DEPARTMENT OF MECHANICAL ENGINEERING

Team A-4
Greenhouse Heating System

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Motivation, Goal, Impact

Motivation

Small scale farmers cannot start seeds early due to lack of greenhouse heating. The houses drop below viable temps (<60° F) in late winter, and existing solutions are too expensive.

Goal

Design a low-cost greenhouse heating system that maintains temps for small scale farmers. Use renewable energy to minimize operating costs.

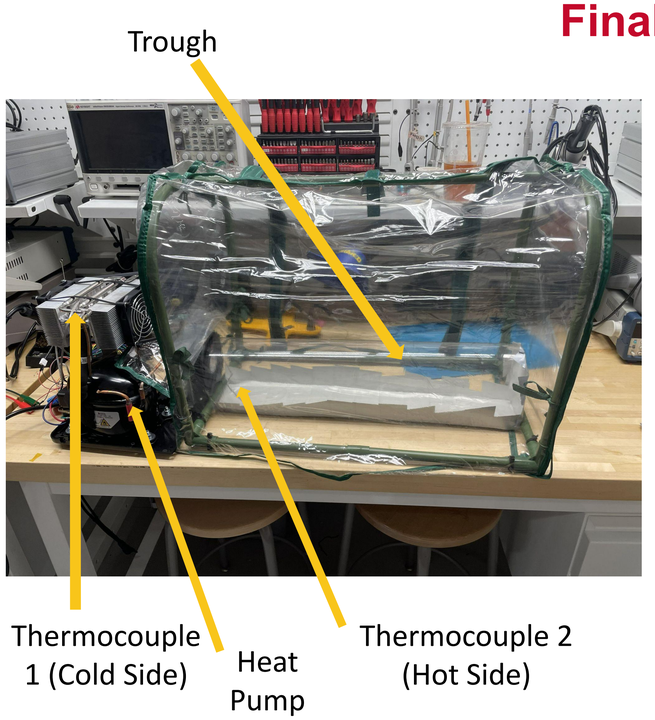
Impact

Enable early seed starting, reduce reliance on fossil fuels, and support small farmers to improve crop output year-round.

Requirements

- ✔ Maintain ≥60°F
- ✔ Heat 4x90’ troughs
- ✔ Low maintenance cost
- ✔ Low installation cost
- ✔ Non-polluting
- ✔ Space efficient

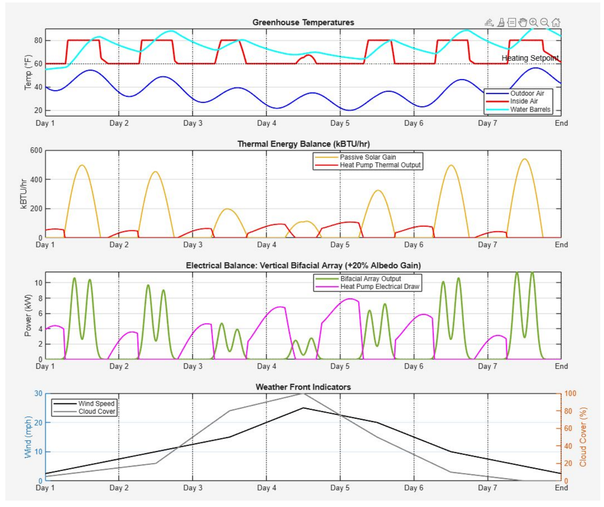
Final Design



- 15 550W bifacial solar panels and mounts
- 3 4x90’ covers with supports
- 3 zone 28,000 BTU air source heat pump
- 50kwh Lithium ion battery and inverter
- 3 circulatory fans
- Microcontroller based thermal management system

Design Calculations & Decisions

Simulation of 7 days:



HEAT PUMP CAPACITY REQUIREMENT (Based on worst hour):
Peak Heat Load Required: 48264 BTU/hr
Min Heat Pump Size: 4.02 Tons (1 Ton = 12k BTU/hr)

TOTAL LOADS (7 DAYS):
Total 7-Day Heating Load: 2076920 BTU
Total 7-Day Electrical Load: 152.2 kWh (with COP 4.0)

VERTICAL BIFACIAL SOLAR ARRAY:
Array Nameplate Capacity: 8.2 kW
Number of 550W Panels: 15 panels (East/West)

BATTERY BANK (STORM BRIDGING):
Max Energy Deficit: 40.0 kWh (Days 3-4 Blizzard)
Battery Capacity Needed: 50.0 kWh (assuming 80% DoD limit)

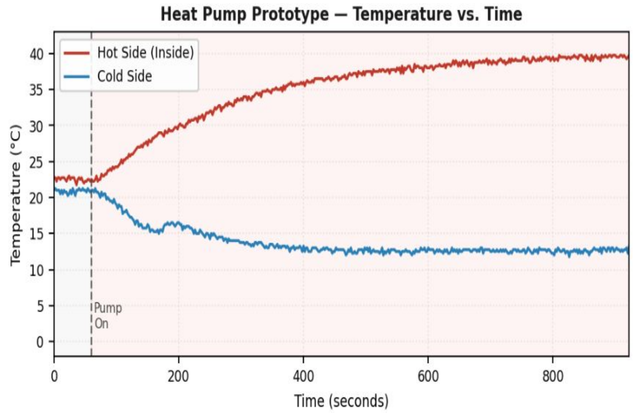
Heating Load: 46,264 BTU/hr (full system), 26,975 BTU/hr (arch system) used to size the heat pump

Heat Pump Selected: 28,000 BTU unit, COP of 3.5 to allow margin for performance in cold conditions

Trough Sizing: 4 x 5 x 90’ to reduce the air volume requiring heating, lowering total energy demand

$$Q_{\text{in}} = \dot{m}\, c_p\, (T_{\text{inlet}} - T_{\text{inside}})\,,\quad Q_{\text{loss}} = U\, A\, (T_{\text{inside}} - T_{\text{outside}})$$

Prototype & Test Results



Greenhouse heats up to viable temperatures for tropical crop seedlings, taking 800 seconds to reach steady state.

Machined Heatsink

Trough and Heat Generator

Solar Panel Frame