Solar Thermal Hut
Harnessing the Heat of the Sun

Ahmad Awan, Qasim Chaudhry, Sonya Graham, Eric Riep, Monique Sangha, Virak Seap
Schulich School of Engineering, University of Calgary

ABSTRACT

Solar energy is an abundant, renewable resource that can be utilized in a variety of engineering applications [1]. Currently, photovoltaics are the dominant technology used to collect solar energy [2], however, there is comparatively little utilization of solar thermal technologies. Solar thermal technologies absorb radiative energy from the Sun, concentrating that thermal energy into a small area which can be easily utilized. The Canadian climate necessitates significant energy requirements for heating throughout the year. Prolonged exposure to cold ambient temperature can carry serious health risks, potentially resulting in fatalities [3]. This project aims to utilize an array of solar thermal vacuum tubes to heat a single-person structure.

A phase change material (PCM) heat exchanger is used to store energy after the sun goes down. Fully refined paraffin wax was selected as the phase change material with an approximate melting temperature of 56°C [4]. The solar tube array was sized to 13 tubes, with each solar tube producing an average of 65 W of power in direct sunlight [5]. The wax within the heat exchanger collects this energy, where it stores latent heat during its phase change from solid to liquid. The hot wax subsequently heats a radiative plate within the hut structure, heating the inside of the hut from a combination of radiative and natural convective heat transfer. The resulting design is entirely passive, requiring no electrical components, user input, or moving parts.

OPPORTUNITY STATEMENT

Develop a solution that provides warmth and comfort to users while spending extended periods of time outdoors during winter months

- As Calgary is known to be one of the sunniest cities in Canada there is a great opportunity to harness solar thermal energy to store heat in winter
- Chance to create a low cost heating alternative which can help the vulnerable population

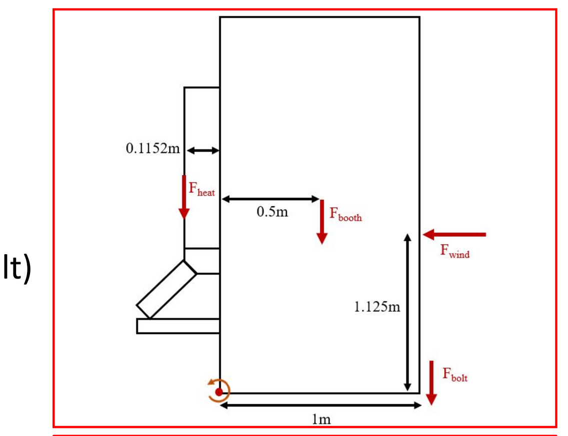
GOALS AND OBJECTIVES

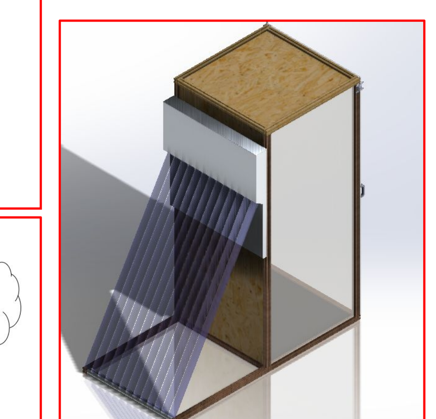
Design and construct a working full-scale prototype of an enclosed, heated booth which operates on the passive collection of solar thermal energy

- Size: 1m x 1m square footprint with a height of 2.25m
- Heating: Keep inside air temperature at 10°C for a minimum of 4 hours while outside air temperature is -30°C
- Cost: Maintain a Bill of Materials within $4000

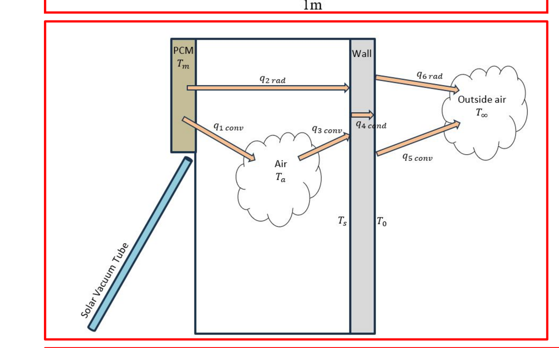
DESIGN METHODS

1) **Structural analysis**
   - Designed to withstand:
     - Highest winds (80 km/h)
     - People climbing (200 lb adult) into the PCM holder

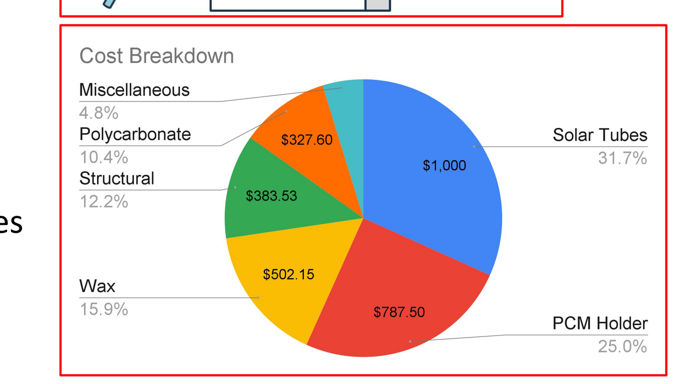




2) **Thermodynamic analysis**
   - Designed to stay:
     - > 10°C inside air while -30°C outside for 4 hours
     - Minimize heat loss



3) **Cost analysis**
   - Target: Cost < $4k
     - Actual: $3.5k
     - Solar tubes: $1k for 30 tubes (surplus of 17 tubes)



TESTING METRICS & METHODS

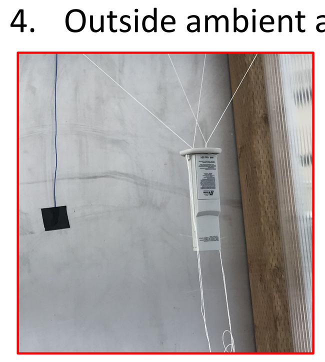
Testing Metrics:

1. Internal temperature - rate of change and max temperature reached
2. Maintaining heat after sundown - how long internal temperature is maintained

Temperature measurements were recorded every ten minutes while the system was outdoors and exposed to sunlight. To simulate sunset, the tubes were covered with a tarp and the temperature was continuously monitored.

Sensors were placed:

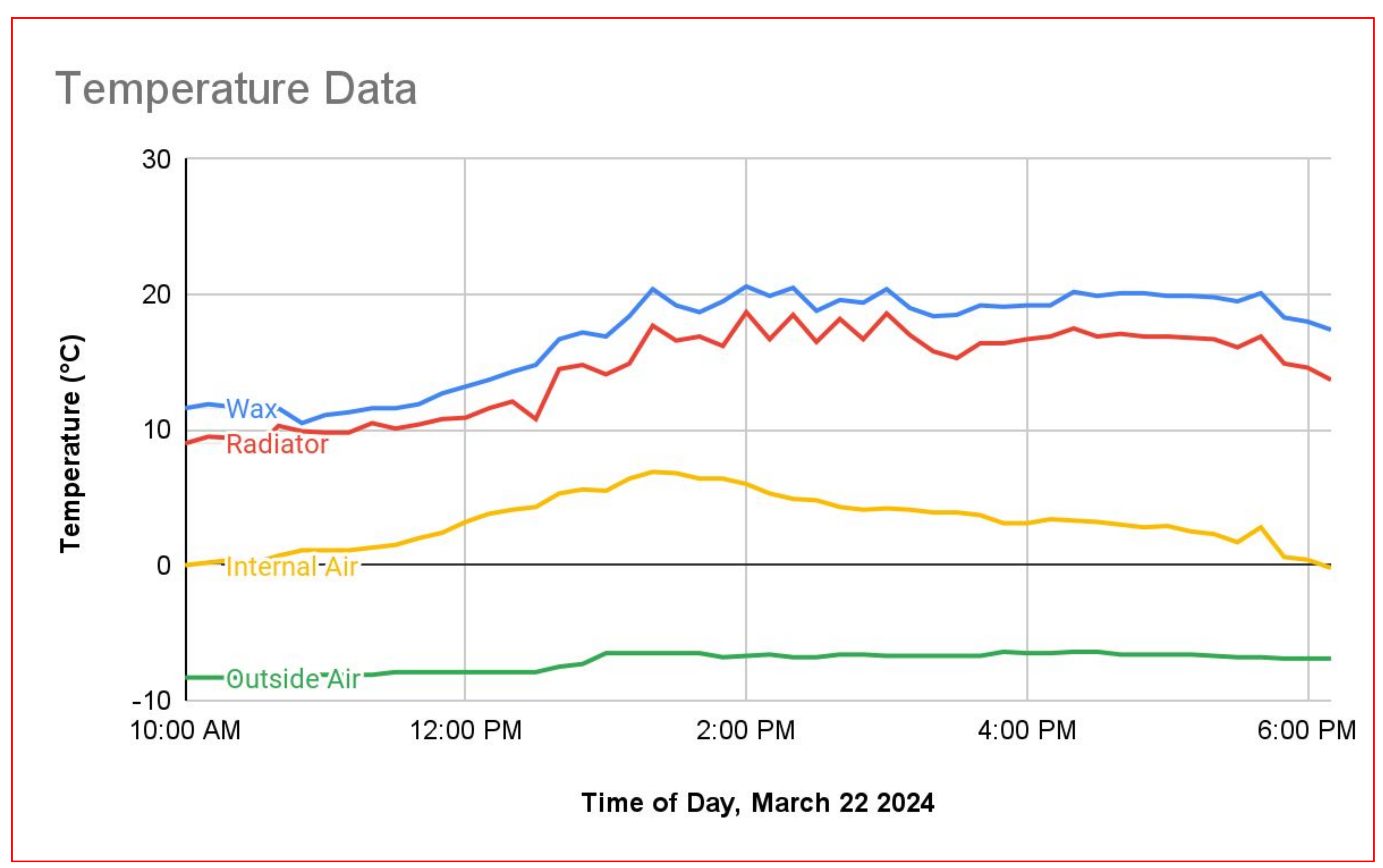
1. Inside the hut in the center of user space
2. Inside hut on the radiating plate
3. Inside the PCM to gauge wax temperature
4. Outside ambient air for comparison


1 and 2


2 and 3


4

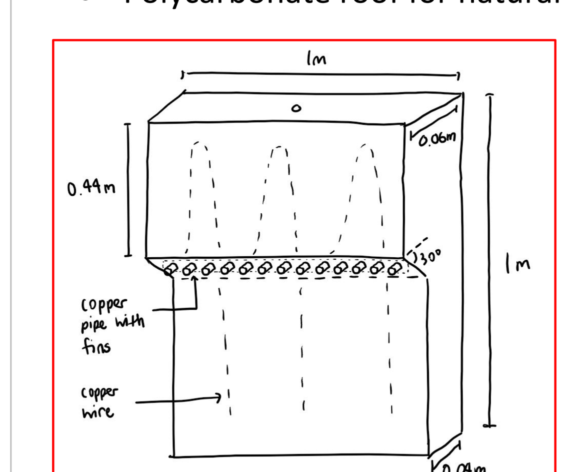
RESULTS & DISCUSSION

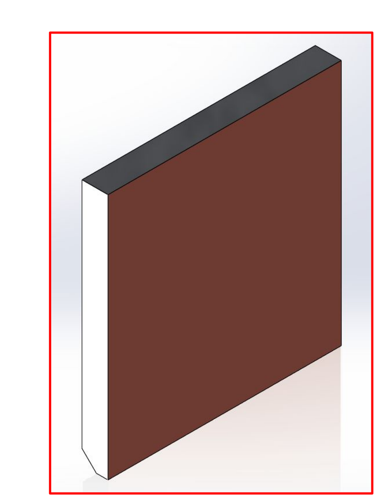


- Even in extremely cloudy conditions, the hut was able to absorb available sunlight to significantly increase the hut temperature
- The general thermodynamic concept was proven:
  - The solar tubes collected available sunlight, heating the up PCM, and then increasing the hut temperature significantly above the outdoor temperature
- The temperature of the wax, radiating plate, and hut was maximized during peak sunlight hours
  - Tubes were covered at 4pm, and heat was retained in the wax, slowing the cooling of the hut

FUTURE RECOMMENDATIONS

- Further insulation
  - Styrofoam on the back wall
  - More insulating tape and caulk on all seams and edges
  - Magnetic strip on door to ensure weatherproof seal
- Better heat dissipation throughout the wax
  - More surface area of copper fin within
  - Shorter height of booth
  - Reduce from 2.25m to 2m
- Replace wood materials
  - Use aluminium T-slots for better weather resistance.
- Use copper radiating plate
- Cover radiating plate with a mesh to prevent potential burns
- Polycarbonate roof for natural greenhouse effect





References

[1] "Solar Energy," SEIA.org, https://www.seia.org/initiatives/about-solar-energy#:~:text=Solar%20technologies%20can%20harness%20this,%2C%20commercial%2C%20or%20industrial%20use. (accessed Mar. 24, 2024).
[2] P. Bojek, "Solar PV," IEA.org, https://www.iea.org/energy-system/renewables/solar-pv (accessed Mar. 24, 2024).
[3] "Cold related illnesses," Centers for Disease Control and Prevention, https://www.cdc.gov/niosh/topics/coldstress/coldrelatedillnesses.html#:~:text=Prolonged%20exposure%20to%20cold%20will,think%20clearly%20or%20move%20well. (accessed Mar. 24, 2024).
[4] "IGI 1230A Technical Data Sheet", The International Group, Inc., https://igiwax.com/upcp_product/igi-1230a/ (accessed Mar. 1, 2024).
[5] B. Zinkan, C. Lassiter, K. Li, M. Henderson, "ENGG 502: SENIOR CAPSTONE DESIGN PROJECT II, Solar Thermal Furniture", April 12, 2021. (accessed Oct. 2023).

Sponsors:
Dr. Arief Budiman
Trina Listanco
James Paterson
Advisor:
Dr. Simon Li

UNIVERSITY OF CALGARY