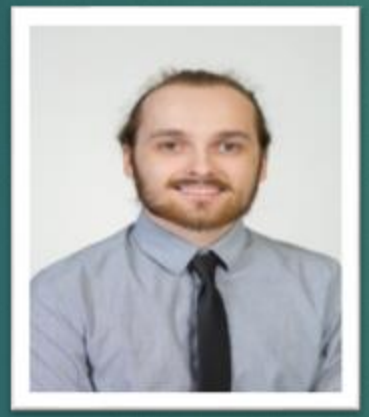
Team 512

Temperature-Sensitive Medication Storage for Natural Disasters

06-FEB-20

Meet the Team

Jesse Arrington
Design Engineer



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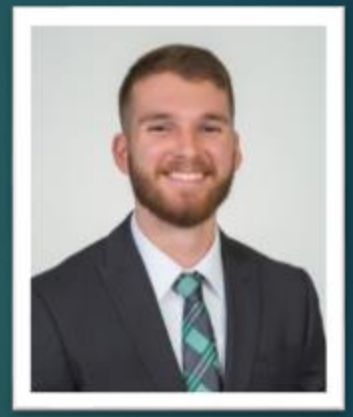
Technical Engineer

Matthew Israel
Thermal Process Engineer

Tyler White
Energy Systems Engineer



Timothy Willms
Production Engineer

Sponsor

Tom Derzypolski
President of BowStern Marketing

- Florida State University graduate
- Bachelor's in Communications with an emphasis on Public Relations
- Decorated veteran of the U.S. Navy
- Member of:
  - Florida Public Relations Association
  - American Advertising Federation
  - Veterans of Foreign Wars

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Overview

- Project Brief Summary
- Targets and Metrics
- Concept Generation
- Concept Selection
- Current Progress
- Planned Tasks/Future Work

Project Brief Summary

Objective

The objective of this project is to provide an affordable and accessible means to keep temperature sensitive medications cool during natural disasters and the days following.

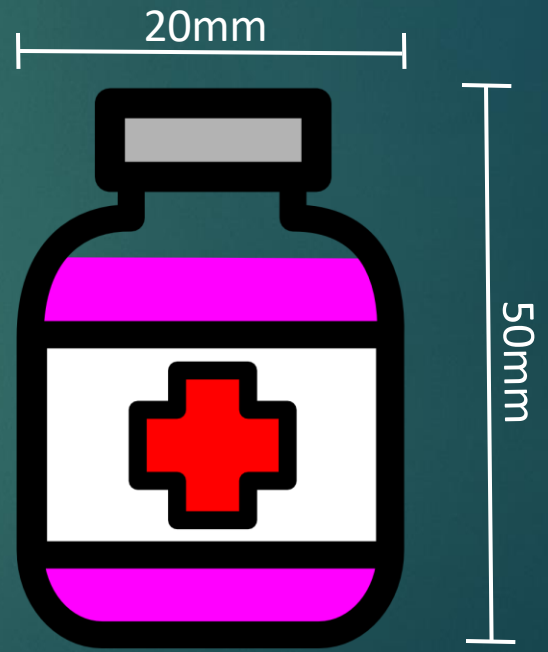
Background

- Puerto Ricans were out of power for an average of 84 days following Hurricane Maria
- 46% spike in diabetes related deaths
- Most common medications need to be between 2°C and 8°C

Targets & Metrics

Targets & Metrics

- Internal volume should accommodate 3 vials of medication
  - 20mm diameter, 50mm tall
- No vials should be broken
- Keep vials within range for at least one week
- Reasonable power usage
  - Common voltages (1.5V-12V)
- Temperature regulation
  - Internal temperature between 2°C and 8°C
  - <15min to reach temperature range



Concept Generation

Medium Fidelity Concept

- Active liquid cooling system
  - Pump circulates coolant through tubing around vials
- Immersion cooling system
  - Submerge vials in coolant
- Miniaturized refrigeration system
  - Solar powered
- Ranque-Hilsch vortex tube cooling system
  - Separates compressed gas into hot and cold streams
- Thermoelectric cooling system
  - Inducing a current in Peltier plate produces cooling effect

High Fidelity Concept

- Miniaturized refrigeration system
  - Single, large internal battery
- Compressed gas cooling system
  - Release of compressed gas provides cooling
- Endothermic chemical reaction cooling system
  - Use chemical reaction in instant cold pack to provide cooling

Concept Selection

Final Selection

- Pugh chart & AHP determined the Compressed Gas Cooling System would be the optimal selection
  - In practicality, this concept is infeasible due to:
    - Difficulty obtaining large quantities of compressed gas
    - High safety risk in handling compressed gases
- Therefore, the TEC System was selected as the final design
  - Second lowest cost & consumption of power
  - Most feasible of remaining concepts

Current Progress

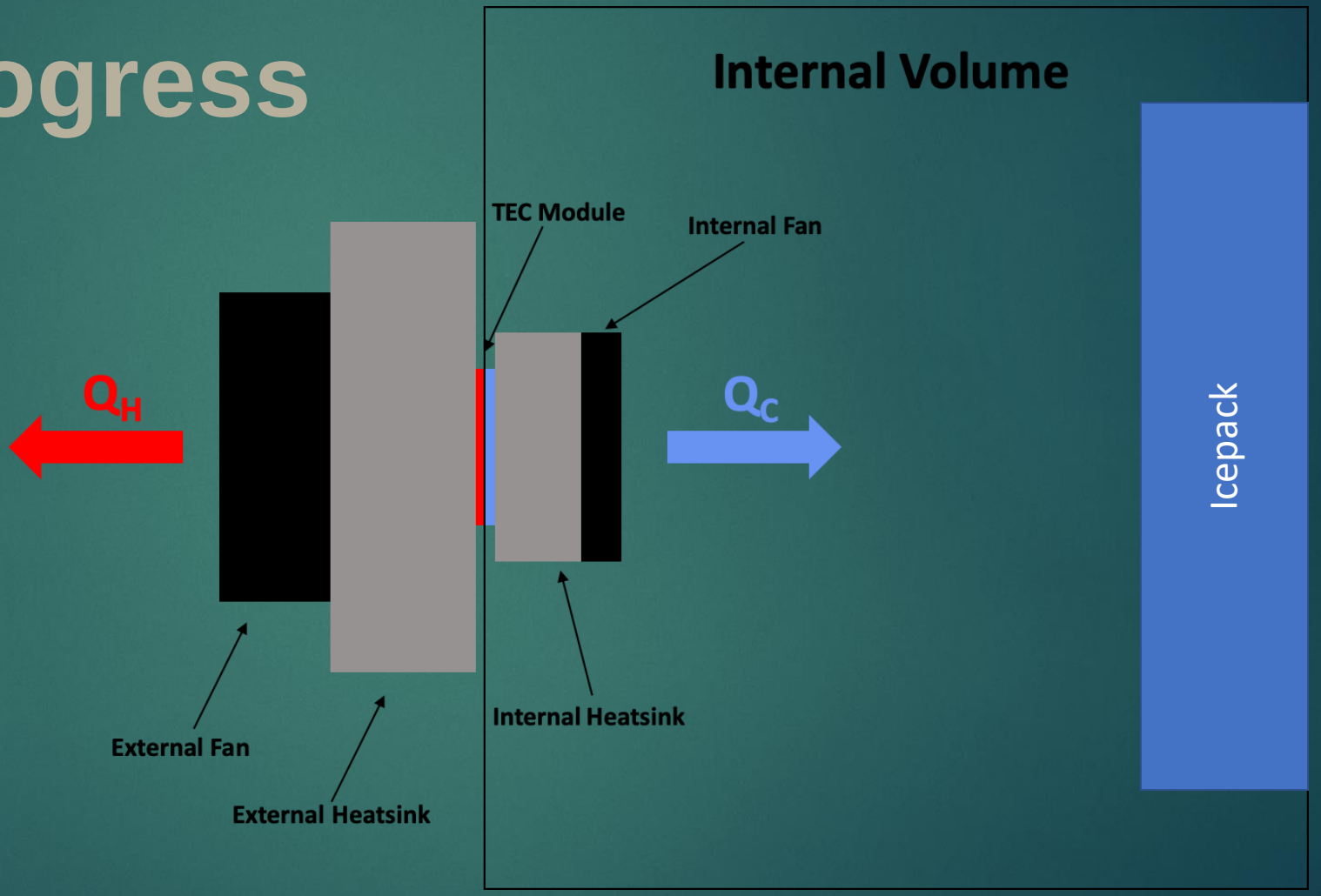
Current Progress

Thermoelectric (TEC) Module Testing:

- Current Prototype model utilizes a hard-shell cooler
  - Internal thermocouple to measure the temperature
  - Two fan, two heat sink configuration
  - Minimized internal volume using foam insulation to approximately 144 in^3
  - Use of icepack to maintain cold within the system
  - Improved insulation around TEC border with cooler

Current Progress

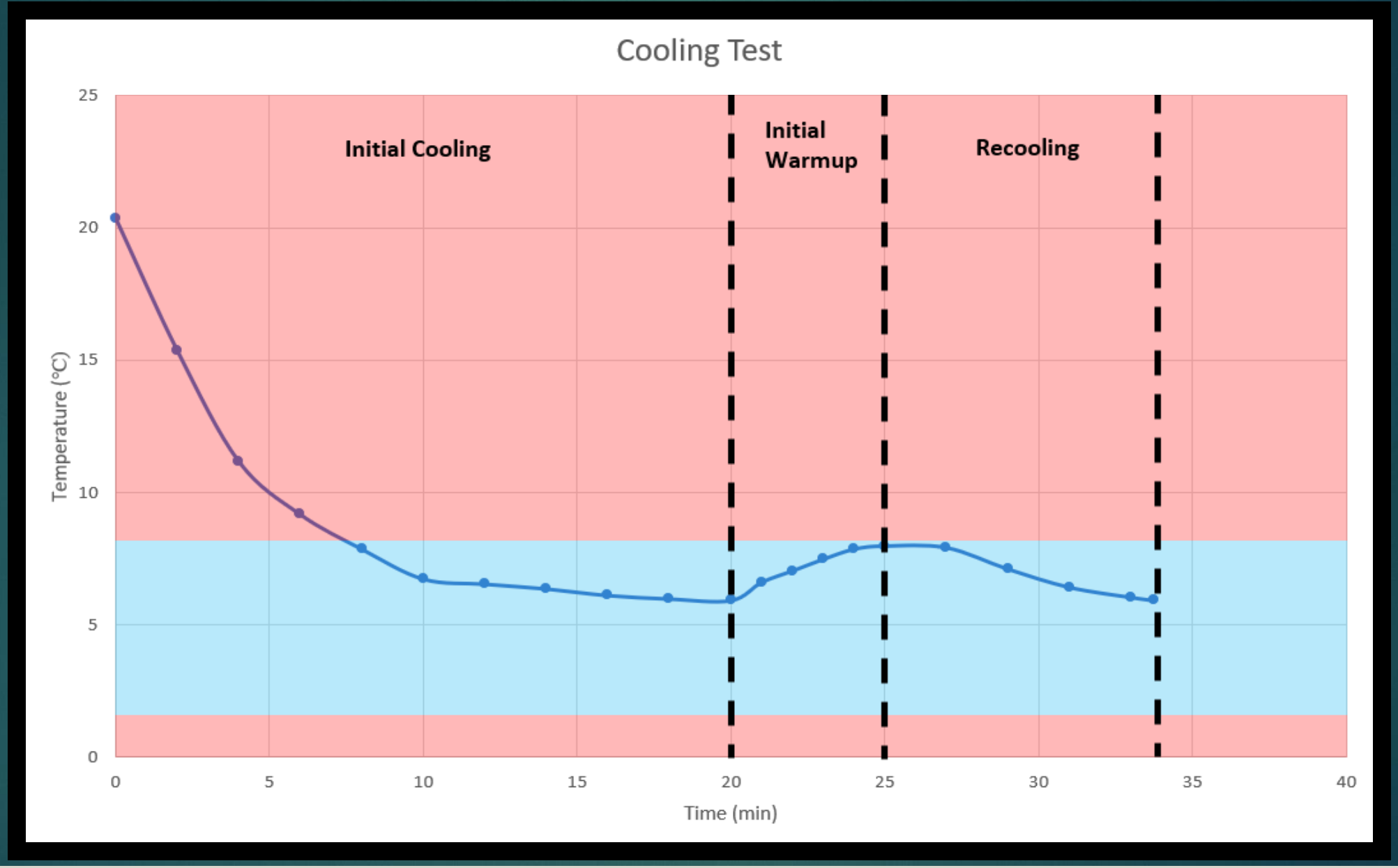
System Design



Current Progress

Testing Phases:

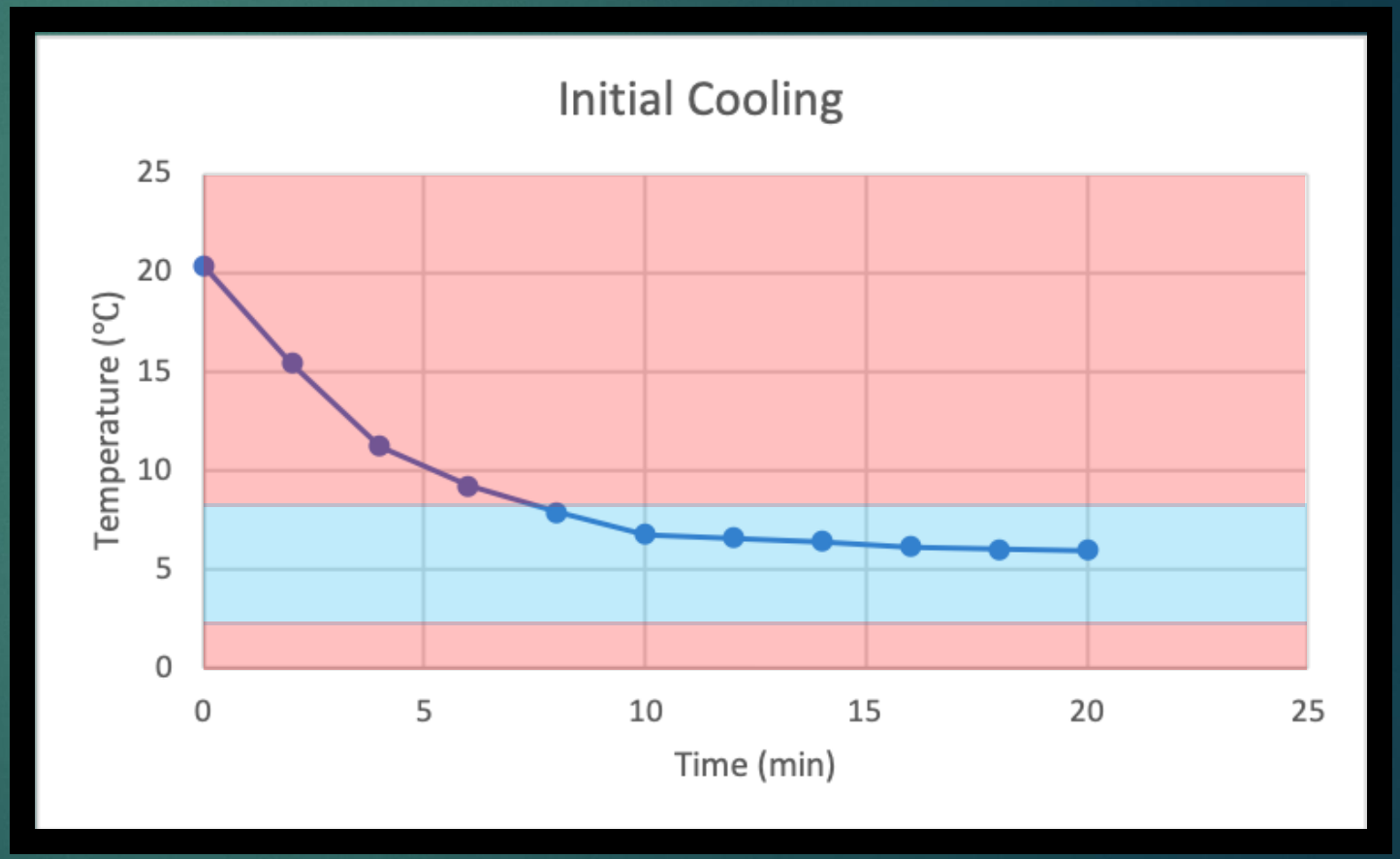
- Initial Cooling
  - Required time to reach appropriate refrigerated temperature from ambient conditions
  - TEC turned on at beginning of this phase
- Initial Warming
  - Once equilibrium temperature is reached, this phase measures the time required to exceed the required temperature range
  - TEC is turned off at beginning of this phase
- Recooling
  - Once the temperature range is exceeded, this phase measures the time required to reach equilibrium temperature again
  - TEC turned on at beginning of this phase


Cooling Test
Initial Cooling
Initial Warmup
Recooling
Temperature (°C)
Time (min)
0
5
10
15
20
25
30
35
40

Current Progress

Initial Cooling:

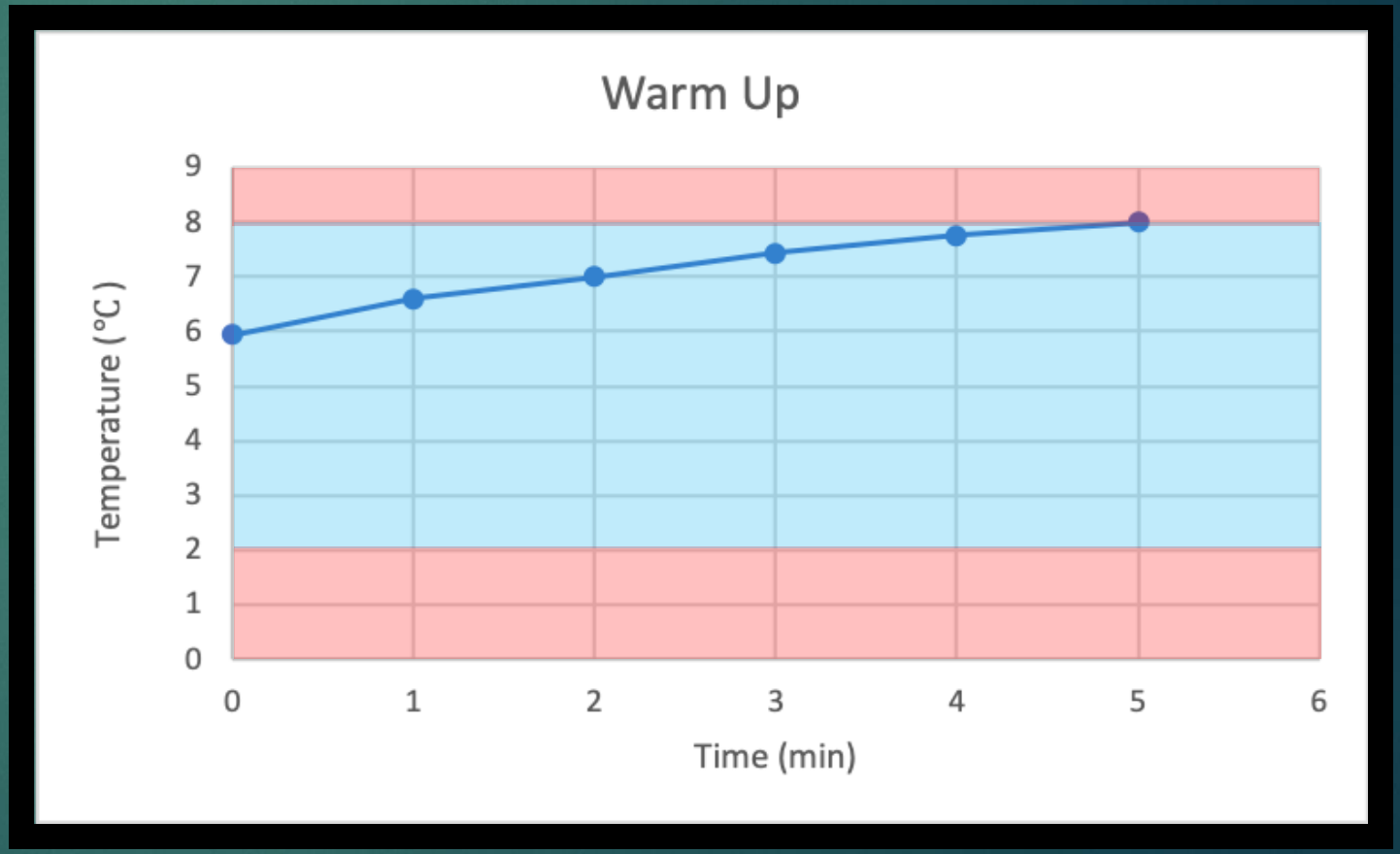
- Reached viable temperature range (2°C<T<8°C) in less than 8 minutes
- Initial Operating Power: 13.85W
  - Operating Voltage: 7.1V
  - Operating Current: 1.95A



Current Progress

Initial Warmup:

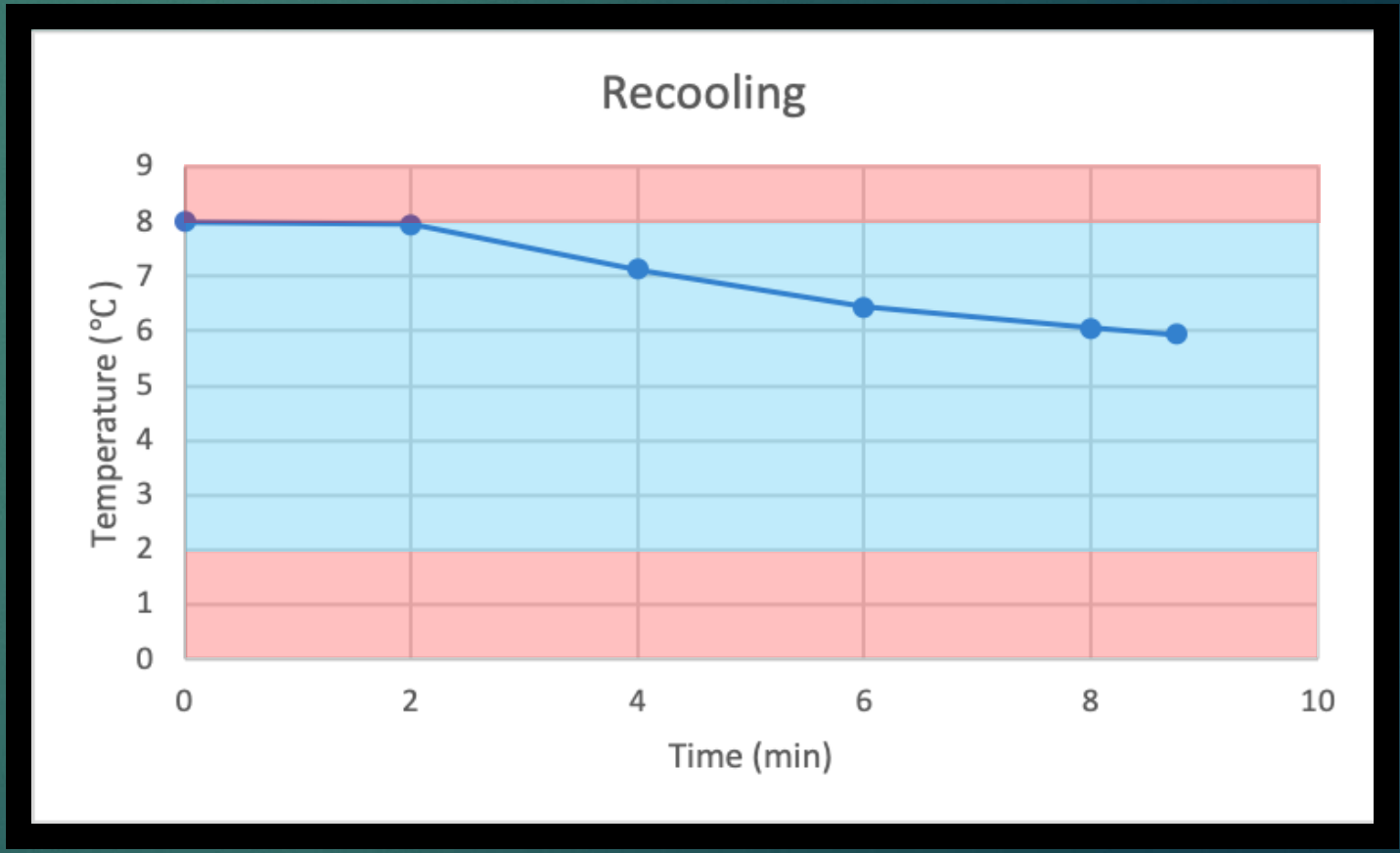
- Complete system shutdown
  - Initial temperature: 5.94°C
- Approximately 5 minutes to reach a temperature outside of the range (>8°C)



Current Progress

Recooling Phase:

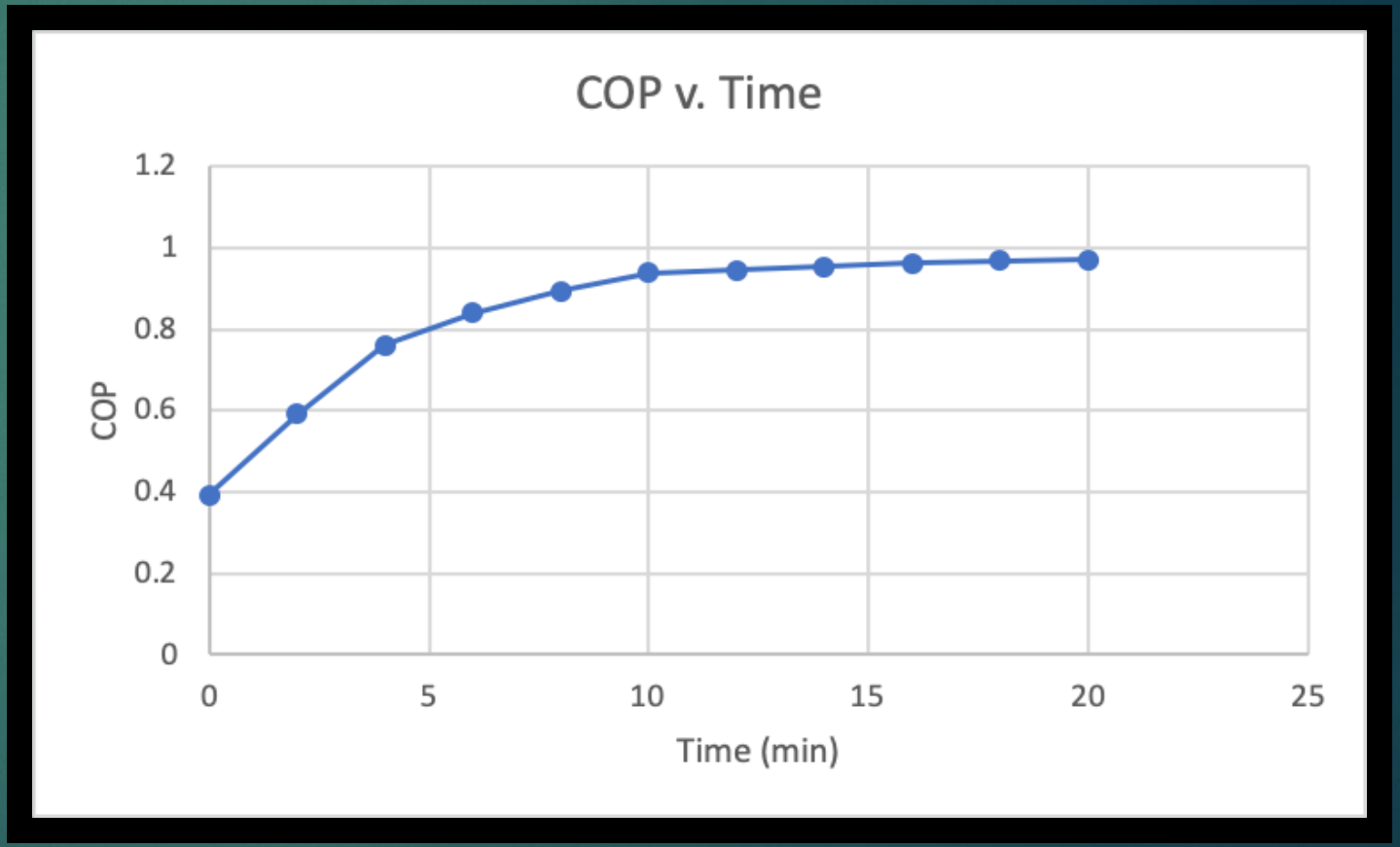
- System was turned on at 8°C
  - Supplied 7.1V, 1.95A
- Reached 5.94°C in less than 9 minutes
- ~2:1 power/no-power ratio



Current Progress

COP of System:

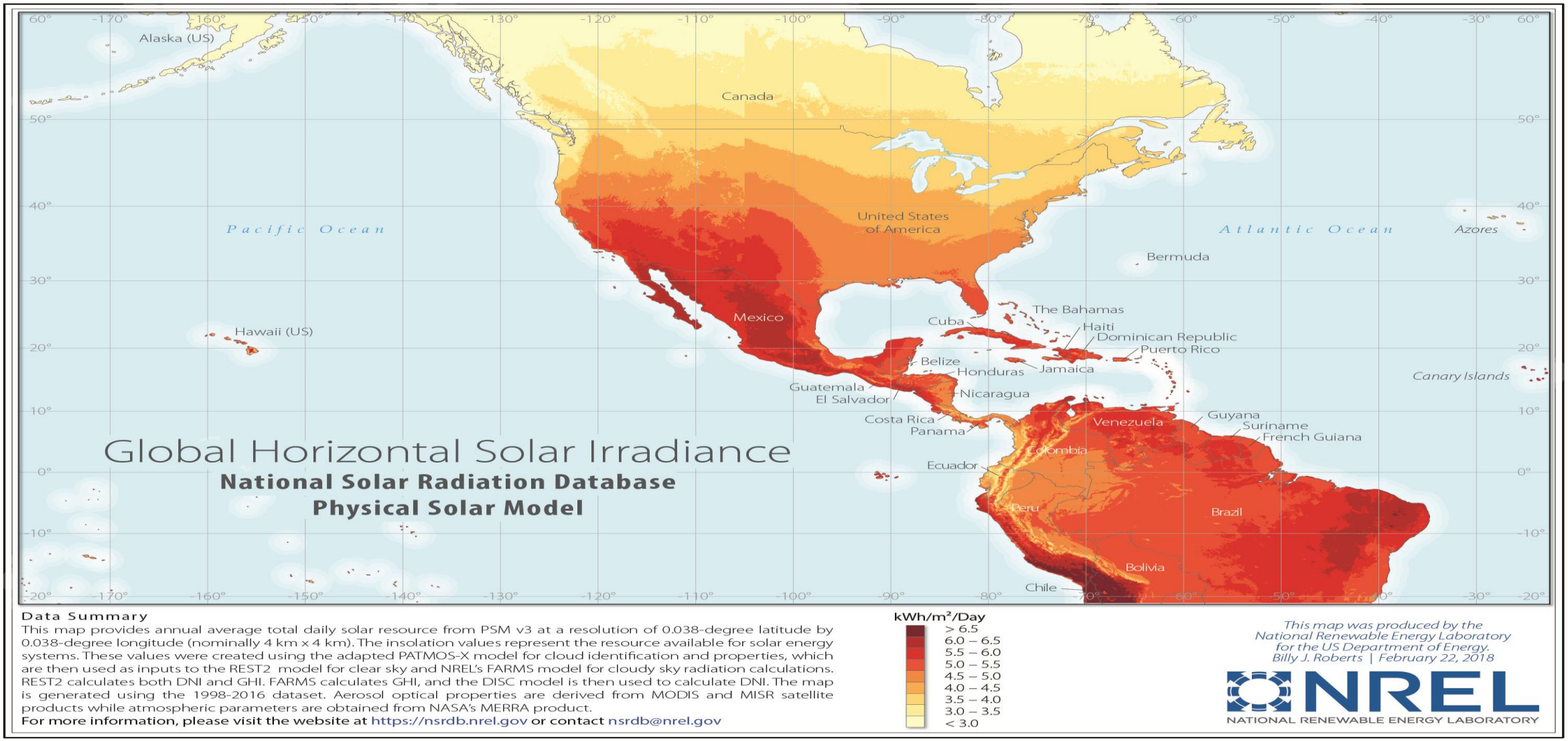
- Highest COP achieved: 0.97
- Lowest COP: 0.39
  - Attributed to the initial startup of the system from room temperature
- Typical maximum COP values for TEC modules are approximately 0.4-0.7 without modification



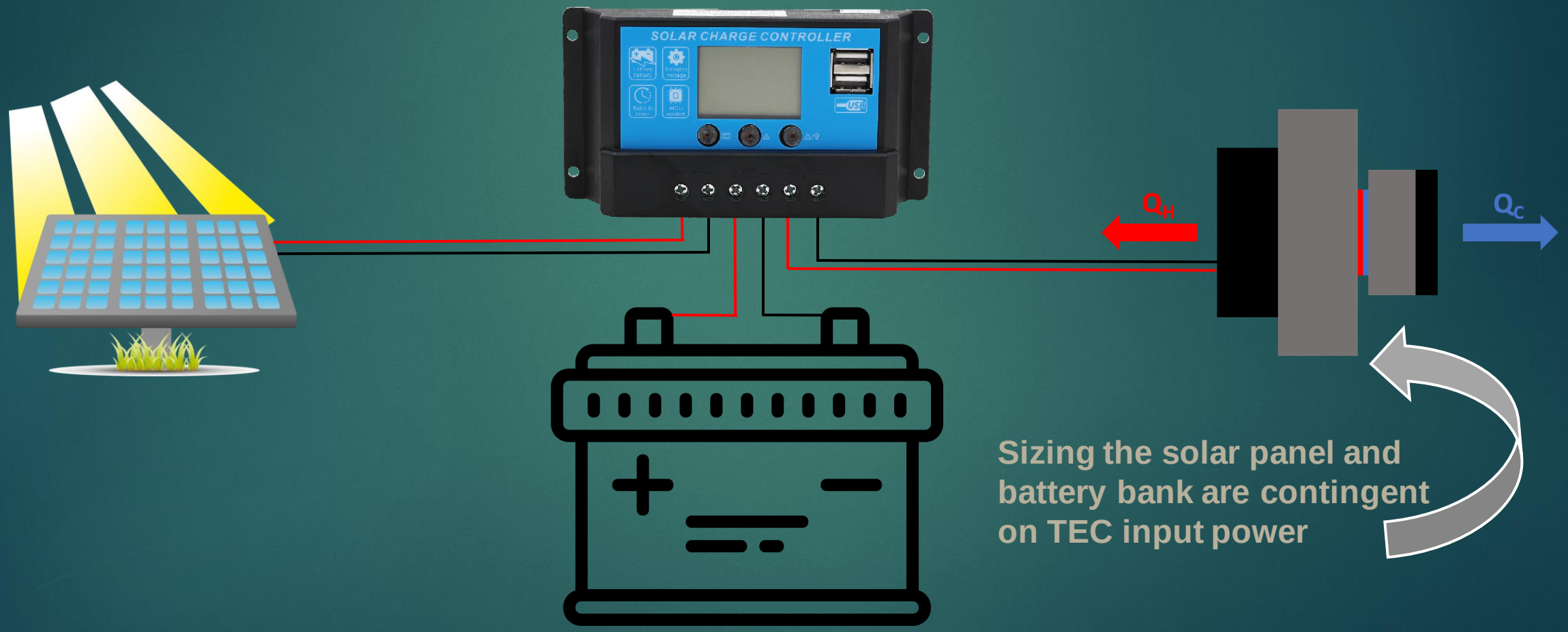
Current Progress

Power Generation and Storage System:

- Research indicates that solar power represents the most viable form of energy production
- Annual solar irradiance map illustrates that most areas struck by hurricanes have relatively high solar irradiance values
- Conservative estimate of 4.5 kWh/m^2 per day
- Hurricane season lasts from June 1st - November 30th, higher irradiance values than annual estimates will exist


Alaska (US)
Canada
United States of America
Pacific Ocean
Atlantic Ocean
Azores
Bermuda
Mexico
Hawaii (US)
The Bahamas
Cuba
Haiti
Dominican Republic
Puerto Rico
Belize
Honduras
Jamaica
Canary Islands
Guatemala
El Salvador
Nicaragua
Costa Rica
Panama
Venezuela
Guyana
Suriname
French Guiana
Colombia
Ecuador
Peru
Brazil
Bolivia
Chile
Global Horizontal Solar Irradiance
National Solar Radiation Database
Physical Solar Model
Data Summary
This map provides annual average total daily solar resource from PSM v3 at a resolution of 0.038-degree latitude by 0.038-degree longitude (nominally 4 km x 4 km). The insolation values represent the resource available for solar energy systems. These values were created using the adapted PATMOS-X model for cloud identification and properties, which are then used as inputs to the REST2 model for clear sky and NREL's FARMS model for cloudy sky radiation calculations. REST2 calculates both DNI and GHI. FARMS calculates GHI, and the DISC model is then used to calculate DNI. The map is generated using the 1998-2016 dataset. Aerosol optical properties are derived from MODIS and MISR satellite products while atmospheric parameters are obtained from NASA's MERRA product.
For more information, please visit the website at https://nsrdb.nrel.gov or contact nsrdb@nrel.gov
kWh/m²/Day
> 6.5
6.0 – 6.5
5.5 – 6.0
5.0 – 5.5
4.5 – 5.0
4.0 – 4.5
3.5 – 4.0
3.0 – 3.5
< 3.0
This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
Billy J. Roberts | February 22, 2018
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Power Generation System Components



Sizing the solar panel and battery bank are contingent on TEC input power

Current Progress

Medicine storage redesign:

- Problem:
  - Locking cylinders are difficult to use
  - Both a twisting and pulling motion
  - Not designed with mobility impairments in mind
- Solution:
  - Sliding drawers for each vial
  - Only one simple motion required
  - Improves storage versatility

Future Tasks

Future Tasks

- Continue testing TEC prototype
  - Improve insulation
  - Reduce input power
  - Improve temperature retention longevity
- Finish redesign of vial storage system
- Finalize power generation and energy storage system design
  - Calculate required battery bank capacity
  - Calculate necessary solar panel rated power

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Questions?

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