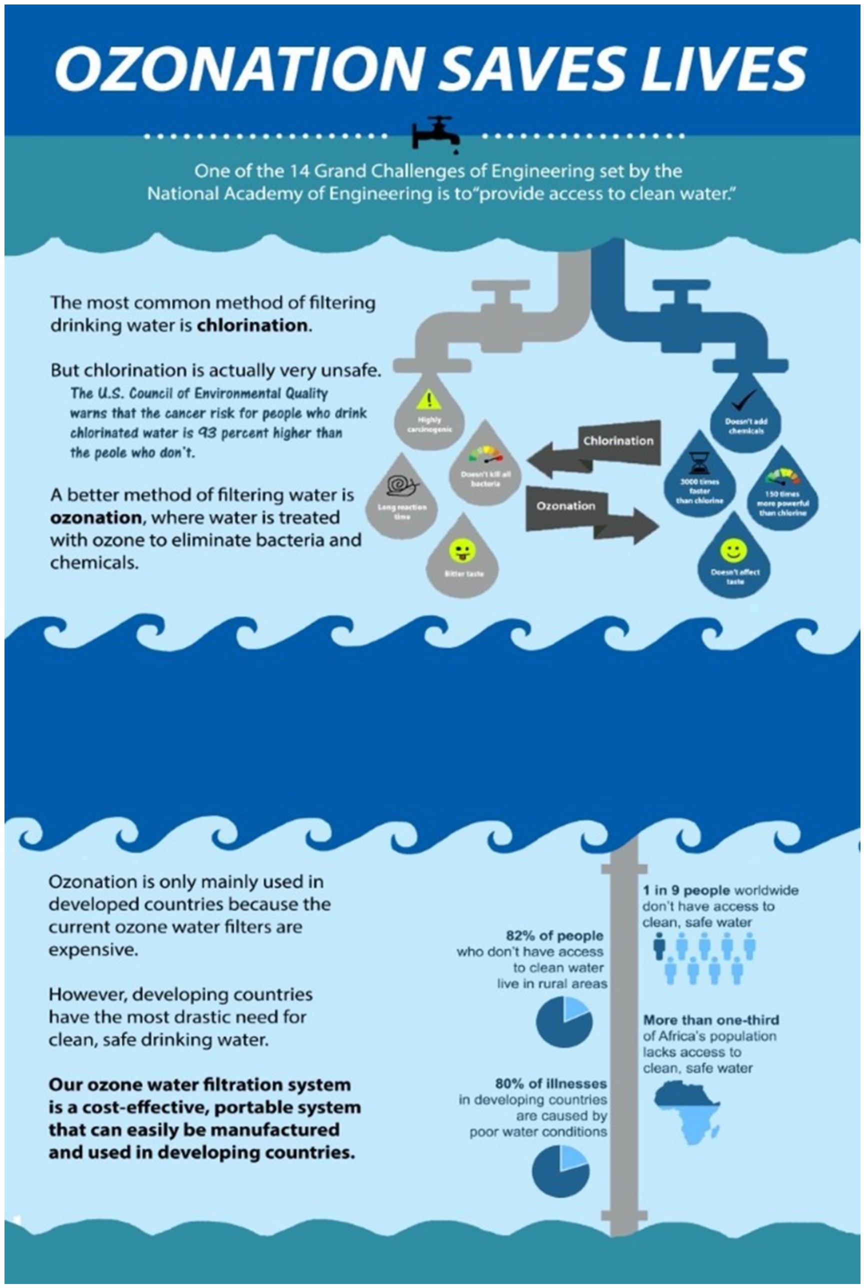
Solar Water Disinfection, or SODIS, is a water purification method that uses solar energy to decontaminate water with biological contaminants in it, such as bacteria, viruses, worms, etc. The three main types of solar water disinfection are ultraviolet, heat, and electrical. SODIS is currently used worldwide, but there are notable disadvantages to this method. For instance, if the water is very turbid (or murky), this process can not be used alone, but only in combination with another process. Also, if the water is left in the dark, the bacteria eliminated through SODIS could potentially reform. Most importantly, this procedure does not remove toxic waste in the water that is commonly seen due to factory spills, and is a major health hazard.

Ozonation has a short reaction time that is over 3000 times as fast as the reaction time for chlorine. Ozone is also effective over a wide pH range, and has a strong oxidizing power that is over 150 times more powerful than chlorine. Unlike chlorine, ozone doesn't add chemicals to the water and cannot be overdosed because the ozone which isn't used escapes out of the water and transforms into oxygen. This makes it a much safer alternative to chlorination. Ozone filters are also cost-effective because they are a one time purchase that last for at least five years. By using ozone filters instead of chlorine, users can save money in two years or less. This makes ozonation a much more cost-effective alternative to chlorination and other filtration systems.

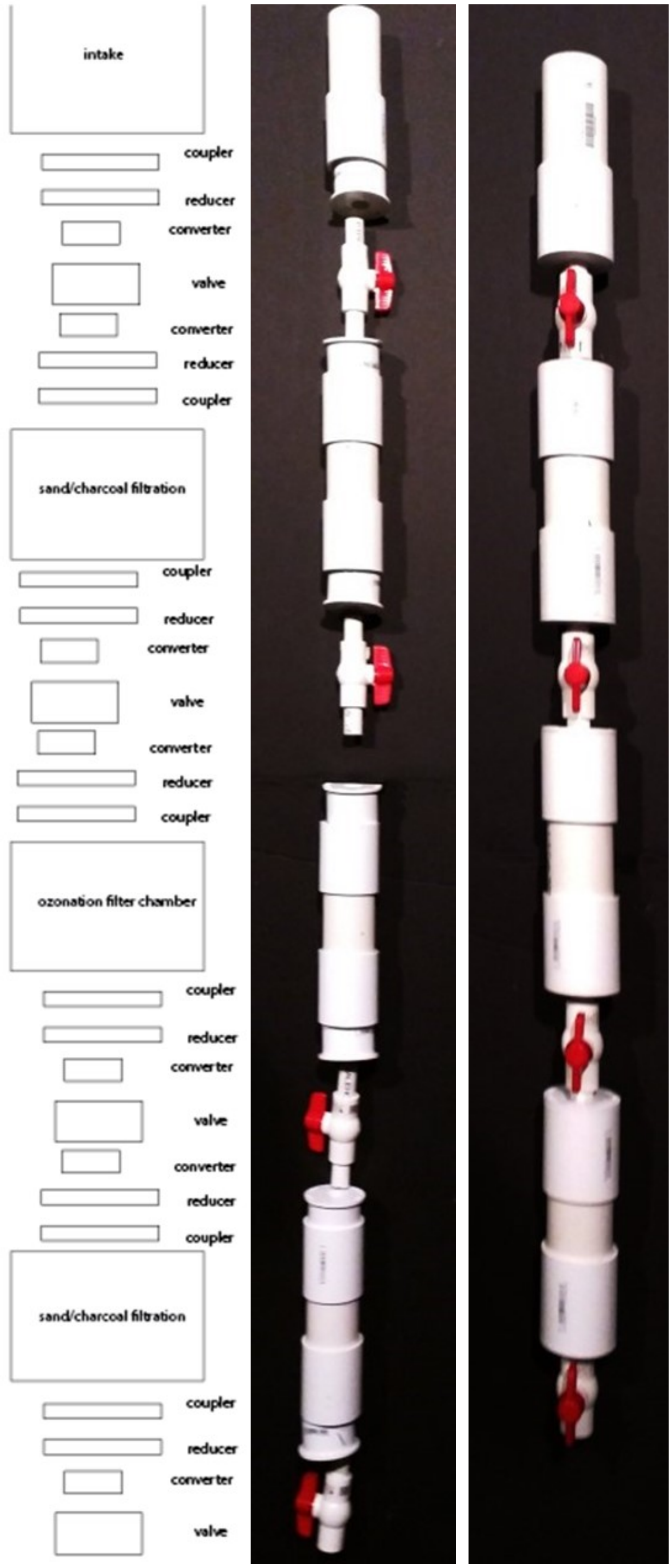
After looking at these purification methods and more, we came to the conclusion that ozonation had the greatest potential for being used in third world countries because of its cost effectiveness, while also being efficient and powerful.

OBJECTIVE

Ozonation is mainly utilized in developed countries because the current ozone filters are too expensive for developing countries.



At this time, ozonation is primary used in European countries and a few cities in the United States and Canada. However, developing countries have the most drastic need for clean, safe drinking water. We were inspired to develop a new ozone water filtration system that is cost-effective and portable and can easily be manufactured and used in developing countries.



QUESTION

How can we construct an inexpensive and safe water filtration system to implement within developing countries?

HYPOTHESIS

If we optimize ozone technology to purify water in a cost-efficient and sanitary method, then ozone water filtration systems can be implemented in third world countries to save millions of people from dying of dehydration or contaminated water without the harmful by-products of chlorination.

PROTOTYPE

Materials

- 7 - couplers
- 7 - reducers
- 4 - valves
- 1 - 2’ x ½ “ PVC pipe
- 1 - 2’ x 2” PVC pipe
- 1 - ozone generator

OZONE GENERATOR

Two methods to generate ozone exist today. One type of ozone generator relies on ultraviolet radiation, and follows a process similar to how ozone is generated by the sun in the upper atmosphere. The other method of generating ozone is through silent corona discharge, which generates ozone in a similar process to ozone generated by lightning. We are currently innovating our filtration system to utilize an environmentally-friendly, solar-powered ozone generator. This would allow our design to be even more environmentally friendly, and could lead to potential breakthroughs in water filtration technology.

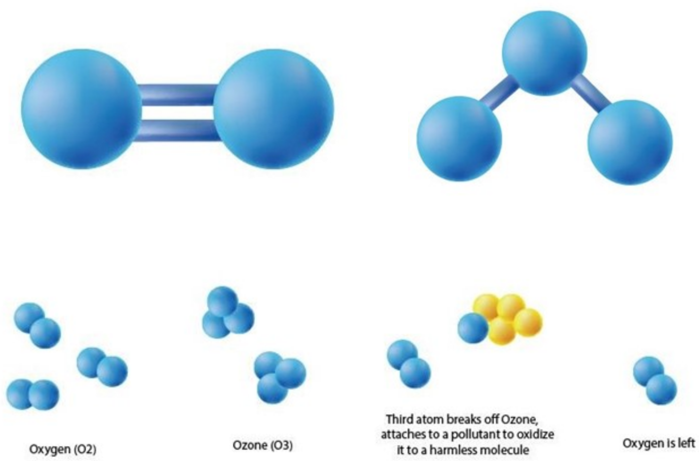
ASSEMBLY

Assembly of the device is simple as the design only requires a few pieces of PVC and filling 2 sections with sand and charcoal for filters while the 3rd section only needs a tube to the ozone generator.

OZONATION PROCESS

Ozonation is a chemical reaction where ozone oxidizes pollutants and other harmful bacteria. Ozone is the triatomic form of oxygen, consisting of three oxygen atoms. On the other hand, an oxygen molecule consists of two oxygen atoms that are bounded by a nonpolar covalent bond. When ozone is released into the ozonation chamber, the second system in our filter, one oxygen atom breaks off and becomes an oxidizing agent. This atom oxidizes harmful pollutants and bacteria, leaving the two oxygen atoms as pure oxygen, meaning the process is not harmful to human health and is environmentally-friendly. As an end result, the water is purified as ozone removes and kills the bacteria and contamination.

Ozone when put into water vs. ozone after the oxygen atom breaks off



CONCLUSION

After conducting intensive research and testing, we made multiple advances in utilizing ozonation technology for implementation in developing countries. We were able to successfully construct a cost-efficient, effective, portable water-filtration system that can purify water in an innovative manner that could lead to future breakthroughs in technology and water filtration systems. Water travels through the three stages: sand/charcoal filter, ozonation chamber, and another sand/charcoal filter. The sand/charcoal filter filters out bacteria and other contaminants, while the ozonation chamber destroys viruses and other contaminants that made it through the first process. Lastly, the sand/charcoal filter captures the remaining contaminants and viruses from the ozonation chamber. In addition, water that travels through our filtration system comes out purified and drinkable, meeting the health regulation guidelines. We had the opportunity to discuss our experiments and system with an engineer, environmental scientist, and a bio-chemist. They were extremely impressed by the innovative, new, design, and believed the system could be feasibly integrated into developing countries to provide purified, drinking water to people around the world, therefore saving millions of lives. Technology utilizing ozonation can continuously be improved on to become more sanitary, cost-effective, and efficient. The tri-stage water filtration system proves it is clear ozonation that will lead to a breakthrough in water purification to improve the quality of lives around the world.

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Aquifer Education Campaign

Sonia Murthy, Vibha Vadlamani, Dinesh Parimi, Sophia Tevosyan, Udit Ranasaria

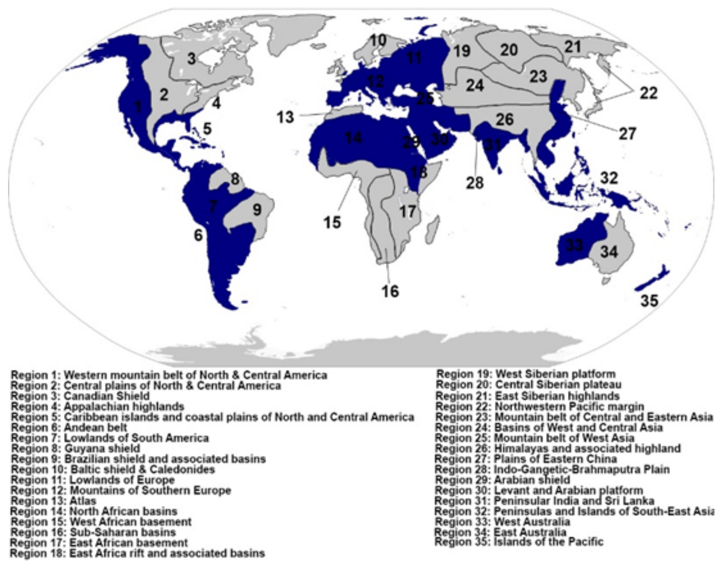
OBJECTIVE

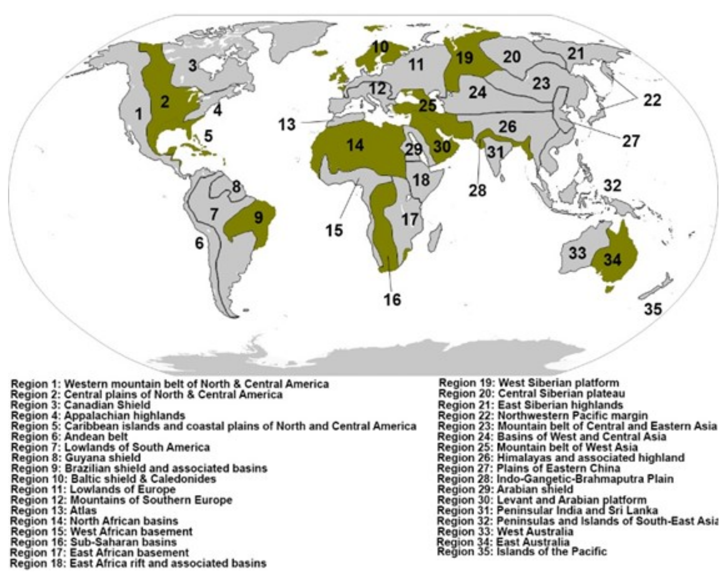
Inspired by our own reliance on an aquifer and our familiarity with the measures that must be taken to preserve the health and safety of its water, we have developed a series of educational materials, including maps, informational posters, PowerPoints, classroom activities, assessments, a website, and an Android application, in order to education the local and global community about the importance of aquifers, swales, and other ground water sources, as well as the anthropogenic threats they face.

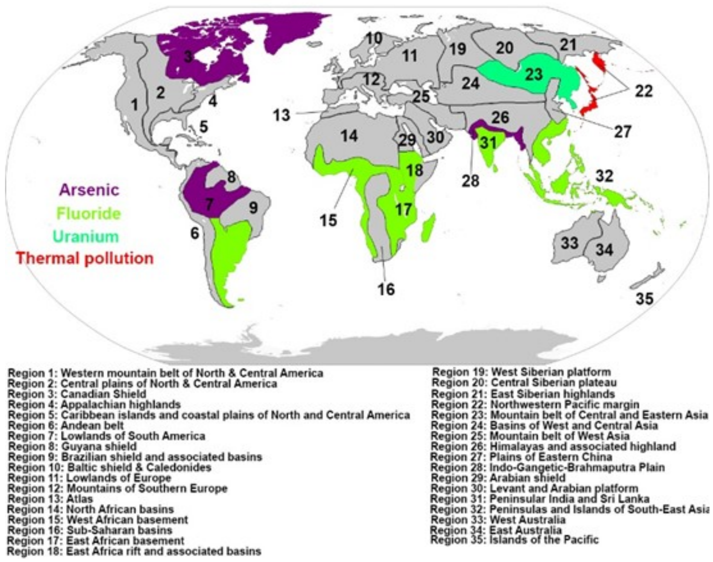
MAPS

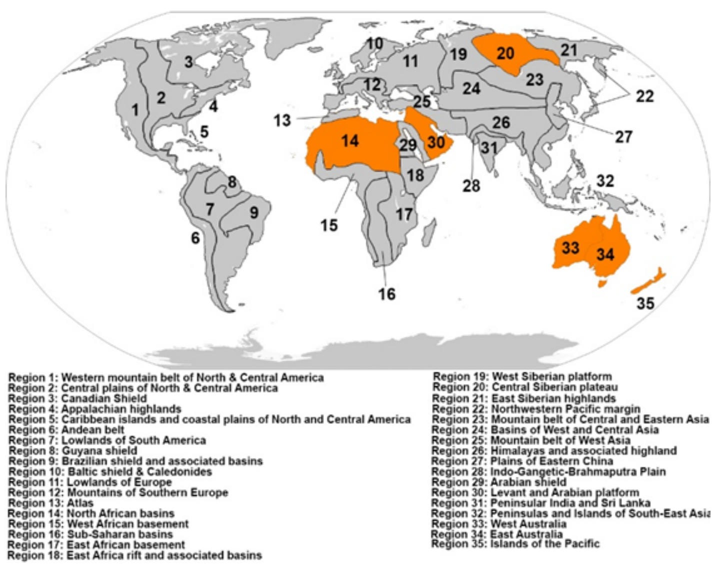
The foundation of our efforts lie in the power of education to change behavior. While we initially began doing this on a level that was much closer to home, our continuing efforts to expand our impact across the world require us to continue with this same education focus, only with globally relevant information and a much larger focus.

In order to do this, we have analyzed data from a number of different countries all over the world, sorted them in to approximately 35 different regions, and identified the major problems threatening the aquifers in those regions. We then created the following 4 maps that not only expose the problem regions around the world for contamination & pollution, saltwater intrusion, slow recharge, and hydraulic fracturing, we also indicate the problems AND possible solutions for them. Data is provided by IGRAC (International Groundwater Resources Assessment Center).









ENGINEERING SOLUTION

Using a basic knowledge of organic compounds and solubility from our chemistry class, we developed an idea on how to decontaminate our local aquifer. By speeding up the degradation of the herbicide, either through a chemical catalyst or biological means, we reasoned it should be possible to neutralize its harmful effects. After extensive research, we found a bacterial strain, Aminobacter, sp. MSH1, that is able to biodegrade the herbicide. When dichlobenil, the herbicide, enters soil and leaches into groundwater, it dissolves into the metabolite 2,6 dichlorobenzamide. The bacteria are able to break down the metabolite into non-harmful by-products with the use of only a few necessary nutrients, and under an optimal pH range of 7 and temperature of 25º Celsius, which matches very well with the conditions of the aquifer.

Aminobacter, sp. MSH1, also adheres strongly to the sandy filter (highlighted red below) found in aquifers. By creating a biofilm of colonized bacteria in the sandy layer of our own aquifer, the bacteria would be able to degrade the dissolved herbicide as the water leaches through towards the bottom layers. Building an intermediate site between the aquifer and water pipes, such as a manmade holding tank with a sandy filter on top, would clean the contaminated water already in the aquifer before its domestic use as well. Doing the same for wastewater exiting the system would ensure that treated water reentering the environment would be further decontaminated.

Another step to prevent the future contamination of groundwater by dichlobenil would be to introduce certain fungal species into the plant communities in the swale system. A swale is a manmade, multistep filtering process that involves plant-covered ditches and artificial filtering tanks that further clean the water entering the aquifer. Research has shown that a certain fungal species, Mortierella sp. LEJ702, is able to work in consortium with Aminobacter to increase the speed and efficiency of its ability to break down 2,6 dichlorobenzamide. By growing fungal-bacterial associations in our own swale system, the water entering the aquifer would be decontaminated not only by the bacteria in the sand filter, but also by the bacteria in the swale ditches as well.

Sonia Murthy, Vibha Vadlamani, Dinesh Parimi, Sophia Tevosyan, Udit Ranasaria

EDUCATION CAMPAIGN

The best way to solve this problem is to increase awareness. Nothing can be done about a problem if not enough people know what the problem is. We realized that educating more people was one of the most important things for our campaign so people can be more cognizant of where their water comes from and how they can take care of it. Lastly, we decided that the most important people to educate was the people this problem would affect the most: the next generation. These are the people who would be making change in their communities next and need to know about these problems. We visited many Elementary and Middle Schools educating students about their water and where it comes from.

We developed a 3-pronged curriculum that was the foundation of our education campaign.

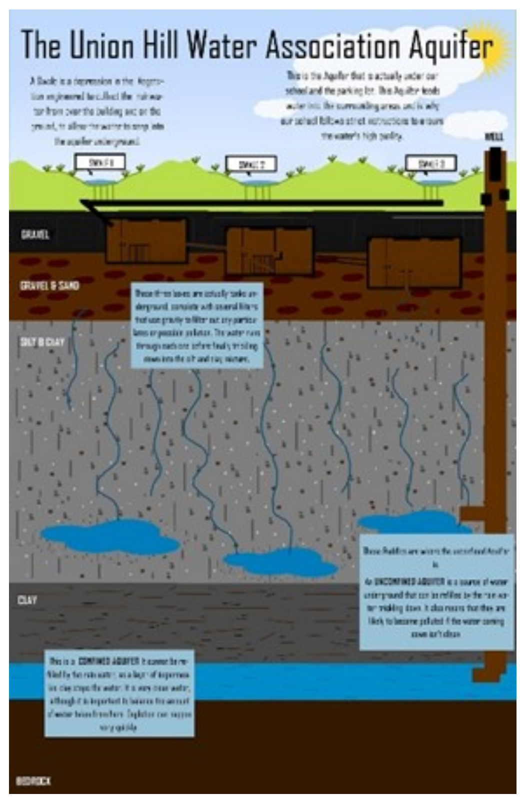
Question Based Learning: Our curriculum and teaching style heavily revolves on student curiosity and analytical ability. We connect situations in their mind and ask questions that make them think about these problems themselves and come up with answers to essentially learn the curriculum by themselves. It is always amazing to see how many questions that these students can come up with at the end of a lesson.

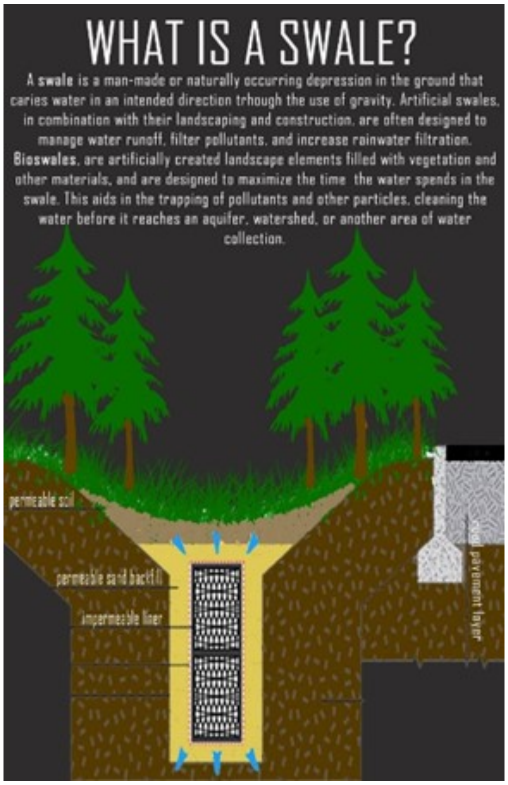
Visual and Demonstrative Learning: We believe that the most effective way for students to absorb information is by seeing many visuals. Our PowerPoint is filled with videos, maps, and diagrams for the students to grasp the enormity or intricacy of a situation in ways words and numbers can't. Our posters are passed around for students to examine closely. We also have demonstrations for every class to represent our information. For example we depicted how the tiniest bit of pollution (a drop of food coloring) can adversely affect the whole aquifer (a large water bottle).

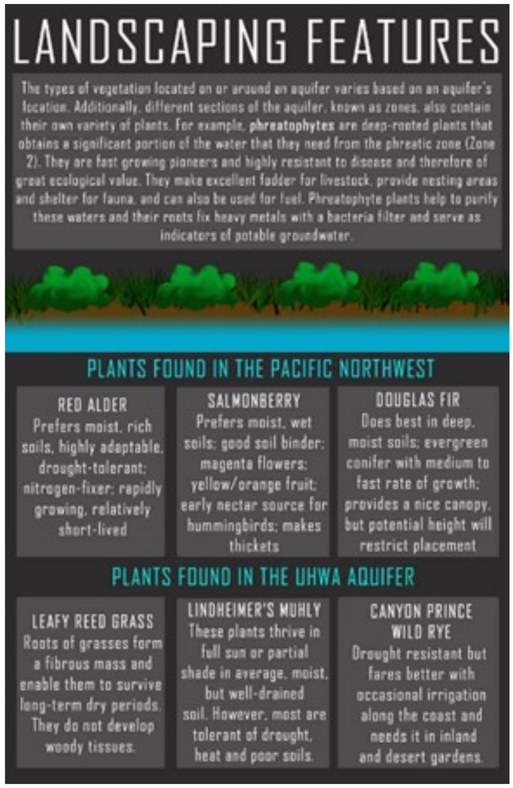
Discussion Based Group Learning: At the end of each lesson we ask the students to perform group activities. In small groups, students are able to collaborate and discuss to do research and come up with solutions to problems that we pose to them, be it solutions to use less water in the house to researching problems in aquifers located outside the US.

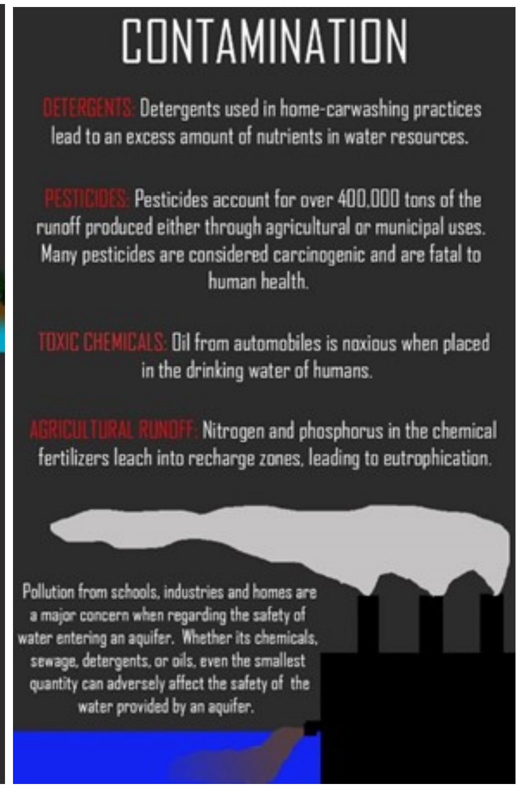
EDUCATIONAL MATERIALS

In addition, we created a set of information posters concerning various aspects of groundwater sources, the anthropogenic threats they face, and the possible solutions.

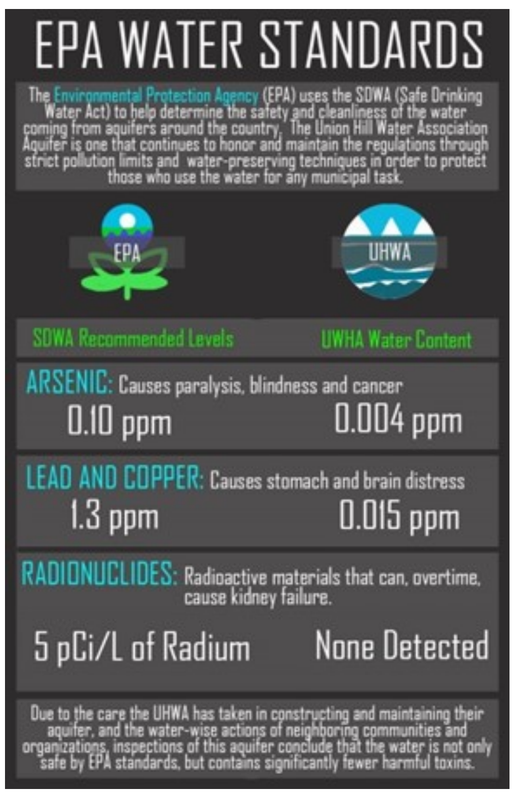


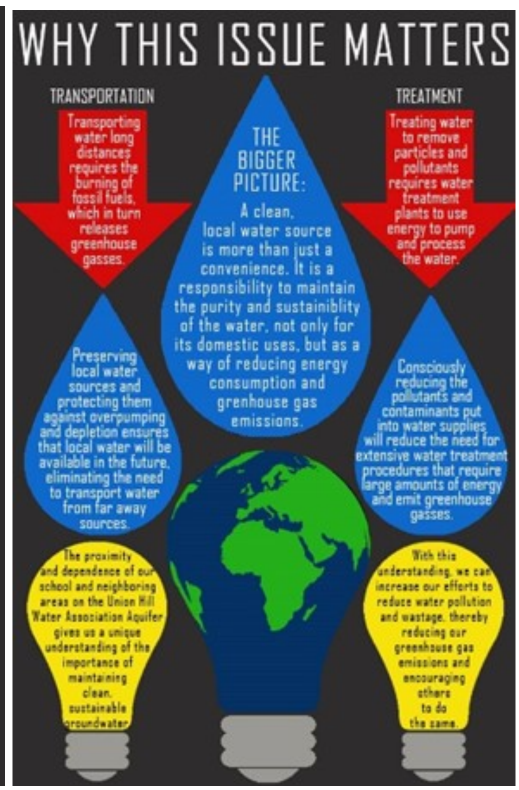

WHAT IS A SWALE?
A swale is a man-made or naturally occurring depression in the ground that caries water in an intended direction trhough the use of gravity. Artificial swales, in combination with their landscaping and construction, are often designed to manage water runoff, filter pollutants, and increase rainwater filtration. Bioswales, are artificially created landscape elements filled with vegetation and other materials, and are designed to maximize the time the water spends in the swale. This aids in the trapping of pollutants and other particles, cleaning the water before it reaches an aquifer, watershed, or another area of water collection.
permeable soil
permeable sand backfill
impermeable liner
pavement layer


LANDSCAPING FEATURES
The types of vegetation located on or around an aquifer varies based on an aquifer's location. Additionally, different sections of the aquifer, known as zones, also contain their own variety of plants. For example, phreatophytes are deep-rooted plants that obtains a significant portion of the water that they need from the phreatic zone (Zone 2). They are fast growing pioneers and highly resistant to disease and therefore of great ecological value. They make excellent fodder for livestock, provide nesting areas and shelter for fauna, and can also be used for fuel. Phreatophyte plants help to purify these waters and their roots fix heavy metals with a bacteria filter and serve as indicators of potable groundwater.
PLANTS FOUND IN THE PACIFIC NORTHWEST
RED ALDER
Prefers moist, rich soils, highly adaptable, drought-tolerant; nitrogen-fixer; rapidly growing, relatively short-lived
SALMONBERRY
Prefers moist, wet soils; good soil binder; magenta flowers; yellow/orange fruit; early nectar source for hummingbirds; makes thickets
DOUGLAS FIR
Does best in deep, moist soils; evergreen conifer with medium to fast rate of growth; provides a nice canopy, but potential height will restrict placement
PLANTS FOUND IN THE UHWA AQUIFER
LEAFY REED GRASS
Roots of grasses form a fibrous mass and enable them to survive long-term dry periods. They do not develop woody tissues.
LINDHEIMER'S MUHLY
These plants thrive in full sun or partial shade in average, moist, but well-drained soil. However, most are tolerant of drought, heat and poor soils.
CANYON PRINCE WILD RYE
Drought resistant but fares better with occasional irrigation along the coast and needs it in inland and desert gardens.


CONTAMINATION
DETERGENTS: Detergents used in home-carwashing practices lead to an excess amount of nutrients in water resources.
PESTICIDES: Pesticides account for over 400,000 tons of the runoff produced either through agricultural or municipal uses. Many pesticides are considered carcinogenic and are fatal to human health.
TOXIC CHEMICALS: Oil from automobiles is noxious when placed in the drinking water of humans.
AGRICULTURAL RUNOFF: Nitrogen and phosphorus in the chemical fertilizers leach into recharge zones, leading to eutrophication.
Pollution from schools, industries and homes are a major concern when regarding the safety of water entering an aquifer. Whether its chemicals, sewage, detergents, or oils, even the smallest quantity can adversely affect the safety of the water provided by an aquifer.


INDIVIDUAL BEHAVIOR
REDUCING WATER POLLUTION
WATER SAVING TECHNIQUES
Choose fertilizers with small amounts of Nitrogen and Phosphorus
Take proper care in the disposal of household chemicals
Get your car's oil changed regularly
Only use non toxic detergents to avoid harmful runoff from entering recharge zones
Use less pesticides and chemical fertilizers when gardening
IRRIGATION
Use water from sinks and showers (grey water)
HOME APPLIANCES
-Low flow toilets
-Front loading washers
-Shorter showers
-Repair leaks
XERISCAPING
Plant drought resistant plants
-Landscape with less grass and lawn
HOW YOUR CONTRIBUTION MATTERS
By conserving water and consciously limiting the amount of waste that could potentialy pollute water resources, YOU are making a change in the cleanliness and sustainiblity of your drinking water.


EPA WATER STANDARDS
The Environmental Protection Agency (EPA) uses the SDWA (Safe Drinking Water Act) to help determine the safety and cleanliness of the water coming from aquifers around the country. The Union Hill Water Association Aquifer is one that continues to honor and maintain the regulations through strict pollution limits and water-preserving techniques in order to protect those who use the water for any municipal task.
EPA
UHWA
SDWA Recommended Levels
UWHA Water Content
ARSENIC: Causes paralysis, blindness and cancer
0.10 ppm
0.004 ppm
LEAD AND COPPER: Causes stomach and brain distress
1.3 ppm
0.015 ppm
RADIONUCLIDES: Radioactive materials that can, overtime, cause kidney failure.
5 pCi/L of Radium
None Detected
Due to the care the UHWA has taken in constructing and maintaining their aquifer, and the water-wise actions of neighboring communities and organizations, inspections of this aquifer conclude that the water is not only safe by EPA standards, but contains significantly fewer harmful toxins.


WHY THIS ISSUE MATTERS
TRANSPORTATION
Transporting water long distances requires the burning of fossil fuels, which in turn releases greenhouse gasses.
TREATMENT
Treating water to remove particles and pollutants requires water treatment plants to use energy to pump and process the water.
THE BIGGER PICTURE:
A clean, local water source is more than just a convenience. It is a responsibility to maintain the purity and sustainiblity of the water, not only for its domestic uses, but as a way of reducing energy consumption and grenhouse gas emissions.
Preserving local water sources and protecting them against overpumping and depletion ensures that local water will be available in the future, eliminating the need to transport water from far away sources.
Consciously reducing the pollutants and contaminants put into water supplies will reduce the need for extensive water treatment procedures that require large amounts of energy and emit greenhouse gasses.
The proximity and dependence of our school and neighboring areas on the Union Hill Water Association Aquifer gives us a unique understanding of the importance of maintaining clean, sustainable groundwater.
With this understanding, we can increase our efforts to reduce water pollution and wastage, thereby reducing our greenhouse gas emissions and encouraging others to do the same.

Prosthesis of the Arts: Application of 3D Printing Technology in the Fabrication of Wrist Joints Designed for the use of String Instruments and Ankle Joints Suitable for Dance

Jennifer Yeh, Reksha Rathnam, Vineeta Parapudi

PURPOSE

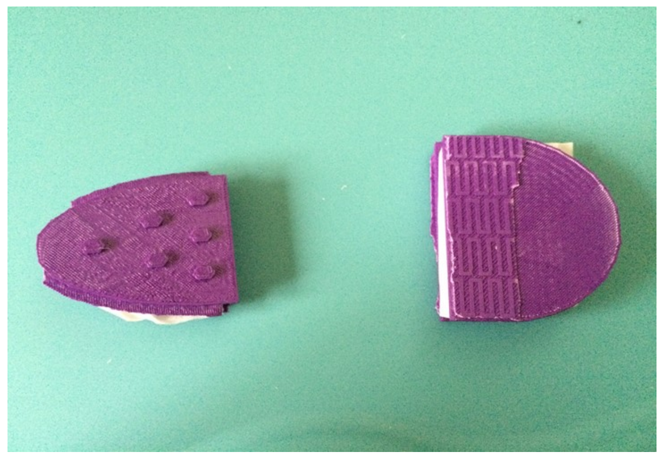
The loss of a limb not only imposes a physical impairment, but it also change the activities people may do for the rest of their lives. Ultimately, our research and 3D printed prosthetic strives to achieve the dexterity of the hands/ feet and the coordination of their rotational movements to provide amputees the ability to live out their passions for the arts.

ABSTRACT

With the hope of producing a prosthesis that does not impose limitations of its mobility, engineers have persistently experimented with different hand and foot prototypes. Many people who have lost a limb are also forced to give up their passion for the performing arts. While adhering to the Grand Challenge of Engineering, our project for the 2015 BioExpo uses 3D printing to create a prosthesis that will enable users to regain the agility without having to sacrifice dexterity. Through our research and collaboration with experts in the arts and engineering, our group learned that the key motion involved in playing an instrument lies in the flexibility of the wrist without losing stability. We also learned poses, spins, and jumps are key factors of dance and add stress and weight on the ankle joint. Through the process of design, our group created a wrist prototype that can achieve the necessary precision of the arts. Furthermore, our design includes prosthetic attachments for the foot that cushions the impact and relieves stress from the ankle joint.

FOOT PROSTHETIC ATTACHMENT FOR DANCE

- Cushioned heel and toes
- Heels have texturing to increase grip
- Front toe portion smooth for spins
- Tissue cushioning for shock absorption during jumps
- Designed to attach to existing prosthetic
- Allows more stability for poses and rigorous steps



WRIST PROSTHETIC ATTACHMENT FOR STRING INSTRUMENTS

- Rotational ability of the wrist
- Steady grip of the bow for control over bow weight/speed
- Bow articulation
- Designed for specific movements of violinists
- Usable for faster bow movement

BIOENGINEERING

Joint: Also known as an articular surface, is essentially the place where bones connect. This connection allows for movement, mechanical support, and can be classified both structurally and functionally.

Structural (tissues)

- Fibrous, cartilaginous, synovial joint
- Functional (movement)
- Synarthrosis—little or no mobility
- Amphiarthrosis—slight mobility
- Diarthrosis—freely movable

The wrist and ankle are classified as diarthrosis synovial joints and more specifically are classified as ellipsoidal synovial joints. Ellipsoidal joints allow for flexion, extension, abduction, adduction, and circumduction movements. Our design focuses on functional classification of the wrist and ankle joint involved in string instrument performance and dance.

Problems with current and available prosthesis involve:

- Limitation in wrist supination, pronation, flexion, and extension movements—no freedom to move which is necessary for dexterity in the arts
- Discomfort, lack of balance, lack of durability
- Inability to absorb the impact of the force involved in leaps, jumps
- Proposal
- Implement a controlled "universal joint" or ball-and-socket structure to provide more freedom for supination, pronation, flexion, and extension
- Prosthetic aids with tissue additions to mimic hyaline cartilage in the spinal cord to absorb shock during movement

TISSUE ENGINEERING LAB

In our bioengineering class, one of our labs involved engineering a synthetic tissue that closely imitated the elasticity of authentic mammalian tissue. Typically this would be used for medical education in Third World countries where resources are minimal. In our project, we utilized our synthetic muscle tissue to create an aid that absorbs shock and pressure to assist in dancing. Furthermore, it will cushion and control movement in the wrist when playing string instruments.

Recipe:

- 3 pulls of silicone caulk
- 5 teaspoons of grapeseed oil
- 1.5 teaspoons of cornstarch

INTERVIEW OF VIDYALAKSHMI VINOD

1.What do you think is the most important part about your feet?

The most important for Bharatnatyam is probably the sole.

2. Are you usually on your toes or flat on your feet?

There are some of both but mostly we dance *using the sole of our feet. When we use the balls of our feet we are usually just standing in one place.*

3.Where do you usually hold your weight?

Generally with our feet flat. So the arch is important so that feet don't hurt too much.

4.What is the most common motion in your kind of dance if you had to pick one?

Probably stomping flat on the bottom of your foot. Many steps in Indian classical dancing are based on the foot hitting the ground flat.

5.Would it be more helpful if you had grips on the bottoms of your feet or if it was smooth?

For classical I don't think there is too much of a preference. Sometimes we will spin so we need a smooth surface at the ball of the foot and sometimes we hold ourselves in a lunge and that would require more grip strength at the ball of the foot.

Project Sustain

Theodore Johannson, Adrian Pang, Caeli MacLennan, Eli George, Mathew von Allmen, Teri Guo, Adi Ramani, Amy Zhang

PROJECT SUMMARY

At this point in history, humans do, in fact, have the technological capability to stop climate change. If that is the case, then why does climate change still remain a constant problem? Those of us on the Project Sustain team believe this is because the public does not know the facts about climate change. Very few people actually understand what climate change is, what causes it, what problems are associated with it, and most of all, how it can be stopped. Our project aims to help educate these people.

Our project does not consist of only one single game but of two separate games. One is a computer video game targeted at the age group embodied by elementary students. In this game, players manage the finances, population, happiness, and energy production in their very own city, but at the same time they must keep track of the amount of pollution they are producing. If they produce too much pollution, they risk unhappy and unhealthy citizens. The player is presented with two mains ways to play the game: they can invest heavily in cheap, abundant fossil fuels, or they can save up for more expensive alternative sources. The first time playing the game, kids are prone to choosing the first option, as it is cheaper and easier. However, they later realize that investing heavily in fossil fuels is not an effective energy plan. When they play the game a second time, they understand some of the problems with fossil fuels, which helps them create a renewable energy plan.

The second game we have created is a card game aimed at an older age group with more analytical thinking. This game is slightly more complicated but for the most part focuses on the same pattern of play as the video game. One major difference is that the card game includes interaction between different players, with each player representing their own country. Not only can players trade with each other, they may also be stuck having to deal with the consequences of other players' actions. For example, if one player heavily invests in fossil fuels and produces a high amount of pollution, then the impacts affect any player in the game.

REVISED NGSS STANDARDS

The current NGSS standards mandate that the following topics relating to the environment must be understood by their corresponding age group by the end of the school year. In the current model, climate change education is not taught until middle school, leaving only a rudimentary understanding of humans' capability of impacting the environment in the lower grades. In our renovated version of the NGSS standards, we are able to take advantage of children's enhanced ability to retain information at an early age by teaching concepts in the earlier grades through the visuals of the computer game and then providing the vocabulary for what they already understand through

Theodore Johannson, Adrian Pang, Caeli MacLennan, Eli George, Mathew von Allmen, Teri Guo, Adi Ramani, Amy Zhang

traditional teaching methods. This allows for enhanced understanding and retainment of environmental topics that can be better applied to making environmentally conscious decisions throughout the rest of their lives.

NGSS Standards 2015				
Subject	**K-2**	**3-5**	**6-8**	**9-12**
ESS3.A Natural resources	- Living things need water, air, and resources from the land, and they live in places that have the things they need. - Humans use natural resources for everything they do.	- Energy and fuels humans use are derived from natural sources and their use affects the environment. - Some resources are renewable over time, others are not.	- Humans depend on Earth's land, ocean, atmosphere, and biosphere for different resources, many of which are limited or not renewable. - Resources are distributed unevenly around the planet as a result of past geologic processes.	- Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.
ESS3.B Natural hazards	- In a region, some kinds of severe weather are more likely than others. - Forecasts allow communities to prepare for severe weather.	- A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts.	- Mapping the history of natural hazards in a region and understanding related geological forces.	- Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales.
ESS3.C Human impacts on Earth systems	- Things people do can affect the environment but they can make choices to reduce their impacts.	- Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. - Societal activities can also help protect Earth's resources and environments.	- Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. - Activities and technologies can be engineered to reduce people's impacts on Earth.	- Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies.
ESS3.D Global climate change	N/A	N/A	- Human activities affect global warming. - Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.	- Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

CURRICULUM

Below are the curriculum guidelines for the four grade categories of NGSS. Each section contains a list of learning objectives, a description of the scenario the students are given, and a timeline of the progression of student learning. The K-2 and 6-8 documents also include a quiz and grading rubric to measure student learning after an hour of playing each game to accompany our testing sessions.

K-2:

Learning Objectives:

Climate Change

- Human activities affect global warming
- Carbon emissions are the source of global warming
- Climate change effects persist even after emissions have stopped

Natural Resources

- Some natural resources are renewable while others can be used up
- Humans use natural resources to build and create energy

Natural Hazards

- The frequency and intensity of natural hazards can be increased due to pollution
- Natural hazards can be predicted and prepared for
- Natural Hazards are measured on a scale based on the damage they do

Human Impacts on Earth Systems

- Humans affect the quality of the water and air
- The quality of the water and air affect human health and happiness
- Individuals as well as cities can make changes to improve and damage their environment

Climate Hardships

- Limiting factors per climate
- Climates include:

    Desert

    Tropical Rainforest

    Temperate Forest

    Tundra

    Grassland

Format:

Time: 4 weeks (45 min per day)

Goal: Maximize happiness

Students are allowed to explore city design given an empty, flat terrain with plentiful resources and a sizeable starting wealth. Over time, they discover the negative health effects of burning fossil fuels and the economic benefits of renewable energy. After allowing time for the students to become accustomed to the variables of city design, they are given another blank slate but this time with a different climate that offers obstacles specific to their environment. They must then learn to work with whatever resources are available to build a sustainable city.

Timeline:

Week 1:

- Game begins with plentiful resources and blank slate
- Students begin to have an understanding of energy sources and pollution due to human

Week 2:

- Begin to understand effects of decisions made in long term

- Understand lag-time response with decisions

Week 3

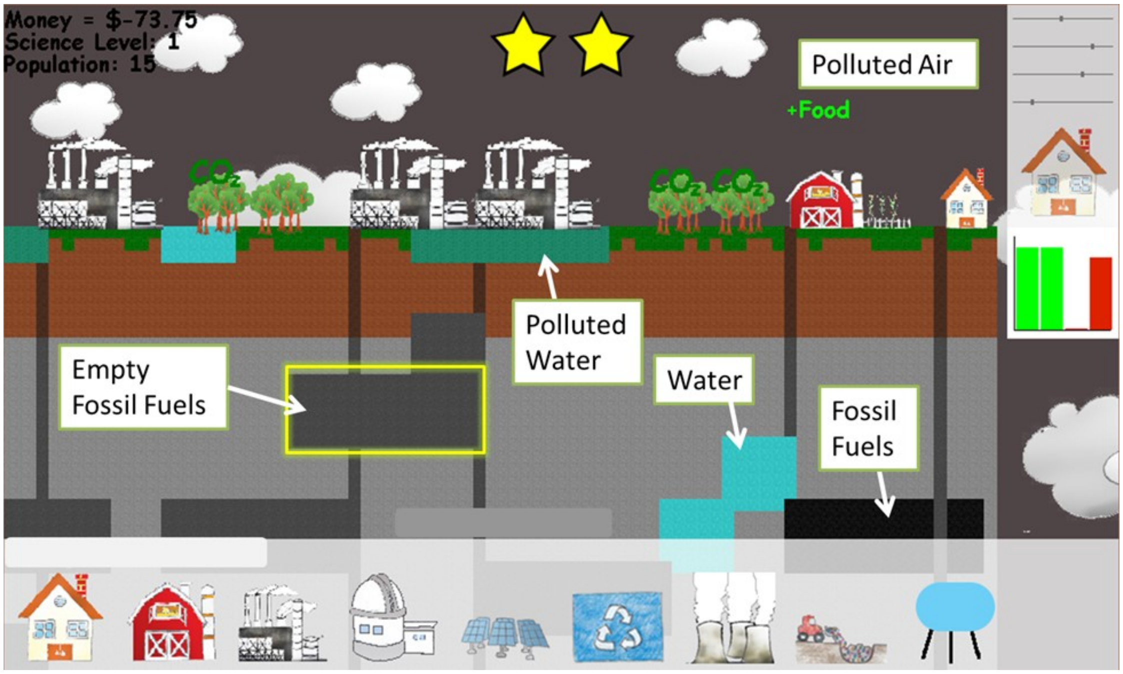
- Should wholly understand game, even with limiting factors/hardships
- Should be able to create functional city
- Should understand all above NGSS concepts

Week 4:

- Students are divided into 5 groups, one for each starting climate
- Each group is given a week to work around their hardships to create a functional city
- At the end of the week, students present their city and how they worked around their hardship to the rest of the class

Quiz to Measure Student Learning:

Students partaking in the testing sessions are given this quiz before playing the game. After playing the game for an hour, students retake the same quiz. The difference in scores is used to measure the effectiveness of the computer game in teaching students the above topics. Questions refer to the picture below.



Question	Answer Key
What is one thing that could have polluted the air? Where did it come from?	Specific polluting substance (i.e. Smoke) (1pt) Correct source of substance (i.e. Fossil fuel power plant) (1pt)
What is one thing that could have polluted the water? Where did it come from?	Specific polluting substance (i.e. oil) (1pt) Correct source of substance (i.e. oil drilling) (1pt)
What happened to the fossil fuels in the empty hole (the highlighted box)? How long will it take to re-fill, if ever?	They were used up (1pt) No, or in a very long time (1pt)
Where does CO_2 come from and what does it do?	Source (i.e. Cars) (1pt) Heats the planet (1pt)
Can the polluted air in the picture ever be cleaned? If so, how does the pollution go away?	Yes (1pt) Trees, or in a very long time through dissipation (1pt)
If you were a person living in this city, What could you change about how you live out your day that will make the city happier and more successful? Think about how you get to school, what you use electricity for, and other every day activities.	Changes (i.e. Use public transportation) (1pt each) Applicability of changes by a citizen (1pt per change) 5 pts total

3-5:

Curriculum Overview:

Climate Change/Environment

- Humans have made prolific effects on the climate
- Climate affects city life
- Climate/environment is severely debilitating civilian life

    Damaging consequences

    Costly

    Shortens lifespan and happiness of citizens

Infrastructure

- Infrastructure already in place

    Cities, houses, buildings designed

    Not allowed to work from a blank start

- Designated resources available

    Allotted what is available

Human Impacts

- City quality

    City qualification drops

- Induced weather events

    Negative effects

Format:

- Time: 4 weeks (45 min per day)

- Goal: Rectify past environmental Injustices

Students are given a preexisting city with infrastructure. The city, polluted by past decision, needs to be saved by the student who starts with nothing more than what they already have. In this setting, the clock ticks down and the player must heal the city and reverse the effects of pollution to safe levels before the game is over. This adds pressure and a sense of urgency to the pollution emergency. By the end of the level the player should have an understanding of methods that do and do not work when combating pollution.

Timeline:

Week 1:

- Game begins with plentiful resources and blank slate
- Students begin to have an understanding of energy sources and pollution due to humans

Week 2:

- Begin to understand effects of decisions made in long term
- Understand lag-time response with decision

Week 3:

- Should wholly understand game, even with limiting factors/hardships
- Should be able to create functional city
- Should understand all above NGSS concepts

Week 4:

- Students are divided into 5 groups, one for each starting climate
- Each group is given a week to work around their hardships to create a functional city
- At the end of the week, students present their city and how they worked around their hardship to the rest of the class

6-8:

Learning objectives:

- Resources are distributed unevenly around the planet as a result of past geologic processes

- Some natural resources are more limited and rarer than others.
- Mapping the history of natural hazards in a region and understanding related geological forces.
- Some natural disasters affect the entire world while others are specialized to a region.
- Human decisions have global impacts.
- Countries need to cooperate in order to succeed.
- Mandates such as cap-and-trade can be used to achieve cooperation
- Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
- Effects of greenhouse gas emissions are global and do not always affect the countries that produce them.
- Some effects due to climate change are irreversible.
- While beneficial in the short run, climate change effects ultimately prevent economic progression.

Format: *See TDD for details

- Time: 1 week (1 hour each day)

- Goal: End the game with the highest energy capacity

- Class: General Sciences

Students start with small groups that grow with each day. As the groups become larger, the game gets progressively harder as players have to be extra vigilant to keep global pollution levels below apocalyptic levels.

Timeline:

Day 1: Groups of 4

Day 2: Groups of 6

Day 3: Groups of 8

Day 4: Groups of 10

Day 5: Groups of 12

Grades 6-8 Grading Rubric	
Question	Answer Key
What kind of power plant provides the highest amount of energy capacity? 1. Fossil Fuel 2. Solar 3. Wind 4. Nuclear	Nuclear (1pt)
Which is the most expensive kind of power plant? Nuclear Wind Hydro Geothermal	Nuclear (1pt)
Which power plant produces the most pollution? Nuclear Solar Fossil Fuel Geothermal	Fossil Fuel (1pt)
Is it economically better to invest in renewable power plants or in non-renewable power plants? For the short-term or the long-term? Relate to the real world and explain the best you can.	Yes (1pt) Long-term (1pt) Reasoning (1pts)
What are two consequences of global pollution? How do they affect people? Explain	2 pts - consequences 2 pts - explanations *-1 point for each wrong explanation
Which power plant has little to no impact on the environment? Relate to the real world and explain the best you can.	Renewable power plant (specifically named) (1pt) Justification (2pts)
Why do you think geothermal is such a rare yet great card, realistically? Relate to the real world and explain the best you can.	Hotspots/hard to find (1pt) Reasoning (2pts)

9-12:

Learning Objectives:

- Decisions made by one country prevent the progression of other countries, which prevents them from transitioning to renewable resources.
- It is easier to start with renewables than to later transition to them.
- Reversing the effects of climate change is difficult without global cooperation across countries.
- Global cooperation is difficult to achieve and requires negotiation. Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales
- Natural disaster relief funds and organizations work in part to relieve and recover from certain natural hazards.
- Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.
- Resources can be traded on a global scale.

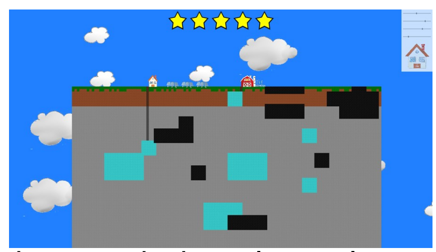
Format: *See TDD for details

- Time: 2 weeks (1 hour per day)
- Goal:
- Class: History

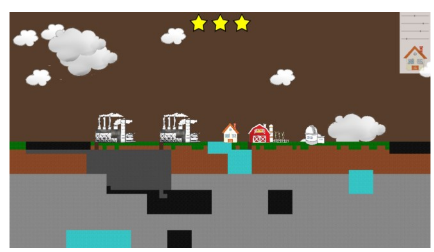
Timeline:

- Week 1: By the end of this week, students should have gone through enough hardships with their individual country to understand the difficulties of global climate regulations. Players should be able to fully comprehend the function and effect of each card.
- Week 2: The class should be able to finish the game without reaching apocalyptic levels of pollution.

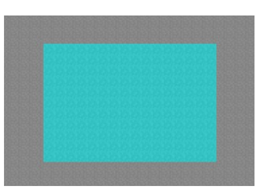
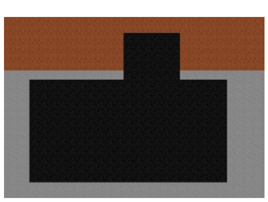
Video Game Tiles

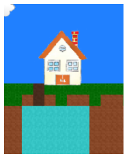
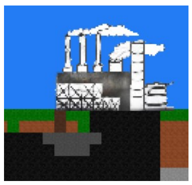
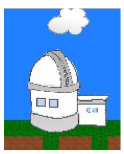
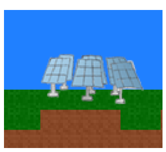
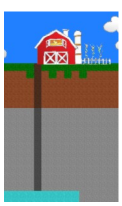


A Five Star City in Early Development



A Polluted City

Block Type:	Image	Description
Water		Place Houses and farms over water blocks so that people can be healthy and farms can produce more food. Try not to put power plants over water because the power plants pollute the water and make it un-
Fossil Fuels		Make sure that you place power plants over fossil fuels so that the power plants can produce electricity.

Building	Image	Description
House		Houses are important because they allow you to keep more people in your city without your citizens becoming unhappy. They use electricity, fossil fuels, and food based on how many people are in the house. Make sure to place the house over water.
Power Plant		Make sure to place the power plant over fossil fuels so that it can dig them up and burn them for electricity. But make sure not to put many down; if you do, they put too much pollution into the air and make people unhealthy. Also, don't put them over water. If you do, the water get polluted and houses and farms won't be able to use it.
Laboratory		Laboratories consume electricity and money, but are the only building that can increase your science level. Your science level is important because the higher your science level is, the more electricity power plants and solar panels can make and the more food farms can make.
Solar Panels		They can produce electricity without polluting the air and water. They also give you money for the energy that they make. Make sure to put down a laboratory when you use solar panels so that your science level can increase and they can become more effective.
Farm		Farms won't use electricity or fossil fuels, and produce food. They make even more food if you place them over water. Make sure that when you put houses down, you put a few farms down too, to make sure that enough food is being produced to feed your population.

<u>Middle School Card Game</u>

GAME CONCEPT

Main Concept: This game is a card game that has the purpose of teaching the players economics of managing certain power plants based on real life events, including cap and trade as well as a pollution factor.

Summary: The players in this game have a goal of obtaining the most energy capacity with the money they have and the power plant cards they obtain. By making purchases strategically, they can either obtain the most energy capacity by means of renewables or non-renewables. Renewables grant positive stipends while non-renewables present problems to come, as based on modern research. By obtaining the most money through economic strategy and with the luck of the draw, players may find themselves winning the game through a means related to renewable power plants.

Core Mechanics: The card game has natural disaster cards which are drawn based on a pollution factor, power plant cards which players either pay to build or hold in their hand, fake money to manage for income purposes, and a 20 sided die for randomizations of events.

Key Features: This game is extremely appealing to all audiences and has been simplified to require less mathematical but more economic management skills. The artwork subtly implies that renewables are much better to put in play in the early phases of the game (without cap and trade) and the natural disasters and fossil fuel plants stress the de-saturated, chaotic feel to discourage players from trying to invest in them. It subtly sends signals to the player of which kinds of power plants are bad. The real life events that this game is based on includes the installment of cap and trade, natural disasters being natural (but more frequent due to pollution), power plant management, actual numbers (GigaWatts per Year and actual costs simplified for game purposes), actual categorizations of natural disasters as well as real natural disasters that seem applicable, and actual scenarios including costs to phase out fossil fuel plants in place or nuclear plants in place versus starting with renewables.

Target Audience: This game is aimed toward all ages but more specifically for a middle-school and older generation to educate them about the economic standpoint of managing power plants and teach the difference between investing in renewables early on versus replacing old fossil fuel plants with new renewables.

ESRB Rating: This game is rated E10+ for Everyone 10 and Older because it is not meant for educating Early Children but has no violence or living entities involved in the game besides what is implied for simulation purposes. The implications require an age of 10 and above to ensure understanding between a card game simulation's implications versus real life correlations.

GAME DESIGN

Purpose: To educate teenagers and adults about the state of our climate, what affects it, and what they can do to reduce their impact on it.

Win Conditions: A single player (or in the event of perfect ties, those specific players) wins when the end of all rounds are met and the player has the highest energy capacity added up from his/her power plants in play.

There are two honorable bonus achievements for the player(s) with the lowest pollution contribution (also added up from their power plants in play) and the player(s) that have the highest solid currency at the end of the game (not including the values of their power plants). First place is awarded for the largest city (and might achieve the highest energy capacity with fossil fuel plants, as it is possible but highly unlikely due to natural disasters) and the first honorable mention is awarded for the best renewable system. The second honorable mention is awarded for the best investor/banker in terms of solid currency.

Lose Conditions: Pollution is a global variable (meaning it affects and is affected by all players) that is altered by certain power plants in play, mainly fossil fuel plants. All players lose when the pollution levels exceed 50, causing severe climate change (and ultimately weather) patterns that disrupt the flow of electrons that we use to transport electricity. Therefore, since no electricity can be transported, all players lose.

There is a dishonorable achievement for the player who contributed the most pollution in this event (and whether that player really wants to consider that a positive achievement, they can deal with all the other dejected and angry players). This shows that pollution is bad and unwanted and can cause issues with the way of life that we are trying to maintain today.

Mindset: Players essentially do not want to utilize fossil fuels in this game as it causes pollution levels to increase and the probability of natural disasters destroying their power plants to increase as well; however, they do provide a slightly higher energy capacity than that of renewables and are also cheaper for short-term reasons. Ultimately, they have a long-term cost for the fossil fuel imports, meaning players seriously do not want to utilize fossil fuels in this game. Nuclear is expensive short-term and also requires a payment each round for long-term maintenance. Solar and geothermal as well as wind and hydro may be costly short-term but actually give a small long-term cash benefit at the end of each round while in play. Winners essentially utilize renewables as much as possible and balance the profits from these renewables to pay for nuclear in order to spike up their energy capacity. However, nuclear may not be the best idea due to its vast amount of cost and the fact that during a natural disaster, if destroyed, a limit is placed on the amount of power plants a player can have in play at a time due to nuclear waste and fallout. Renewables depreciate in price, unlike fossil fuels for which import prices steadily increase as rounds progress (not initial purchasing of the plants themselves, however. Those remain stagnant). Nuclear power plants are the one exception; their price remains steady throughout the game. Within this simulation, players manage energy as electricity companies, whether for a city they want to solely benefit or essentially for business reasons only. The hand players draw from the power plant deck determines the suitable conditions they receive for each power plant drawn; if a player draws a geothermal plant, they have a hotspot on their land and can purchase this power plant while other players may not necessarily have one. For nuclear and hydro, rivers are required, and for solar, substantial amounts of sunlight (such as deserts) are greatly optimized for solar while wind requires windy areas whether high in altitude or breezy from oceans. These land constraints are not actually represented in the game but instead through the simulation of the game for conceptual reasons.

CORE MECHANICS

Materials of Gameplay: There are two different decks of cards and one 20-sided die. One deck of cards consists of power plants, whether fossil fuels, renewables, or nuclear, and the other deck consists of natural disasters which includes hurricanes, tornadoes, tsunamis, earthquakes, volcanic eruptions, and even lack of sun or heat waves. Each natural disaster targets either a specific kind of power plant or, based on a die roll, removes power plants of certain players at random.

<u>Gameplay</u>

Starting Up: There are no more than 12 players for this game. Otherwise, the game logic and calculations break, and since there are 5 cards per hand and there are 60 cards, 12 is the maximum number of players possible.

Players draw a set hand of five cards of power plants during each turn. They draw a card before the start of their turn each round. Rounds end when all players have made their turn. The order of turns in a round is based on die rolls, and players should move accordingly to be oriented in either a clockwise or counter-clockwise chronological order based on the die rolls. The highest number rolled goes first, the lowest number goes last, and the middle players play in numerical order. If ties are met in a die roll, players only re-roll to determine the placement of the two tied players (for example, if someone rolled an 18 and is going first and two other players tied on a 15 and on the re-roll one of the tied players rolls a 20, that player is still placed second after the person who rolled the 18 and is going first.)

Each player also receives an initial currency of $5, and all money is in units of thousands for simulation purposes (therefore, each player starts with a figurative amount of $5,000 but is represented by $5 for simplicity).

During Rounds: Players can put their power plants into play instead of holding them in their hand by purchasing them with the currency in the game. This currency is earned through carbon credits at the end of each round and can be altered based on which power plants are in play. At the end of each round, players with negative carbon credits have to either pay a set price or bargain with other players for their credits, and players with positive carbon credits can either gain a set price or barter off their credits via auction with other players. These trades are not one-to-one as anyone can jump in, but the seller ultimately decides where the credits go. (Carbon credits do not come into play until half of the rounds have been completed).

Then a die is rolled initially by the first player to determine natural disasters, and as each next round comes to their ends, the next player in order rolls the die to determine natural disasters. This next player also goes first in the round afterward (so once a player goes first in a round, he/she rolls the natural disaster die and then is the last player of the upcoming round.)

The game is over when all players have made their natural disaster rolls (meaning the number of rounds is equal to the number of players in the game) and one last round after the last player made the natural disaster roll is complete (meaning there is one final round after the last natural disaster roll).

Ultimately, players can discard their entire hand, giving up their turn entirely, and drawing an entire new hand; however you cannot discard your hand if you purchase a power plant (by putting it into play) during that turn.

User Interface: A fancy way of saying the perspective of the player, from the point of view of a player, he/she is in competition with other players to try and buy as many power plants as possible to raise their energy capacity.

They come to dread fossil fuel plants due to the natural disaster chances being high, dread nuclear plants when other players put them in play due to the large energy capacity it gives, and aim for renewables as much as possible.

Geothermal, being rarer than other cards, are the most sought-out cards. The next card in terms of rarity, though substantially more frequent, is nuclear. After that, wind and hydro are next in terms of frequency, followed by solar and finally fossil fuels, the most readily available card.

The restriction of not being able to discard your hand unless you make no play that turn discourages players from discarding their hand as to not fall behind other players in terms of purchasing energy capacity.

As mentioned previously, players seek to win the game but if they want to shoot for an honorable mention (or dishonorable, if really desired), they can change their strategy to do so easily. Renewables are a source of stable income if purchased early, but prices depreciate as the rounds progress only for renewables, making them cheaper later in the game. If a player can find a balance between these two mediums, they can achieve both honorable mentions.

LEVEL DESIGN

Game Flow: Within a round, players can either purchase power plants or discard their entire hand and redraw while losing their turn (meaning they cannot have purchased power plants at all to discard their hand). They can also barter off their power plants for money if any other player is willing to purchase their power plant, and the energy capacity as well as carbon tax modifier is moved to the player who purchased the power plant.

Once every player has made their turn, the end-of-round carbon taxing/carbon credit auction occurs (only in play once half the rounds have progressed) and then the roll for natural disasters occurs. After those two events, the next round starts.

Progression: As rounds progress, factors change. Prices of renewables decrease exponentially while income remains stagnant, and import prices of fossil fuels steadily increase while initial purchasing remains stagnant as well.

Nuclear purchasing and maintenance remain stagnant throughout the game. The currency granted to players at the end of each round increases by a small but steady factor, and renewables are the power plants that grant subsidies to players while fossil fuels take away from these end-of-round currency gains through carbon taxes.

As stated before, if a player cannot pay off his/her carbon tax and is in debt, he/she ultimately loses and must drop out of the game. The power plants in play for that particular player are auctioned off to other players or discarded, but regardless the pollution contributed always remains. Players must take note of this elsewhere to keep track of the global pollution.

DEVELOPMENT

Cards: There are two card decks: a power plant deck that players draw from to place in their hand, and a natural disaster deck that players draw short-term and place back to the bottom of the natural-disaster deck. There is also a discard pile for power plants and if all power plant cards in the draw deck have been exhausted, the discard pile is shuffled and reused as the new power plant draw deck. (Pollution still remains even after certain power plants are destroyed via natural disasters and therefore discarded).

The natural disaster deck is only shuffled at the beginning of each entire game and is never shuffled during the game (there is only one kind of each natural disaster within the deck and theoretically there should be no repeats of the same natural disaster unless all different kinds of natural disasters have actually been put in play (the chances of this are low due to a pollution factor restriction resulting in a unanimous loss, but it is entirely possible, although highly unlikely, to have a large quantity of players and extremely bad luck of drawing a natural disaster card every round.)

Variables: Each player keeps track of his/her own money and energy capacity through simulated money and by adding up the energy capacity numbers of the power plants in play. Pollution is a global variable kept track of by adding up all the pollution factors of all fossil fuels in play of all players combined. The modifier list provided alongside the natural disaster card deck tells players when to draw a natural disaster card based on the die roll and the pollution factor; the higher the pollution, the more numbers are added that result in the drawing of a natural disaster card.

The carbon credits are also factored in based on the pollution number on each power plant card, and as mentioned before, these determine whether players gain money or lose money at the end of each round. The carbon credits do not come into play until half the rounds have been completed (since there are a number of rounds equal to the number of players participating in the game, if there are an odd number of players then divide by two and truncate, or round down.)

GRAPHICS

Natural Disasters: Natural disaster cards try to look as accurate as possible, if not portrayed as chaotic. There is no need to give it a horrific theme besides making it look chaotic and realistic, as everyone has seen/heard of natural disasters and the damage and destruction they bring. Since every natural disaster is essentially negative in the game, we do not have to give contrasting themes of “good” vs. “bad” but instead just leave it as realistic and relatively chaotic to instill some sense of dread but not scare our players in any way if they are a younger audience.

Power Plants: Each fossil fuel plant looks grey, drab, desaturated, spotted, and wholly polluted. There are blotches of gross muck of color that are desaturated for fossil fuel plants, and nuclear is similar but much lighter and less mucky. Renewables are bright, lively, new, shiny, colorful, vibrant, and essentially make players feel better looking at. These themes subtly tell players to not use fossil fuels but use renewables.

Timeline/Schedule:

February 27, 2015: Game design formulated, algorithms formulated, production starts.

March 1, 2015: Game design document completed.

March 14, 2015: Art Assets for all cards completed and implemented.

March 18, 2015: Draft card game created digitally and physically.

March 21, 2015: Draft card game play-tested fully.

March 22, 2015: Card game algorithms simplified and changed.

March 24, 2015: Technical design document completed. Game concept document completed. Individual cards completed and ready for publishing.

March 25, 2015: Tesla STEM Mock presentation to competition advisor.

<u>**TECHNICAL DESIGN DOCUMENT**</u>

<u>Variables:</u>

Global Variables: There is really only one global variable, and that is the pollution factor. Everyone’s individual pollution in play adds up to the global value which affects the natural disaster frequency (and therefore intensity).

Individual Variables: Each individual player has two variables, not including their individual pollution factor. These two variables are their money and energy capacity. Whatever physical money they own they can exchange for purchases, and whatever power plants in play adds up to their total energy capacity. The winner at the end of the game has the highest energy capacity at that moment; the optional achievements are most money accumulated at the end of the game (physically), most renewables in play, and most individual pollution (as a dishonorable achievement). Theoretically, their carbon credit amount is more like a rate of earnings for their physical money, but if need be players can keep track of that as well.

Initialization:

Starting the Game: To start the game, five power plant cards are dealt to each player (assuming the deck is well shuffled). Each player also receives five thousand dollars. Then, each player rolls the die to determine the order of the game. The higher the roll, the farther up in chronology (a 20 ensures that player goes first). If a tie roll is rolled, the subsequent rolls between those two players only determine where in placement one goes in front of the other, excluding all the other determined positions (for example, if two players rolled a 17 but another already rolled an 18, the two players that tied reroll to determine which goes second; if one of the tied players rerolls a 20, the person who already rolled 18 still goes first but the 20 in the reroll ensures that the rerolling player goes first between the tied players).

Once the die roll order is formulated, players should change their seating orientation to sit in the order in which they play. The order matters, but it ends up being fairer than players initially think. Firstly, a turn is made when a player declares he completed his turn after purchasing his power plants or doing other actions; a round is made when all players have made a turn. However, the order in which the turns go change every round by rotation; the person who rolled highest goes first in the first round, but the person who is determined to go second goes first in the second round, and as follows for all participating players in the game. This ensures that every player gets a chance to go first in a round, and when the last player finally goes first in a round, that is the final round of the entire game.

GAMEPLAY

Game Loop:

Turns: In a turn, a player can make purchases for the power plants he holds in his hand. Other options include paying two thousand dollars for clearing and discarding a power plant built in play, discarding his entire hand (without being able to make any purchases that turn), bartering with other players to trade their power plants in play, blindly swapping one card each from two players within their hand, or choose to remain passive in his turn.

Rounds: Once all players have made their turn, the player which has gone first in their round rolls the die to determine natural disasters. Based on the chart given, the pollution factor added up with all cards in play determines whether or not to draw a natural disaster card. For natural disaster mechanics, see the section in Scenarios for how natural disasters work.

Halfway through the game (meaning once half the players have gone first in a round; if there is an odd number round up), carbon credit numbers come into play. Cap and trade is therefore allowed; if players are negative, they can barter with other players to temporarily work their way out of their debt. If players are positive, they receive a stipend from the bank based on the new government policy that has been instated. If a player is unable to pay off his debt, he loses the game. See the section in Scenarios for how to work with the situation when a player loses the game.

<u>Scenarios:</u>

Winning: Theoretically, if a player invests only in renewables early in the game and no natural disasters hit them, they can save up enough money from carbon credits to essentially buy more power plants as long as they receive good cards in hand (meaning no fossil fuel plants). Alternatively, players can win by playing fossil fuel plants and receiving enough lucky natural disaster rolls to destroy the other players' power plants and not their own, although that is actually a serious gamble.

Losing: If a player is in debt, he must drop out of the game. His power plants are then put in auction for other players to try and claim; if no players feel like claiming the power plants, they are discarded. However, if there is pollution in the cards about to be discarded, they still remain and must be taken note of elsewhere by players.

Natural Disasters: Each time a natural disaster roll is met, players must brace for destructive action. The player who rolled the die then shuffles the natural disaster deck and blindly draw a natural disaster card. Then, the player rolls again to determine the category of intensity of said disaster drawn. The category determines how many power plants are lost to the disaster. Then, the die is rolled the same number of times as the category determined earlier. These subsequent die rolls determine which players lose their power plants (as determined by a chart given to players). Then, once all players are selected, the fate roller must check which power plants are affected by the disaster and count each of those per player who is affected, and then once again roll the die to determine which power plant is destroyed (or in some cases, benefits and return double the energy capacity). Then the round is officially over once all destruction is complete, and reconstruction shortly commences. (For simulation purposes, reconstruction costs nearly as much as construction, and builders find it hard or impossible to build on a destructed site. The game is as follows for simplified reasons.)

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CARDS, CHARTS, AND TABLES

Power Plant	Initial Cost (in thousands of $)	Pollution	Carbon Credit Worth (in thousands of $; if -, tax; if +, stipend)	Energy Capacity (in GigaWatts per year)	Frequency (# of cards in deck)
Fossil Fuel	$2.00	3	-$3	3	20
Nuclear	$8.00	1	$0	4	12
Hydro	$5.00	0	$2	2	8
Wind	$3.00	0	$2	1	8
Geothermal	$4.00	0	$4	3	4
Solar	$5.00	0	$3	1	8
Total Cards					60

# of Players	Ranges for rolling
2	Odds and Evens OR 1-10 and 11-20
3	1-6, 7-12, 13-18
4	1-5, 6-10, 11-15, 16-20
5	1-4, 5-8, 9-12, 13-16, 17-20
6	1-3, 4-6, 7-9, 10-12, 13-15, 16-18
7	1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14
8	1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16
9	1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16, 17-18
10	1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16, 17-18, 19-20
11	Each player picks a number
12	Each player picks a number

Round #	Fossil Fuel	Nuclear	Hydro	Wind	Geothermal	Solar
1	$2.00	$8.00	$5.00	$3.00	$4.00	$5.00
2	$2.10	$8.00	$5.00	$2.90	$4.00	$4.70
3	$2.20	$8.00	$5.00	$2.80	$3.90	$4.40
4	$2.40	$8.00	$5.00	$2.70	$3.90	$4.00
5	$2.60	$8.00	$5.00	$2.60	$3.80	$3.60
6	$2.90	$8.00	$5.00	$2.50	$3.80	$3.30
7	$3.20	$8.00	$5.00	$2.40	$3.70	$3.00
8	$3.60	$8.00	$5.00	$2.30	$3.70	$2.80
9	$4.00	$8.00	$5.00	$2.20	$3.60	$2.60
10	$4.50	$8.00	$5.00	$2.10	$3.60	$2.40
11	$5.00	$8.00	$5.00	$2.00	$3.50	$2.30
12	$6.00	$8.00	$5.00	$1.90	$3.50	$2.20

Pollution Modifier (Total #)	Natural Disaster Dice Rolls (D20)	Non-Natural-Disaster Dice Rolls (D20)
0	20	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
1	1,20	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
2	1,20	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
3	1,10,20	2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19

4	1,10,20	2,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18,19
5	1,10,15,20	2,3,4,5,6,7,8,9,11,12,13,14,16,17,18,19
6	1,10,15,20	2,3,4,5,6,7,8,9,11,12,13,14,16,17,18,19
7	1,5,10,15,20	2,3,4,6,7,8,9,11,12,13,14,16,17,18,19
8	1,5,10,15,20	2,3,4,6,7,8,9,11,12,13,14,16,17,18,19
9	1,5,7,10,15,20	2,3,4,6,8,9,11,12,13,14,16,17,18,19
10	1,5,7,10,15,20	2,3,4,6,8,9,11,12,13,14,16,17,18,19
11	1,5,7,10,12,15,20	2,3,4,6,8,9,11,13,14,16,17,18,19
12	1,5,7,10,12,15,20	2,3,4,6,8,9,11,13,14,16,17,18,19
13	1,3,5,7,10,12,15,20	2,4,6,8,9,11,13,14,16,17,18,19
14	1,3,5,7,10,12,15,20	2,4,6,8,9,11,13,14,16,17,18,19
15	1,3,5,7,10,12,15,17,20	2,4,6,8,9,11,13,14,16,18,19
16	1,3,5,7,10,12,15,17,20	2,4,6,8,9,11,13,14,16,18,19
17	1,3,5,7,8,10,12,15,17,20	2,4,6,9,11,13,14,16,18,19
18	1,3,5,7,8,10,12,15,17,20	2,4,6,9,11,13,14,16,18,19
19	1,3,5,7,8,10,12,13,15,17,20	2,4,6,9,11,14,16,18,19
20	1,3,5,7,8,10,12,13,15,17,20	2,4,6,9,11,14,16,18,19
21	1,3,5,7,8,10,12,13,15,17,18,20	2,4,6,9,11,14,16,19
22	1,3,5,7,8,10,12,13,15,17,18,20	2,4,6,9,11,14,16,19
23	1,3,4,5,7,8,10,12,13,15,17,18,20	2,6,9,11,14,16,19
24	1,3,4,5,7,8,10,12,13,15,17,18,20	2,6,9,11,14,16,19
25	1,3,4,5,7,8,10,12,13,14,15,17,18,20	2,6,9,11,16,19
26	1,3,4,5,7,8,10,12,13,14,15,17,18,20	2,6,9,11,16,19
27	1,3,4,5,7,8,10,12,13,14,15,17,18,20	2,6,9,11,16,19
28	1,3,4,5,7,8,9,10,12,13,14,15,17,18,20	2,6,11,16,19
29	1,3,4,5,7,8,9,10,12,13,14,15,17,18,20	2,6,11,16,19
30	1,3,4,5,7,8,9,10,12,13,14,15,17,18,20	2,6,11,16,19
31	1,3,4,5,7,8,9,10,11,12,13,14,15,17,18,20	2,6,16,19
32	1,3,4,5,7,8,9,10,11,12,13,14,15,17,18,20	2,6,16,19
33	1,3,4,5,7,8,9,10,11,12,13,14,15,17,18,20	2,6,16,19
34	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,20	2,6,19
35	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,20	2,6,19
36	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,20	2,6,19
37	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,20	2,6,19
38	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	2,6
39	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	2,6
40	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	2,6
41	1,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	2,6
42	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	6
43	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	6
44	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	6
45	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	6
46	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	N/A
47	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	N/A
48	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	N/A
49	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	N/A
50	GAME OVER FOR ALL	GAME OVER FOR ALL

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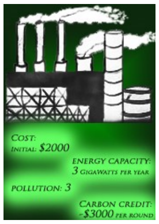
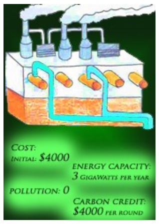
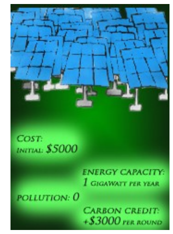
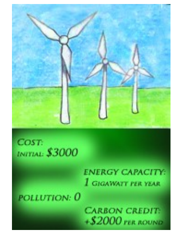
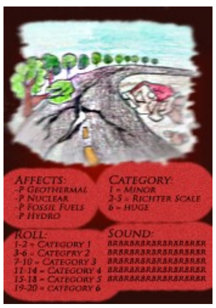
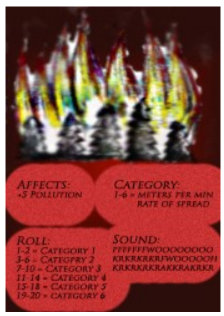
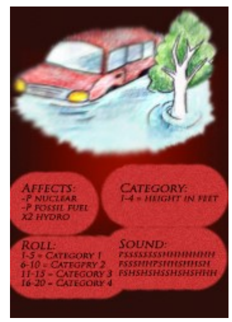
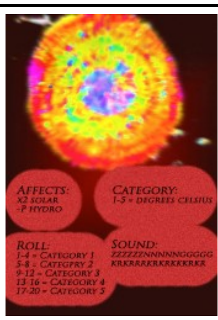
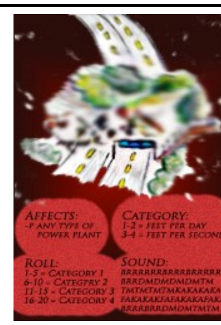
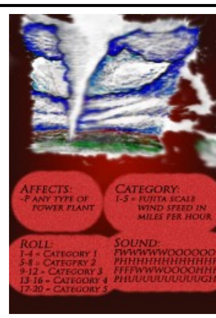
Cards:

Power Plants					
Fossil Fuel	Geothermal	Hydro	Nuclear	Solar	Wind
					

Natural Disasters		
Earthquake	Wildfire	Flood
		
Heat Wave	Huricane	Landslide
		
Blizzard	Tornado	Tsunami
		

MODEL UN HIGH SCHOOL CARD GAME

Game Concept Document

Concept: To use real life events in a simulation game which helps kids learn about climate change indirectly while learning about history, therefore overcoming the barrier in which some states like Florida have banned the use and the teaching of climate change.

Design: As it is a simulation of real world events, the best way to start is to include the important countries in the United Nations in terms of climate change, as well as the big countries around the world. These countries are; China, India, the United States, Great Britain, Australia, Germany, Bangladesh, Brazil, France, Japan, Mexico, New Zealand, Russia, Switzerland, and more countries if needed. Each country is given a starting cap number and a total amount of money which they can spend, all depending on the current situation of the country. Also, depending on the country, their carbon cap space is full, overflowing or slightly empty. Each country is also given its own needs, depending on the current situation. These needs range from needing more jobs available to needing more power. In addition to all of this, each country is given a number of coal, nuclear and natural gas power plants to start with. (Ex: America is given a carbon cap space of 20 and a starting amount of 2 billion and their cap space is currently overflowing with 25 and they need to have more jobs available and they have 10 coal, 10 nuclear, and 15 natural gas power plants).

Gameplay: Over the course of the game, the players are having discussions with other players (countries) to make agreements that both benefit their economy and reduce their cap space as low as they can while still meeting their needs. The players are able to buy carbon space from other countries for any price that is asked for and they are also able to come in agreements with other countries to reduce their pollution levels for benefits (For example, the US agrees with Germany to start turning their coal power plants into solar power plants provided Germany pays for the solar power plants). In addition to making agreements with other countries, players can buy renewable power plants for arranged prices.

This game lasts 10 rounds (each round acts as a year and each round lasts for 20 minutes), with each round the cap space going down, and the pollution levels going up.

Goal: The goal of this game is to create the most budget, meet the most needs and be the most environmentally friendly every year. The country that does that wins an extra 10 million dollars for their country every year. At the end of 10 years, the country with the most needs met, the most money and the best cap to actual space used ratio wins. The way this is calculated is by having the money (in billions of dollars) multiplied by a factor of $.3^{(1/x)}$ (in which x is the highest amount of money for a country divided by the amount of money for the specific country) , the needs met (in a ratio of how many there are total divided by how many are met) multiplied by a factor of $.3^{(1/x)}$ where x is the number of needs that they have, and how environmentally friendly a country is (total cap space divided by amount of cap space in use) multiplied by a factor of $.4^{(1/x)}$ (where x is the difference between the current cap space and the original cap space) and then those three things are added together. The country with the highest number at the end of this is the winner.

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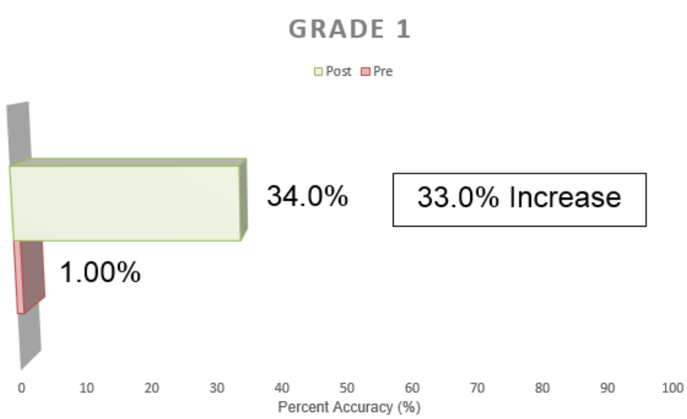
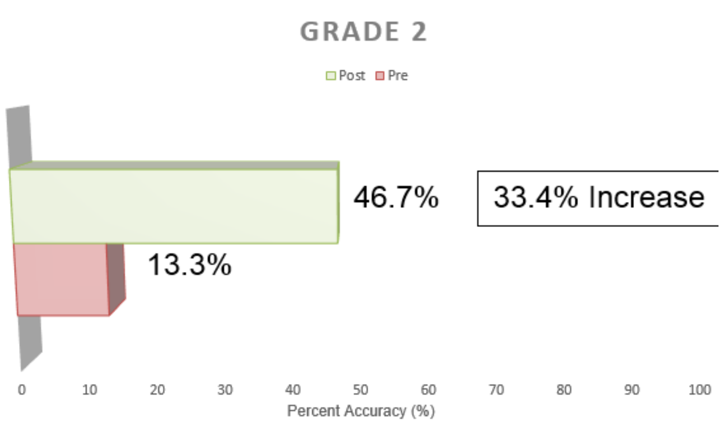
Costs: (Not Final)

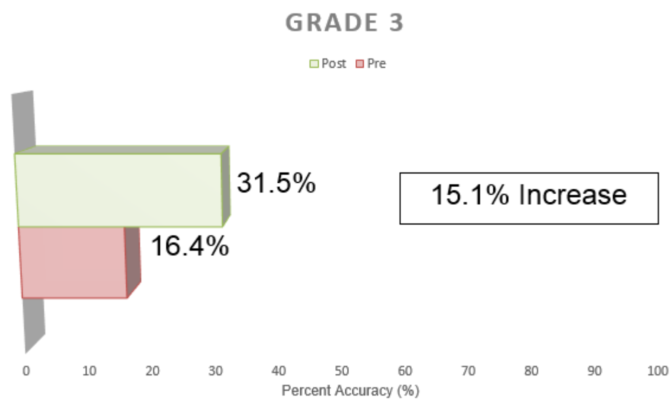
- 1 Coal Power Plant: 10 million dollars, .75 cap space + .35^(x years)
- 1 Nuclear Power Plant: 20 million dollars, .25 cap space + .5^(x years)
- 1 Natural Gas Power Plant: 10 million dollars, .5 cap space + .25^(x years)
- 1 Solar Panel Plant: 25 million dollars, 0 cap space
- 1 Hydro Plant: 25 million dollars, 0 cap space
- 1 Geothermal Plant: 50 million dollars, 0 cap space

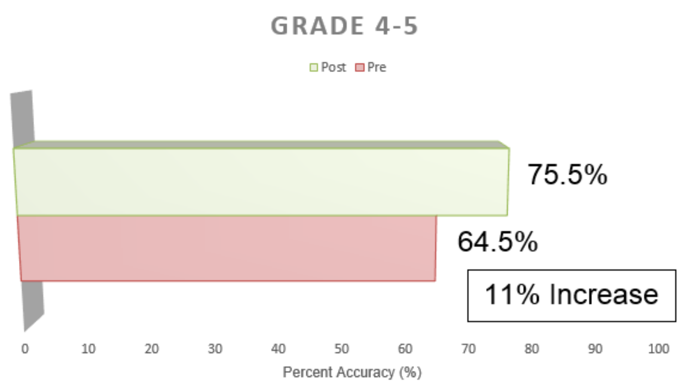
<u>RESULTS:</u>

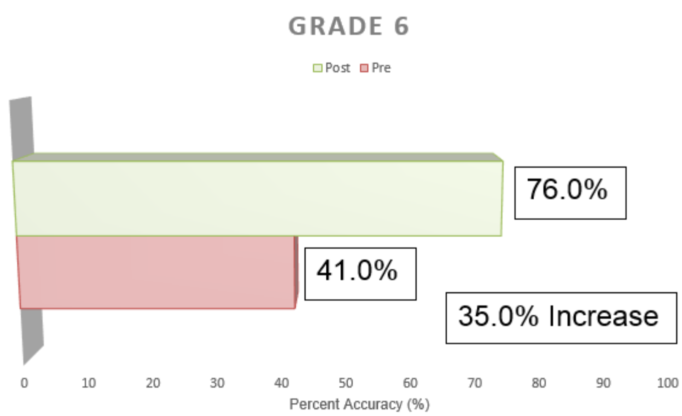
<u>By Grade:</u>

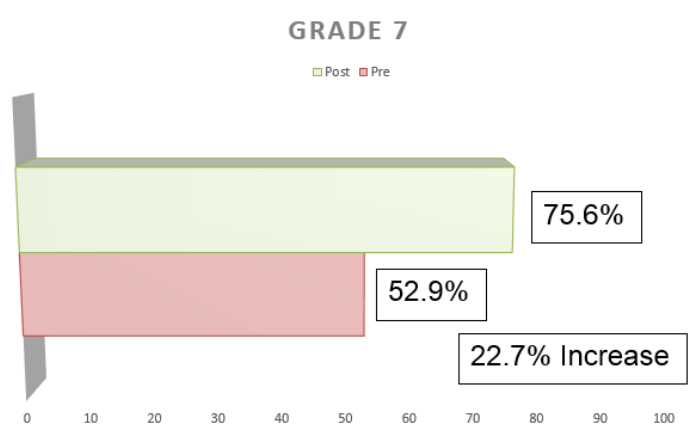












By NGSS Subject:

Subject	K-2	3-5	6-8	9-12
ESS3.A Natural Resources	- Living things need water, air, and resources from the land, and they live in places that have the things they need. - Humans use natural resources for everything they do. 28% Pre 40% Post	- Energy and fuels humans use are derived from natural sources and their use affects the environment. - Some resources are renewable over time, others are not. 28% Pre 40% Post	- Humans depend on Earth's land, ocean, atmosphere, and biosphere for different resources, many of which are limited or not renewable. - Resources are distributed unevenly around the planet as a result of past geologic processes 38% Pre 65% Post	- Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits. 19% Pre 57% Post
ESS3.B Natural Hazards	- In a region, some kinds of severe weather are more likely than others. - Forecasts allow communities to prepare for severe weather.	- A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts.	- Mapping the history of natural hazards in a region and understanding related geological forces. 48% Pre 73% Post	- Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales.
ESS3.C Human Impacts on Earth Systems	- Things people do can affect the environment but they can make choices to reduce their impacts. 28% Pre 45% Post	- Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. - Societal activities can also help protect Earth's resources and environments. 33% Pre 56% Post	- Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. - Activities and technologies can be engineered to reduce people's impacts on Earth. 55% Pre 71% Post	- Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies. 54% Pre 82% Post
ESS3.D Global Climate Change	N/A	N/A	- Human activities affect global warming. - Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics. 48% Pre 72% Post	- Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

CONCLUSION

Testing results from several classrooms, each numbering 20-30 students, showed significant increase in knowledge of the Next Generation Science Standards environmental curriculum. Classes as young as the first grade were able to comprehend middle school topics in just an hour of playing. Students across all grades demonstrated a heightened understanding of current environmental issues and why it is important for humans to preserve the world around them. Middle school students also deepened their perception of the environment in politics and understood why it is beneficial for countries to invest in renewable energy. In addition to learning, students were excited by the challenge of their task and eager to continue playing. Testing has proven both games to effectively teach the NGSS curriculum at a faster pace than traditional methods while keeping students intrigued and encouraging them to learn outside of the classroom.

Tesla EV Conversion Project

Pauline Pfaffe, Ethan Perrin, Jacob Lee, Suraj Buddhavarapu, Daniel Goto, Sohaib Moinuddin, Morgan Gilbert

BACKGROUND

With global warming being a looming issue in the new millennium, it has become increasingly important to find ways to reduce our carbon footprint. Motor vehicles are an essential part of our everyday lives, and are thus becoming a pivotal aspect in our societies' transition to sustainable design. Many new electric vehicles are coming into the automotive market to attract people to this concept of new, ecologically-friendly cars, but some prefer to look to the past for clean transport. Gas to electric conversions have been performed on many car models, but often times the effort needed to convert seems overly difficult and nearly infeasible. However, our team wanted to prove that while an electric conversion may appear intimidating at first, it is a completely reachable goal. We took a then inoperable Mazda RX7, courtesy of one of our team member's father, and challenged ourselves with the task of converting the vehicle into an electrically-powered vehicle.

METHODS

Our process for converting the Mazda RX7 was split into several stages: Design, disassembly, acquisition, and construction. The first stage, design, was focused on planning for the other stages. We identified components of the car that had to be removed, which electrical components and tools we would need to purchase, and how those components would fit into the vehicle. After we were finished planning, we moved onto the disassembly stage. We carefully removed the parts required for a gas-powered engine, cleaned them and put them up for sale in order to help with the next stage, acquisition. Acquisition was centered around finding funding to buy the electrical components of the car. We started a crowd-funding campaign and handed out flyers at multiple events to gather financial support. We also contacted many automotive and electric car companies asking for help, and ultimately received the aide of many large corporations such as Microsoft, Les Schwab, Patriotic Motors and more. After receiving all the necessary parts, we moved onto the final stage, construction. We implemented our design ideas for how the electrical motor, batteries, wiring and part mounts would integrate into the RX7. Eventually all the mounts were created and the parts are in place.

RESULTS

The conversion of the Mazda RX7 proved to be a success. Overall, the sustainability, efficiency and performance of the vehicle was improved in many ways:

- No longer produces greenhouse gasses
- Cheaper to charge electric vehicle than to fill gas vehicle, cutting prices down to an eighth of their original figures
- Uses less energy to run every year
- With Sustainable resources, will never run out of fuel

- Allows for regenerative braking, further increasing efficiency

When compared to the Nissan Leaf, the most popular electrical vehicle currently in the market:

- Higher MPGe than Leaf (130 vs 114)
- Much higher torque in ft-lbs (316 vs 187)
- Higher kWh capacity in battery (26 vs 24)

CONCLUSION

Overall, we were very pleased with the finished conversion. It proved to be far more sustainable, economical, and impressive than its previous gas-powered design. While the work was very intensive, we proved that an electrical conversion can be accomplished with time, money, and determination. As high school students with previously insignificant automotive knowledge, we have also proved that limited knowledge does not keep people from being able to convert their vehicle. The results show that electrical conversions, even for cars without kits or blueprints for converting, are feasible and desirable projects that can improve upon current gas-powered vehicles. We hope this shows one of the paths to a new era of sustainable design.

Pauline Pfaffe, Ethan Perrin, Jacob Lee, Suraj Buddhavarapu, Daniel Goto, Sohaib Moinuddin, Morgan Gilbert

FACTS SHEET

Weight:

Old Curb Weight = 2,954 lbs Batteries = 624 lbs

Empty = 2,431 lbs Motor = 120 lbs

New Curb Weight = 3,433 lbs Transmission = 98 lbs

Motor: HPEVS AC-51 $4,200

Torque @ 0-5000 rpm = 110 ft/lb

90 HP

Acceleration 0-60 mph = 7.08 sec

Top Speed = 161 mph

Chose AC over DC because…

- Flatter torque curve from 0-4000 rpm provides constant power and efficient operation
- Allows regenerative braking integration
- Safer: if controller were to fail in the “on” position, rather than accelerating to speed as with a DC motor, AC motors require digital commutation and stop immediately.

Batteries: LiFePO4 $9,200.00 total

48 Lithium Iron Phosphate cells split evenly between front and back

180 Ah per cell 540 A continuous current capacity

3.2 Volts per cell 144 Volts total

25.92 kwh

21 usable kwh at 80% of battery pack

- Safety from puncture or impact explosions (they are functionally inert and nonvolatile)
- Longer life, low self discharge (longer shelf life)
- Higher Power density, which makes them inherently safer chemically and more stable thermally

Transmission: Standard 5 speed manual

Torque = 316 ft-lbs in 5th gear to 1571 ft-lbs in 1st gear from 0-4000 rpm

Transmission Ratios:

1st = 3.483 2nd = 2.015 3rd = 1.391 4th = 1.00 5th = 0.719

We kept the transmission versus doing direct drive because…

- Provides correct right gear ratios and torque curve to interface with LSD
- Provides a robust connection point between motor shaft, tail shaft, and differential.
- Leaving the car in 3rd gear optimizes the torque and HP curve to ~100mph

PARTS LIST

Removed

Multiple Radiator Igniter Starter motor Ac compressor Power steering pump Intake manifold Throttle body Engine control unit Fuel lines Battery	Alternator Exhaust manifold Exhaust Catalytic converter Cooling fan Air box Turbocharger(s) Oil filter Fuel filter Gas tank Clutch assembly	Engine Muffler Exhaust pipes Multitude of Wires Air filter Bottom plastic underbody High-pressure air compressor fittings All cables and hoses connecting radiator to cooling fans

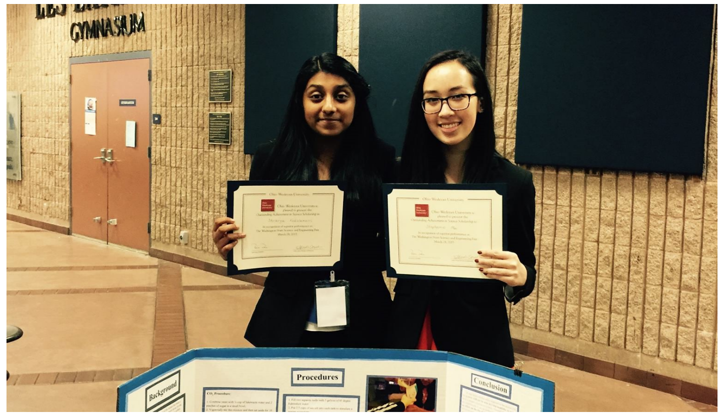
Added

Motor Flywheel Flywheel hub Transmission adapter plate Motor mount plate Support frame	J1772 charging port Charger mount plate Power steering pump Brake vacuum pump Power steering reservoir 12v DC-DC converter Motor controller	Charger Battery management system Throttle switch Water cooling pump Watercooling radiator Contactor, relays, fuses

COMPARISON CHART

Accord Hybrid	Ford F-150	93 Mazda RX7	Specs	Mazda Conversion	Nissan Leaf	Mitsubishi i-MiEV	Chevrolet Spark	Tesla Model S	BMW i3	Fiat 500e	Ford Focus Electric	Kia Soul EV	Smart Fortwo	Volkswagen E-Golf
$29,300.00	$26,100.00	$36,000.00	Cost	$20,000.00	$29,800.00	$23,800.00	$26,000.00	$71,000.00	$43,300.00	$32,600.00	$30,000.00	$34,500.00	$25,700.00	$36,300.00
124	529	420	Range miles epa (on full charge)	80	84	62	82	265	81	87	76	93	68	83
50	23	21	MPGe (miles per gasoline equivalent)	130	114	112	114	96	124	115	105	105	107	116
195	334	255	HP	90	110	66	84	359	170	111	143	109	74	115
124	23gal	20 gal	Motor KW	90	80	49	105	380	125	83	107	81	55	85
226	338	217	Torque ft/lb	316-1571	187	145	83	380	184	147	147	210	110	199
lithium ion	-	-	Battery Chemistry	LiFePO4	LiMnO2	LiCoO2	LiFePO4	LiNiCoAl	LiCoO2	Li	LiMn-Spinel	LiPo	LiNiCoMn	LiNiMnCoO2
6.7	-	-	Battery kWh (kilowatt hours)	26	24	16	18.4	78	22	24	23	27	17.6	24.2
7.2	6.5	5.5	Acceleration 0-60 mpg in seconds	7	9.4	13	11	5.1	7	8.4	9.5	12	9.8	8.9
117	107	156	Top speed in mph	161	93	80	103	140	92	88	84	124	78	94

Investigating the Fluctuation of CO_2 Composition of the Ocean and its Effect on Oyster Life



Shravya Kakulamarri and Stephanie Mai

ABSTRACT

Analysis of CO_2 fluctuations in the ocean have intrigued scientists around the world. The local Puget Sound has experienced immense fluctuations, thereby causing an alteration in the marine life, specifically oysters. The purpose of this experiment is to find a correlation between the extent to which oyster life is affected by the amount of CO_2 present in the body of water. We performed this experiment by altering the CO_2 content of the water in tanks in which oysters were placed. The independent variable is the added CO_2, while the dependent variable is the response of the oysters that is elicited due to the excess CO_2. After a week of being exposed to superfluous amounts of CO_2, the oysters' shells displayed discoloration and altered ridges, and were slightly brittle; four of the eight oysters in the experimental tank also died within the first four days. Through our experiment, we have predicted that oyster life can be obstructed by excess CO_2. In the long term, oysters will have trouble making their shells and sustaining themselves due to the biogeochemical cycle and its irregularities over time.

INTRODUCTION

Oceanic dissolved carbon in the oceans has been a problem for many years, posing as a major threat for the creatures inhabiting the oceans. Anthropogenic carbon dioxide (CO_2), also known as man-caused CO_2, plays a major role in the determination of the future of marine life. The ocean is an important reservoir for taking up anthropogenic CO_2. This helps the atmosphere; however, it has adverse effects on the marine life. With increased CO_2 levels absorbed within the oceans, the oysters' respiration and healthy development would be negatively impacted.

If the CO_2 level is high, the rate at which oysters grow and make their shells will be slowed down, and their growth may be stunted; furthermore, the superfluous amounts of CO_2 may cause abnormalities in the shells of the oysters. The purpose of the lab is to determine whether or not CO_2 could negatively affect the oysters' physical and physiological characteristics.

The Puget Sound has recently been absorbing a surfeit of CO_2, which has aided in the increase of its acidity. pH levels less than 7.6 are already common in the Puget Sound. The model for this experiment, however, does not mimic the predicted future characteristics of the Puget Sound because those characteristics are far too extreme. Extreme characteristics are often used in labs to generate sped up biological processes ("Ocean Acidification", 2012).

From combustion of fossil fuels to pollution from gasoline cars, carbon is released into the atmosphere and the oceans, thereby affecting marine life in a hostile manner, while much of the human race is oblivious to this abnormality.

When oceans absorb CO_2, a chemical reaction occurs, forming H_2CO_3, also known as carbonic acid; this acid lowers the pH, increasing the acidity, of the oceans. Furthermore, echinoderms and organisms with shells, need to pull in calcium and carbonate (CO_3) ions from CO_2 the ocean. However, the hydrogen in the ocean reacts with the CO_3 ions, lowering CO3 availability to organisms. The rate at which oysters and clams make their shells is slowed down due to the excess CO_2, which means that many may end up dying due to lack of an adequate and proper habitat. More than 30% of Puget Sound's marine species are calcifiers ("Ocean Acidification", 2012). Furthermore, emissions of nitrous oxides and sulfur oxides have been seen to affect the pH as well. According to previous studies, over the last 250 years, the average upper-ocean pH has decreased by about 0.1 units, and at the current rate of carbon dioxide emissions, the average acidity of the surface ocean is expected to increase by 100 to 150 percent over preindustrial levels by the end of this century ("Ocean Acidification", 2012).

Additionally, nutrients can enter the Puget Sound through point or nonpoint sources. Point sources include discharges from municipal and industrial wastewater treatment facilities, large storm water outfalls, and concentrated animal feedlots ("Ocean Acidification", 2012). Nonpoint sources include runoff from on-site septic systems, improperly managed farms, excessive fertilizers from residential lawns and gardens, etc. ("Ocean Acidification", 2012). These nutrients will promote the growth of algae and plants in the water; when these algae and plants die and decompose, the dissolved oxygen in the water is greatly reduced. This decomposition process also releases CO_2 into the water, thereby lowering the pH.

Previous studies have shown that nutrients and organic carbon intensify and speed up the process of ocean acidification, however, the magnitude of the impact has remained a mystery.

METHODS

Top and bottom of an oyster from the experimental tank after being exposed to excess CO2 (shown above).

Two aquarium tanks are filled with 5 gallons of 45 degree water and then mixed with 2.5 cups of sea salt solution to better represent the ocean habitat for the oysters. Eight Pacific oysters, more specifically, Fanny Bay oysters from Taylor Shellfish Farms, are then added systematically to the tanks, after in-depth observation and measurements of their physical characteristics. These observations are vital in understanding the changes the oysters underwent after being exposed to the excess CO2. One tank is the control while the other is the experimental. The experimental tank will consist of the additional CO2. A baking soda and yeast reactor is made to add great amounts of the CO2 to the tank. A teaspoon of yeast is combined with lukewarm water and two pinches of sugar in a small bowl to activate the yeast; this

Shravya Kakulamarri and Stephanie Mai

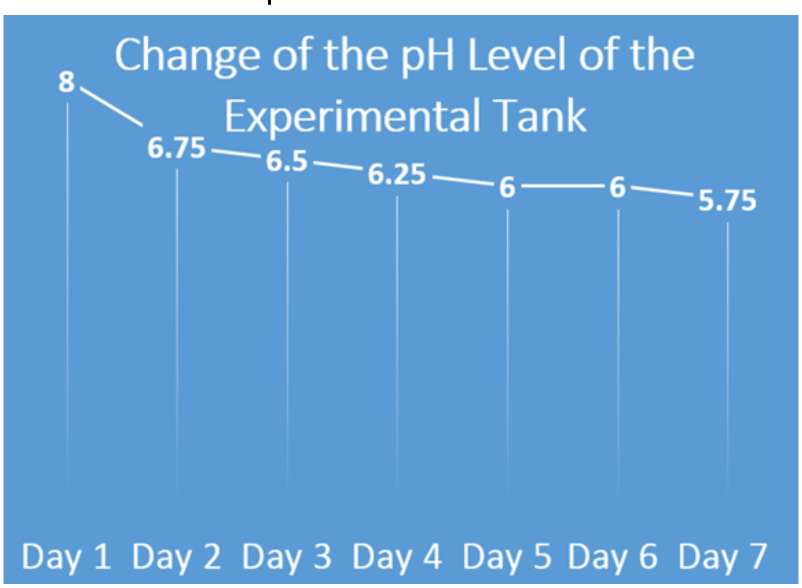
mixture should be set aside for ten minutes. A two-liter bottle is then filled up two-thirds of the way with lukewarm water, and then three cups of sugar, along with one teaspoon of baking soda are added to the bottle. After vigorous shaking, the sugar and baking soda should be completely dispersed in the water. After ten minutes, the yeast mixture should be added to the bottle, and a tube is put over the top of the bottle immediately, and duct tape must be used to seal the tube in the opening of the bottle to ensure that there is no leakage. The other end of the tube is then put into the water of the experimental tank. Within several hours, the CO2 should be diffusing into the water of the experimental tank. A pH test strip must be taken soon after to measure the amount of CO2 dissolved; however, this cannot be done precisely without the acquisition of high level technology. However, it is known that the more CO2 present, the lower the pH, because the more the acidification, due to the creation of H2CO3 (carbonic acid). The pH of each of the tanks is recorded every ten hours. The oysters and any major changes in their physical characteristics must also be recorded. This experiment can be conducted for any duration of time, but for this scenario, it was conducted for one week.

Setup of the control and experimental tanks with Fanny Bay oysters and CO2 reactor (shown above).

RESULTS

Top and bottom of an oyster from the experimental tank after being exposed to excess CO2 (shown above).

The CO_2 had adverse effects on the experimental tank as opposed to the control tank. The Fanny Bay oysters in the control tank remained alive for the duration of the experiment, and were not affected in any manner by the replicated habitat, showing that the replicated habitat was akin to their original environment. In the experimental, four oysters died in one week. The other four oysters experienced slight discoloration on the surface of their shells. While the oysters in the control tank were a dark shade of forest green, the oysters in the experimental tank were shown to exhibit color changes, particularly of a shade slightly lighter than forest green. Also, the shells of the oysters became more brittle and fragile. Furthermore, the pH decreased at a steep rate for the first ten hours, and then stabilized for the rest of the duration of the experiment. The pH started out at 8, and in the first ten hours, decreased to a pH of 6.75, making it acidic due to the carbonic acid. The temperature of the tanks was constant for the entire experiment as well.



CONCLUSION

The future of oceanic dissolved carbon is particularly captivating. Many issues in the past regarding oceanic dissolved carbon have been confirmed now; the next step is to identify the major sources of preventing more damage to the marine species.

It was believed that when exposed to the excess CO_2, the oysters will not be able develop healthily, as well as have a proper respiration system. Through the results of the experiment, it can be deduced that the CO_2 did have an effect on the life of the oysters, due to the fact that all the oysters in the experimental tank were negatively impacted; four died and the other four experienced slight discoloration. Furthermore, the brittleness of the shells caused by the excess pH would result in the oysters not being properly sheltered in the ocean. A strong wave could easily cause the oysters' shells to break apart. The findings from the experiment did support the hypothesis that an increased amount of CO_2 would cause physical abnormalities in the oysters.

In the future, the pH of the Puget Sound will continue to decrease at a rapid rate. According to a study by the University of Washington, "when atmospheric carbon dioxide concentrations reach 460 ppm (currently expected by 2050), more than half the marine waters in our region will be corrosive to oyster larvae and other calcifying species.

It can also be concluded now that when exposed to a pristine environment without the trace of any CO_2, the oysters will thrive, as seen in the control tank. By reducing carbon emissions immensely, oysters will be able to develop healthily.

If CO_2 emissions were reduced, the CO_2 in the ocean surface water would soon equilibrate with that in the atmosphere and the rate of removal would be determined by the slower processes, like transfer into the deeper layers of the ocean; this could be beneficial to the marine species, because the intensity isn't as high when the process takes place on a larger time scale (IPCC, AR2).

While all the studies in the past have shown that oyster life will be altered due to the excess CO_2, this experiment was conducted to show the extent to which the oysters were injured, because that has always been a conundrum of the studies regarding biogeochemical cycles.

Through extensive research of the UN Treaty and President Obama's climate change plan, we have developed three strategies that will aid Washington in the survival of the oysters. One strategy that must be implemented in the near future to ensure the survival of the marine life is developing vegetation-based systems of remediation for use in upland habitats and shellfish areas. Since plants absorb CO_2, the use of plants in shellfish areas would hinder the CO_2 from making its way into the water and affecting the marine life. This would protect the shellfish from acidification. Another strategy that must be implemented in the near future is providing Washington residents with a monetary incentive if they raise oysters. For example, the state of Maryland offers a $500 tax credit to residents who raise oysters because of the ecosystem services they provide. And lastly, shells of millions of oysters consumed at restaurants currently go to landfills. Calcium carbonate is present in great amounts in the shells of oysters. By spreading shell material in shallow waters, the survival of bivalve larvae can be sustained. When the calcium carbonate in the deposited shells dissolves in the water, the pH increases, further decreasing the effects of ocean acidification on the marine life.

It's really disappointing how much of the human race is not aware of the fact that CO_2 has an adverse effect on marine life. Many think CO_2 only affects the human race, however, many of us don't realize how it has the ability to make its way into the oceans and affect the marine life as well. We believe scientists should strive to educate the general audience about this issue. As a society, if we were to come together and take that extra step in reducing our CO_2 emissions, we would make the world a better place for the humans as well as the animals, which could essentially be considered an environmental utopia.

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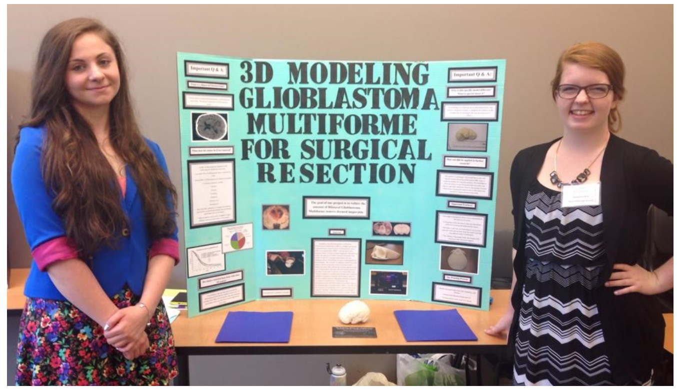

3D Modeling Bilateral Glioblastoma Multiforme for Surgical Resection

Madeline Vassallo and Alexandra Rice

ABSTRACT

Spanning over both hemispheres of the brain, Glioblastoma Multiforme (GBM) is a deadly and inoperable tumor seen in about 14,000 patients a year. Due to its inoperability GBM's will kill most of its patients within 10 years of being diagnosed. Our goal is to reduce the amount of GBM's deemed inoperable. Our model for the 2015 bioexpo demonstrates the life-changing effects 3D printing can have if implemented in neurosurgery. The concept of modeling a deformity in the body in order to surgically correct it has been done before; however, this concept has not been applied to any type of brain tumor. Having a physical representation of the tumor in the brain to practice on from an MRI scan, will give surgeons a reusable and efficient way to practice methods of resection. Surgeons will be able to plan out the least harmful and least damaging methods of surgery, on a patient to patient basis. 3D printing from personalized scans will help surgeons get a better idea of the characteristics of an individual's tumor. Currently we have printed a 3D prototype to give a general idea of our proposal. Our hope is that implementing 3D printing in this field will give brain cancer patients a brighter future.

BACKGROUND

A Bilateral Glioblastoma Multiforme (GBM) is a brain tumor spanning over both hemispheres of the brain, touching multiple lobes. This tumor is also known as a butterfly tumor and is seen in 12,000-14,000 Americans each year. Unfortunately this deadly tumor is deemed inoperable in 90% of patients. Brain surgery is dangerous enough and many variables affect neurosurgery mortality rates; however, about 7,000 people die in surgery each year. Brain cancer is the third deadliest form of cancer; less than ten percent of patients will live beyond ten years. Glioblastoma Multiforme's are mostly seen in men; however the men to woman ratio are fairly even at 11:9. More common in patients in the age demographic of 45-74, this tumor can be seen in patients of all ages. Our mission is to reduce the amount of Bilateral Glioblastoma Multiforme's deemed inoperable by applying 3D modeling technology. Innovating new surgical resection methods is the key, yet not every brain tumor is the same. Resection is the surgical removal of all or a part of an organ, tissue or structure such as a tumor. Each resection needs to be carefully tailored to each person. Currently, we have printed a 3D prototype to give a general idea of our proposal. We propose that the medical field begins taking MRI scans of GBM's, 3D printing them, and using the model as practice tools in order to map out a way to resect the tumor. Why is our model so special? This concept of modeling a tumor in the body in order to surgically correct it has been done before. It is very common to see cardiothoracic surgeons employ this with congenital heart disorders, and also to model out respiratory tumors. However, this concept is fairly new to the medical field and has yet to be applied to any type of brain tumor, let alone GBM. Our hope is that 3D printing will give brain cancer patients a brighter outcome.

FUNCTION

Our group's ultimate goal is to lower the rate of tumors diagnosed as inoperable, and this can be done by 3D modeling of the tumor itself. By creating a physical representation of the tumor, surgeons can better understand the actual tumor, and feel more confident going into the surgery. This method also helps surgeons plan out the least harmful and most effective resection possible. We are advertising our final project as a model for planning out surgeries, as well as an educational device to teach physicians more about the nature of this particular tumor.

IMPORTANT FEATURES

Our model is designed in 5 parts. We have two parts of a skull; the top half is able to be separated by the bottom half. Next we have two brain hemispheres that also come apart. The final piece is the tumor itself, which can be found in between the two brain hemispheres when split apart. We include all of these pieces because we want surgeons to be able to completely visualize the situation, and be able to take in all factors, instead of just the tumor itself.

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Solar Water Disinfection Kit

Sahil Agarwal, Luigi Coltorti, Natalie Harris, Shravya Kakulamarri, Varun Kedia, Calvin Kordel, Christopher Sota

PURPOSE

The purpose of our project is to create a cheap kit made out of commonly used materials that effectively exterminates harmful bacteria in drinking water. The challenge we created involved using objects that would otherwise be disposed of: plastic Starbucks cups (insulators) and used aluminum filters (electrode). For our energy source, we decided to implement electricity from solar panels into our project because of their decreasing price in today's economy. As solar panels become thinner and more efficient, their increasing electrical productivity can be used to almost instantaneously kill bacteria while remaining cost-effective. Previous methods of purifying water are either expensive, introduce other toxins and chemicals, or take a long time, which would be inefficient. For example, using chlorine is not effective in developing countries because it not only makes water taste bad, but isn't as readily available, doesn't always kill all bacteria (oftentimes coliform bacteria survive), and is potentially carcinogenic if used in improper amounts. After making easy-to-build kits with everyday materials, we created and tested a cheap and effective method of disinfecting water without the addition of harmful chemicals and without the wait involved with other methods by pouring local lake water in the system and sending a direct current through it. The absence of bacteria showed that the system is successful and can be implemented as a common water treatment method to replace chlorination. Since cholera and typhoid are common water-borne bacterial illnesses in third world countries, our system can help kill these infections cheaply and efficiently.

CHALLENGE

Finding a way to use basic knowledge about electricity and everyday materials to design and build a cheap and effective system to kill bacteria and provide drinkable water.

OUTCOME HYPOTHESIS

Based on our previous research, using electricity will be the most efficient method because only a very small current is needed to lyse bacteria cells. It would also be the cheapest method due to the decreasing trend in the price of solar panels and the use of everyday materials, such as aluminum filters or aluminum wool (possibly created from recycled soda cans), re-engineered into electrodes. Also, based on a previous experiment done by Stanford University, a direct current running through two thin copper wires in water containing E. coli bacteria does decrease bacteria count; however, it doesn't completely eliminate the bacteria after five minutes. These findings showed us that in order to effectively eliminate bacteria, we must create bigger electrodes in our final design to ensure that the current flows through all the water and therefore reaches all of the bacteria. Our current use of aluminum filters allows the apparatus to be easily cleaned or replaced with little to no cost.

RESEARCH

In recent years, the cost of solar panels (industrial/residential) has experienced a downwards trend. Since 1998, photovoltaic system prices have fallen by 6-8% per year on average. From 2012 to 2013, reported prices fell by $0.65 per Watts (12%) for systems that

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had less than 10 kW and by $0.70 per Watts (15%) for systems over 100 kW. In our final design, we implemented small 10 Watt solar panels to provide the electricity that will purify the water.

Aluminum is the third most common element in the Earth's crust with 82,000 parts per million, behind silicon (used in solar panels) and oxygen. It also doesn't rust easily, which is why it was used in the final apparatus instead of steel wool. Aluminum Residential Air Filters are cheap and easy to work with making them the perfect conductors for this experiment. Although there are other elements (such as copper) that are more electrically conductive than aluminum, aluminum is much more abundant and cheaper which is why aluminum was specifically chosen for this experiment.

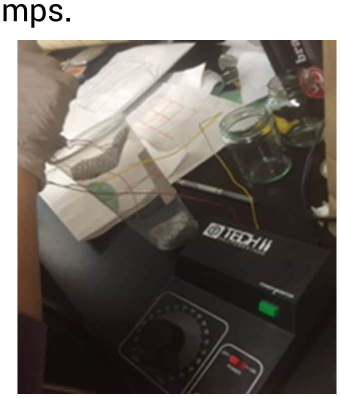
Electricity should be used instead of traditional methods of disinfecting water such as chlorine, boiling or UV light because it is the cheapest, uses the least energy, and doesn't present any heath risks. Chlorine, which is often used as a disinfectant, tastes bad and also isn't readily available for use in developing countries. Boiling water uses up immense amounts of energy compared to electricity while fuel is scarce in third world countries. Finally, UV light is effective, but also expensive. While electricity was the best obvious choice for disinfecting water for developing and undeveloped countries, it would also save time and money if implemented into water treatment processes in developed countries as well.

Shortly after our decision to focus on utilizing electricity to purify water, we found a project undertaken by scientists at Stanford University that was similar to ours. Their main goal was to use cheap materials in order to create a system that would effectively kill bacteria using nanotechnology. In lab tests, over 98 percent of Escherichia coli bacteria that were exposed to 20 volts of electricity in the filter for several seconds were killed. However, we wanted to simplify their design even further. By focusing on implementing recycled materials, we aimed to create a system that was more sustainable while remaining inexpensive, therefore environmentally friendly and usable in poorer, underdeveloped countries.

The optimum angle for solar panels if the latitude is below 25° is the latitude multiplied by 0.87. If the latitude is between 25° and 50°, multiply the latitude by 0.76, then add 3.1 degrees. This information is necessary for setting up the kit so that the solar panels can be as efficient as possible as the more energy the panels generate, the quicker the bacteria can be eliminated.

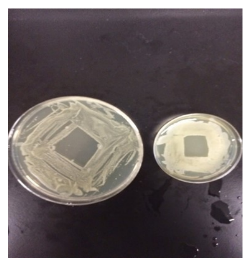
EXPERIMENT DESCRIPTION

The following experiment we designed to determine if an output of less amps than the solar panel we've decided on would effectively kill coliform bacteria. Due to varying output of electricity from the solar panels, using a transformer will keep the current constant and allow us to determine whether or not our system will be possible. The transformer used was a model train transformer that we measured using a multimeter to have an output of 14.38 volts and 0.0015 amps.



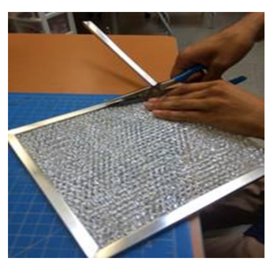
PROCEDURE

1. Use new inoculation loops when prompted and wear gloves to prevent any form of contamination that can potentially skew results.
2. Hydrate a strain of coliform bacteria and spread onto petri dishes with agar gel using a pipette and inoculation loop.
3. Let grow in an incubator set to 350 degrees F overnight.
4. Fill the glass beaker with 200 mL of tap water.
5. Using a new inoculation loop, gather up colonies of coliform bacteria grown previously and swirl into the beaker.
6. After bacteria is mixed into the beaker, use a new inoculation loop and spread water onto an agar plate to create the control for the experiment.
7. Set the stirrer into the mixture and set onto the stirring plate.
8. Attach two wires to each of the two DC screws on the back of the transformer.
9. Hold the other ends of the wires [electrodes] into the beaker of water and coliform bacteria.
10. Switch on the transformer; very small bubbles (hydrogen gas) should form around the negative electrode, indicating that current is flowing through the water.
11. Keep electrodes in for 10-second intervals and take samples and spread onto agar plates after every interval, using new inoculation loops each time. (We took 4 samples)
12. Take one last sample after a longer period of time. (We chose a total of 5 minutes to take the last sample for a final outlier)
13. Incubate agar plates overnight and observe growth.
14. Gas should form around the negative electrode, indicating that current is flowing through the water.
15. Keep electrodes in for 10-second intervals and take samples and spread onto agar plates after every interval, using new inoculation loops each time. (We took 4 samples)
16. Take one last sample after a longer period of time. (We chose a total of 5 minutes to take the last sample for a final outlier)
17. Incubate agar plates overnight and observe growth.



FINAL DESIGN

Our final design evolved from using soda cans to enlarge the electrodes within to using steel wool to an aluminum air filter.



Remove the edging from the aluminum air filter.

Using the cup as a template, trace a circle on to the aluminum air filter for the top of the cup. Do this step again for the bottom of the cup by flipping the cup and tracing the edge.

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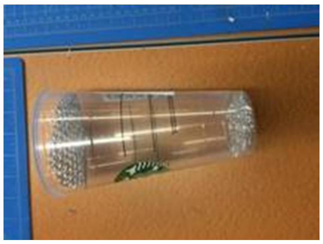
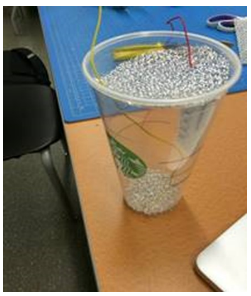
Using scissors, cut the circle drawn out from the previous step. Repeat this step for the bottom circle.



As shown in the diagram, place the circles of aluminum in the bottom and top of the cup.



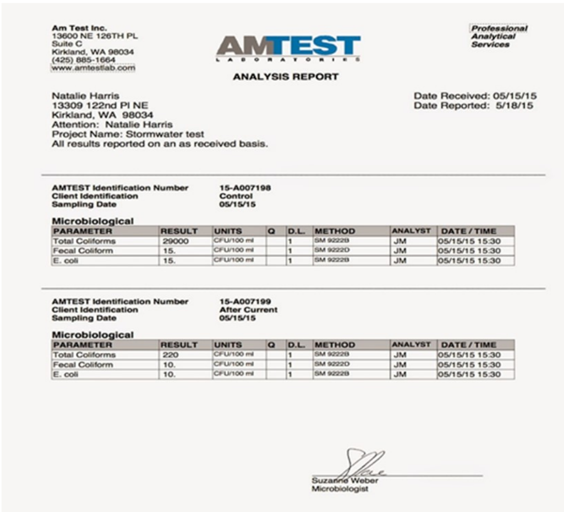
Attach the negative electrode to the bottom circle and the positive electrode to the top circle as diagramed.

For the final apparatus, water from a local stormwater pond will be used and electricity run for twenty minutes. Samples of the water before and after electricity will be sent to AmTest, a water testing lab, to get quantified data. Outlier samples of ten and thirty minutes of electricity will be tested using an EPA approved testing kit.

RESULTS

From our baseline test, we observed bubbles forming around the negative electrode, that we later determined to be hydrogen gas. We realized this could be an easy test to make sure whether or not electricity is flowing through the water. This is important to note because in a third world country, multimeters won't be readily available to see if electricity is present in the water and killing bacteria, so it's important to look for the hydrogen gas bubbles that form to ensure that bacteria is being killed. This influenced our final design by ensuring that the negative electrode was at the bottom of the apparatus so that the bubbles could be easily seen collecting along the bottom, then rising to the top of the cup. The results we received after five minutes are shown in the picture (from left to right, after five minutes with electricity and before electricity).

Using our final design, we decided to get two sets of water tested, a control and after electricity. We approximated twenty minutes as the appropriate time to eradicate all bacteria and chose to test the water for fecal coliform, to look at a broader spectrum than just E. Coli. The table we received from Amtest water testing lab is shown with "control" as water tested from the storm-water pond and "after electricity" as the water treated for twenty minutes with electricity from our transformer. Contacting this local water testing facility gave us quantified data as well as professional advice as to how to improve our own microbiological tests (like our baseline procedure).



Am Test Inc.
13600 NE 126TH PL
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Kirkland, WA 98034
(425) 885-1664
www.amtestlab.com

AMTEST LABORATORIES

Professional Analytical Services

ANALYSIS REPORT

Natalie Harris
13309 122nd Pl NE
Kirkland, WA 98034
Attention: Natalie Harris
Project Name: Stormwater test
All results reported on an as received basis.

Date Received: 05/15/15
Date Reported: 5/18/15

AMTEST Identification Number 15-A007198
Client Identification Control
Sampling Date 05/15/15

Microbiological

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE / TIME
Total Coliforms	29000	CFU/100 ml		1	SM 9222B	JM	05/15/15 15:30
Fecal Coliform	15.	CFU/100 ml		1	SM 9222D	JM	05/15/15 15:30
E. coli	15.	CFU/100 ml		1	SM 9222B	JM	05/15/15 15:30

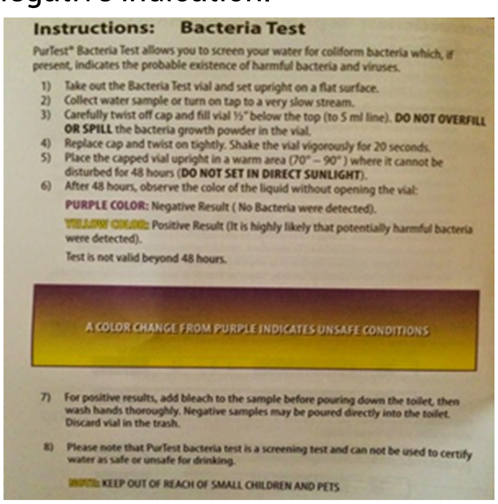
AMTEST Identification Number 15-A007199
Client Identification After Current
Sampling Date 05/15/15

Microbiological

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE / TIME
Total Coliforms	220	CFU/100 ml		1	SM 9222B	JM	05/15/15 15:30
Fecal Coliform	10.	CFU/100 ml		1	SM 9222D	JM	05/15/15 15:30
E. coli	10.	CFU/100 ml		1	SM 9222B	JM	05/15/15 15:30

Suzanne Weber
Microbiologist

We did a separate test along with this experiment using PurTest, EPA approved home testing kits at intervals of ten and thirty minutes as outlying tests. This was just an approximate test that allowed us to better pinpoint the amount of time needed to kill the bacteria. Our results are shown in the picture below, as well as the instructions from the kit to perform the test. This showed us that closer to thirty minutes are needed to effectively kill all bacteria present in the water, which was longer than we expected. The test tubes labeled "C" was our control, "10" was after ten minutes of electricity was run through the water, and "30" after thirty minutes. The yellow color indicates a positive indication of bacteria, while the purple is a negative indication.



Instructions: Bacteria Test

PurTest® Bacteria Test allows you to screen your water for coliform bacteria which, if present, indicates the probable existence of harmful bacteria and viruses.

1) Take out the Bacteria Test vial and set upright on a flat surface.
2) Collect water sample or turn on tap to a very slow stream.
3) Carefully twist off cap and fill vial ½" below the top (to 5 ml line). **DO NOT OVERFILL OR SPILL** the bacteria growth powder in the vial.
4) Replace cap and twist on tightly. Shake the vial vigorously for 20 seconds.
5) Place the capped vial upright in a warm area (70° – 90°) where it cannot be disturbed for 48 hours (**DO NOT SET IN DIRECT SUNLIGHT**).
6) After 48 hours, observe the color of the liquid without opening the vial:

   PURPLE COLOR: Negative Result (No Bacteria were detected).

   YELLOW COLOR: Positive Result (It is highly likely that potentially harmful bacteria were detected).

   Test is not valid beyond 48 hours.

A COLOR CHANGE FROM PURPLE INDICATES UNSAFE CONDITIONS

7) For positive results, add bleach to the sample before pouring down the toilet, then wash hands thoroughly. Negative samples may be poured directly into the toilet. Discard vial in the trash.
8) Please note that PurTest bacteria test is a screening test and can not be used to certify water as safe or unsafe for drinking.

[illegible] KEEP OUT OF REACH OF SMALL CHILDREN AND PETS

CONCLUSION

After sending a direct current through the dirty water, almost all of the bacteria was killed. Having electricity run for 10 minutes and 20 minutes, the coliform bacteria was significantly reduced but not completely eradicated. However, an EPA home testing kit revealed that 30 minutes of consistent direct current being sent through the water completely killed all the bacteria previously living in the sample. Our tests are fairly reliable as they were either conducted by an EPA approved test or a testing laboratory that used procedures derived from EPA protocols.

These results prove that it is indeed possible for our apparatus to kill bacteria, as long as the direct current is strong enough and passes through the water for at least 30 minutes. This could actually be completed in a shorter time frame, as we used a transformer to send the current through the water, but in our final design we will use a solar panel. The solar panel we purchased to be used in our system will be able to generate more volts than the transformer. Due to the fact that only a short period of time is necessary to purify the water and it can be produced sustainably with a solar panel, using electricity as the method to purify water is the best option.

Though our experiment was efficient and accurate, there are many ways to improve the method of killing coliform and test how much bacteria is left alive in the water. For example, the Vernier site has an efficient way for finding the amount of coliform in a water sample which could replace our procedure for testing water as it was created by professional scientists so it is probably more reliable. This would be helpful to reference while creating a more quanti-

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fied procedure for determining fecal coliform bacteria in a water source. Another improvement that could be made to improve the speed of our system is adding a capacitor, which would increase the amps and volts of the direct current sent through the water. By increasing the intensity of the current sent through the water, the addition of the capacitor might decrease the time needed to purify it. However, further testing and research would be needed to make sure that our solar water disinfection kit remains cheap and efficient.

ACKNOWLEDGEMENTS

We would like to acknowledge our AP Biology teacher, Mrs. Nelson, for helping us grow bacteria and use it for testing our methods of electrifying bacteria. She also reviewed our procedure which helped us be able to create a final, working process that matched our experiment. We would also like to acknowledge our Engineering teacher, Mr. Leslie, for advising us to constantly document our experiment and research in order to create a clear and concise project that could be understood by others. His encouragement and optimism helped our innovation and inspired us to think creatively so we could create an organized and inspirational project.

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Growth Analysis of *Clostridium Thermocellum* on "Dirty" Substrates

Ben Zabback, Margo Nanneman, Maheck Jerez, Zechariah Cheung, Claire Yin

ABSTRACT

To help assess the viability of large-scale H_2 gen-eration using Clostridium Thermocellum and cellulose sources available from municipal yard waste, C.Thermocellum's growth rate was measured on MTC medium containing "dirty" cellulose substrates: balsa wood (commercially bought), brown rice, printer paper, and avicel/cellobiose as positive controls. Growth was measured by volume of CO_2 produced by colonies over a 48 hour growth period. Results suggest that, apart from avicel, C.Thermocellum showed the largest growth on substrates of printer paper. Very little growth was observed when colonies were grown on rice and wood, which may have resulted from high xylan and lignin content in these substrate, as well as exterior factors stemming from the commercial nature of the wood (potential chemical treatment of the wood may have hindered growth). Other groups have recorded high levels of growth by C.Thermocellum on delignified wood [4] suggesting that results may be improved via delignification.

INTRODUCTION

As global climate change becomes an increasingly imminent problem, the world is searching for environmentally friendly and economical alternative energy sources to replace existing sources such as the burning of coal and natural gas. The generation of hydrogen from bacteria for use in large-scale centralized-generation power plants has been proposed in the past, but various economic issues have kept this idea from coming to fruition. Today recent advances in several fields related to bio-hydrogen generation may make it possible for the bacteria C.Thermocellum (an obligate an-aerobe, thermophilic, and cellulose consuming bacteria which produces hydrogen and carbon dioxide as byproducts of respiration) to be used in large scale H_2 production.

Although plenty of research has been done concerning the growth of C.Thermocellum on laboratory cellulose sources such as avicel and cellobiose, little is known about the ability of C.Thermocellum to use "dirty" cellulosic materi-al-sources of cellulose which are available in nature and, unlike pure crystalline cellulose substrates such as avicel, contain molecules such as hemicellulose and lignocellulose. This information is important to the design of a large-scale bio-hydrogen production plant as the fuel for such a facility would likely be dirty cellulose sources like those found in yard or agricultural waste. The goal of this study is to measure the ability of C.Thermocellum to metabolize the dirty cellulose sources of wood, paper and rice compared to a laboratory cellulose source: avicel.

MATERIALS

- 1x 250ml Vernier Thick-Plastic gas collection bottle 2x Vernier CO_2 sensor
- 2x 1m of 5mm laboratory tubing with Luer-Lock fittings

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- 2x serum bottle containing MTC medium and a 5g/L concentration of Avicel
- 2x serum bottle containing MTC medium and a 5g/L concentration of shredded 8.5x11in. white printer paper
- 2x serum bottle containing MTC medium and a 5g/L concentration of shredded brown rice
- 2x serum bottle containing MTC medium and a 5g/L concentration of saw dust
- Culture of C. Thermocellum
- Air tight sealant (Plumber's Goop)
- 8x butyl rubber serum bottle stoppers
- 1x Vacuum pump
- 25x Luer Lock tube needle
- 1x incubator

METHODS

C. Thermocellum was grown in 250ml glass serum bottles with butyl rubber stoppers. Each bottle contained 50ml of MTC medium [3], N_2 gas and 1.25g of various cellulose substrates. Each bottle was inoculated with a sterile syringe and grown at 60°C. During incubation, each bottle was connected via impermeable tubing with Luer-Lock needles to a 250ml sealed plastic gas collection bottle with a Vernier CO_2 sensor to measure CO_2 levels (see fig. 1). All bottles including the source inoculum were stored at 0°C in a refrigerator. Bottles with medium were inoculated and then incubated for 24 hours before data collection. Each bottle was kept in the incubator for another 24 hours while data was collected. After each trial, the gas collection bottle was emptied using a vacuum pump.

RESULTS AND DISCUSSION

Each sample experienced a small spike on concentration initially which can be accounted for

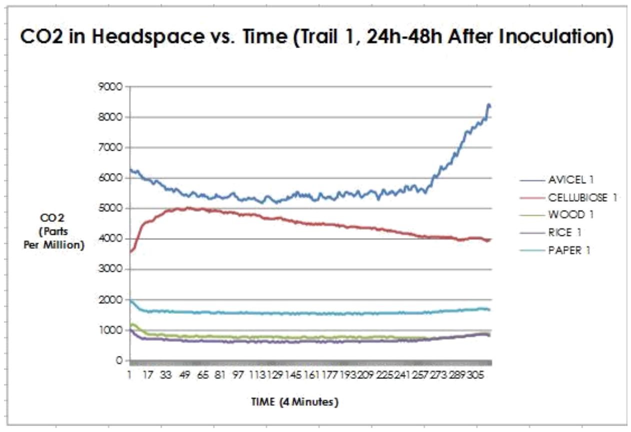

Figure 1

by small amounts of CO_2 entering the sample when it was connected to the CO_2 sensor bottle. The CO_2 from initial introduction appears to diffuse into the bottles after a short period of time. Differences in initial CO_2 concentrations were likely caused by slight differences in the preparation of the gas collection bottles, for example the number of people breathing nearby when the bottles were sealed, and are not thought to be significant. Because there were variations in initial CO_2 concentration measured in each sample, growth on each sample was compared to total change in CO_2 concentration between the minimum concentration and the final concentration (the graph of cellobiose does not show this trend because of probable early growth, so CO_2 was measured with absolute minima and maxima).

Substrate	ΔCO_2
Avicel	3555ppm
Cellobiose	1452ppm
Wood	179ppm
Paper	246ppm
Rice	104ppm

The greatest change in CO2 was seen in samples grown on avicel by a factor of 2.3 more than the next greatest: cellobiose samples. The dirty cellulose substrates saw dramatically lower ΔCO2s than the laboratory substrates, ranging from 179-268ppm compared to avicel's

1452ppm ΔCO_2. Rice showed the least CO_2 production, with wood doing slightly better and paper showing the greatest ΔCO_2 of 246ppm among the dirty cellulose substrates. Dirty substrates could show less growth for a several reasons. Each of the dirty substrates was available to C.Thermocellum as large polymers, as opposed to avicel and cellobiose which are both monomers. Carbohydrate polymers require hydrolysis before they can be consumed which may have hindered C.Thermocellum's ability to consume them. Additionally, although all substrates were autoclaved before addition to the medium, harmful chemicals or indigestible carbohydrates likely stayed on the substrates, especially the wood, and also affected C.Thermocellum's ability to consume them. The composition of the dirty cellulosic material also has significant amounts of hemicellulose and lignin that the monomer sugars lacked. These are carbohydrates that C.Thermocellum can process enzymatically, but the products of these catalyzed reactions cannot be used by C.Thermocellum for growth or metabolic processes. Growth in Co-Culture with Clostridium Thermosaccharolyticum would allow for these components of the dirty cellulose sources to also be metabolized, namely by the C.Thermosaccharolyticum.

All samples that showed growth appeared to reach an exponential growth phase at approximately 41 hours after inoculation except for the sample containing cellobiose, which appears to have reached exponential growth at the beginning of 24 hours after inoculation. Cellobiose may have seen an early growth curve because it is soluble, unlike the other substrates, and so may have been more readily available to the bacteria, allowing for earlier growth. The decrease in CO_2 concentration after this initial hump may have been due to the CO_2 gas dissolving into the medium as the metabolic products of C.Thermocellum interacted with the CO_2 already dissolved into the medium, or it may have resulted from a small leak in the gas collection bottle (although this is probably not the case since the CO_2 concentration in the lab where the samples were incubated varies with time as people work during the day and equilibrium is reached with the outside air at night but the graph shows no such variation).

Printer paper may have had the greatest change in CO_2 concentration because it contains high amounts of cellulose and is delignified when it is manufactured [1]. This is significant because C.Thermocellum may be unable to digest lignocellulose [4]. Since lignocellulose is present in wood and rice, C.Thermocellum might have had a harder time digesting those substrates. C.Thermocellum has also been shown to be unable to consume xylan, a type of hemicellulose commonly found in plants, due to a lack of enzymes which break down xylan. Wood and rice contain xylan in addition to consumable cellulose [2]. The presence of these indigestible polymers in the wood and rice reduces the total consumable cellulose in the substrate and the concentration of consumable cellulose in the substrate compared to paper and substrates which were purely consumable cellulose by weight (i.e. avicel). Although paper contains xylan, both of these factors could have made these substrates more difficult for C.Thermocellum to consume and resulted in paper showing the greatest ΔCO_2 of the dirty substrates.

CONCLUSION

Laboratory substrates showed the greatest growth while samples grown on shredded printer paper showed the greatest potential for growth among the dirty substrates tested. Our results suggest dirty substrates are viable for use in large scale hydrogen production with C.Thermocellum, however delignification may enhance results. Further study is required to determine methods of improving growth and cellulose yield from dirty substrates such as paper.

ACKNOWLEDGEMENTS

We would like to thank Dr.Lee R. Lynd and Julie Payne, M.D. at Dartmouth College for supplying the bacteria samples and bottles with prepared medium, as well as working with us to ensure our protocol for growing C.Thermocellum would grow the organism success-fully. We would also like to thank Erica Danaee, our biology teacher, who worked with us tirelessly to help us complete this experiment and who donated several pieces of lab equipment to our project. Without help from all these people this project would not have been possible.

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Awards Won by Tesla STEM High School Students

Washington State Science and Engineering Fair

- 1st place in Health and Biomedical Sciences, Senior Division; Wolfram Alpha Mathematica Award

  Prerana Annapantula, Elysia Midorikawa and Sindhooja Mullapudi: *The Effects of Withania Somnifera (Ashwagandha) and Terminalia Arjuna (Arjuna) on Adolescent Athletes' Performance*

- 1st place in Earth and Environmental Sciences, Senior Division; National Oceanic and Atmospheric Administration (NOAA's) 2015 Taking the Pulse of the Planet Award; Graphic Design Award; Wolfram Alpha Mathematica Award; Scholarship to Ohio Wesleyan College

  Sabreen Mohammed: *Projecting Mercury Flux Due to Arctic Sea Ice Melt with Machine Learning*

- 1st place in Behavioral and Social Sciences, Senior Division; Wolfram Alpha Mathematica Award; $80,000 scholarship to Ohio Wesleyan College

  Meena Reddy: *Investigating the Effect of Video Exposure Of Urban and Natural Environments on Recorded Stress Levels*

- 1st place in Engineering Mechanics, Senior Division; Bonneville Power Administration Achievement in Energy and Environment Award

  Sonia Murthy, Ethan Perrin and Sophia Tevosyan: *Implementation of a Carbon Dioxide Refrigeration System as a Cogeneration Appliance and Alternative to Halocarbon-based Refrigeration Systems*

- 1st place in Embedded Systems, Senior Division; Wolfram Alpha Mathematica Award

  Udit Ranasaria: *An Educational Game Console*

- 1st place in Animal Science, Senior Division; Wolfram Alpha Mathematica Award; $80,000 scholarship to Ohio Wesleyan College each

  Shravya Kakulamarri and Stephanie Mai: *Investigating the Fluctuations in Carbon Composition of the Ocean and It's Effects on Oyster Life*

- 1st place in Behavioral and Social Sciences, Senior Division; American Psychological Association Certificate Award

  Pauline Pfaffe and Jacob Lee: *Bystander Reactions to Domestic Hostility*

Imagine Tomorrow Science Competition

- Design 1st place

  Surya Cidambi, Colby Colson, Atul Madhugiri, Kevin Nakahara, Naveen Sahi: *Redesigning Seattle Transportation Plan*

- Design 3rd place

  Teri Guo, Udit Ranasaria, Ben Trowbridge, Dinesh Parimi, Suraj Buddhavarapu: *UN Climate Change Treaty*

- Bio Fuels 1st place

  Ben Zabback, Margo Nanneman, Claire Yin, Maheck Jerez, Zach Cheung: *Recycling Waste Heat for Bio Hydrogen Generator*

- Bio Fuels 2nd place

  Saakshi Dulani, Meena Meyyappan, Daaniya Iyaz, Waarisha Soomro, Reksha Rathnam: *Aquaponics*

- Behavior 3rd place

  Caeli MacLennan, TJ Johansson, Eli George, Adrian Pang, Matthew Von Allmen: *Project Sustain Climate Change Game*

- Technology 4th place

  Pauline Pfaffe, Morgan Gilbert, Daniel Goto, Sohaib Moinuddin, Jacob Lee: *Electric Car Conversion*

Jostens National Yearbook Program of Excellence Award

- Editors: Martin Berger, Julia Rettig, Yotam Ofek, Meena Meyyappan, Marissa Loya, Jennifer Herron, Amy Zhang
- Staff: Daniel Goto, Hunter Gordon, Emma Morrison, Gabby Fox, Bryn Allesina-McGrory, Yogi Sunkara, Sam Brick, Udit Ranasaria, Nanda Sundaresan, Shravya Kakulamarri, Waarisha Soomro, Daniel Mar, Rishi Ramesh, Patrick Mao, Allison Tran, Carolyn Clark

Hunt the Wumpus- Coding Challenge

- 1st Place

  Nicholas Bo, Kaelin Laundry, Sonia Skarbek, Kyran Adams, Abhinav Gottumukkala, Nikolay Bykov: *Implementation of C#*

Northwest Association for Biomedical Research Student Biology Expo

- 1st place

  Alexandra Rice, Madeline Vassallo: *3D Modeling Bilateral Glioblastoma Multiforme for Surgical Resection*

- 2nd place

  Vineeta Parupudi, Reksha Rathnam, Jennifer Yeh: *Prosthesis of the Arts: 3D Printing Aids for Wrist and Ankle Joints*

- 3rd place

  Audrey Hyem, Jenna Oratz: *3D Modeling the Effects of Vitamins on Osteoporosis*

- Honorable Mentions

  Tyler Daniel, Tristan Heywood, Banning Lyth: *3D Printed Proportioned Prosthetic*

  Matt Dulski, Claudia Nguyen, Emily Yang: *Developing a Synthetic, Bio-integrated, Mechanized Lymph System for Post Lympadenectomy Cancer Patients*

Youth App Challenge Winners: Western Washington Division – High School Level

- Katrine Bjorner, Isaac Perrin, Rachel Ray & Marius Repede: *Camping Connections*
- Rafia Khatri, Anne Lee, Gregory Moore, Suchi Shridar & Mac Thompson: *Pen Pal*
- Gabriel Gaertner, Calin Gavriliuc, Nicholas Gomez & Artem Romanenko, Tyler Warden: *Shaky Security*

Intel International Science and Engineering Fair

- Environmental Engineering 3rd place and Special NASA Award

  Sonia Murthy, Ethan Perrin, and Sophia Tevosyan: *Implementation of a Carbon Dioxide Refrigeration System*

American Association of University Women Awards

- Recognized as scholars

  Mathematics: Sonia Murthy

  Technology: Emma Morrison

  Science: Miranda Pehrson

Washington Aerospace Scholars

- Liam Jaffe
- Yash Pahade
- Dinesh Parimi
- Matthew Suhy
- Chinmay Upadhye

Future Business Leaders of America State Competition

- Business Procedures 4th place

  Sonia Murthy

- Mobile App Development 3rd place

  Miranda Pehrson, Suraj Buddhavarapu, Apoorv Khandelwal

- Business Plan 5th place
  Yash Pahade, Nolan Orloff, Vishal Noonavath
- Introduction to Parliamentary Procedure 1st place
  Anne Lee
- Introduction to Parliamentary Procedure 3rd place
  Neha Hulkund
- Introduction to Business Communication 1st place
  Vaishnavi Phadnis
- Introduction to Business Communication 5th place
  Suchi Sridhar
- FBLA Principles and Procedures 5th place
  Audrey Tseng
- Help Desk 1st place
  Apoorv Khandelwal
- Help Desk 4th place
  Udit Ranasaria
- Future Business Leader 1st place
  Sonia Murthy
- Marketing 2nd place
  Karan Narula and Hemil Gajjar
- Intro to Information Technology 1st place
  Apoorv Khandelwal
- Business Calculations 1st place
  Dinesh Parimi
- Computer Problem Solving 1st place
  Daniel Mar
- Intro to Business 4th place
  Neha Nagvekar
- Business Math 2nd place
  Vaishnavi Phadnis

- Emerging Business Issues 1st place

  Sonia Murthy and Sophia Tevosyan

U.S. National Chemistry Olympiad

- Qualified for the National Chemistry Olympiad exam

  Udit Ranasaria and Aditya Ramanathan

Technology Student Association Washington State Competition

- Music Production 1st place

  Surya Cidambi, Naveen Sahi, Aditya Ramani

- Scivis 1st place

  Pranav Vasudha, Mrigank Bhardwaj, Madison Minsk, Kaanad Deodhar, Aaron Johnston, Devansh Kukreja

- Software Development Top 5

  Patrick Mao, Aditya Kumar, Abhinav Singh

- Video Game Design 3rd place

  Abhinav Singh, Patrick Mao, Aditya Kumar, Jake Newfeld, James Kusardi

- Webmaster 1st place

  Kaanad Deodhar, Aaron Johnston, Madison Minsk, Alka Pai, Patrick Mao

- Technology Bowl Team Top 5

  Aaron Johnston, Kaanad Deodhar, Christopher Yu

- Robotics 1st place

  TJ Hori, Alex Ilias, Schawn Lin, Daniel Mar, Sriram Natarajan, Udit Ranasaria

- Prepared Presentation 3rd place

  Meena Meyyappan

- Technology Bowl Written 1st place

  Naveen Sahi

- Engineering Design 1st place

  Saakshi Dulani and Meena Meyyappan

- Biotech Design Top 5

  Saakshi Dulani, Meena Meyyappan, Reksha Rathnam, Divya Cherukupalli, Anjali Rajah

Health Occupation Students of America-Future Health Professionals Washington State

- Medical Innovation 2nd place
  Saakshi Dulani, Jennifer Yeh, Meena Meyyappan, and Claudia Nguyen
- Biotechnology 3rd place
  Claudia Nguyen
- Biomedical Debate 2nd place
  Audrey Tseng, Prerana Kulkarni, Andrea Dang, and Amulya Paramasivam
- Extemporaneous Health Poster 2nd place
  Oisin Doherty
- Extemporaneous Health Poster 3rd place
  Sabreen Mohammed
- Job Seeking Skills 1st place
  Vaishnavi Phadnis
- Job Seeking Skills 2nd place
  Shravya Kakulamarri
- Medical Assisting 1st place
  Shravya Kakulamarri
- Public Health 1st place
  Saakshi Dulani. Meena Meyyappan, Daaniya Iyaaz
- Medical Math 1st place
  Vaishnavi Phadnis
- Medical Math 3rd place
  Neha Hulkund
- Pathophysiology-Knowledge Test 3rd place
  Claudia Nguyen
- Human Growth and Development-Knowledge Test 2nd place
  Shravya Kakulamarri
- Nutrition-Knowledge Test 3rd place
  Dipti Dhond

- Transcultural Healthcare-Knowledge Test 1st place

    Sabreen Mohammed

- Pharmacology-Knowledge Test 1st place

    Jenna Oratz

- Medical Law and Ethics-Knowledge Test 1st place

    Catalina Raggi

- Medical Law and Ethics-Knowledge Test 2nd place

    Jenna Oratz

Lexus Eco Challenge

- 1st Place

    Udit Ranasaria, Sophia Tevosyan, Vibha Vadlamani, Sonia Murthy, and Dinesh Parimi

Central Sound Regional Science and Engineering Fair

- Organismal Science: Animal, Plant 1st place

    Marko Lysyk: *The Benefits of Companion Planting: Sage and Arugula*

- Organismal Science: Animal, Plant 3rd place

    Shravya Kakulamarri and Stephanie Mai: *Investigating the Fluctuations in Carbon Composition of the Ocean and It's Effects on Oyster Life*

- Behavioral and Social Sciences 1st place

    Meena Reddy: *Investigating the Effect of Video Exposure Of Urban and Natural Environments on Recorded Stress Levels*

- Behavioral and Social Sciences 3rd place

    Pauline Pfaffe and Jacob Lee: *Bystander Reactions to Domestic Hostility*

- Energy and Transportation 2nd place

    Vibha Vadlamani: *Increasing the Efficiency of Photovoltaics by Concentrating Visible Light Through Reflection*

- Medicine and Health Sciences Honorable Mention

    Prerana Annapantula, Elysia Midorikawa and Sindhooja Mullapudi: *The Effects of Withania Somnifera (Ashwagandha) and Terminalia Arjuna (Arjuna) on Adolescent Athletes' Performance*

- Electrical and Mechanical Engineering, Materials and Bioengineering 1st place

    Christina Dias: *Investigating Ideal Material Composition for Tissue Engineering of Muscle, Tissue and Fat*

- Electrical and Mechanical Engineering, Materials and Bioengineering 1st place

  Sonia Murthy, Ethan Perrin and Sophia Tevosyan: *Implementation of a Carbon Dioxide Refrigeration System as a Cogeneration Appliance and Alternative to Halocarbon-based Refrigeration Systems*

- Electrical and Mechanical Engineering, Materials and Bioengineering 3rd place

  Udit Ranasaria: *An Educational Game Console*

- Electrical and Mechanical Engineering, Materials and Bioengineering Honorable Mention

  Alana Wang: *Incorporating SMA Wire Into Textile Fashion*

- ASM Materials Education Foundation Award

  Jim Lacher: *Improvements of Wing Performance at Various Speeds through Adjustment of Wing Minutiae and Coating Materials*

- American Psychologial Association for Achievement in Research in Psychological Science

  Meena Reddy: *Investigating the Effect of Video Exposure Of Urban and Natural Environments on Recorded Stress Levels*

- Inspiring Excellence Award

  Anthony Hoffman: *Studying the Ability of Written Code Switching in Bilingual Readers*

- National Oceanic and Atmospheric Administration (NOAA's) 2015 Taking the Pulse of the Planet Award

  Shravya Kakulamarri and Stephanie Mai: *Investigating the Fluctuations in Carbon Composition of the Ocean and It's Effects on Oyster Life*

- Ricoh Sustainable Development Award 2015

  Sonia Murthy, Ethan Perrin and Sophia Tevosyan: *Implementation of a Carbon Dioxide Refrigeration System as a Cogeneration Appliance and Alternative to Halocarbon-based Refrigeration Systems*

- Sigma Pi Award

  Christina Dias: *Investigating Ideal Material Composition for Tissue Engineering of Muscle, Tissue and Fat*

- US Public Health Service Surgeon General's Special Science Award

  Pauline Pfaffe and Jacob Lee: *Bystander Reactions to Domestic Hostility*

- The Grand Prize

  Sonia Murthy, Ethan Perrin and Sophia Tevosyan: *Implementation of a Carbon Dioxide Refrigeration System as a Cogeneration Appliance and Alternative to Halocarbon-based Refrigeration Systems*

Model United Nations State Competition

- Outstanding Position Papers Prize

  Nivida Thomas: Representing Morocco at the "International Court of Justice"

  Catalina Raggi: Representing Serbia at UNESCO

Math is Cool Washington State Math Competition

- 1st Place

  Abishek Hariharan, George Stepaniants, Rahul Nene, Rishi Ramesh, Neha Nagvekar, Lawrence Atienza, Tudor Fanaru

VEX Quantum Robotics Awards

- **917A**: Mrigank Bhardwaj, JD Daly, Madison Minsk, Pranav Vasudha, Andrew Wang

  Judges Award, Exothermic Winter VRC Challenge

  1st Place, VEX Game Design Animation Challenge

  Competed at VEX World Championship

- **917B:** Sai Gandham, Alexander Hoar, Apoorv Khandelwal, Devansh Kukreja, Yash Pahade, Udit Ranasaria, Joseph Zhong

  Tournament Champions, Wahluke VEX Tournament

- **917C:** Kanaad Deodhar, Christina Dias, Josh Eversole, Aaron Johnston, Hana Keller, Lynsey Liu, Christopher Yu

  Tournament Finalists, Auburn VEX Tournament

  Tournament Finalists, Exothermic Winter VRC Challenge

- **917S:** Tyler Hori, Alexander Ilias, Schawn Lin, Daniel Mar, Sriram Natarajan

  Tournament Champions, Washington Jump Start Tournament

  Excellence Award, Wahluke VEX Tournament

  Tournament Champions, Wahluke VEX Tournament

  Robot Skills Winner, Wahluke VEX Tournament

  Tournament Champions, Exothermic Winter VRC Challenge II

  Excellence Award, Western Washington High School Championship

  Tournament Finalists, Western Washington High School Championship

  Robot Skills Winner, Western Washington High School Championship

  Competed at VEX World Championship

- **917T:** Daniel Goto, Liam Jaffe, Emma Morrison, Nolan Orloff, Matt Suhy

  Tournament Champions, Washington B Team Tournament

- **917X:** Aashray Anand, Andreas Hindman, Pavan Kumar, Sohaib Moinuddin, Srikar Murali, Vishal Noonavath, Abhishek Sangamesawaran, Jay Tayade, Richard Wen

  Tournament Finalists, Exothermic Winter VRC Challenge

  Amaze award, Exothermic Winter VRC Challenge

- **917Z:** Divya Cherukapali, Saakshi Dulani, Reksha Rathnam, Rose Matta, Meena Meyyappan, Anjali Sribalaskandarajah, Varsha Veeramachaneni, Jennifer Yeh

  Judges Award, Wahluke VEX Tournament

  Judges Award, Washington B Team Tournament