Solar Thermal Evaporation and Purification Apparatus

Stony Brook University
Honors College
Electrical and Computer Engineering

Mentor: Dr. Matthew Eisaman
Charles Patterson, Christopher Romeo,
Daniel DeGennaro, Kyle McGrady

Background

In 3rd world countries, as many as 2.1 billion people do not have access to potable water [1]. An inexpensive way to create potable water from dirty water is a solar still. As the water evaporates over the course of a day, the sediment and dirt are left behind in the trays, while the clean water is transferred to an output tank. An inexpensive and optimized solar still could have a profound impact on many people in water-challenged parts of the world.

Objective

We sought to create a still that could output 5L/day in a region with an average of 5 PSH. To verify the water quality, we also sought to make a sensor kit to measure the cycle count, hot side temperature, and the turbidity of the output actively, as well as, pH and salinity through passive gauges.

Research

Target Latitude/Slope: After analyzing the following map of the distribution of human populations, a target latitude of 25°N was chosen as it coincides with the maximum population density as well as water-stressed regions. An important design parameter to maximize the still's collected power is the slope of the still. To keep the collection area on average perpendicular to the sun's rays at our target latitude, we found that the optimal slope of the still would be β = 25°.

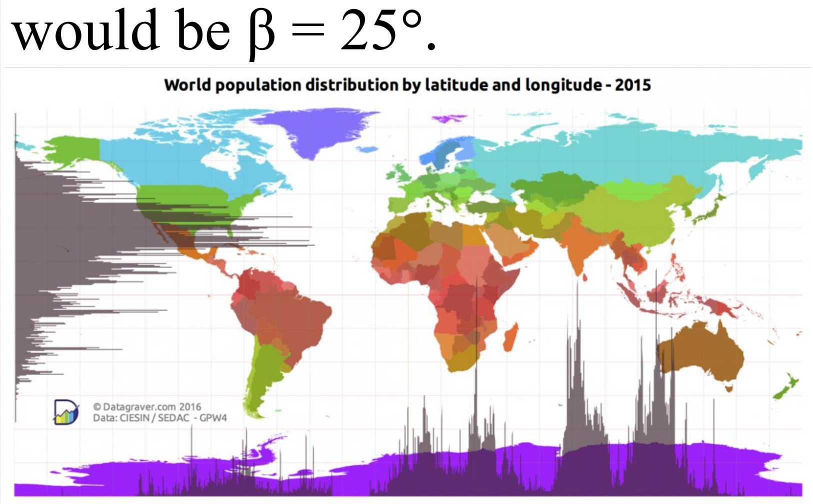

Figure 1: World population distribution by latitude and longitude – 2015 [2]

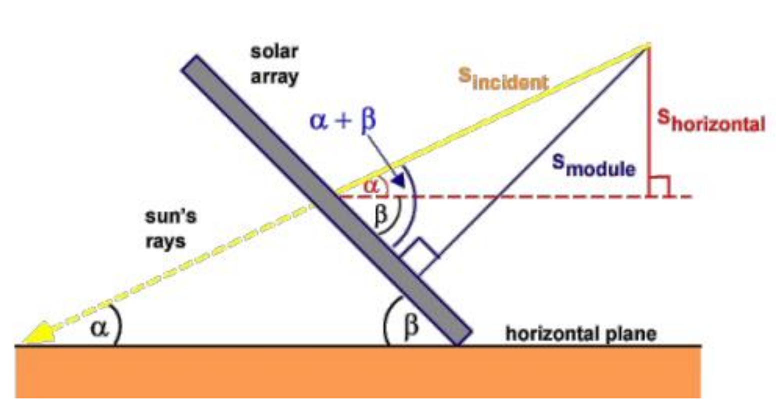

Figure 2: Relationship between elevation angle α to the tilt angle β

Thermodynamic Analysis: To verify our target 5L/day objective, we examined the thermodynamics of the still. Using the temperature dependence of vapor pressure, we determined the concentration gradient of water across our still at given absorber side and condensing side temperatures, T_H and T_C respectively, separated by a distance *d*. This determines the diffusion rate of the water vapor and ultimately the output rate of the still. We determined that minimizing d had more impact on the output rate than increasing the temperature difference, as shown in the figures below. Thus, we brought the surfaces as close together as our slope angle allowed.

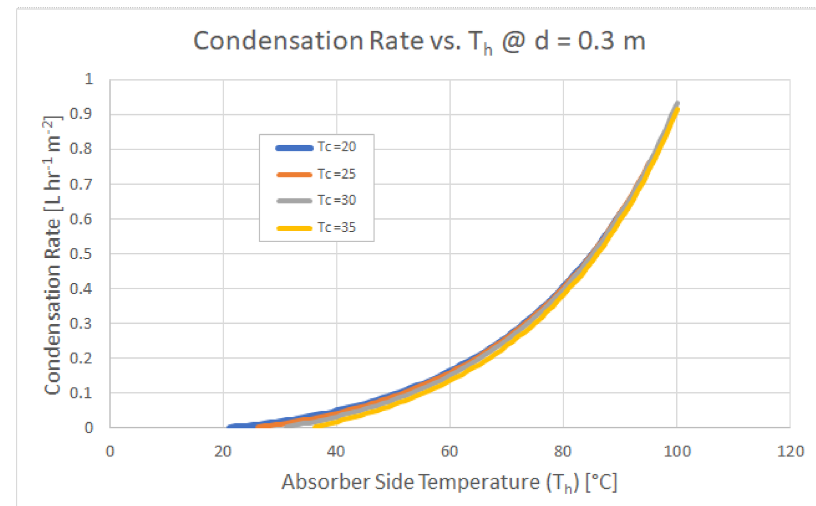

Figure 3: Condensation Rate vs. T_H at d = 0.3 m

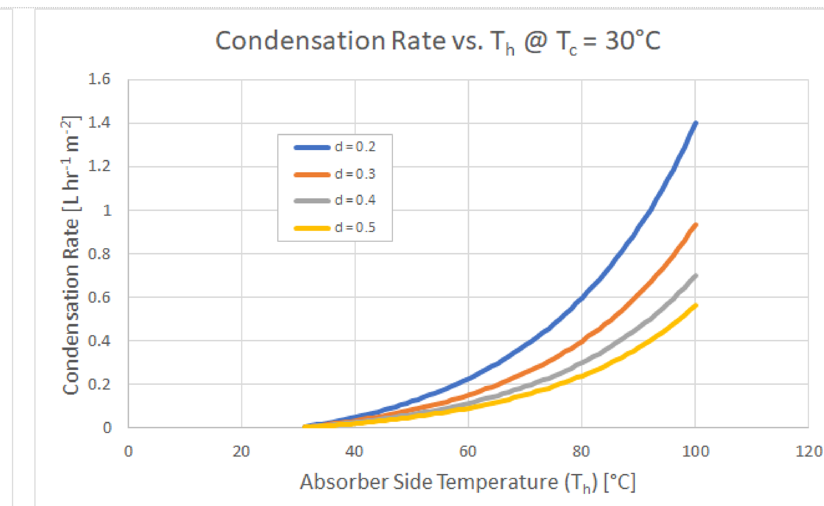

Figure 4: Condensation Rate vs. T_H at T_C = 30°C

Results

Electronics: For the electronics, we opted to create two boards with similar layouts allow for a single PCB with perforations to be ordered. As seen in both schematics, the controller, power, and I2C connections are uniform on both boards, while the inputs and outputs of each correspond to their intended usages.

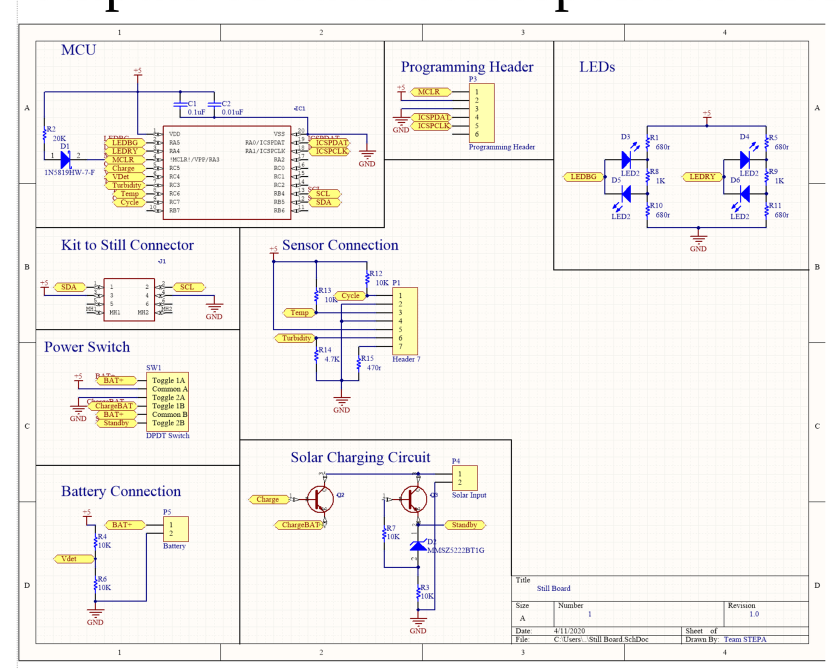

Figure 5: Circuit Schematic for the Sensor Array

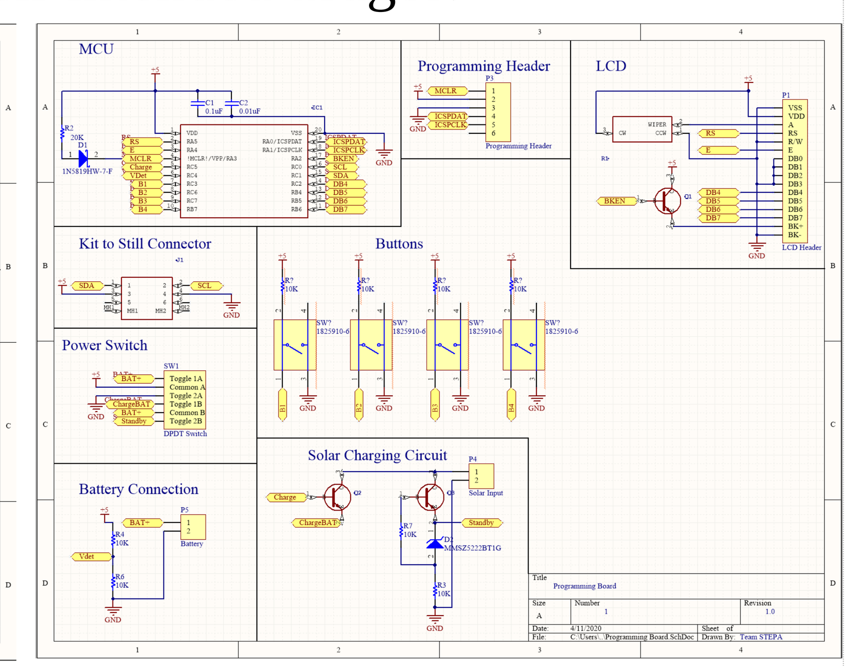

Figure 6: Circuit Schematic for the Service Board

Economic Analysis: We calculated the LCOW of our solar still to get an overall metric for how much the water filtered by our device would cost, in $/L. Capital and maintenance costs were annualized over the still's projected lifetime and divided by the projected lifetime output. For our prototype, a sensitivity analysis showed lifetime had the largest impact on LCOW, followed by the presence/lack of a filter. For the commercial model, it was nameplate capacity and the filter. We outlined testing to determine if a filter was necessary for a commercial unit, and we researched materials to increase product lifetime.

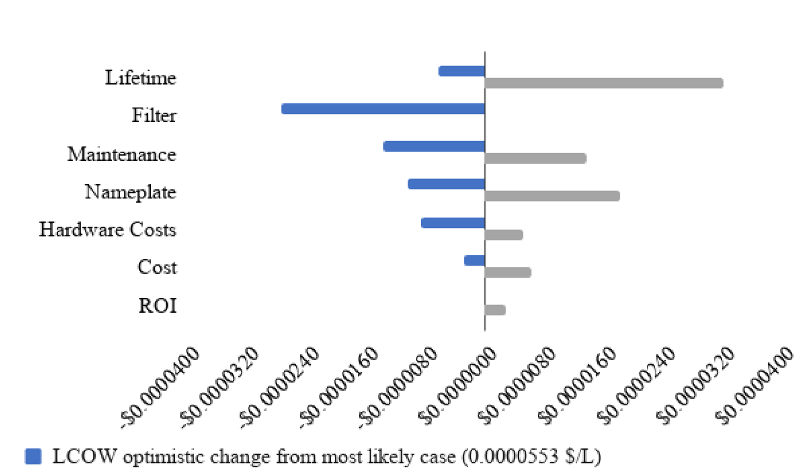

Figure 7: Sensitivity Analysis for Prototype Still

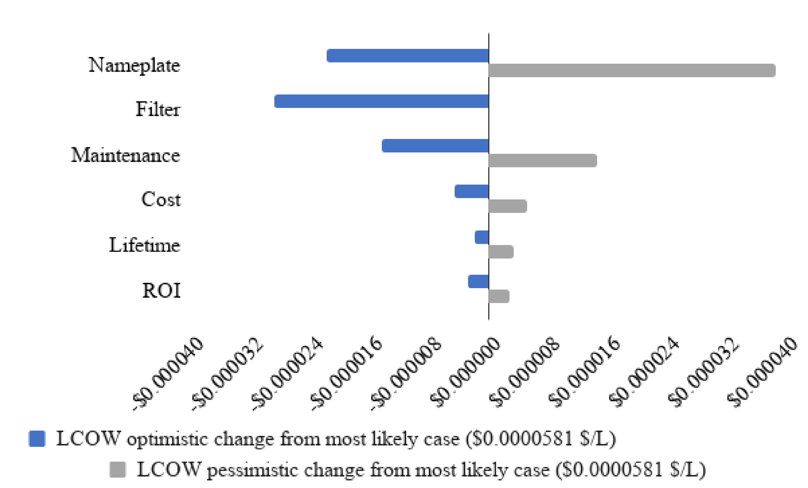

Figure 8: Sensitivity Analysis for Commercial Still

Conclusion

While we were unable to complete our project as anticipated due to COVID-19, in lieu of an operational prototype unit, we completed an economic analysis of our solar still and a commercialization plan for it. In these, we determined the major factors that affect the LCOW of the proposed commercial unit, the risks faced in commercialization, and we researched other competitor products that are currently on the market. While we were obviously disheartened by being unable to finish building our device the way we had planned, we hope to do so in the near future, when it is safe and feasible.

Prototype Pictures

References

[1] UNICEF. (2019). Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines
[2] "World population distribution by latitude and longitude - 2015," Datagraver

Glossary

LCOW - Levelized Cost of Water; PSH - Peak Sun Hours
LED - Light Emitting Diode; LCD - Liquid Crystal Display
TDS - Total Dissolved Solids; Potable - suitable for drinking
Turbidity - cloudiness or haziness of a fluid;
Nameplate Capacity - expected daily water output

Acknowledgements

We would like to thank Professor Eisaman for his advice and support, Kyle's parents for storing the prototype, and the ESE department for providing access to the necessary facilities and equipment.

Team S.T.E.P.A