IRC New Roots Farm, Sacramento
Coolbot Coolroom
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Design Brief

The International Rescue Committee is an organization that responds to world crises by delivering immediate aid and being involved in long-term recovery of the people involved [1]. The New Roots Farm in Sacramento, a program of the IRC, provides refugee families with a plot of land to produce for personal consumption or for economy.
Our project goals were to calculate the power needs of a Coolbot coolroom to be installed in an existing storage container at the farm, design an appropriate photovoltaic system to support the load, design the structure to mount the required solar panels, and make a recommendation of a shade structure to span the area between the panel mounts.

Design Process and Methodology

Our project has a number of components that required individual analysis to understand each part and then a combined analysis to optimize the system. A physical prototype is not being assembled at this time but compiling this information will allow for increased ease upon construction.

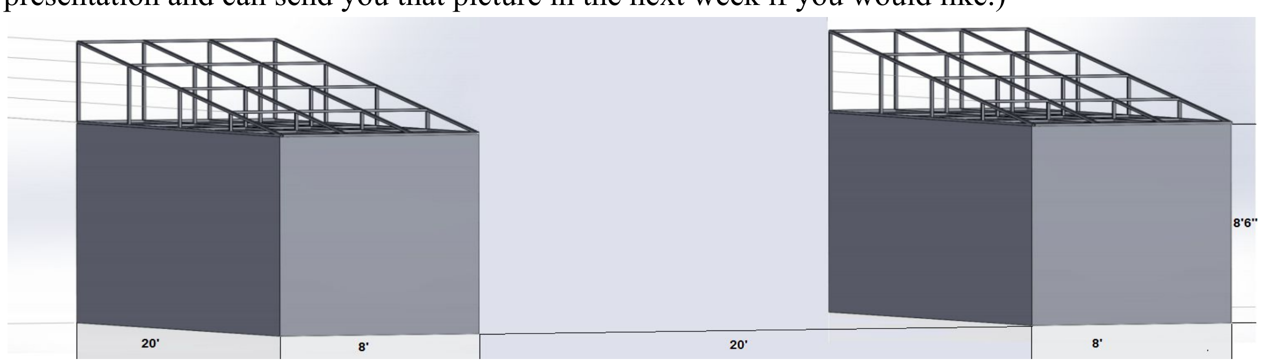
Four main parts:

1. Coolroom Power Requirements
2. Solar Power Analysis
3. Solar Mounting Design
4. Shade Structure Recommendations

Main constraints:

1. Minimizing cost is very important for this project because all materials must be donated or purchased via grants or donated funds.
2. New Roots Farm has no access to the local electrical grid so the system must be completely powered by renewable energy.

For ease of discussion, a sketch of the area of the New Roots Farm being assessed is below. On top of each storage container is a solar mount and in between the containers lies a wash station. (Note: We would like to replace this image with a picture of the poster we used in our presentation and can send you that picture in the next week if you would like.)



Coolroom Power Requirements

The main goal of our project and construction phases is a solar-powered Coolbot coolroom located in half of a standard shipping container. A Coolbot is a device that hacks conventional AC units to decrease the minimum cooling temperature to near freezing. To understand the power requirements of the proposed coolroom, data was gathered from a slightly smaller, grid-powered Coolbot coolroom on the grounds of the UC Davis Student Farm. Using a watt meter and temperature loggers placed inside and outside the coolroom, information on the power consumption of the coolroom based on the temperature difference was collected and analyzed. This data was used as a minimum estimate of the expected energy consumption of and power required for the coolroom for the New Roots Farm. This data was also used to recommend the sizing of the AC unit.

Solar Power Analysis

The primary requirement for the solar power analysis is to design a solar power system that can provide sufficient power and energy to the proposed AC unit. As stated above, the amount of power and energy needed was estimated by monitoring and analyzing a Coolbot coolroom at UC Davis. The total available daily energy was calculated using the specifications for the solar panels donated to the farm and literature on the amount of solar radiation based on geographical location [2,3]. The intermediate components including the charge controller, batteries, and inverter were analyzed to ensure that the input and output specifications of each component were compatible. A charge controller, inverter, and battery pack was donated to the New Roots Farm for long term loan [4-7].

Solar Mounting Design

Noting that all 24 donated solar panels were needed to satisfy the power requirements of the coolroom, three possible designs to mount the panels were created. The considerations taken into account were as follows:

1. Minimum complexity because much of the project labor force will come from people with no formal construction training.
2. Low cost because funds will be provided solely through donations or grants.
3. Design considerations for working around a vent located at the top center of each shipping container.
4. Aesthetics to promote a cohesive display on the farm.
5. Ease of integrating a shade structure for general use.
6. The ability to move the system was considered because the farm is currently leasing their property.
7. Shading the coolroom and arranging the panels to have high efficiency is important to minimize the load required and increase available power.

With our client, each consideration was assigned a weight and a design was chosen as displayed in the matrix below.

Consideration	Weight (1-5, 5=Important)	One structure on each side, angled west and east	Two structures on each side, angled south	One structure on each side, angled south
Min. Complexity	2	4	3	4
Low Cost	5	4	3	4
Vent Considerations	3	3	4	2
Aesthetics	5	3	4	5
Ease of Canopy Incorporation	1	5	3	4
Mobility	3	5	5	5
Shades coolroom	4	5	3	4
Power Efficiency	4	3	4	5
Total Score:		104	99	114

Shade Structure Recommendations

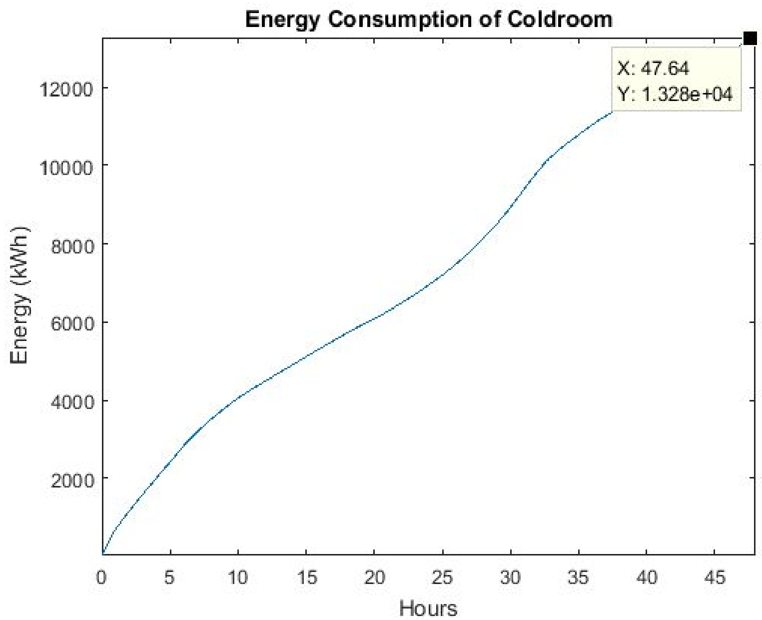
In addition to the coolroom system, our client requested information on installing a shade structure between the two storage containers. The most important criteria included its ability to provide shade to the wash station between the two storage containers, ease of installation, and nature as a commercially available kit to expedite permit applications. After discussing concerns of strong winds and heavy rain, our best options were either a strong canopy structure mounted to the edges of the containers or a freestanding structure.

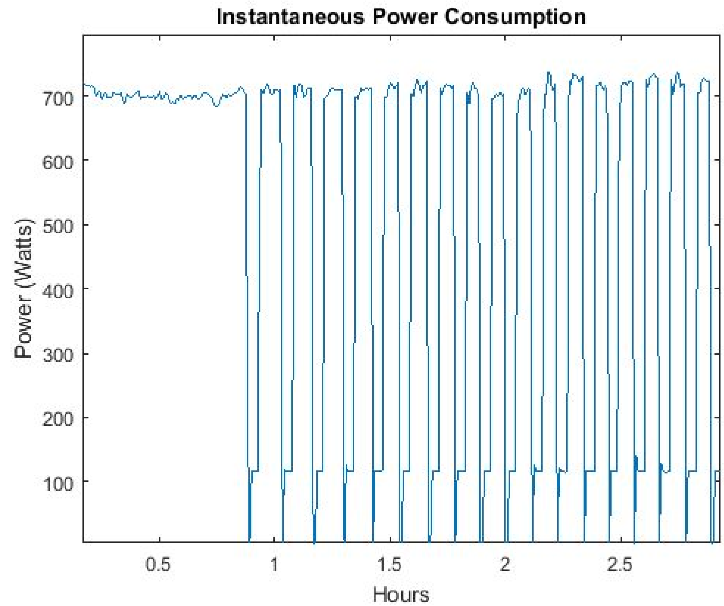
Results and Discussion

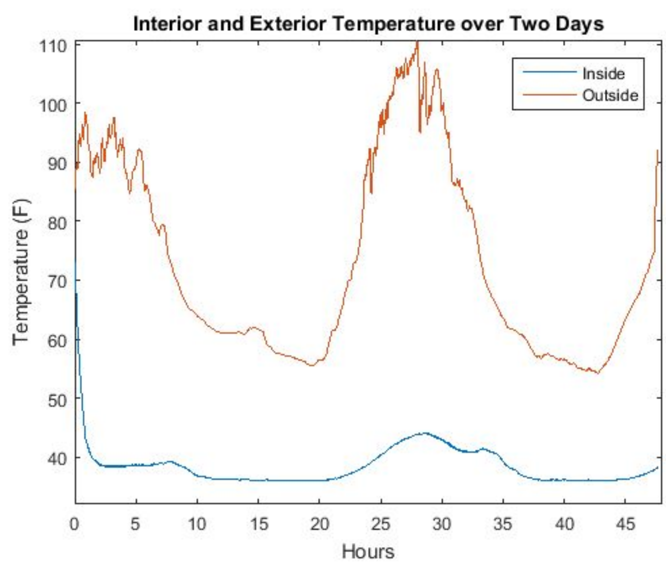
Coolroom Power Requirements

The figures below display data gathered from the Coolbot coolroom on the grounds of the UC Davis Student Farm. The data shows the air conditioner requires 700W when on and consumes a total of 13.25 kWh over two days. Despite this, the graph titled "Interior and Exterior Temperature over Two Days" displays that the air conditioner was not able to cool the coolroom to the desired temperature if the outside temperature is very high. This data requires that a higher BTU AC unit than what was used in this coolroom is desired for our system and the expected power will be greater than what was measured.

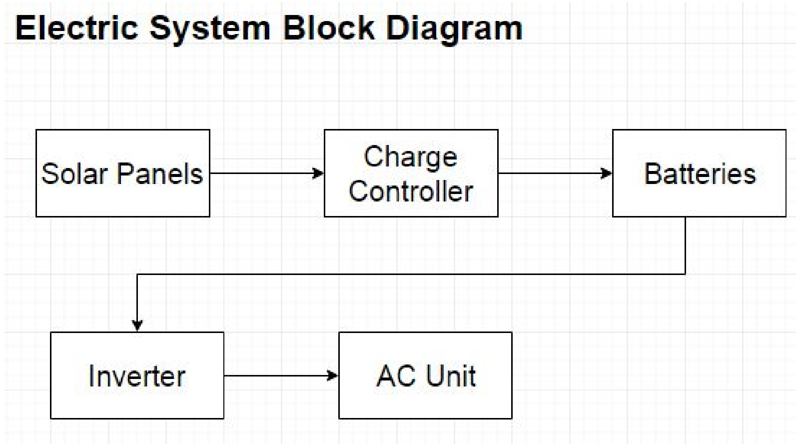
Upgrading from a 8000 BTU to a 12000 BTU air conditioner is suggested. This will allow for a shorter temperature pull-down time and increased ability to maintain a temperature. This increases the instantaneous power draw of the AC to 1050W when on [8]. Because the BTU/hour-watt is constant among different BTU rated ACs, the total energy consumption is not expected to increase due to this substitution. However, our coolroom will have higher energy demands because the area will be larger and the room will be full of produce to cool.


Energy Consumption of Coldroom
X: 47.64
Y: 1.328e+04
Energy (kWh)
Hours


Instantaneous Power Consumption
Power (Watts)
Hours


Interior and Exterior Temperature over Two Days
Inside
Outside
Temperature (F)
Hours

Solar Power Analysis
Below is a breakdown of the components required in the electrical system.



Solar Panel - Charge Controller Compatibility
The specifications of the solar panels and the loaned charge controller were used to check their compatibility.

Solar Panel Specifications:		
Max Output Voltage (V)	Max Output Current (A)	Max Output Power (W)
16.8 DC	7.12 DC	120

Charge Controller Specifications:		
Max Input Voltage (V)	Max Input Current (A)	Output Setting (V)
125 DC	45 DC	12V

Given the number of solar panels available at the farm, their specifications, and specifications of the charge controller, there are two appropriate configurations.
1) Connect 6 panels in series and have four of these groups in parallel.
2) Connect 4 panels in series and have six of these groups in parallel.

Setup 1		Setup 2	
Max Current (A)	Max Voltage (V)	Max Current (A)	Max Voltage (V)
28.5	100.8V	42.75	67.2

While both configurations are compatible with the system, the first setup is recommended for the simplest panel wiring and to set panel current and voltage sufficiently far from the limitations of the charge controller. This setup has the six panels of each rig connected in series and then each of the four rigs wired in parallel to the battery. It is important that all wires and connections for the panels are capable of running at least 30A of current; each wire connecting the panels to the charge controller should be at least 8 gauge wire.

Charge Controller - Battery Compatibility
If the voltage of the battery pack is 12, 24, or 48V, the charge controller and battery set will be compatible. For best practice, the batteries should have the capacity to store approximately two days worth of load, or a minimum of 1 day. According to data collected, the required energy for two days is approximately 13.25 kWh. For our application, this should be increased by ~15% to account for increases in load due to a larger area, hotter days, and added produce added. This yields 15kWh for two days storage and 7.5 kWh for one day.

Limitations in battery pack voltage exist because the donated inverter only works with 12V battery packs. Three options are available: use the two donated 6V batteries as a 12V battery pack, use three 12V battery packs in parallel, or purchase a new inverter that works for 24V battery packs and use two 24V battery packs in parallel. It is not advised to use more than three battery packs in parallel because mismatch in the packs cause significant decrease in lifetime.

Setup	Number of batteries	Capacity (kWh)	Cost [6,7] ($)
1	2	2.5	0
2	6	11.2	2100
3	8	16.5	2950

The last option is more than two days worth of load and may be more than what is needed. The second option is the best compromise between performance and cost. The first option does not have the ability to store one day worth of load so the system may lose functionality overnight and during cloudy days.

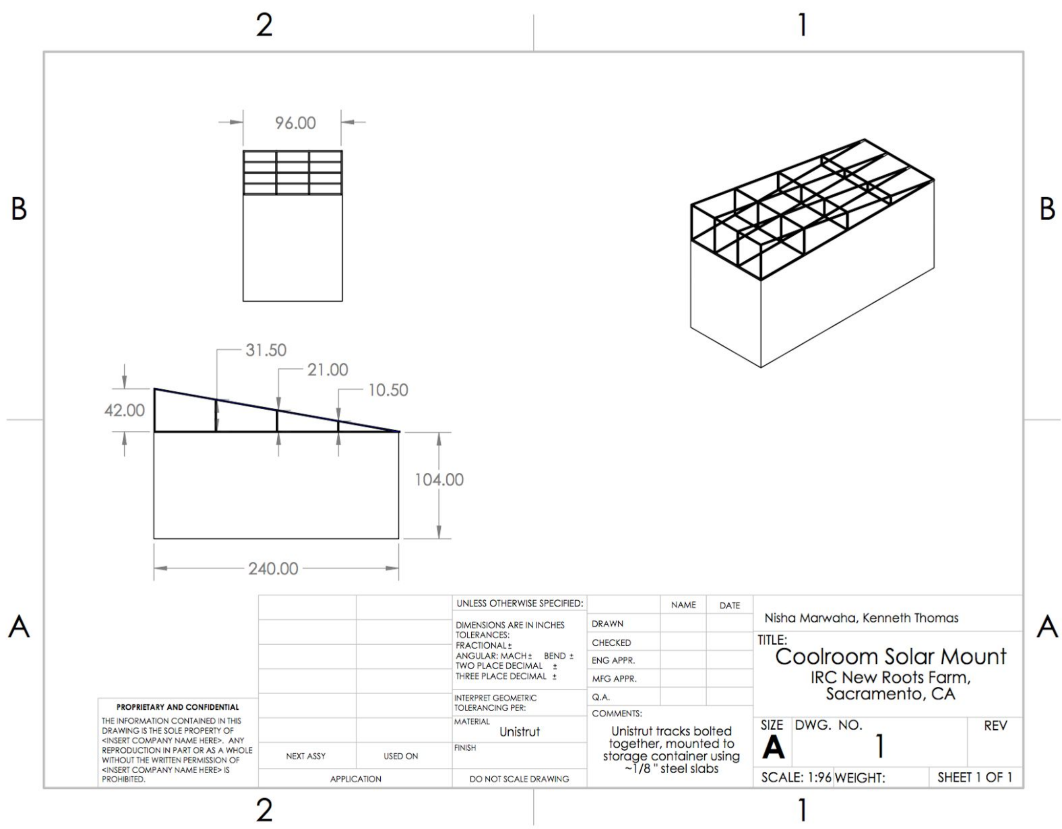
Battery - Inverter Compatibility
The only constraint is that the donated inverter must have an input of 12V. The load the inverter places on the batteries during operation was taken into account when sizing the battery packs.

Inverter - AC Compatibility
The donated inverter can output 2500W and the recommended AC unit runs on approximately 1050W. The AC will not compromise the load limitations of the inverter so excess energy could

be used to power other electronics on the farm.

Solar Mounting Design

The image below is a drawing of how the solar panels will be secured to the storage containers. The frame will be constructed of unistrut, a steel track, and smaller components including clamps, bolts, steel slabs, and L-joints to secure the track to other track pieces and to the container. These particular heights were chosen to accommodate an 18”-tall vent that lies in the center of the containers. Sourcing the unistrut from an industry professional, the cost of the total footage of unistrut needed will be approximately $735 (~457 total feet needed to mount on both containers at $1.60 per foot). A rough cost estimate of the smaller components reaches a total of approximately $300 but a finer estimate will be created as more information on the amount of donated materials is available[9].



Shade Structure Recommendations

Initially, we worked with a tarp design hung using clamps and cables. After further discussion with our client we moved towards a sturdier model that could be attached to the edges of the storage container or a freestanding option. Based on energy and cost restraints, we have recommended a freestanding model that will not interfere with the proposed solar mounts. An image of the recommended carport canopy is below[10].

Conclusions

Coolroom Power Requirements

The coldroom power and energy requirements were estimated by taking power and temperature measurements from an existing Coolbot coolroom. While this should provide a good estimate of the power consumption of a similar system, it is important to understand in what ways the measured coolroom differs from our designed coolroom. The measured coolroom was empty, slightly smaller, and powered by the local electrical grid. To refine our measurements, data should be gathered when the coolroom contains produce and at a time more representative of a hot summer day.

Solar Power Analysis

The solar panel analysis guarantees that if the equipment works as specifications, the electronics will be able to power the coolroom. The analysis ensures that the available components to the farm are compatible. Despite this, the donated batteries may not be able to support the system so three options for energy storage were proposed.

Solar Mounting Design

The design that was made for mounting the solar panels matches the specifications of our client. Construction will ensue after funds are allocated and any further obstacles that may arise will be solved then.

Shade Structure Recommendations

The recommendation for the shade structure fits the client's wants and needs. It is within the available budget, can be easily ordered and quickly delivered to the farm, is a commercially available kit that requires little expertise to construct, and shades the one side of the coolroom.

Recommendations

Coolroom Power Requirements

A few additional tests should be run on the UC Davis coolroom.

1. Fill the coolroom with a significant amount of thermal mass to see the temperature

distribution at night.
2. Add a model of the produce to the coolroom to observe how the power and energy requirements change.

The physical coolroom on the New Roots farm needs to be designed and constructed after appropriate funds are allocated.

Solar Power Analysis
The desired battery configuration must be chosen and, if necessary, ordered. Once the solar mounting structure is finished, the solar system should be assembled.

Solar Mounting Design
The materials to build the solar mounts need to be ordered. A finer cost estimate should be assembled for the clamps and other small pieces that will be extremely helpful in construction.

Shade Structure Recommendations
The recommended shade structure can be ordered and constructed.

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