Project Bhaskar

Water Cooling Techniques for Building Integrated Photovoltaics

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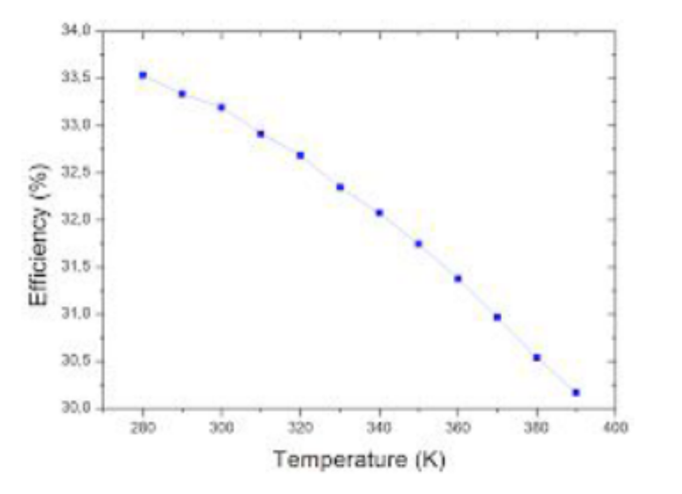
Problem

- Solar PV Performance suffers under higher ambient temperatures.
- Cooling systems needed to enable wide scale proliferation of renewable energy, particularly in the Global South



Egbert Rodriguez Messmer (March 6th 2013). Solar Cell Efficiency vs. Module Power Output: Simulation of a Solar Cell in a CPV Module, Solar Cells, Arturo Morales-Acevedo, IntechOpen, DOI: 10.5772/52707.

Objectives

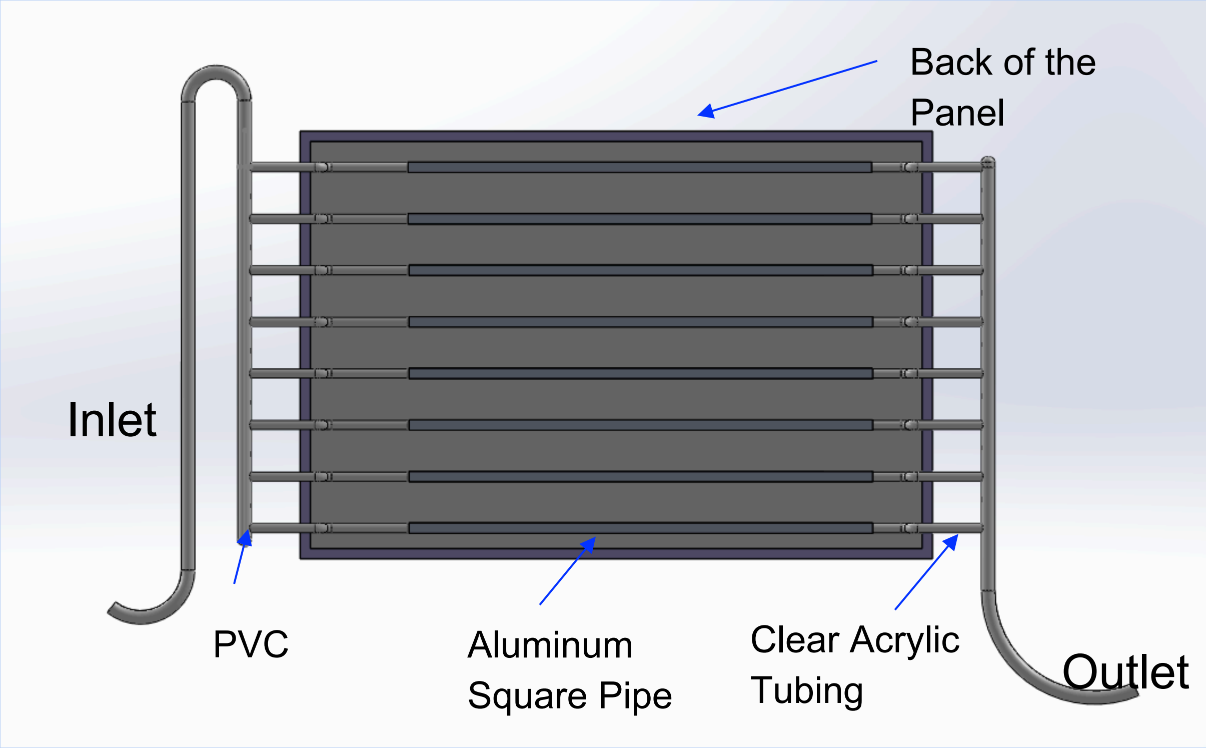
1. Find a cooling mechanism for building-integrated photovoltaics and validate it under field conditions.
2. Build a long-term project targeting PV cooling in the developing world.

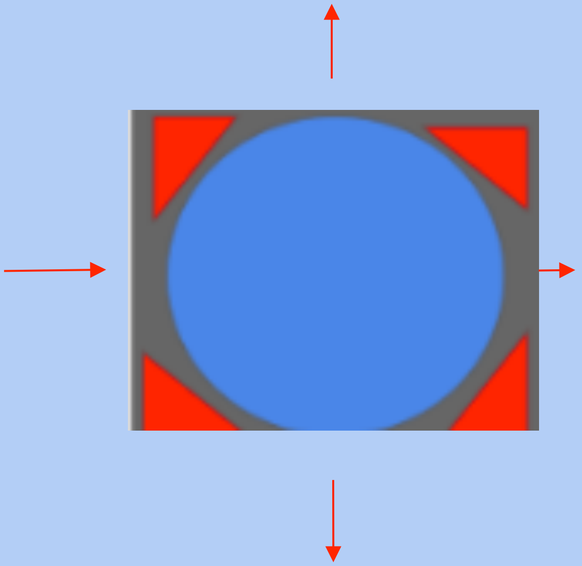
Methodology to achieve objectives

1. Choose a cooling mechanism
2. Create CAD Design of cooling system
3. Construct system
4. Take experimental performance

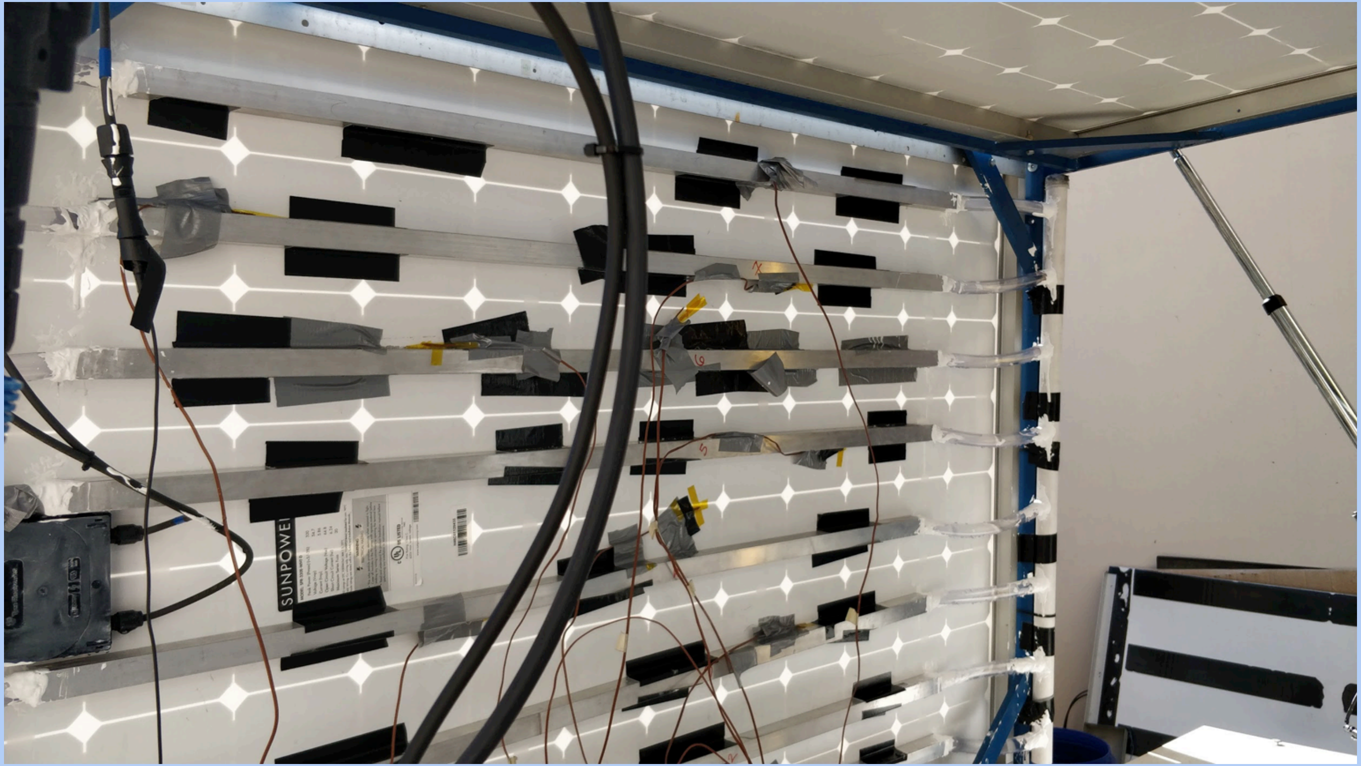
Mechanism

Design - Back of PV Panel

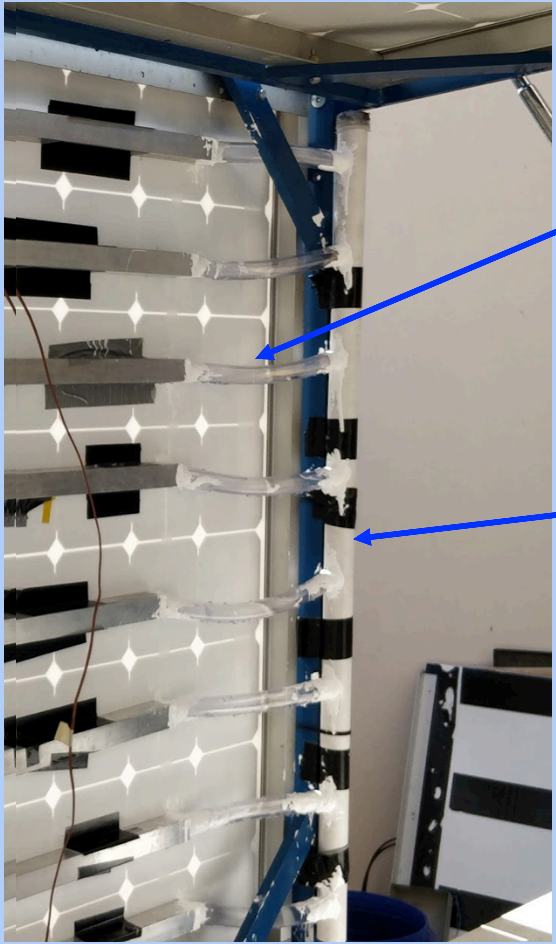




Overall Structure



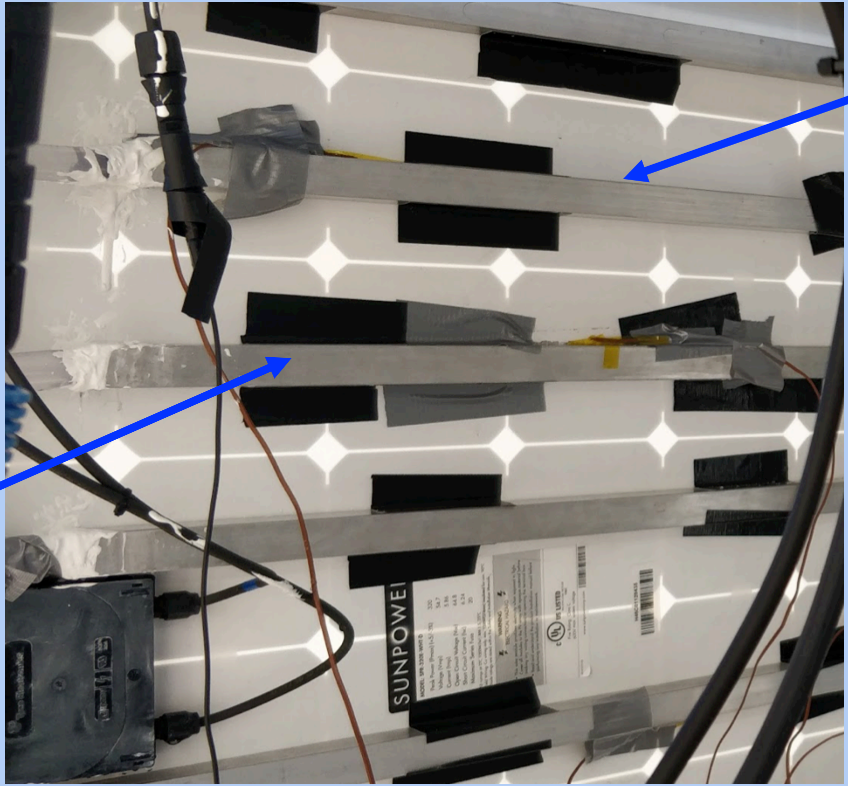
Tubes



Clear Acrylic Tubing

PVC

Piping



Thermal Conductive Glue with 1.2 W/m-K

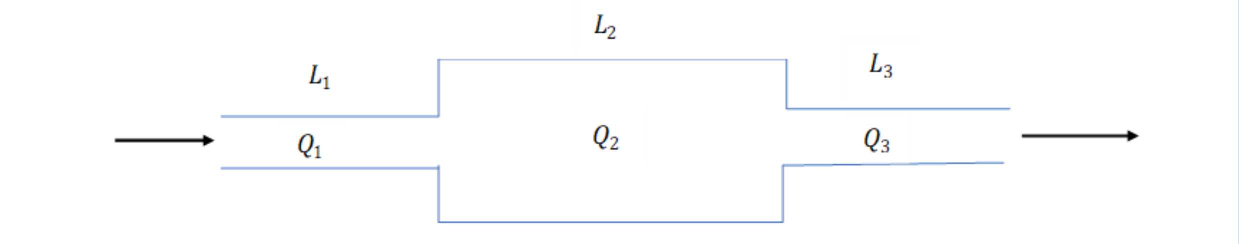
Aluminum pipes 1 in X 48 in with 1/20 in thickness

Water Supply

Water Supply

Q = 1.23 * 10^-4 m^3/s

Water Flow Calculations Through Pipes



$Q = discharge \left[\frac{m^3}{s}\right]$

$L = length\ [m]$

$d = diameter\ [m]$

$d_h = hydraulic\ diameter\ [m]$

$V = velocity \left[\frac{m}{s}\right]$

$A = cross - sectional\ area\ [m^2\}$

$d_1 = 0.0159\ m$

$d_{h2} = 0.3048\ m$

$d_3 = 0.0159\ m$

$L_1 = 0.3048\ m$

$L_2 = 1.2192\ m$

$L_3 = 0.3048\ m$

For pipes in series

$Q = Q_1 = Q_2 = Q_3$

$Q = 1.23\ x\ 10^{-4}\ \frac{m^3}{s}$

Water Flow Calculations Through Pipes

Find velocity $\mathbf{V_1}$ using $Q = V_1A_1$

$$V_1 = \frac{Q}{A_1} = \frac{Q}{\frac{\pi}{4}d_1^2} = 0.62\,\frac{m}{s}$$

Find $\mathbf{V_2}$ using continuity equation

$$Q = V_1A_1 = V_2A_2$$

$$V_2 = 0.22\,\frac{m}{s}$$

Find $\mathbf{V_3}$ using continuity equation

$$Q = V_2A_2 = V_3A_3$$

$$V_3 = 0.62\,\frac{m}{s}$$

Determine Reynold’s number at each section @ T_{water} = 20 C

$Re < 2300\ laminar$

$Re > 10{,}000\ turbulent$

$Re > 4000$ in many cases the flow becomes fully turbulent at this point

$$Re = \frac{Vd}{\upsilon} = \frac{\rho Vd}{\mu}$$

$Re_1 = 9{,}822\ assume\ turbulent$

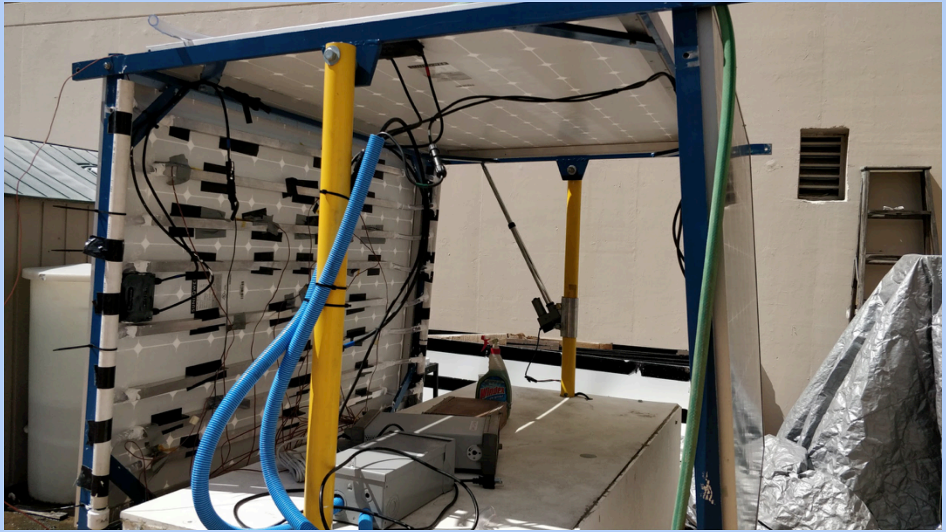
$Re_2 = 67{,}157\ turbulent$

$Re_3 = 9{,}822\ \ assume\ turbulent$

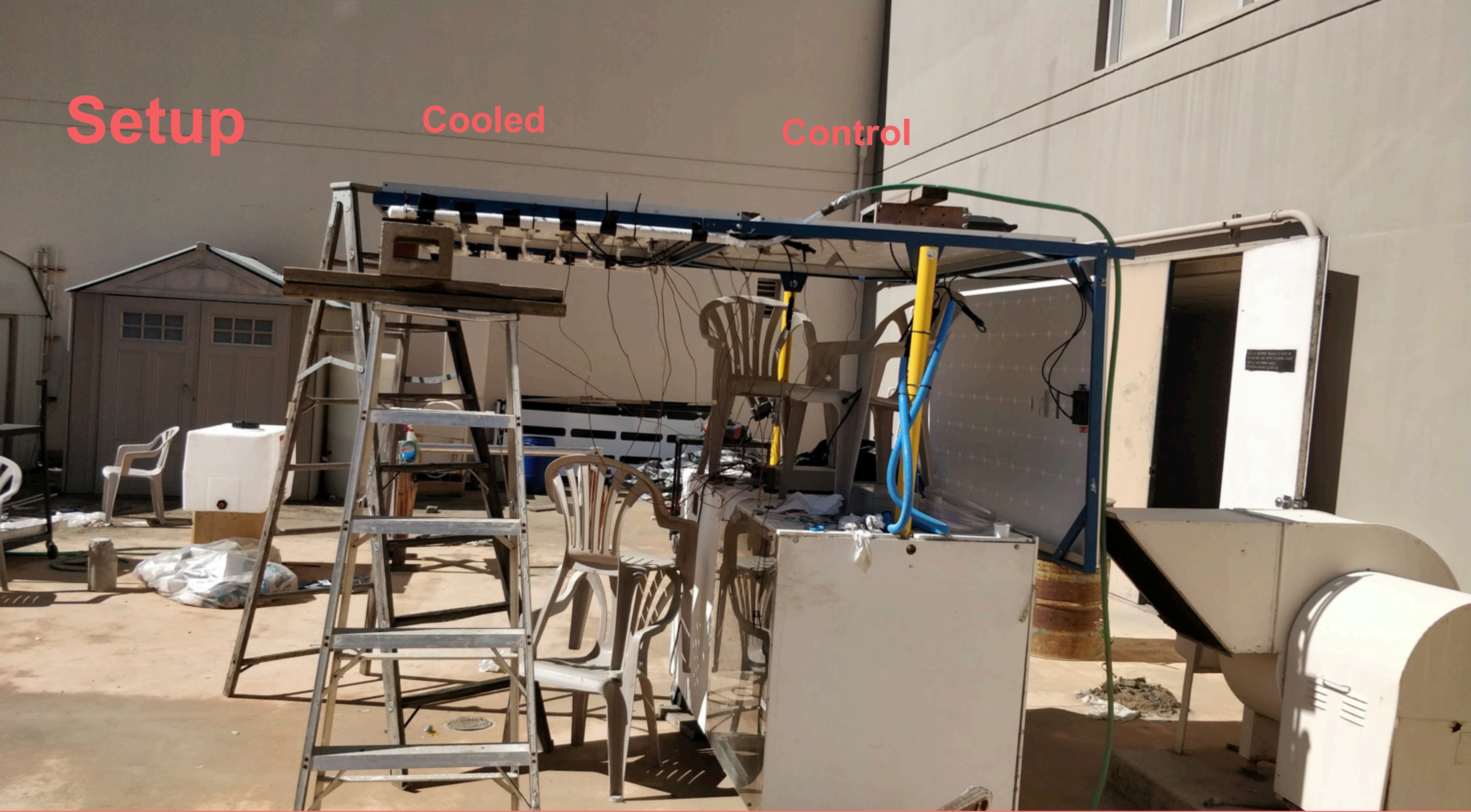
Experimentation

Experimental Apparatus

- Flexible solar rack
- 61.39 x 41.18 x 1.18 inches
- Base panel for test measurements



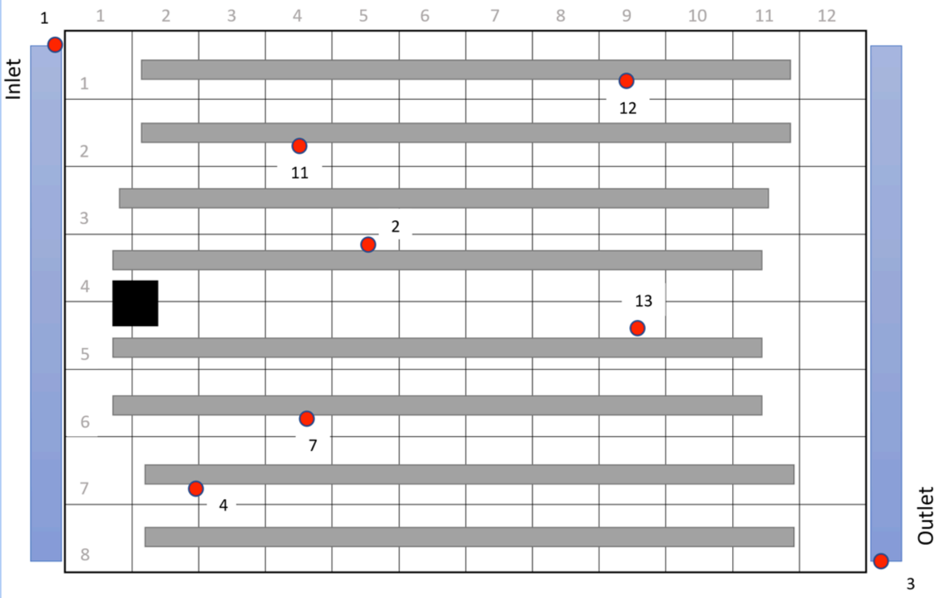
Setup



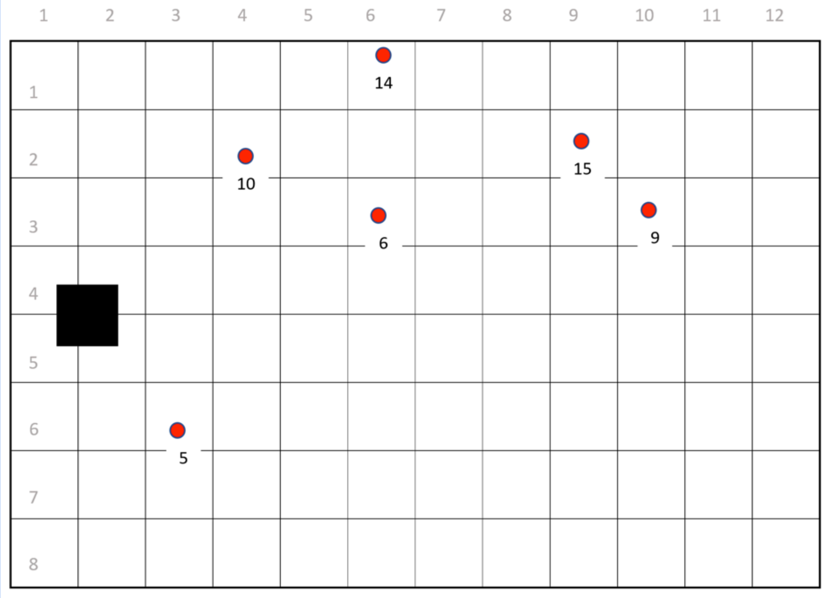
Tools

- Thermocouples
  - T-type
  - 14 in total
- Pyranometers
  - 2 LI-COR - LI-200SA
- DAQ
  - Agilent 34970a → Thermocouples
  - Li-Cor 1500 Logger → Pyranometers
  - Keysight BenchVue

Thermocouple Placement Experimental



Back surface of solar panel with cooling system



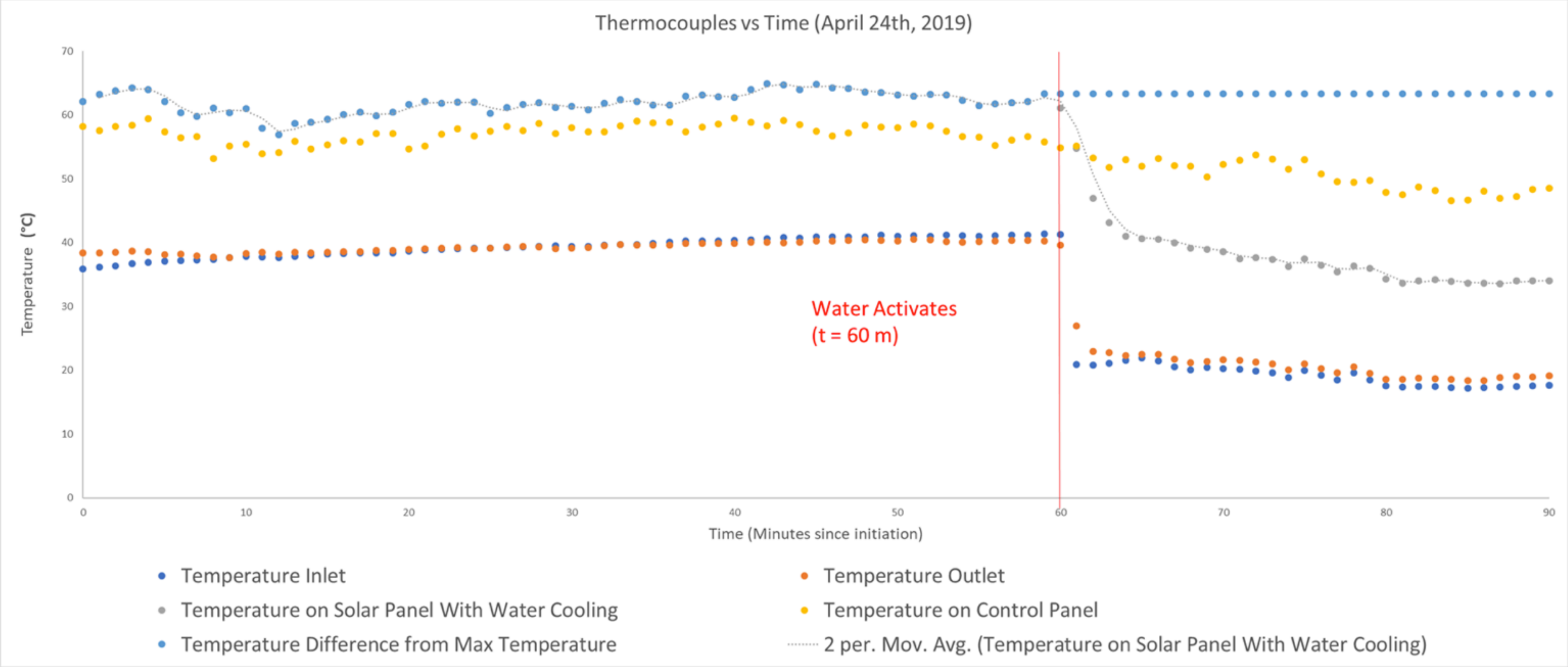
Back surface of solar panel without cooling system

Procedure

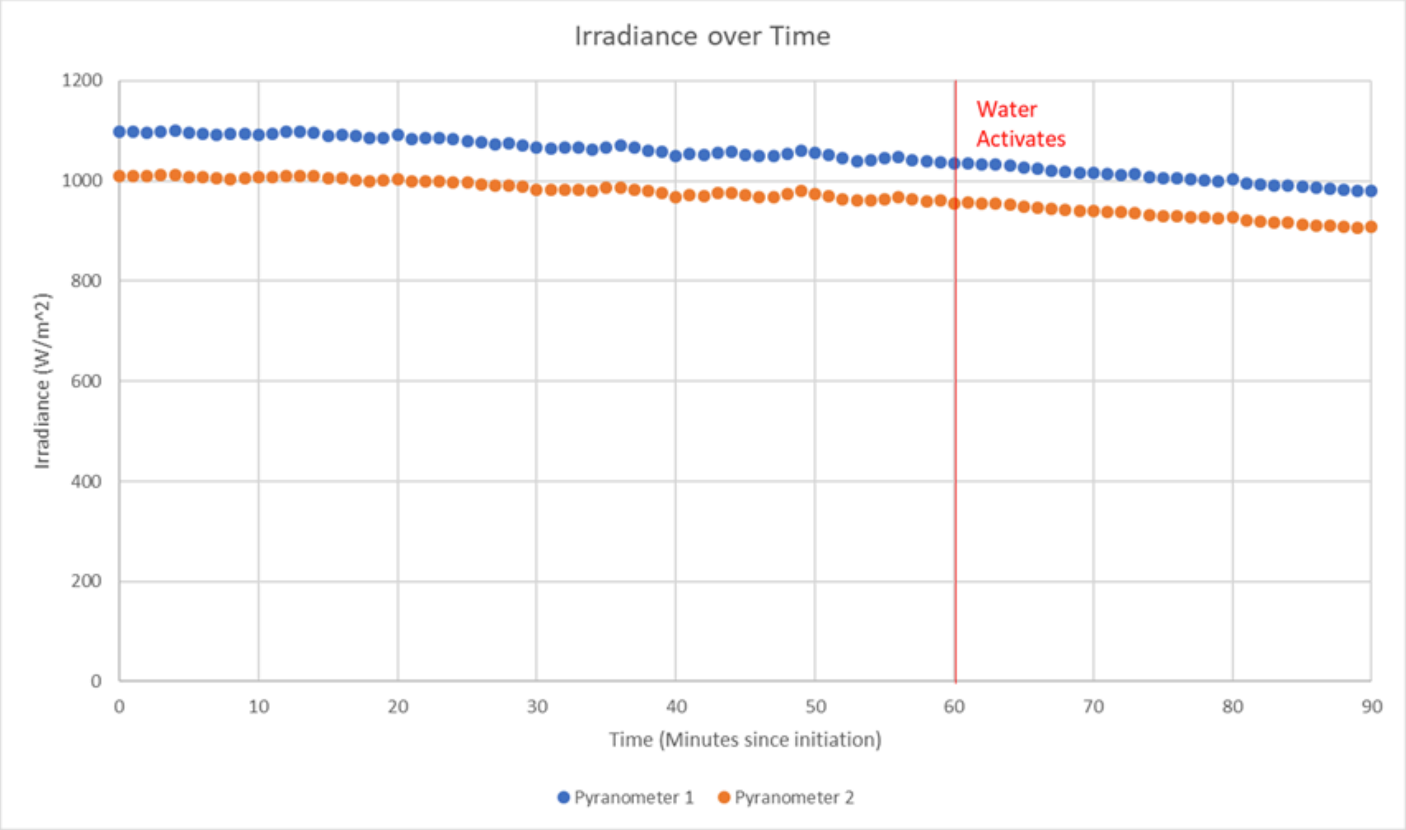
- Set data reading frequency to once per minute
- Take data without running water for one hour
- Activate water after one hour, take data for 30 more minutes
- Compare cooled panel and control panel

Experimentation - Thermocouples - April 24 2019

Ambient Temperature 32.2 C,
Target Temperature 25.0 C



Experimentation - Pyranometers - April 24 2019



Conclusion

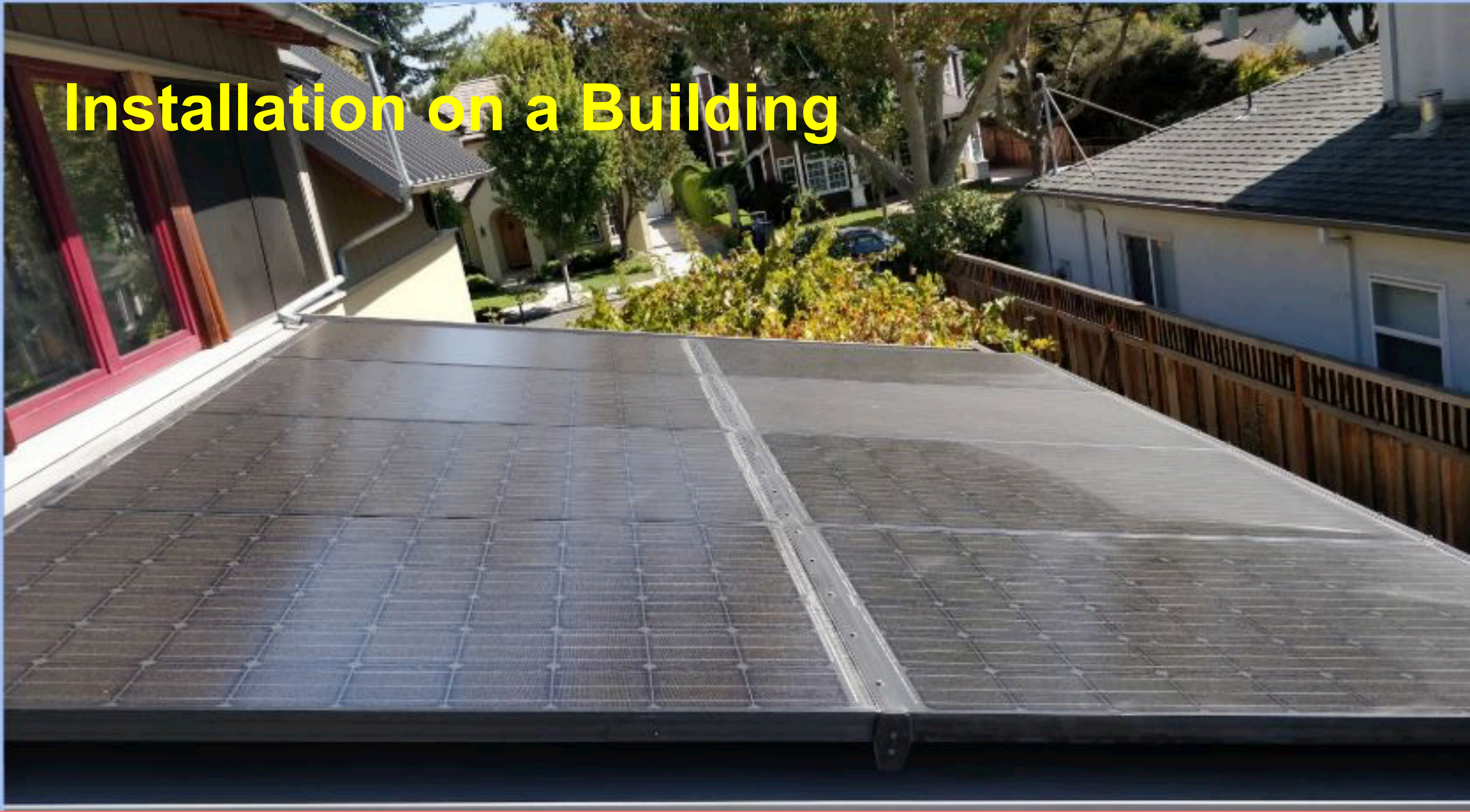
- The minimum average temperature at the back panel with cooling after activation was 36.9 degrees C, compared to 48.9 degrees C for the control panel
- The minimum average temperature was 32.4 degrees C, which is 7.4 degrees higher than the desired temperature of 25 degrees C.
- It is important to note that the ambient temperature at the day of experiment was 32.2 C, making it extremely difficult to achieve the desired temperature of 25 degrees C
- Surprisingly, outlet water temperature was only slightly higher than the inlet temperature. This indicates that due to higher thermal conductivity of aluminum the heat was dissipated from water through aluminum structure.

Future work

New Team

Design Passive Cooling Mechanism

Installation on a Building



Acknowledgments

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Thank You ASES!!!