"Made in Kenya"

– An appropriate and "appropriable" thermal desalination device for low income rural households and communities in arid and semi-arid areas.

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Summary:

We have been developing an affordable and technologically appropriate thermal solar desalination device that can be made in Kenya or other developing countries. It can run without power from the grid, and it can be "appropriable" by rural households or small communities. We're aiming at creating a not-for-profit Kenyan entity to lead on a Product Development and Cost Reduction programme, to increase yields, optimize the fabrication process and create a market-ready product.

- Kenya is a good choice because much of its water supplies comes from boreholes that produce water that is often brackish or with excessive fluoride content.

- Our current prototype built in Northern Kenya has been a successful proof of concept, but needs to go through a programme of targeted improvement and optimisation to increase yields of water and decrease costs (we have many opportunities for improvement; some idea of where to source good mechanical engineers in Kenya; and we know what the competition looks like too when setting targets)

- We have a good team of collaborators on the ground from different Kenyan research institutes and the Strathmore Energy Research Centre in Nairobi, with successful experience in engaging with communities, and we endeavoured to build and test our prototypes with them. We are determined that the device be "appropriable" by local communities and businesses regarding its manufacture, sale and maintenance.

- Ideally, the not-for-profit company could be set-up and led by the Kenyans themselves, and able to operate in Kenya right away. A company registered in Kenya in the first place and wholly or mostly run by Kenyans could make the technology more appropriable.

- This company would require funding of about £100,000 for delivering the Product Development and Cost Reduction programme.

- This funding would allow the company to hire a workshop, buy materials and employ a qualified engineer for six months to develop the prototype further by incorporating the various improvements to design and construction that we have identified. This would allow us to bring the yields of freshwater to the minimum range of 10 – 15 L/day, potentially more. This could be followed by a focused cost-reduction programme, alongside community engagement exercises where potential user would be encouraged to use the device for free with assistance from the company, and give us their feedback.

- However, who will take this on, and will make it easier or harder for the company to raise funds? I do not know yet the answer to these questions, we're starting to look, e.g. through contacts at Strathmore Business School.

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Figure 1: Locally built solar thermal desalinator, Lodwar, Kenya (December 2018)

1. Motivation for a new type of solar desalinator – who would benefit?

The nutrition, health and livelihood of many Kenyans depend on scarce freshwater, especially in the arid North where boreholes supply most of the water but elsewhere too. This groundwater is often saline, an issue for human consumption, plant growth and livestock. In addition, a relatively high proportion of boreholes supply water may have excess fluoride beyond the 1.5 ppm limit specified by WHO, as we observed in Nairobi and in Turkana, but this includes wells that are otherwise compliant with respect to salinity levels.

Desalination is thus critical to any development in the Counties, as testified by the very wide range of stakeholders who are supporting this proposal. However, given the low income status and remoteness of the region, solutions must be locally sustainable and appropriable. One resource that is locally abundant is solar energy, which can provide the driving force for desalinating water, either using thermal or electrical-powered devices.

However, the availability of infrastructure, technical skills and supporting businesses need to be carefully considered:

- Grid electricity is available in some areas but not others, and power cuts a concern; solar PV is expanding; Reverse Osmosis desalination works but is expensive and requires robust power supply, financial planning and technical support;
- Metal working and motorcycle maintenance and mending are widely practised and well regarded occupations for skilled homegrown technicians, but plumbing is not. Even hand pumps for boreholes are often in disrepair and not being mended for lack of skills tools and appropriate ownership structure or perception.
- Businesses that supply water may feel that competition from desalination devices is harming them. On the other hand, the opportunities could be lucrative for businesses making, maintaining and mending desalination devices, or operating them for their operations or for sales.

This project aims at developing a solar thermal desalinator that can be locally constructed, maintained and repaired, using components for which a supply chain can be established, and in areas where grid power is not available or reliable.

In this respect, Turkana County is an ideal location to develop technologies and business models that can be applied in other parts of sub-Saharan Africa that face similar challenges and are sunny. In other region of the world, for example in India, similar situations may prevail regarding salinity and contaminants such as fluoride and arsenic in areas where communities are living on very low incomes.

A first prototype ("Mark I") was built and operated in November 2016 in Lodwar (Turkana), with a local fundi then building a replica that achieved the same performance. The design was very crude and yields of freshwater low (2 L/day), but we achieved our aim of demonstrating the principle of using local resources and skills. A second prototype (Mark II) was built there again in October 2018 with improved yields, in collaboration with local researchers.

2. Specifications

Following established figures that were determined by aid agencies, the minimum requirement for drinking water is about 2.5 – 3 litre per person per day (lpd). To this should be added
3 – 6 lpd for cooking, for which the contribution to daily intake of toxic substances like fluoride and arsenic may be significant. Generally, the additional intake of contaminants may be through that which is present in the food itself because plants were cultivated or animals were reared using water that contained that contaminant. However, many foods will absorb water during cooking e.g. rice ,and we also observed that people in Turkana and other areas in Kenya enjoyed eating food (my suggestion that food could be steamed met with amused rebuttal).

Therefore we considered the case of a household that needs to supply as a minimum its needs in fresh water for drinking, a minimum of 10 – 15 L/day for 4 – 6 people. Ideally, they would be able to own and operate a device that would supply this need, or their community would be able to do so for the benefit of all its members.

3. Our device and its Unique Selling Points

The device that we have been developing is a solar thermal desalinator, or solar still, i.e. most of the energy used in solar heat. It requires some electrical power, representing a small proportion of the total energy input. This power comes from a solar photovoltaic panel (either directly or through a battery).

In addition, the device has the following distinctive features, which differentiate it from other currently available designs:

1) It is made using materials that either are locally available, or are relatively straightforward to procure, and local labour, technical skills and entrepreneurship.
2) It aims at being economical to build, operate, maintain and repair.
3) It should be relatively "low tech", though it may incorporate reliable, ready-made components if these can be cheaply procured.
4) Low yields are a well-known shortcoming of solar stills. To increase yields, the device should have at least two stages operating a two different pressures ("double effect"), where the heat of vapourisation captured in one stage is recovered during condensation to allow the vapourisation of additional water at a lower temperature in a second stage.
5) Solar concentration should be used, for the following reason: It could be developed into a device for sterilizing water where salinity is not an issue (not requiring evaporation and condensation, just heating the water and holding it at high temperature for long enough for sterilization); or a solar cooker (probably coupled with a heat store); and potentially the higher temperatures that may be reached could allow further use of "double effect" for increasing the yields of fresh water.

1) and 2) are aimed squarely at providing resilience and economic opportunities to the poorest communities. 3) is for reliability as well as affordability. 4) and 5) are for meeting very demanding specifications as well as allowing different applications in the future.

4. Existing devices - the competition!

We have looked at patents belonging to companies that have developed commercial solar thermal desalination. Note that both have succeeded in getting funding e.g. by DfID and others, and independent validation by ARUP and others. We ought to find out if F Cubed or Desolenator currently have ongoing testing or customers in Kenya.

- **F Cubed** with its Carocell and ZLD technology. This seems to be based on the work of the late Peter Johnstone. Strength seem to be a good distribution system at the top of the panel (including if necessary through a wick), as well as hydrophilic transparent materials on top to both transmit solar light and trickle down a film of water on the underside, which (I believe) would prevent a fog from blocking the light. A hydrophilic fabric also seems to be soaking the saline water as it trickle down, although one learns helpfully that for example the oxidized surface of aluminium is hydrophilic and helps with that already. There does not seem to be a "double effect" where the heat released by condensation is reused for evaporating more water under conditions of lower vapour pressure, yet they do seem to reach the landmark of 10 $L/m^2/day$, which our prototype Mark 2 would in principle be capable of achieving. I would be a bit concerned that their apparent reliance on fabric materials potentially could make it easier to breed pathogenic microbes, and also it is possible that the water flowing behind clear cover leads to algal growth.

http://www.fcubed.com.au/aspx/home.aspx

- **Desolenator**, the brainchild of a Johannus Janssen, simply proposes to use a solar panel to provide electrical heating, which vapourises the water. Again, it seems not to use a "double effect" but simply recover waste heat from the PV conversion and from the condensation of vapour and heated residual brine. Water seems to be flowing up the panel in tubes on its way to get vapourised. They are now associated with Imperial college. I like the way that they are proposing to add a microchip for monitoring and for enabling micropayments.

  http://desolenator.com/product/

5. Current status of our prototype

A prototype Mark II was built in Lodwar (Northern Kenya) in one week in October 2018 by a team of researchers from the University of Edinburgh, Strathmore University, Kenya Forestry Research Institute in Turkana, Kenya Water Institute and Kenya Agriculture and Livestock Research Organization. Funding from the British Council as part of the Newton scheme is gratefully acknowledged. The prototype was commissioned and tested in December 2018 over a mere couple of days. It demonstrated the following:

- Construction in local conditions, involving local traders and skills.
- Proof of principles of double effect (through air humidification / dehumidification in the second stage)
- Production of 2.9 litres of water in 3 hours (figure 2), for a collecting area of 2 m^2. While this is short of target (2 L/hour), there is much to celebrate. Considering that this was a first prototype using a stainless steel sheet as reflector and a homemade humidifier / dehumidifier; that the orientation of the parabolic trough had not been optimised; and that there are many areas of the design where we are aware of straightforward and low cost improvements, this result is very encouraging.

6. Further work: from prototype to product

Prototype Mark II was built in Kenya in record time, with three academics from the University of Edinburgh leading the operations and many inputs from their Kenyan colleagues.

What is required now is to transfer ownership to a Kenyan entity that would lead on a Product Development and Cost Reduction programme, to increase yields, optimize the fabrication process and create a product that can be marketed. We are proposing to create a Not-for-Profit company in Kenya, assuming that this is something that can be done under Kenyan corporate law.

This company would require funding of about £100,000 for delivering this programme.

This funding would allow the company to hire a workshop, buy materials and employ a qualified engineer for six months to develop the prototype further by incorporating the various improvements to design and construction that we have identified. This would allow us to bring the yields of freshwater to the minimum range of 10 – 15 L/day, potentially more. This could be followed by a focused cost-reduction programme, alongside community engagement exercises where potential user would be encouraged to use the device for free with assistance from the company, and give us their feedback.

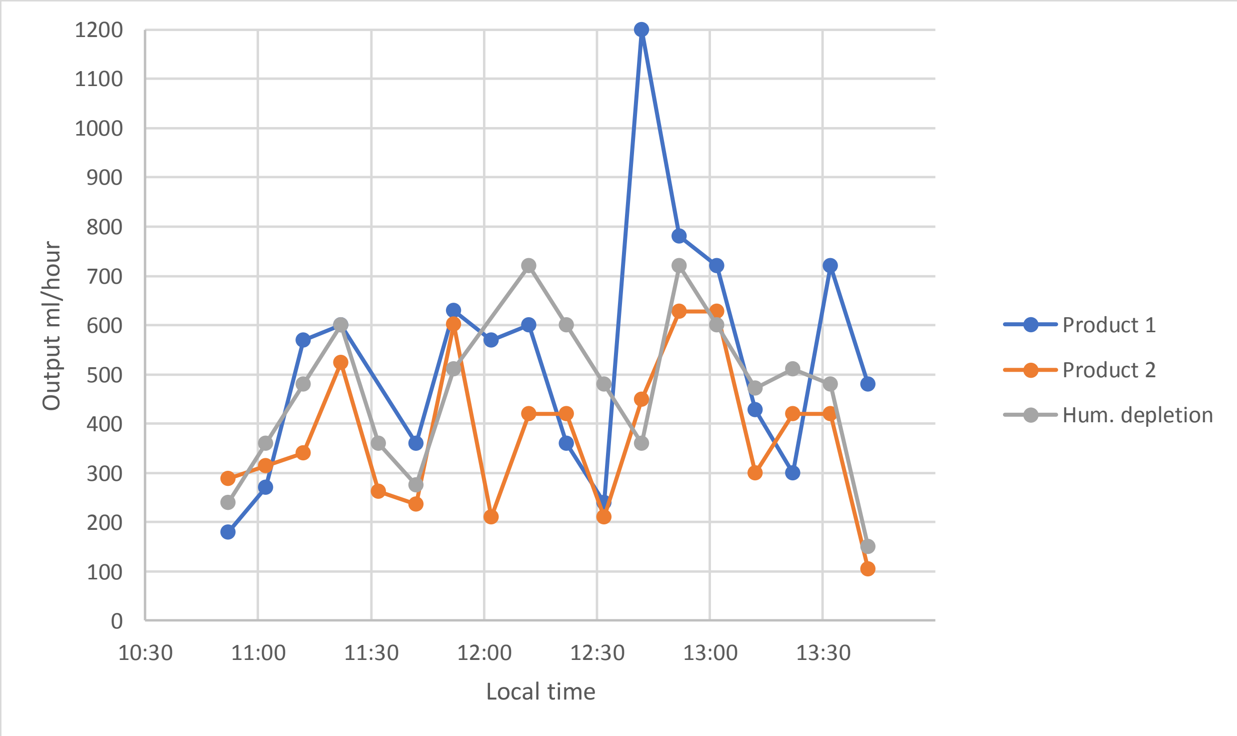

Figure 2: System water production on 7th Dec 2018. Product 1 is fresh water from direct condensation of steam, and product two comes from the humidification / dehumidification of air.

Figure 3: Building the prototype, October 2018

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