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Problem Statement

GE gave us the objective of designing a telecom base station system that makes the most effective use of our environment. In order to complete this objective we must use sustainable energy sources, a diesel generator system, and sodium metal halide batteries that model green energy used to run the telecom base station. The base station should be able to run in places with no available energy grid.

Our area of choice is Nakuru, Kenya, which may cause a few problems. In order for this to work we must create a telecom base station that can be available to those in Nakuru. The population of Nakuru is about 300,000 and 50% are below poverty. The poverty percentage does not affect the purchase of cell phones; 63% of people have cell phones. There are many pros and cons when it comes to cell phones. Cell phones are used to help rural citizens keep in touch with urban citizens, money transfers can be made through phones, it can also boost the economy by allowing people to find more jobs, helps in emergency situations, and it can be a step further in technology. On the other hand cell phones can be a great distraction, people might spend money on phones instead of needs (food, medication, etc.), the disposal of phones and batteries harms our environment, and too much of a technology jump.

Research

From researching about the location of where we are creating this project for we found that in Nakuru Kenya it has very high temperatures and the atmosphere is dry the majority of the time. There is hardly any wind blowing thus we knew our station had to be able to withstand the conditions. The station had to be very efficient and reliable to meet the requirements needed.

Figure 1: GraceSolar 6kW

We chose to use a 6kW photovoltaic system. The 6kW GraceSolar System was the system we chose. It is easy to install and had great flexibility. Flexibility was important because we knew that the site of this station is on the a high plane in Nakuru and the system would require flexibility in certain times. This particular PV System has a guaranteed life span of 10 years on all of the components used which fitted perfectly into our goal of a nine year pay back. The system was bought for $19,080.
http://www.alibaba.com/product-gs/310883617/solar_mounting.html

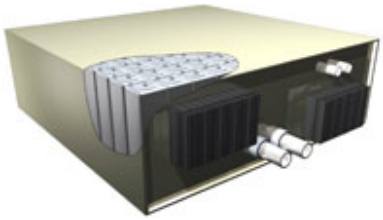
Figure 2: Onan Homesite 2400

Our system is combined of a generator that is required to supply 2kW of power and we decided to use a diesel Generator. We got the Onon HomeSite 2kW Diesel Generator for $566 which we also bought a fuel tank for the generator that held enough fuel to run the generator for an entire year.
http://www.poweredgenerators.com/onan/homesite-power2400.html

Figure 3: Box Brains BTS24

In search of a suitable Base Transceiver Station we thought it would be best to find one that was already proven to be effective and efficient in Africa. With much research we found the Box Brains Model: BTS24 which is a station that has been already used in Africa and has been successful. It can withstand the weather conditions in Africa and also this station is configured to use solar power which would fit perfectly into our System design. Finally it is insured to last 20 years, which exceeds the years the system needs to pay itself back.
http://www.alibaba.com/product-free/103946281/Solar_BTS_Transceiver_Station.html

Figure 4: GE Durathon Type A1 & A3 Batteries



We also needed to find suitable batteries that we needed for the station. We decided to use the G.E Durathon Batteries. With the option of three types of G.E batteries we decided to go with the G.E type A1 and the type A3. This decision was made because with a required 20kWh we realized that by using the type A2 which is 24.8kWh it would exceed the value that we needed causing a waste of power and could also cause damage to our system. However the type A1 combined with the type A3 produced 20.6kWh which is much closer to the required amount and which will then be more efficient and productive. Both the type A1and A3 gave a cost of $11,587.50

Figure 5: Outback Power FLEXmax 60

With all these components in our system we needed a controller to manage all of our power processes. The model of charge controller we decided to use was the Outback Power Flexmasx charge controller. This charge controller was had an efficiency of %98.1 which would enable us to be very precise and efficient with out power usage. It would also help us save energy as well. This charge controller cost $539.
http://www.outbackpower.com/products/charge_controllers/flexmax/

Analysis

The photovoltaic cells activity helped us understand how different factors and characteristics influence the output of a solar cell. Factors consist of shading, tilt, reflectors, and temperature. This project also showed us how solar cells are formed to create solar panels. In this activity we had to use a digital multi-meter to measure the current and voltage of a PV panel. A multi-meter is used to measure different variables of an electrical circuit, which are voltage, current, or resistance. The black wire is the negative side and the red wire is the positive side. We first cut a piece of cardboard and folded it in half in order for the PV cells to stand then we taped the panels onto the

cardboard. We first attached one PV cell to a multimeter and placed the panel facing the sun to figure out how shading affected the cell's output. The amount of the panel that was shaded varied from 0 to all. After the shading we wanted to determine if the angle of the panel had an effect on its power output. We used a protractor to measure the angle between the ground and the panel using angles from 0 to 90 degrees. We came to the conclusion that all these factors do indeed influence the output of a solar cell.

In deciding what type of system we should use, concerning energy production, we took into account how long the entire system would last. All of the components averaged to about 10 years and so we decided to choose the system that would be most cost effective in about 10 years. From the table below, the type of system that is most cost effective at about 10 years is the 6Kw Photovoltaic system. As you can see from the table, it is by far the superior system when compared to an all Fossil Fuel or an all-Renewable energy system.

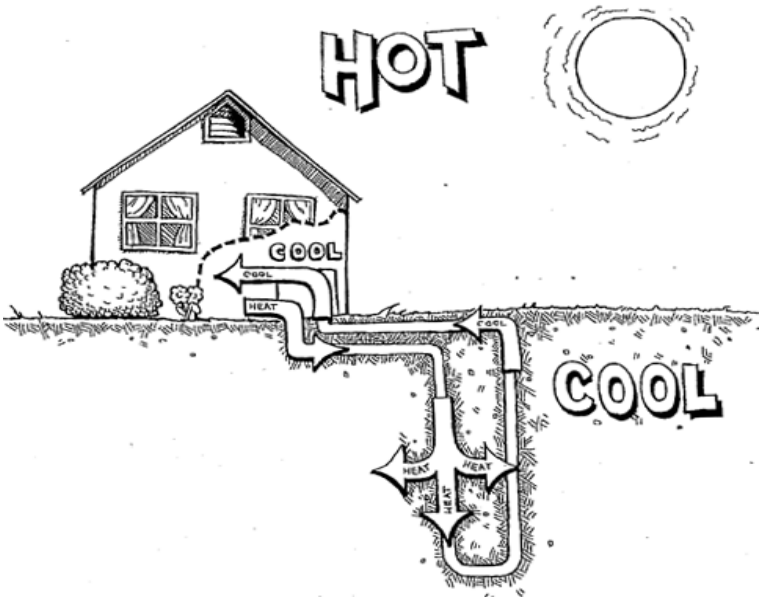
Figure 6: Cash Flow of PV, Battery Size, and Fuel Options

PV Size	Batt size	Fuel Use	3yr	6yr	9yr	15yr	30yr
(kw)	(kwh)	(gal)	($)	($)	($)	($)	($)
0	0	1138	17070	34140	51210	85350	170700
1	0	927	17405	31310	45215	73025	142550
2	4	745	20425	31600	42775	65125	121000
3	8	562	23430	31860	40290	57150	99300
4	12	380	26450	32150	37850	49250	77750
5	16	199	29485	32470	35455	41425	56350
6	20	58	33120	33990	**34860**	36600	40950
7	24	7	38105	38210	38315	38525	39050
8	28	0	43750	43750	43750	43750	43750

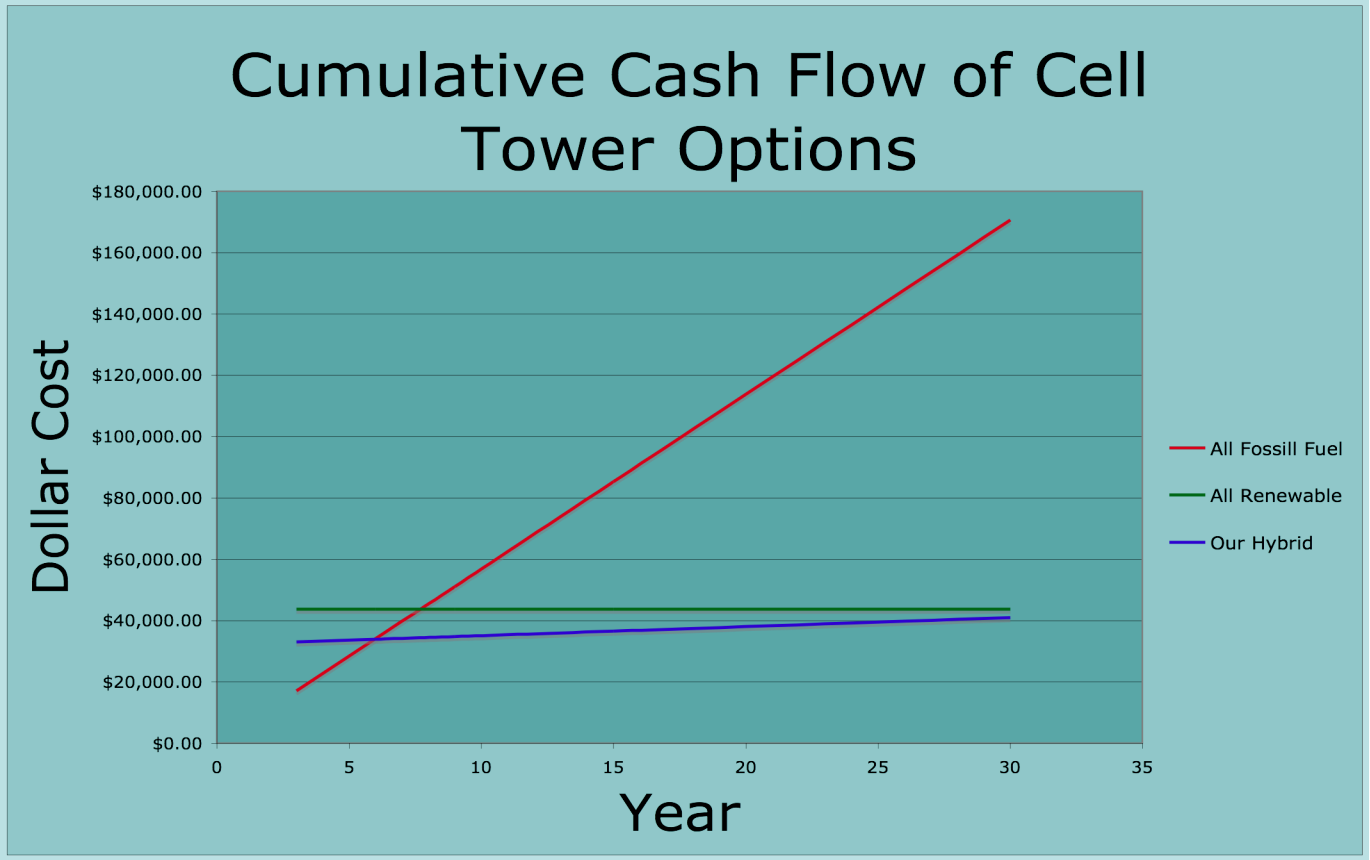
We decided which batteries to use for the system by computing how much energy is needed to keep the Base Transceiver Station tower running overnight. From our calculations, we came up with 20 Kwh every night and so we would need the batteries to hold at least 20 Kwh. The Type A2 battery was an option because it met the energy requirement, but it turned out to be more economical while still meeting the stored energy requirement to utilize the Type A1 and A3 batteries. The benefits to our choice are that we saved $2,362.50 and also eliminated any excessive use of battery storage.

GE Durathon Battery			
	Type A1	Type A2	Type A3
Stored Energy (Kwh)	12.4	24.8	8.2
Price	$6,975	$13,950	$4,612.50

In deciding how we are going to air condition the hut, we searched for an air conditioning method that would be cost efficient in 10 years, be eco-friendly, and also be easily maintained. The Earth Cooling Tubes method was found to meet these specifications. The Earth Cooling Tubes system that we decided to use are Polypropylene tubes of 8 inches in diameter and placed 6 feet underground leading from an intake on the ground outside of the hut to a ground opening inside of the hut. This system is cost efficient because it only requires an initial cost (with low maintenance cost), is eco-friendly because it has virtually no significant impact on the environment since it is underground, and is easily maintained by placing rain covers and filters on both ends of the tubing to prevent flooding, insect infestation, and molding. (A basic model of an Earth Cooling Tube system is shown below.)



An economic analysis shows that our 6 Kw Photovoltaic-Fossil Fuel system is a much more economical choice as compared to an all fossil fuel system and an all-renewable resources system. As shown by the graph below, the initial cost of our hybrid system is much lower than that of an all-renewable system, and while the initial price of an all fossil fuel system is nearly half of our hybrid system, the cumulative price to fuel the diesel generator skyrockets past the price of our hybrid with 7 years. (A list of the prices for each component is included below the graph of *Cumulative Cash Flow of Cell Tower Options.*)

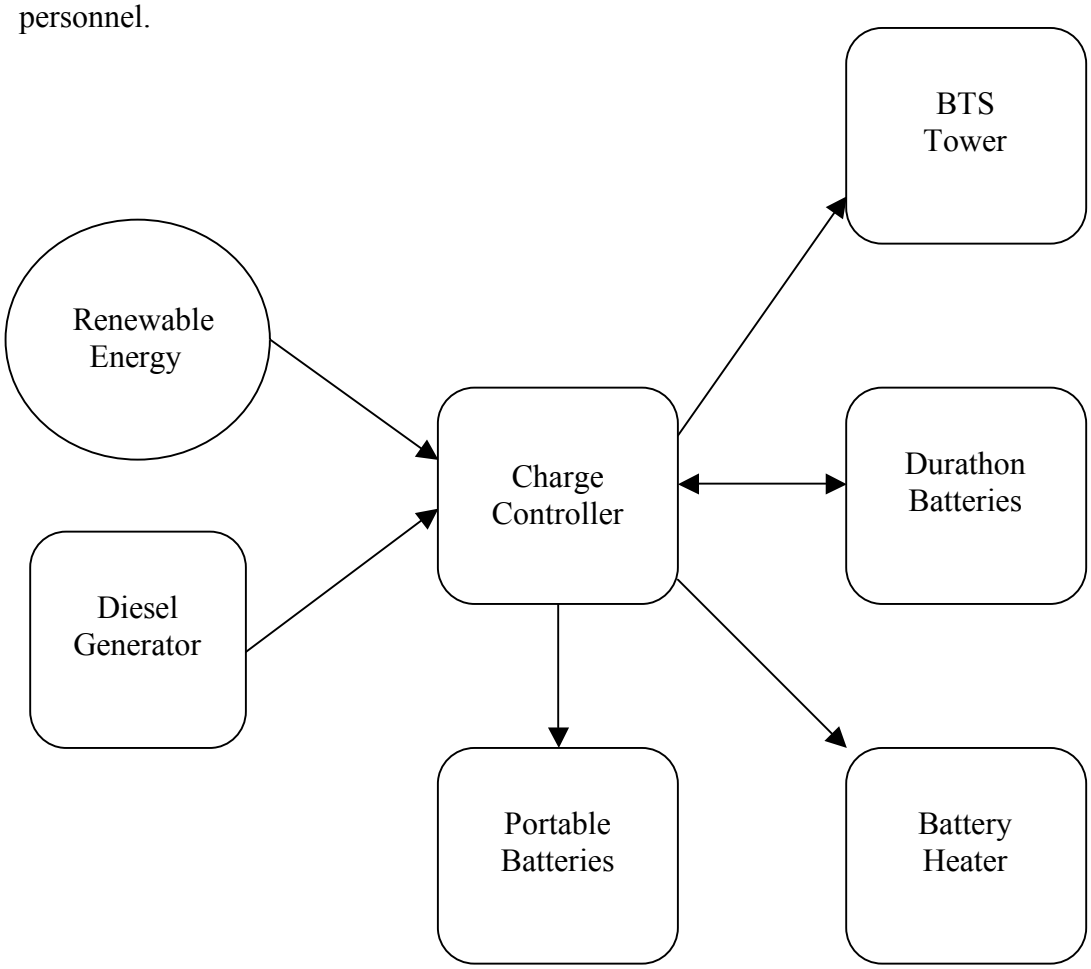


*The price for our hybrid system in the graph above does not include the cost of the Earth Cooling Tubes.

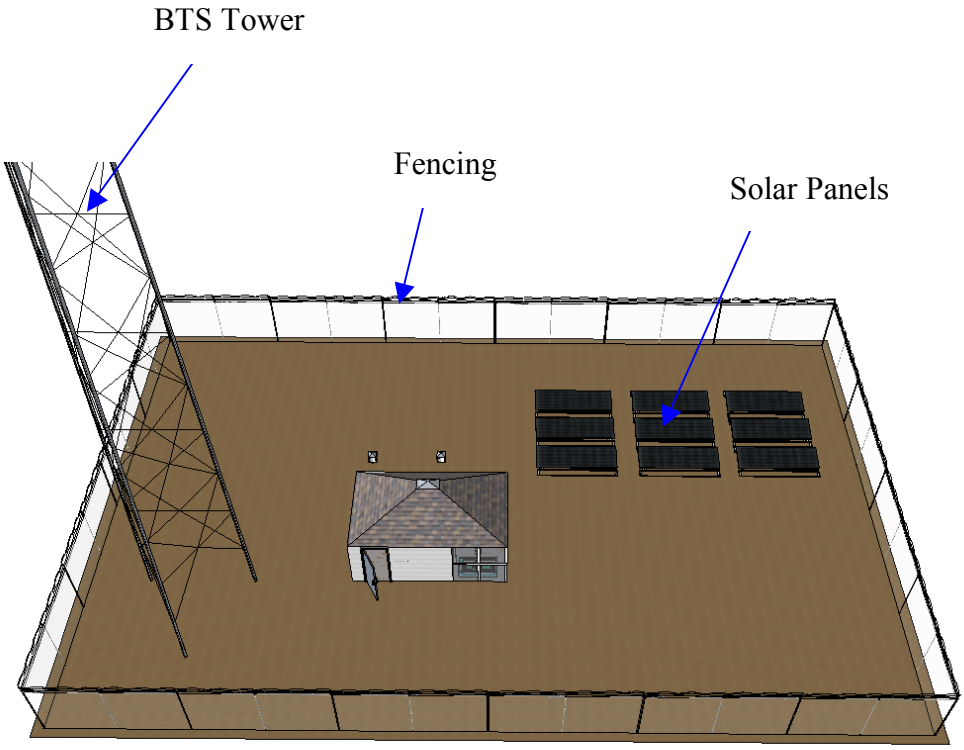
Components	Dollar Value
Earth Cooling tubes:	3,180.00
BTS System:	4,000.00
Batteries:	11,587.50
PV System:	19,080.00
Diesel Generator:	566.00
Charge Controller:	539.00
Total Cost:	**$38,952.50**

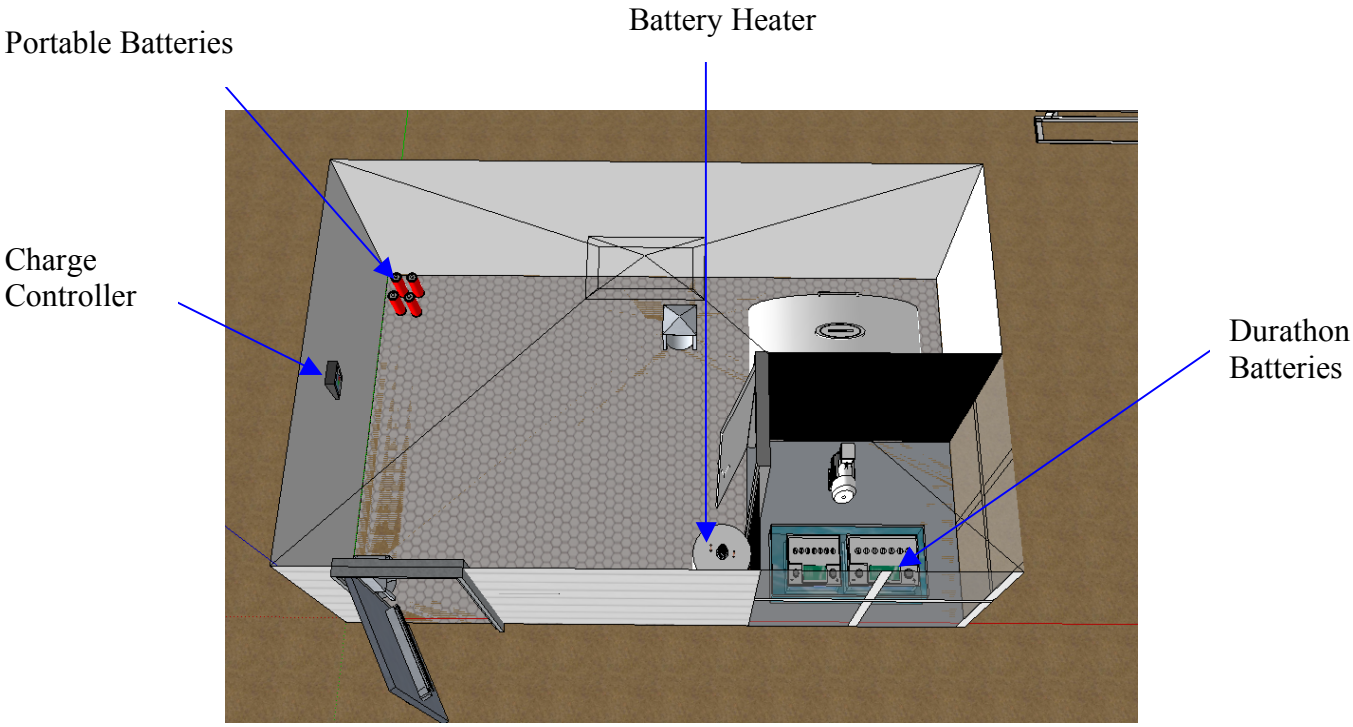
Detailed Description

As shown in the diagram below, the system used two different energy sources to create the electricity needed to run the system. Using solar power, the renewable energy came from the sun, and used solar panels to convert the solar energy to electricity. Additionally, the diesel generator used diesel fuel to create electricity. Both sources transferred the electricity to the charge controller, which could send out the appropriate amounts to the various loads in the system. There were three main loads that the electricity was delivered to, the BTS Tower, the Battery Heater, and the Batteries. Due to the system being a majority solar powered, during uncomplimentary weather such as clouds and stormy days, the Durathon Batteries would use the stored electricity from complimentary days to power the BTS Tower and Battery Heater. The charge controller regulated when and where the electricity was delivered from each source to the loads. Although minimized as much as possible, the excess energy that was gained from the system, but did not have a place to be stored, was routed to portable batteries by the charge controller. The hut that all the equipment would be placed in was build with enough space for the components and for maintenance processes. With the location of the Station a fence was placed around the hut to keep out animals and unauthorized personnel.

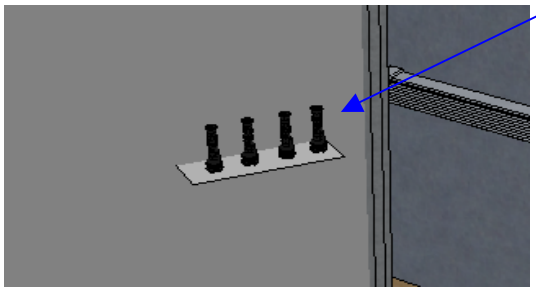


The main components of this system are displayed below with a Google SketchUp model of the model:



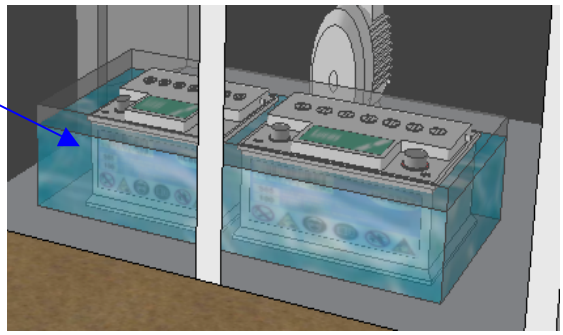


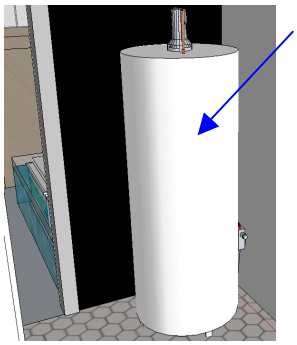
In addition to the main components of system, small features of this design saved a great deal of energy. Some of these smaller features include Crank-to-Charge Flashlights, the submersion of Durathon Batteries in a heated liquid, earth cooling tubes for natural air conditioning, the selling of charges from dump energy, passive solar heating of the Durathon Battery room, and placing the Diesel Generator in the Battery room. Each is described below:



Crank-to-Charge Flashlights are on a shelf immediately as you walk in the door. This is for maintenance workers, or any operating personnel to use inside of the hut. Using this type of lighting uses none of the system's electricity, whereas overhead lighting would.

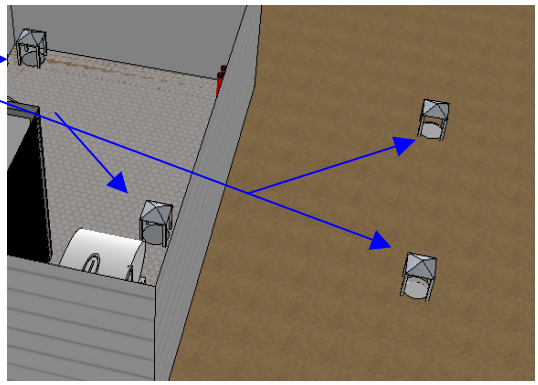
Submersing the Durathon Batteries in a low specific heat liquid will allow for less energy to be consumed in heating the batteries. The complication arises with finding a liquid that will not evaporate at 300°C but still will not let the battery heat escape into the surrounding air.

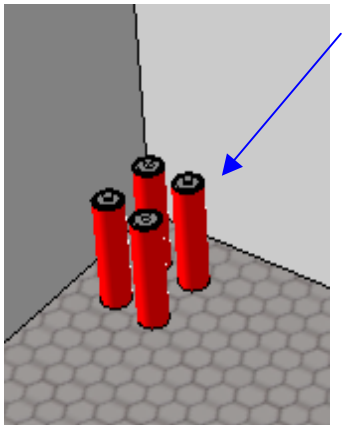




A 'water' heater located just outside of the Durathon Battery room would heat the liquid surrounding the Durathon Batteries. Simple modifications could be made to a normal water heater to accommodate for the acidity, viscosity, or any other complications of a foreign liquid different from water.

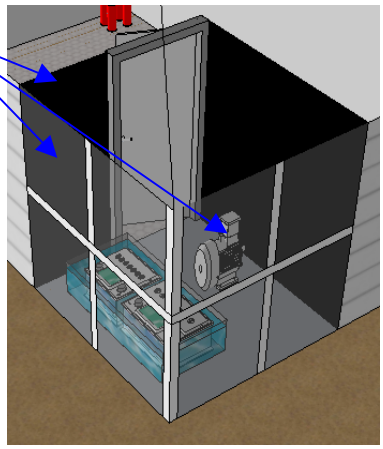
Earth Cooling Tubes located underground were used to cool the hut, excluding the Durathon Battery room. This natural air conditioning saved a great deal of the systems energy by not having to power an electric air conditioner. Aluminum coverings as well as tube filters prevented undesired objects from entering either end of the tubes.





Portable Batteries were utilized to put the 'dump' energy of the system to use. Any excess electricity that is created by the system, yet unable to be put to use, is routed to these portable batteries. Then, once the batteries are full, locals can transport them into the local towns and sell charges for civilian's cell phones. This will help bring in money for the system, and decrease the payback period. However most importantly, not waste any energy the system creates.

To help reduce the electricity needed to heat the Durathon Batteries, the Durthon Battery room has external windows that encompass two of the four walls. In addition, the other two walls are painted black, and the Diesel Generator is placed in the room. All three of these features help to heat the Durathon Batteries, causing for the 'water' heater to do less work. With the Battery Heater doing less work, more electricity is saved, and the overall system costs decreases because less electricity needs to be created.



Conclusion

The designed model met GE Transport requirements in all fields, and fulfills the desired specifications. Using minimal resources, and green energy, this model can safely be implemented in countries across the world. Not only does this allow for globalization through cellular equipment, but it gives cellular capabilities to those most in need. The most important characteristic of this model is that it can aid those who truly need to use cellular devices in an area where long-distance communication is a difficult obstacle to overcome.