Where there is no engineer – designing for community resilience

Irish Aid Development Education Design Challenge 2015

Project:	***MODIFIED AIRDROP SYSTEM***
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Abstract:

Kenyan cover 581,309km^2 and is divided into 70 districts supporting over 44milion people, the main water source in Kenya comes from surface and groundwater. However, these both rely on rainfall to replenish the natural system, unfortunately due hot air from Indian ocean the climate tis mostly hot and humid with low annual rainfalls of around 600mm. this means the Kenya struggles to meet the minimum demands of 5.5l/person/day. This means a new source of water is required. This project looks at the possibility of extracting moisture directly from the air, by adapting and modifying a new technology which was developed in Australia for crop irrigation. The main focus these modifications would be to backwards engineer this technology and redevelop it in a low tech, low cost way which could then be utilized by the people of Kenya.

Program Theme: *Please select the program theme under which your project / concept is being submitted by placing an "X" in the appropriate column.*
(note you can select more than one thematic area)

1. Climate Resilient Infrastructure	
2. Self-Supply Water and Sanitation	**X**
3. Community Participatory Health	
4. On and Off (Micro) Grid Energy Systems	
5. Food Security	
6. Applying Big Data in the Community	

Objective (What You Are Planning To Do):

To create a system to provide a new water source which is both low cost, and is independent from existing bodies of water, so that it can be utilized in harsh environments. That this system would easily replicable by the Kenyan people to implement and adapt to their own need.

Background (Why you are doing it):

Kenya is a country located on the east coast of Africa along the equator. It covers 581,309km^2, and is divided into 8 provinces and 70 districts. Rising from sea level to 5199m above at the top of Mt. Kenya, the country comprises mostly of arid and semi-arid areas with near-desert landscapes, giving way to shrub and grasslands in the south. The climate is hot and humid; this is mostly due to the effects of the hot air from the Indian Ocean. This high heat and humidity results in a low annual rate of precipitation, typically occurring from March to June, and yielding an average of 630mm/year with a variant of 200mm. This creates a problem, as Kenya's two main sources of potable water is from surface water and groundwater, both of which relay on a rainfall for replenishing these natural systems. This means that Kenya's natural water resources, do not meet the demand placed on it by its population, which is estimated to be 44.35 million from the 2013 census and growing at a rate of 2.6%, this leaves most of the population without any fresh water.

In 2003 the World Health Organisation reviewed the requirements for water for health-related purposes to derive an acceptable minimum to meet the needs for consumption. Based on estimates of requirements of lactating women who engage in moderate physical activity in above-average temperatures, a minimum of 5.5 litres per capita per day will meet the requirements of most people under most conditions. This volume does not account for health and well-being-related demands outside normal domestic use such as water use in health care facilities, food production, economic activity or amenity use. To meet this standard in Kenya due to its limited and degrading water sources there is a need for new and innovative solutions to this water problem.

Our proposal to alleviate this problem is not to focus on refining an already dwindling water source, which is inadequate both in volume and quality, but rather to focus on creating a new water source from relatively underutilized natural resource, which can be found in the air itself. This natural resource is water vapour in the atmosphere. The climatic conditions which prevent precipitation from occurring are in part due to high levels of relative humidity, which in Kenya range from 79 to 64%on a monthly average, with an annual average of 72.8%. This is where our proposal comes in to look at the potential for extracting water directly from the atmosphere. Upon our initial investigation of this concept we found that the idea was not altogether alien, and that research had being carried out in the area.

One such project investigating the potential of harvesting atmospheric water was a study in the International Journal of Physical Sciences Vol. 2 in the article '*Potential of harvesting atmospheric water over urban cities in Kenya'*. In this study atmospheric water extraction was suggested through the use of fog water collection technology, which consisting of a fog collector screen made up of polypropylene mesh which was mounted vertically on two or more posts. Based on efficiencies of 10-30% and the maximum potential water harvesting form eight different wind directions, data was compared. For example based on device efficiency of 10%, stations around Nairobi city indicated the maximum water harvesting of 3.2, 1.4 and 2.9 litres/m^2/day respectively, and showed that most urban cities in Kenya have high potentiality of water harvesting from fog and air humidity (J.N, Opere, J., MNg'etich, Ongoma, & Mutai, 2014).

Another approach which focuses on the same concept of extracting moisture from the atmosphere, but achieves it through an alternate means is the Warka Water Towers. These were originally designed by Arturo Vittori. The design of these towers was inspired by the many plants and animals that have developed unique micro- and Nano-scale structural features on their surfaces that enable them to collect water from the air and survive in hostile environments. Vittori specifically studied the Namib beetle's shell, lotus flower leaves, spider web threads and the integrated fog collection system in cactus in order to identify specific materials and coatings that can enhance dew condensation and water flow. The resulting towers consist of an outer frame structure, made with split bamboo elements with plastic mesh that collects droplets of water from the high humidity in the air and a collector where the dew condensation can happen at night located within the structure. Though designs may vary from tower to tower typical estimates for water collection are in the range of 13-26 gallons/day, and should take six workers roughly four days to complete at a cost of approximately €1000. Potential evaporation rates were initially analysed and mapped by T. Woodhead in 1968. His research revealed that the mean monthly evaporation ranged between 85 and 260 mm. the study also revealed that months with the least precipitation had the highest evaporation rates. This indicates that the Warka Water Towers would be more effective during drier months.

Figure 1 fog water collection

Figure 2 Warka Water Tower

Though both these options have being proven to be viable for water generation, the fact that both are passive systems means that they are inherently limited to the amount of water they can produce. The application of such systems to supply a medium to large population would require a large area and a significant capital investment. This in combination with the on-going maintains that would be required make both systems economically infeasible for large scale production.

Therefore these systems could not be utilized to achieve the goals of our project. Instead we looked at a relatively new design which we discovered known as The Airdrop Irrigation System. The system was designed by an Australian designer called Edward Linacre, for the purpose of providing water for irrigation. The design won the James Dyson Award an international design award that celebrates, encourages and inspires the next generation of design engineers.

The system itself consists of a solar powered fan that feeds air into pipe that flows into a subsurface coiled copper pipe which in turn feeds into an underground storage tank. As the humid air is drawn into the system the rapid reduction from ambient to subsurface temperatures causes the moisture in the air to condense and form water droplets. From the tank the water can then be extracted and distributed along the top layer of soil for irrigation using a pump and pipe system. According to the inventor *"11.5 millilitres of water can be harvested from every cubic meter of air in the driest of desert"* this number was based of arid lands in India with humidity levels of 54% (Heimbuch, 2011).

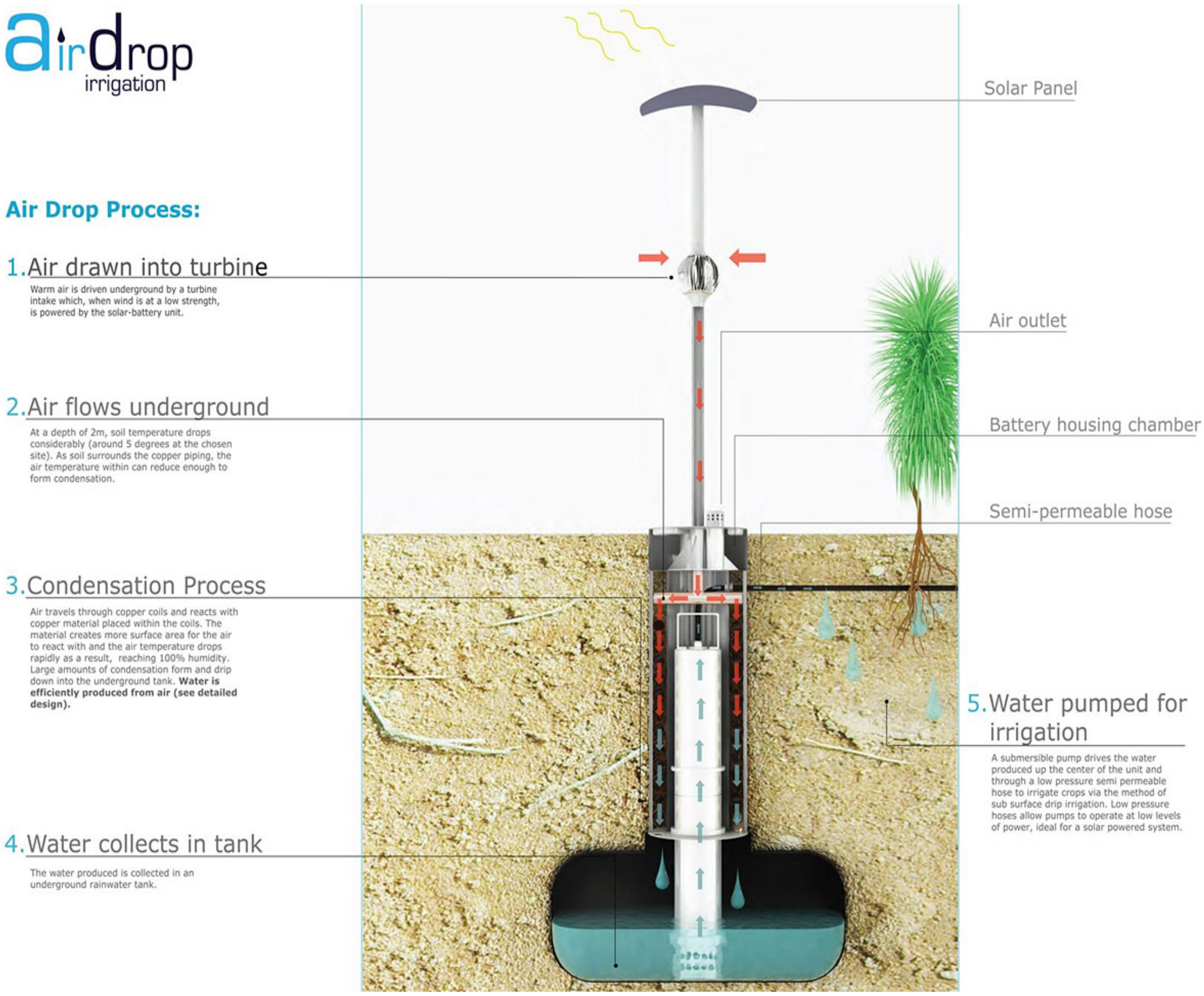

Figure 3 Air Drop Irrigation

Our concept will revolve around redesigning this system repurposing it to use a source of drinking water and to be overall more cost effective, which will be referred to as the Modified Airdrop System. The main elements of this redesigning will be to identify alternate materials which can be utilized, and to replace solar energy as the system driver with a less technical of wind energy.

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As converting from solar to wind was one of the main modifications we first had to establish whether or not the potential wind energy required is available. From our research we found that over the course of the year typical wind speeds vary from 0m/s to 9m/s, rarely exceeding 18m/s, with the average daily maximum wind speed is 8m/s. This indicates that modifying the airdrop system to use wind energy is a possible.

For the wind harnessing system a vertical axes windmill was selected. The benefit of this type of windmill as opposed to a more traditional windmill is that it allows for a direct drive of the intake fan below. The vertical windmill also has the added benefit of an increased efficiency due to the fact it has a larger wing area allowing it to harnesses more of the energy. Basic design considerations for the windmill assembly were that it had to be low cost, light weight, and easy to assemble. For these reasons the main wing assemble utilises a 55 gallon plastic drum which is quartered and orientated between two plywood plates around a central aluminium shaft which extends from the top of the windmill assembly to the top of the intake fan 500mm below its base, where it acts as a drive shaft. The efficiency of this windmill is determined by the revelations per mint RPM achieved at varying wind speeds. The calculation below was used to determine this.

$$RPM = \frac{\left[\left(\frac{1}{8}\rho\pi D^2 V^3\right)(A_w)(60)\right]}{W/C}$$

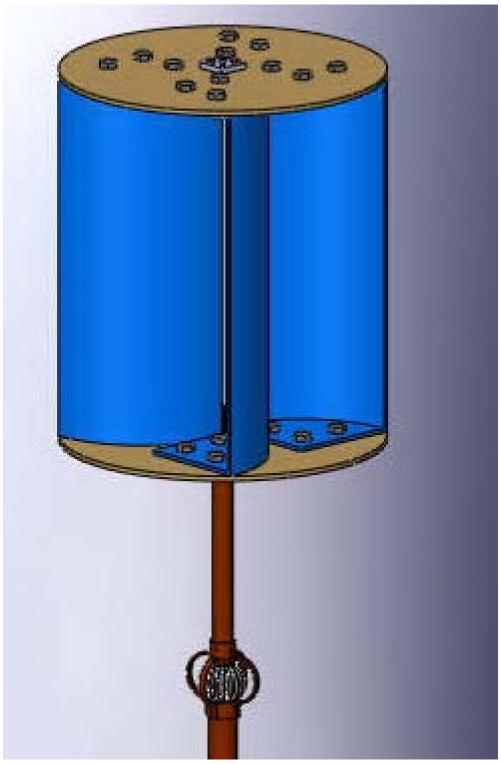

Figure 4 Modified Airdrop System

The intake fan takes the humid air from the atmosphere and drives it into the condensation coil. The fan is designed to rotate at a ratio of 4:1 whit the windmill above, this is achieved by using gears which are connected to the base of the drive shaft, and allows the fan to reach a higher capacity by revolving at a higher RPM. The fan is made from lightweight aluminium material, but could be made from other lightweight such as tin or plastic. The fan 20 blades has height of 90mm, has an intake volume of 0.0056m^3 per rotation.

For the condensation coil the original Air drop system used a copper pipe packed with copper wool to increase the surface area where condensation could occur, and also to create turbulent flow in the pipe. As copper is an expensive material it was decided to replace it with a more cost effective alternative. The selected alternative was a corrugated PEX pipe, this material was selected as it had similar properties to the copper pipe at less than a tenth of the cost, and the corrugations provided the increased surface area and turbulent flow. This pipe was then placed in a 500mm ∅ coil which started 500mm below ground surface and extended down for 2000mm. however in order to estimate the yield from the PEX pipe a new set of equations had to be developed from the basic principles governing phase change, in order to determine the heat transfer coefficient and the rate of condensation. The heat transfer coefficient for the PEX was determined to be 43.8W/m^2°K and was calculated using the following equation:

$$hc = \left(\frac{k}{D}\right) St Re Pr$$

Where:

Re = Reynolds Number

$$St = \frac{\frac{f}{8}}{0.9 + \left(\frac{f}{8}\right)^{\frac{1}{2}}\left[g(h^+, Pr) - 7.65\right]}$$

$$f = \left\{-2.0\log_{10}\left[\frac{\frac{k_s}{R}}{7.4} - \frac{5.02}{Re}\log_{10}\left(\frac{\frac{k_s}{R}}{7.4} + \frac{13}{Re}\right)\right]\right\}^{-2}$$

$$k_s^+ = \frac{u_b k_s}{\vartheta}\left(\frac{f}{8}\right)^{\frac{1}{2}}$$

‘h = k_s’

$$g(h^+, Pr) = 0.55(h^+)^{\frac{1}{2}}\left(Pr^{\frac{2}{3}} - 1\right) + 9.5$$