Ra Power
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Proposal

Problem Statement:

How might we provide sustainable and cost-effective electricity to off grid homes in Tanzania using existing concepts and technologies for small daily devices?

Significance:

The challenge of providing electricity to Tanzania is a difficult but highly important one. If left to their current state, with 85% (40 million people) of the population without electricity (World Bank 2015), the country will remain below the extreme poverty line. In addition, the developing countries that lack sustainable electricity account for a large portion of greenhouse gas emissions (Ahuja 2009). Without sustainable electricity, Tanzia actually spends more on trying to import means of electricity. If they developed an electricity infrastructure, they would actually save money by not importing gas (Ahuja 2009). Therefore, if developing countries like Tanzania fail to develop a sustainable electricity infrastructure they will stay in poverty, waste money on importing other forms of energy, and will hurt our environment. Furthermore, 20 million people in Tanzania have cell phones but no access to electricity and must resort to charging stations and alternative sources of energy. There is clearly a big group of people who need electricity but cannot afford it because solar panels and other solutions are so expensive.

The main reasons Tanzania lacks electricity is due to the high costs of electricity, and lack of access to an electricity grid (World Bank 2015). Only 10% of Tanzania is connected to a grid, therefore it is impossible for 90% of the population to have power. The reason there is no grid is because of high electricity costs and government control. The government owns all the land in Tanzania and hasn't implemented an energy infrastructure. Grid extension is very costly which is likely why it hasn't been implemented. However, even if there was electricity available with the average salary of $50 a month (World Bank 2015), electricity would likely not be prioritized. Therefore, providing electricity is considered a risky investment. The last issue is with current droughts in Tanzania. Tanzania did have limited hydropower, however, that has not been very helpful in the past five years with droughts.

One of the main ways to increase GDP and move above the poverty line is to provide cost-effective electricity. There has been shown a significant correlation between GDP and electricity, especially in developing countries (Chen 2007). In order to progress as a country, Tanzania needs sustainable electricity. Gaining a new energy source would also save money by diversifying energy sources and decreasing the reliance on one (Ahuja 2009). Providing a sustainable energy source would also significantly reduce greenhouse emissions.

In conclusion, providing developing countries like Tanzania with electricity is essential for the well being of not only the country but the whole world. Other countries that share the same conditions and fate as Tanzania, but also have an appropriate climate and income for electricity include Central African Republic, Lesotho, Mali, Mozambique, Niger, South Sudan, Uganda, Zambia, Zimbabwe, Burkina faso, India, and Bangladesh.

Stakeholders:

Some of the parties that will be impacted by our project are the government in Tanzania, citizens in poverty, electrical company competitors, and renewable energy organizations.

The Tanzanian government is encouraging investments to expand electricity access, reform the distribution system, and develop new indigenous sources of energy" (Tanzania Investment Brief). The government is looking toward the public sector to help with their energy deficiency problem. They have eliminated investment barriers to make it easier for outsiders to invest in Tanzania energy. Therefore, the government would likely be thrilled to hear and help our solution. They do, however, have very tight control of the company, owning all the land. Therefore, we would have to get their approval to help their people.

Around 40 million citizens in Tanzania live without electricity. This is because they aren't connected to a grid and are unable to afford electricity. If we could connect them and provide them with cheap electricity their lives would be greatly improved. Not everyone would love to have our solution implemented, though. Tanzania Electric Supply Company is the government owned electricity company. If they felt that our solutions competed with them, they would likely try to stop us.

Other start-ups that are currently trying to harness energy to Tanzania could also be affected by our solution. For example, there are organizations trying to install solar panels in homes in Tanzania. Start-up companies like these could see us as competition, or they could try to work alongside us to help out the citizens of Tanzania.

Context and Existing Solutions:

The vast majority of Tanzania does not have electricity and almost eighty percent of developing countries lack power. Many companies, nonprofits, and government have been trying to bring electricity to these off grid homes; however from 2010 to 2012 the population of electricity having citizens of Tanzania only increased two percent. This draws attention to the fact the the solutions currently being implemented are not working, but why? Let's take a look at the first and most common solution, solar power.

Solar power requires the use of solar panels which are efficient however expensive. For the standard solar panel, silicon crystals are necessary for its production. These crystals are difficult to grow which results in high costs of production for solar panels. Installation of solar panels are complicated and expensive as well. Also since the homes that are being targeted in our problem statement are off grid, it poses another problem for solar panels as they need batteries when off grid. They are also notably more inefficient when alone rather than in a solar farm. Another solution is the use of fossil fuels to provide energy. There are several obvious drawbacks to this method however one perk is the existence of technology and infrastructure already meant for processing fossil fuel energy. One drawback is the necessity to keep getting more fossil fuel; therefore using this to power a home is not a one time cost but a fixed one meaning there are continuous payments necessary to keep power running. Another drawback is the effect on the environment. Developing nations are some of the best places to target using green energy as they lack a lot of the infrastructure present in developed nations. This means that they do not need to backtrack or “throw out” previous infrastructure to implement new energy sources. These solutions do not adequately address the problem and have been proven to be ineffective.

Why is it still a problem?

As mentioned before the current solutions have the drawbacks. Solar panels are too expensive, hard to install, and most inefficient when working singularly off grid. Fossil fuels are a detriment to the environment and present a fixed cost, not to mention the time, money, and energy needed to constantly transport the fuel. Cost and accessibility are the biggest factors in determining whether a solution for energy will take hold in developing countries. The average electricity lacking citizen in Tanzania will probably not pay his half his year’s salary (300 USD) for a solar panel that can power his tv. This creates the problem of having the technology to create the energy but not the technology to make it affordable across the board. It is obvious to the average Joe in America to use solar panels for off grid homes in America but what is feasible for America is not for Tanzania. Fossil fuels require a transportation system and a fixed cost both of which may not be realistic to implement in some villages in Tanzania.

The most challenging part of our project will be the technical aspect. However, we plan to take advantage of experts in thermoelectrics on Tech’s campus such as Dr. Yee. Also, we will take advantage of P.I’s in the invention studio and Louie in the machine shop to help us use tools and equipment to build prototypes. We also are a group comprised of a variety of different majors (CS, ChemE, ME, EE, BME, and Business), so each person brings knowledge of a different field to the group. These resources make the research and design stages of the project doable.

The implementation of our product we will create is feasible because it is low cost due to the fact that it does not utilize a battery. It will also be made up of easily accessible materials so that it can be constructed in Tanzania. The simple design that also allows for construction of the product in Tanzania makes the implementation more feasible because we do not have to worry about shipping. Also we do not have to worry about the sustainability of giving handouts but will aim to contribute to the local economy by eventually setting up the infrastructure to make our product in Tanzania, making our product a lasting solution.

Proposed Work

Goal:

Millions of people around the world lack access to electricity while having an average income that is less than the cost of a sufficient solar panel. We want to create a system that is affordable and sustainable to provide these people with electricity and help them begin to move out of poverty.

We are focusing on how we can provide electricity to people in Tanzania that is low cost and sustainable using thermoelectrics to help provide people with light, hot water, phone charging to help bring them out of poverty.

Objective:

- Develop device that can create a potential difference of at least 12 Volts. 12 Volts is more than enough of a potential difference to provide voltage to an LED lightbulb (>3 Volts), a phone charger (>5 Volts), and a system of boiling water(~12 Volts). These are big three necessities that people in Tanzania and countries alike want most.
    - Assuming a relatively high energy consuming cell phone, specifically an IPhone 5, we have discovered that this phone requires 5.45 watt hours of energy for a full charge.
    - Using basic chemistry, in order to fully heat up one liter of water 100 degrees Celsius is equal to Q = (1000 grams)*(4.186 Joules/gram)*(100 degrees Celsius), which evaluates to 418,600 Joules which is equivalent to approximately 117 watt hours.
    - If we assume that the average home in Tanzania will use the equivalent of a 40 watt bulb and that lighting will be used for 4 hours, lighting will account for 160 watt hours.
    - Thus, the total amount of energy needed to power a home in Tanzania is about 282.45 watt hours.

    - If we assume that all this energy will be used in 36 hours, and our device acquires the minimum amount of energy of 282.45 watt hours, the instantaneous power would be (282.45 watt hours)/36 hours which is 7.9 watts.
    - We are also engineering our device so that there is at least a potential difference of 12 volts and so since instantaneous power is equivalent to current times voltage, our device needs to be able to produce a current of (7.9 watts)/(12 volts) ,which yields a current of 0.66 Amps.
    - This current and potential difference are both feasible and so as a group, we are comfortable continuing with our project.
- Develop a device that costs less than $30. The average annual income in Tanzania is $600/year. As a result, we concluded a $30 cap would be reasonable and feasible for people living in off-grid homes in Tanzania; we also took into research about the people who have paid more than a month's salary for a solar panel or the cumulative cost of charging a phone daily.
- Develop a structure that is easily portable. To power a device daily, the structure must be connected to the device. As a result, for the device to be useful and practical it must be easily portable.
- A person in Tanzania should be able to build the device provided with materials and instructions. It is not practical to go to every home and build a device there or ship a built device to every home, but an easy assembly process is practical.
- Ensure the heat irradiation is not harmful to a person or their environment. It is possible for the thermoelectric generator to become hot enough to burn, which would be a liability.
- Create lens structure to provide energy regardless of sun's position during the day. This devices is driven by solar energy. Therefore, getting energy for only a part of the time the sun is out is inefficient. If a structure modification can use solar energy during all times, the power output is greatly increased as well as the practicality of the device.
- Determine size and type of lens needed to capture 12 volts of a potential difference under Tanzanian conditions. The type of lens is critical because it is related to how well the sunlight can be focused, and the size is significant because it helps account for the sun's different angles.
- Determine best thermoelectric generator. There are many different forms of conductors and thermoelectric generators. We need to determine which generator provides the best efficiency for a feasible price.
- Determine best heat sink. This is essential to our devices because it plays a big role in the electron flow that creates the current from our device.

- Develop a storage device for the energy. In the future, it might be feasible for some areas to afford storage devices that way they can power more devices because this device does not provide long-term storage.

Background:

The development of a practical energy solution in Tanzania is important due to the need for electricity. The population of Tanzania is 50 million and only 7.5 million have regular access to electricity. It is virtually impossible to not be in poverty without access to electricity to power your home. Lighting and power to basic appliances is a basic need for humans in the 21st century no matter if they live in a 1st or 3rd world country. If this problem continues to go unaddressed we will continue to see a reduced quality of life in this country, and countries with similar problems. Tanzania doesn't even scratch the top 60 countries in overall quality of life (U.S. News and World Report 2015). Allowing this dire need to go unresolved would be to sentence another generation of children and families to live without any many basic needs we take for granted in the developed world.

If this problem isn't addressed, the consequence may be that nonrenewable sources will have to be used and also that the cost of implementing these other solutions will be very expensive which could affect the family's budget on items such as food, education, and transportation.

Methods:

1. Decide upon the proper thermoelectric materials to test for most efficient design
2. Create a prototype with the proposed design
3. Monitor devices energy output for a day and interaction with the sun and then make modifications accordingly
4. Use a voltmeter to check if the voltage is at least 12 volts
5. Test different lenses to determine which lens would work best for our device
6. Determine the optimal size and shape of the magnifying device(s)
7. Monitor temperature of generator and glass for a long period of time
8. Test different heat sinks to determine most efficient for cost value
9. Test/Research different thermoelectric generators as a part of the design
10. Review different outputs for each material, lens, and temperature
11. Add up costs of materials needed to make the device in bulk
12. Determine whether or not a battery would be necessary/feasible given the output and best material determined
    a. Test batteries and/or capacitors

13. Develop easy to comprehend manual on how to build device without using written language (only pictures or other form of communication to address language barrier).
14. Contact any available local distributors of the materials used and determine cost of each
15. Research available grants and funding options
16. Get volunteers to build the device with given resources only
17. Analyze systems that could distribute electricity (small vs. large grids, grid vs no grid, etc.)
    - If idea is proven to be a viable source of electricity, determine best way to scale up the system, and design systems to distribute the electricity

Outcomes:

- Whichever lens heats up the generator the fastest and focuses sunlight the best while remaining safe. This would help make the device most efficient because it will contribute to a greater temperature differential; however, another factor is that this difference must last for a long time.
- Whichever generator can get the hottest but remain safe because this will help create a greater temperature differential.
- Whichever sink can dissipate the heat most effectively. This will help keep the generator temperature under control while maintaining a good enough temperature differential.
- The voltmeter should read above 12 Volts for multiple trials to ensure the device will be useful.
- Total cost per device including shipping and everything should be less than $50 for it to be affordable to most people in Tanzania and countries alike.
- A user should be able to build and use the device all day with ease. This is extremely significant because without achieving this, the device would not be very useful.
- Temperature of the fresnel lens and generator should not be dangerously hot at any time during the day. This would could easily burn someone and be a liability.
- Graph of energy output over time for one day. This measure would allow us to determine when the device has a low output and how that is related to the sun's position.
- Average number/use of small electronic devices increases over given timeframe. This helps determine if the device is providing enough output for consumers to purchase other electronics to use.
- Number of homes with electricity increases consistently over a given timeframe to see whether or not our solution is realistically affordable and practical for off-grid homes.

Anticipated Problems:

There are a few problems that we foresee which may cause some hindrance. One problem is shipping costs and transportation. If we ship the product to Tanzania we must increase its costs significantly as it is a fairly large object and must travel very far. To overcome this problem we aim to create a factory within the country itself and instill a local economy. This would nullify extensive shipping costs and create jobs with in Tanzania. It would also allow for the prices to be much lower as the costs of materials in Tanzania is much lower than it is here. Another problem we face is insulating the dome structure around the heat sink. We must find a cheap, efficient material that will be capable of withstanding the temperatures of the heat sink as well as not letting heat escape easily.

Some other problems that might arise are communication and collaboration with local government, volunteers, suppliers, and recipients. We must also gain the trust of the local people in order to work with them.

Project Team:

For our team we need members with incredible problem solving skills. We hope to have a highly knowledgeable team that is adaptable and persistent. We also want people who are highly passionate and outgoing. We already have five committed team members whose expected contributions are listed below.

Pranov has the problem solving skills we are looking for. His computer science and physics background will be helpful for run simulations and help with prototyping.

Sebastian is incredibly knowledgeable about energy. He is especially good with working with systems conversion and analyzing system efficiencies. He will run matlab simulations, conduct seminars for the product, and help with the actual engineering of the product. He also has connections and access to energy labs.

Parth also has great problem solving skills as he has worked through numerous challenges in his biomedical engineering classes. He also has materials science experience, therefore he will work with experimenting with different materials for the product. He is also great at research and he will spearhead finding partnerships.

Zoe has valuable invention studio and CAD experience. She will work on designs for the device. She is also very realistic and therefore can serve as a valuable skeptic in the group.

Jon is generally very knowledgeable on a variety of subjects. He is also very resourceful. His analytical mind will be helpful in planning the solution. He will also serve as the team leader as he naturally keeps the morale of the team up.

We have a committed sponsor for next year, Weipeng Zhuo. He was our facilitator this year. We believe he will be a valuable sponsor because he understands our group dynamic, and is able to assist in resolving group conflicts. In addition, Weipeng has provided us with contacts to interview about the problem space and potential solutions to the problem.

Lastly, we do not have a contact on the ground in Tanzania, but in the near future we will be contacting NGOs in Tanzania find a contact on the ground. Currently, Tom Zeeland at Raise Energy Solutions is a great contact who has implemented energy solutions in Tanzania and many other countries in Africa. Additionally, Parth is currently working with Engineers Without Borders and is working on making contacts with some people he has met who have lived in Tanzania, been there, or know someone who lives there.

Timeline:

Fall 2016
September - Come up with 3 possible designs and establish ground contact in Tanzania
October/November- Prototype Designs
December - Design Tests to implement test next semester

Spring 2017
January - Implement Tests
February - Analyze Data and figure out which is our best solution to pursue
March/April - Make edits and run tests again

Materials and Supplies:

- Cheap disposable phone
- Battery
- Wood
- Screws
- Fresnel lenses about $2 for sheet of paper size
- Different metals to test as conductors (copper, steel, aluminum)
- Different insulators to test (ceramic, sand)
- High temperature cable
- Generator (We are unsure whether we are going to make it ourselves or buy one). ~ $1.50 for business card size
- Variety of p-type and n-type semiconductors to test

Equipment:

- Solidworks

- 3D printers
- Glove box - (If we build generator, needed to construct generator without contamination)

Services:

- None needed

Travel:

- Eventual trip to Tanzania to implement solution when complete

<u>Expected Outcomes and Future Direction</u>

- Collaborate with an NGO in Tanzania to help provide guidance and provide feedback and updates when we are not in Tanzania. This will also help us gain a better understanding of villages where we can begin implementation and their cultural background.
- Implement the device in a small village, make observations, talk to the users, and then make adjustments to the device accordingly over time.
- Provide alternative source of energy for people in developing countries where there are no electrical grid. The plan is to target this certain niche
- Powers small devices that are used daily, such as a water heater, cell phone charger, a light bulb, etc.
- Distribution via affordability to the poor, and there will be an option to have a battery for storage for area that can afford a battery.
- The device will continue to be developed and made more cost-effective.

<u>Sources:</u>

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