Regional Environmental Council

Mobile Farmers Market

An Interactive Qualifying Project
Submitted to the faculty of
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In partial fulfillment of the requirements for the
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Abstract

Food insecurity is a growing problem in the United States. In Worcester, the Regional Environmental Council started a Mobile Farmers' Market to sell, local grown, nutritious food to food insecure neighborhoods. To help them diversify the products they carried and increase the profitability of the operation, we designed a solar powered refrigeration system and a new product storage system.

Acknowledgements

The Mobile Farmers' Market team would like to thank everyone who helped with our project.

We would first like to thank our advisors, Prof. Hersh and Prof. Schuberth, whose immense contributions were pivotal to the quality and completion of this project.

We would also like to thank Casey Burns, Anthony Gardner, Danny Nguyen, and Brian Montevard for giving us the opportunity to help them in their mission, and for working so closely with us over the course of the project.

We would also like to thank the participants of our focus group, who helped us understand what customers' needs and interests for the mobile market were.

Executive Summary

In the United States, access to healthy and nutritious food for many low income households is decreasing. The USDA defines access to healthy food as food security, which is "access by all people at all times to enough food for an active, healthy life" (USDA 2012, p. 2). The USDA has 2 different levels of food insecurity, the first being low food security, which they define as "multiple indications of food access problems, but typically have reported few, if any, indications of reduced food intake" (USDA 2012, p. 4). The second is very low food security, which is defined as "multiple indications of reduced food intake and disrupted eating patterns…" (USDA 2012, p. 4). In 2003 the USDA found 11.2% of U.S. households were food insecure, and increase of 3.7% over 8 years (USDA 2004, p. 3).In 2011, the USDA found that 14.9% of U.S. households were food insecure and 5.7% had very low food security.

The Regional Environmental Council (REC) is working to address food insecurity in Worcester with its Food Justice Program. This program includes farmers' markets, youth outreach programs like YouthGROW, and other programs to teach Worcester residents about healthy eating habits and provide healthy food to these residents. Unfortunately, food insecurity remains a growing problem in Worcester despite these programs.

Last year the REC started the Mobile Farmers' Market. This mobile market, a converted van, travels to low income areas in Worcester to sell healthy food at discount prices to provide the residents with a healthy diet. Currently, the market sells fruits and vegetables at each of their stops, while one of their suppliers, Schultz Farm, follows with their own van to sell products the REC does not sell, such as meat and dairy products. The mobile market ran 2 days a week during its pilot season, and this year, to expand food access in more Worcester neighborhoods, it will run 3 days, and make stops in 5 different neighborhoods in Worcester. Our goal was to help the REC expand access to healthy, nutritious food in low income areas of Worcester and to diversify the product line on the van. To accomplish this, we identified how we could redesign the market to better fit the needs of the REC and its customers.

Milk, meat and eggs are an important part of a nutritional diet and providing these items in low income areas for low prices would be beneficial to the residents of these areas. The REC wants to offer these products for the upcoming year and asked us to design a system that would include two units, a freezer for meat and a refrigerator for milk and eggs. The meat would be given to the REC frozen, and they would like to keep the meat frozen until it is sold. The REC wanted the refrigeration units to be powered by solar panels mounted in the roof of the mobile market. This would allow them to operate while the market is not running. The budget for the entire solar power system, including the refrigerator and freezer, was $3,000.

The Figures 1, 2, and 3 below show our final designs for the market. Figure 1 shows a diagram of the solar powered refrigeration system, while figures 2 and 3 show the physical van layout design.

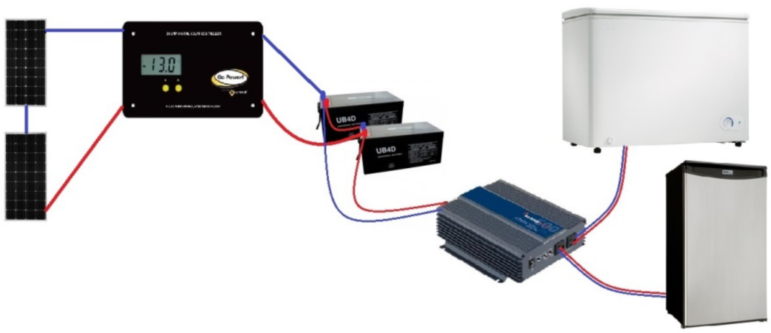

Figure 1: Components for the solar power system connected.

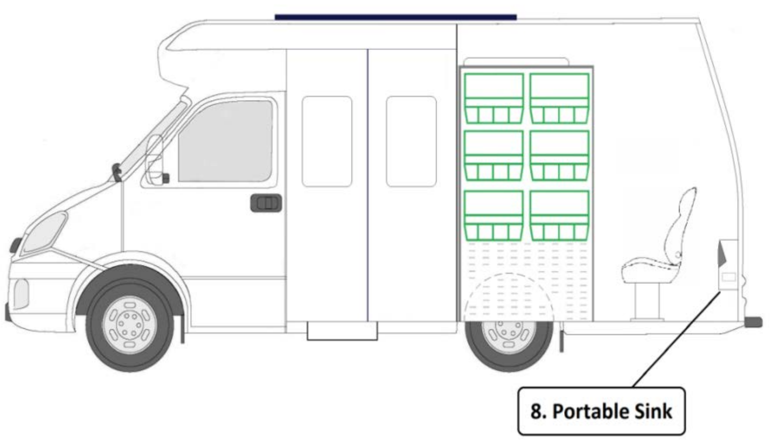

Figure 2: Final design of the interior right side of van

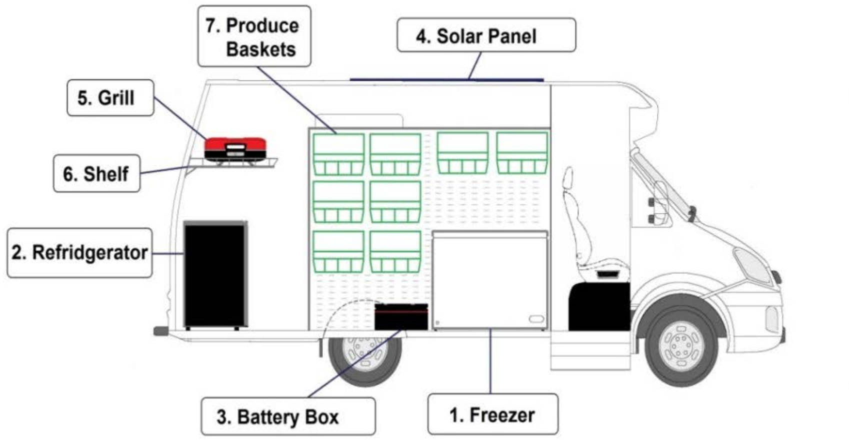

Figure 3: Final Design of the interior right side of van.

To design the solar powered refrigeration system, we learned we needed solar panels to generate electricity, batteries to hold the energy from the solar panels, a charge controller to regulate the current to the batteries, and an inverter to convert the DC signal from the batteries to an AC for the refrigerator and freezer.

The refrigerator and freezer we chose required 240 watts of power to operate. We decided on 2 12V panels, which output 155W each for a total of 310 watts, to meet this power requirement. We chose panels which output more than the required power because the rating of a solar panel is for ideal conditions, rather than real-world performance. The panels were wired in series, to create a 24V panel to properly charge the batteries.

We decided to use 2 12V batteries, each with a 200AH capacity. These were wired in series to create a 24V battery bank, with a total battery life of 23 hours. A charge controller from the same company as the solar panels was chosen to regulate the current to the batteries, to prevent damage from over charging. The chosen inverter was 600 watts, and was a pure sine wave inverter, which does not degrade the signal from the batteries, allowing for the highest efficiency.

Figure 4: The grill to be added on the van

The REC will start a new program called Share Our Strength's Cooking Matters, which will teach customers of the market how to prepare and cook the products sold on the market. To do these lessons, the REC wanted a grill to cook with. We chose a small, portable gas grill which will sit on a shelf in the van, which is part of our interior design above.

Figure 5: The sink to be added to the van

According to Massachusetts general laws, anyone preparing food for public consumption in a commercial setting is required to meet certain sanitary standards. The REC needed a sink to ensure they could wash their products and their hands while giving cooking lessons to meet this requirement.

Our recommendations involve both improving the operations of the mobile market, and improving the solar powered refrigeration system. They include:

1. Assess the effectiveness of the solar powered refrigeration system, and possibly upgrade to a more efficient refrigerator and/or freezer.

2. Using Coolbot technology, build a freestanding refrigerator to store produce and add flexibility to the mobile market's operations
3. Use the Mobile Market to help launch other direct food marketing initiatives, such as a community supported agriculture scheme and buying clubs.
4. Design an attractive trailer that could be pulled by the mobile van to increase the availability of products.

Recommendation 1 involves adding a more efficient refrigerator and freezer. Our final design allows for a full day of power if the batteries are fully charged. While this used the greatest battery life available to the REC, they may need to unload the meat and dairy products during the week if there is not enough sunlight to recharge the batteries. There are more efficient refrigerator and freezers available, such as the products from Sundanzer, which use 25% of the power the refrigerator and freezer we chose use. However, as can be seen in the table below, these were too expensive to include in the final design.

	Solar panels	Charge Controller	Batteries	Inverter	Refrigerator and freezer	Total
Final design	2@ $335 each	$135	2@ $350 each	$240	$200 and $300	$ 2295
Design with Sundanzer	2@ $335 each	$135	2@ $350 each	$0	$1,149 and $1,189	$ 3843

Table 1: Cost of our final design, compared with the cost of using Sundanzer products.

The second recommendation asks the REC to consider building a large, private refrigerator to store the mobile market's products. In the 2012 season they kept their products at the Worcester Senior Center. We recommend creating their own space to store their products so they have access to them at any time, and possibly keep them closer to the REC.

We recommend a Coolbot refrigeration system, which uses a window air conditioner to keep a room between 35-36 degrees Fahrenheit. This is done by using a device called a Coolbot, which measures the temperature of the room and keeps the air conditioner on long enough to maintain the desired temperature.

Recommendation 3 asks the REC to use the mobile more during the week. In the 2013 season they plan to only use the van 4 days a week. We would like to see that increased, possibly by using the current off days to serve a community supported agriculture program, or other food delivery service.

Recommendation 4 discusses using a trailer as additional storage for the mobile market, as a secondary market. This could either be a Coolbot refrigerated unit the mobile market brings with them, or an unrefrigerated market which travels to places the mobile market does not go.

Authorship

Jerome Anaya led the design of the product display outside the market. He also researched portable grills for cooking demonstrations and portable sinks to meet cleanliness standards on the market. Jerome was the primary author for the background chapter, as well as the operations, physical layout, and economics sections of the findings chapter. He also authored the Recommendation 3 of the recommendations chapter. He also edited the methodology, and helped edit and format the final report.

Matthew Coughlin researched components for the solar powered refrigeration system, including the refrigerator, freezer, solar panels, and solar charger. He was the primary author of the abstract, executive summary, and introduction. He was the primary author for the introduction, and refrigeration sections of the findings, and the first recommendation of the recommendations chapter. Matthew helped edit the findings, recommendations, and background chapters, and helped edit and format the final report.

Ritesh Adhikari led the design for the power storage of the solar powered refrigeration system. He researched solar panel and battery technologies to determine the design which would yield the greatest battery life. He was the primary author for the methodology chapter, the solar panel, battery, and final design sections of the findings chapter. He too, helped edit and format the final report.

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Chapter 1: Introduction

Access to affordable and nutritious food in low-income communities is a growing problem in the United States. The United States Department of Agriculture (USDA) defines this problem as food insecurity, which they have given 2 levels of severity. The first is low food security, which the USDA defines as "multiple indications of food access problems, but typically have reported few, if any, indications of reduced food intake" (USDA 2012, p. 4). The second and more severe degree of food insecurity is very low food security, which is defined as "multiple indications of reduced food intake and disrupted eating patterns…" (USDA 2012, p. 4). If a family or individual does not have access to quality, healthy food in proper quantity, they are considered food insecure. 14.9% of U.S. households were considered food insecure in 2011 by the USDA, with 5.7% considered to have very low food security (USDA 2012, p. 4). This number increased by nearly 500,000 households from 2010 (USDA 2012, p. 6).

The federal government has implemented various programs to help reduce food insecurity. These programs include the Supplemental Nutrition Assistance Program (SNAP) and Women, Infants, and Children (WIC). SNAP is available to any individual or family who is considered to have an income too low to properly support them. SNAP was previously the Food Stamp Program. WIC is targeted to women, infants, and children up to the age of 5, to help with both nutritious food access and provide healthcare referrals. Both SNAP and WIC recipients can use Electronic Benefit Transfer (EBT) to pay for their food, using a state issued debit card linked to the recipient's benefits. This system makes purchases easier, which is intended to increase use of these programs by eligible individuals and families.

The residents of Worcester's 14 low income neighborhoods are among the millions of food insecure people in the U.S. The Regional Environmental Council's (REC) Food Justice Program has put forth a large effort to reduce the amount of food insecure residents in Worcester. The Food Justice Program has 4 programs to reduce food insecurity, which are UGROW, YouthGROW, farmers markets, and Share Our Strength's Cooking Matters. UGROW is a community garden network which connects small community farms in Worcester focused on low income individuals and families. YouthGROW employs low income high school teenagers for urban agriculture projects. The REC holds a farmers' market every Saturday during the summer to provide a place for Worcester residents to buy fresh, healthy food. The Share Our Strength's Cooking Matters program teaches how to prepare and cook healthy food.

As an extension of their farmers' market program, the REC started a Mobile Farmers' Market. This market is able to travel throughout Worcester to offer healthy food at a low cost to areas of low income and at risk of food insecurity. The REC's Food Justice Program has identified key low-income areas that need better access to fresh produce. The Mobile Market's current process includes buying the produce directly from the farmers at the beginning of the week and storing it at the Senior Center. The produce is sold on Tuesdays and Thursdays, and any produce not sold is donated to a local food bank.

This year the REC hopes to offer meat and dairy products as well to increase their product diversity and to give more options to their customers. To do this, they would like to add refrigeration units and asked us to design a solar powered system. The REC van, however, has limited space to carry additional products. The van would benefit from a redesign of its display of produce. Currently, REC market staff simply use a table at each stop to setup their produce. We examined options to better display their produce and to improve the shopping experience of their customers.

The goal of this project was to improve access to affordable, healthy, and fresh food for the most underserved areas in the city of Worcester by meeting two objectives. The first is to identify an effective and economically feasible solar powered refrigeration system and the second is to make the van more attractive to local customers through design.

Chapter 2: Background

To provide a broader context for our project, we will first discuss trends in food insecurity in the United States. Next, we will discuss programs for addressing food security, and then consider how problems with food security are being addressed in Worcester. In order to give a full account of why the REC's Mobile Farmer's Market was started, we will discuss the background of the REC Food justice Program and the current market.

2.1 The Extend of Food Insecurity in the US

The United States, as well as the rest of the world, is facing a potential crisis in terms of food security. The USDA defines food security for a household as access by all members at all times to enough food for an active, healthy life. In order for a house to be food secure, the members of the house must have access to readily available food that is nutritionally adequate for a balanced diet. We would also require the household have the ability to acquire acceptable foods in socially acceptable ways (that is, without resorting to emergency food supplies, scavenging, stealing or other coping strategies).

In a survey conducted by the USDA's Economic Research Service, it found that an estimated 85.1 percent of American households were food secure throughout the entire year in 2011, meaning that they had access at all times to enough food for an active, healthy life for all household members. The remaining households (14.9 percent) were food insecure at some time during the year, including 5.7 percent with very low food security, which means the food intake of one or more household members was reduced and their eating patterns were disrupted at times during the year because the household lacked money and other resources for food. (USDA, 2012, p. 4)

One of the main causes of food insecurity is food deserts. The USDA defines food deserts as urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable food. Instead of supermarkets and grocery stores, these communities may have no food access or are served only by fast food restaurants and convenience stores that offer a limited amount of healthy, affordable food options. The USDA has been able to designate food deserts in assessing food security though the USDA Economic Research Service.

Current research services by the USDA have been able to pinpoint four food deserts in Worcester, which have an estimated 14,484 people with low access to affordable and nutritious food, and 3,579 of those people are considered to be low-income. This low-income group is considered to be more vulnerable to food insecurity because they face difficulty both physically and economically in obtaining nutritious food.

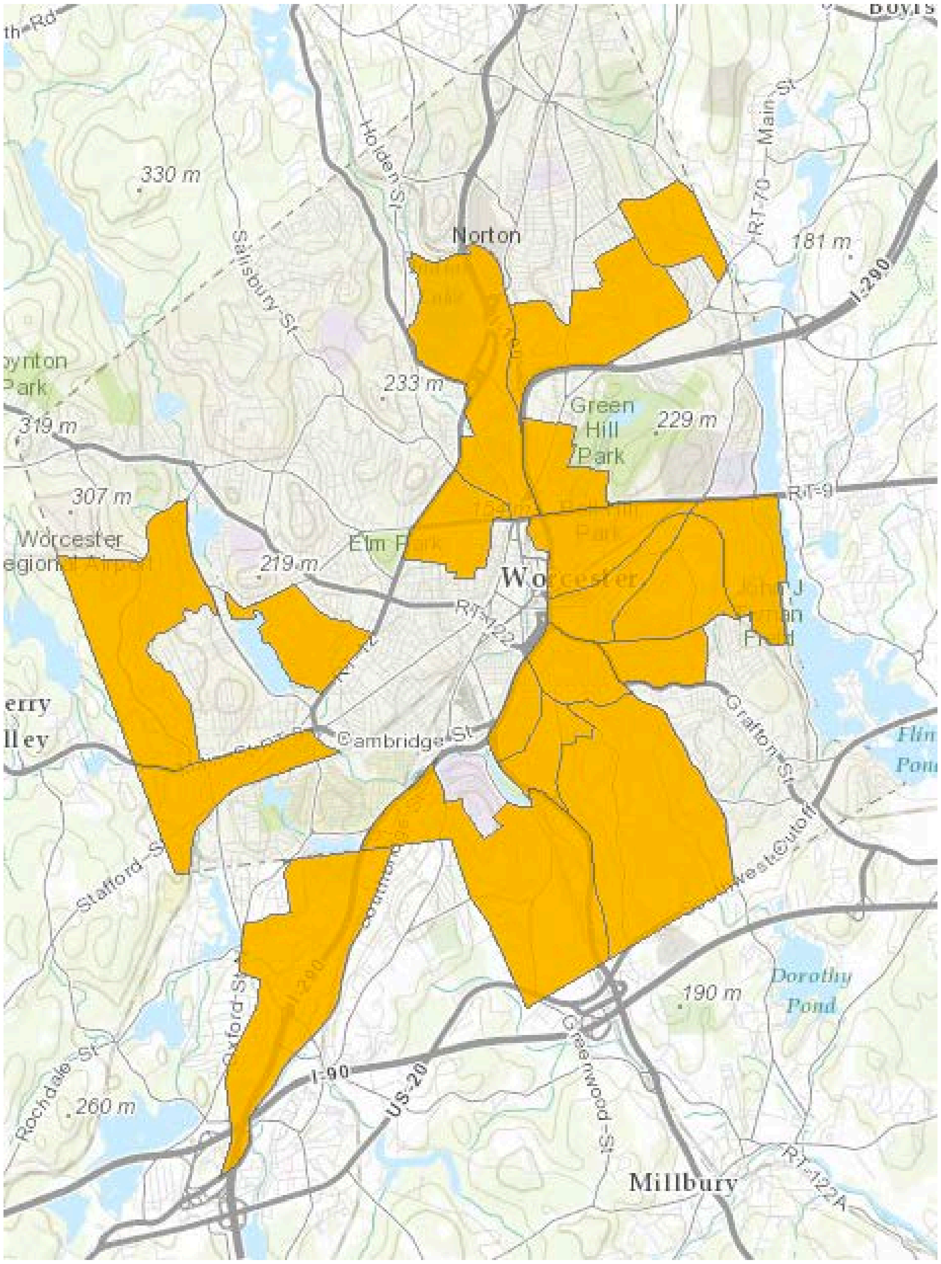


Figure 6: USDA 2013 Food Desert Map at ½ Mile Radius

2.2 Current programs to address food insecurity are inadequate

In order to address food insecurities, a number of initiatives have been established. There are three large Federal Food Assistance Programs solely meant to financially help citizens to attain healthy, appropriate foods. Many domestic and local programs have been established to address food deserts, including farmers' markets, Community Supported Agriculture groups, community gardens, and farm stands.

Federal Assistant Programs

The three largest Federal Food Assistance programs are the Supplemental Nutrition Assistance Program (SNAP), the National School Lunch Program (NSLP) and the special supplemental nutritional program for Women, Infants and Children (WIC). SNAP provides benefits through electronic benefit transfer (EBT) or paper coupons to low-income households for purchasing nutritional food. Similarly WIC provides coupons or EBT cards to pregnant and breastfeeding women, infants and children under 5 years of age in low-income families. NSLP is a federal subsidies program that serves free or reduced-price lunches to students from low-income families in public schools throughout the U.S. With all these programs targeting low-income households, it can be derived most of the food insecure fall under the low-income class.

These programs are only partially effective in reducing food insecurity. In a 2012 study that sought to measure the effectiveness of SNAP, it found that SNAP reduces the likelihood of being food insecure by roughly 30 percent and the likelihood of being very food insecure by 20 percent (Ratchliffe, 2010). However, the type of food the participants buy may not be sufficiently nutritional because they may trade the nutritional, more expensive food for the cheaper, higher volume food. Ploeg (2010) states in his book, "Low-income households shop where food prices are lower, when they can." He further mentions that SNAP is used for more canned foods and other low nutritional foods because they are cheaper.

Local Initiatives

There is a need for locally grown fresh and nutritional food to be easily accessible at affordable prices. To address this component of food insecurity, some groups focus their resources towards local programs such as farmers' markets, Community Supported Agriculture groups, community gardens, and farm stands. These programs are meant to serve communities by providing the cheapest costs of produce for the consumers.

Farmers' Markets are markets where a group of farmers come together to sell food products directly to the public. Farmers' markets benefit both the consumer and the farmer because they eliminate the "middle man". In this case, the "middle man" is the retailer who sells the food, including convenience stores and super markets. The retailer buys the produce from the farmer, and resells it at higher prices to the public. Therefore, cutting out the middle man reduces the price of products for consumers, as well as helps local and domestic farmers. One study carried out by University of Toronto, Department of Geography and Planning, suggests that farmers' markets not only offer lower prices, but also improve access to healthy produce (Larsen, 2009).

The major obstacle that farmers' markets face is reaching SNAP participants. Not all farmers' markets accept SNAP or WIC benefits, but a majority of the farmers' markets nationwide accept SNAP and WIC benefits. The federal government has taken several initiatives to help address the issue of food insecurity by providing large amounts of funding through grants for farmers' markets, especially to provide additional discounts for those who use SNAP benefits (USDA, 2009). Farmers' Markets stand to gain a significant amount of revenue if they increase the number SNAP customers.

Another direct marketing method is Community Supported Agriculture (CSA). In a CSA, the consumer provides up-front support by buying shares of produce from local farmers before the season begins. Throughout the season, the consumer receives their shares of the harvest from that same farm. Each share is defined differently depending on the farmer, but a share usually includes enough vegetables and/or fruit for two adults to last a week.

CSA's are relatively flexible as long as there is a farmer who can provide the land and is willing to transport the produce. The success, however, depends on a few variables, including management and proper support. There are also a few major risk factors in CSA systems. Risk factors include injury, crop failure, and instability of market prices carried by the farmer (Cone, 2000). This has a major impact on the consumer, especially if the consumer is completely dependent on the system. The consumer may fail to finance the farmer because they do not have cash available to the farmer in advance. This is one of the major difficulties that a low-income community faces in the establishment of a CSA.

2.3 Improving Food Access through Mobile Farmers' Markets

The defining feature of food deserts is the lack of supermarkets or other food retail outlets where residents have access to healthy food choices. In low income neighborhoods the problem of food access is exacerbated by poor public transportation; people often cannot use buses to get to supermarkets outside of their neighborhoods. Moreover a larger proportion of persons living in low income urban neighborhoods do not own automobiles, which means they have to carry their groceries home, and some people physically cannot carry heavy groceries, such as the elderly. One recent trend across the nation has been the growing activity of mobile farmers' markets. Mobile markets are a type of business that provides fresh produce for consumers. A mobile market usually consists of a group who sources produce from two or more farms, and travels to various locations to sell the produce. Some even deliver directly to consumers. When a mobile market is set up, there is usually a set schedule for the stops. The consistency of the market location allows consumers to plan their schedules around the stops, thus making it easier for them to make it to the market.

The following sections describe a few established mobile farmers' markets and their operation.

Baltimore Big Blue Mobile Farmers Market:

Operated by the Real Food Farm organization, the Big Blue Mobile Farmers' Market is currently serving in Baltimore, Maryland. They primarily focus on neighborhoods where low-income residences have limited access to fresh produce. The van was purchased and retrofitted in March 2011 and has been providing fresh produce to food deserts of the Baltimore area (Sutton, 2011). One of the Real Food Farm's missions is to improve neighborhood access to healthy food by bringing fresh, pesticide-free produce to the neighborhoods. In an effort to appeal to more costumers, they deliver the produce to individual's homes, in addition to providing discounts to customers who use SNAP.

Figure 7: Baltimore's Big Blue

Farm to Family Veggie Bus:

The Farm to Family "Veggie Bus" is another successful example of a mobile farmers' market. The business began in June of 2009 (Lilly, 2010). Serving the area of Richmond, Virginia and Washington DC, local products are sourced from anyone who grows fresh produce within a 150-mile radius of the van (Lilly, 2010). This market delivers fresh produce to lower income areas of Richmond because farmers' markets and vendors of fresh and healthy produce do not traditionally serve them.

Figure 8: The FarmBus

These markets each vary from the REC's mobile farmers' market in different ways. Some, like Baltimore's market, have a pullout mechanism, which stores the food on the market, and allows for easy setup and sale of the products at each stop. Others are redesigned school busses, with the products on counters where the seats once were. Still some have pre-cooked food made from the products sold at the market, or even cook food at the market. These demonstrations are usually intended to teach customers how they can use the products at the market, to encourage healthy eating. Each market, however, has the goal of promoting healthy lifestyles. Some may also be a primary income source for the farmers, but they all believe in promoting healthy living, especially through healthy foods.

2.4 Addressing Food Insecurity in Worcester: The Regional Environmental Council (REC)

The REC has a division called the Food Justice Program, whose primary goal is increasing food security in Worcester. As stated on their website, "the Food Justice Program has focused its efforts on four project areas city wide: a community gardens network (UGROW), youth development through urban agriculture (YouthGROW), farmers markets, and a new healthy cooking education project (Share Our Strength's Cooking Matters)," (Regional Environmental Council, 2012). The farmers' market began 5 years ago as a way to provide healthy food to the food insecure areas of Worcester, and to support local farmers. Holding only a single market did not meet the needs of all the areas of Worcester the REC hoped to provide the service too, so they held a market in Great Brook Valley as well (Burns, personal communication, September 13, 2012). However, this market was not sustainable enough to keep vendors at the market (Burns).

To reach more people the REC decided to run a mobile farmers' market (Burns). The Worcester Regional Transit Authority (WRTA) provided the REC with a van to outfit as the mobile market, and funding from Harvard Pilgrim helped outfit and run the market (Burns). The purpose of this market is to travel throughout Worcester stopping at public areas, to make it easier for everyone in the community to access healthy foods. More emphasis is being put on this market due to its potential to have a greater impact on Worcester's food security. In the first year, stops were limited to ten throughout the city, five on Tuesday and five on Thursday. Through the interview with Ms. Burns, we learned that the sales from the Tuesday stops are sufficient and the Thursday morning stops sales are satisfactory (Burns). These stops have been chosen to effectively deliver the food to low-income areas. This shows there is interest from both farmers and patrons for the mobile market, which could help ensure its future.

Physical Van Use

Figure 9: The mobile market setup when selling produce at a stop.

Customers are not allowed onto the market in its current form. The vehicle is too small for more than two people to be inside at once, which means a table is setup outside the van, with the food displayed there. If the food could somehow be displayed while still on the market, customers would still be able to choose their own products, while saving time for REC employees. An interesting new design could also help attract more business, which would aid in the REC's mission to reach more people.

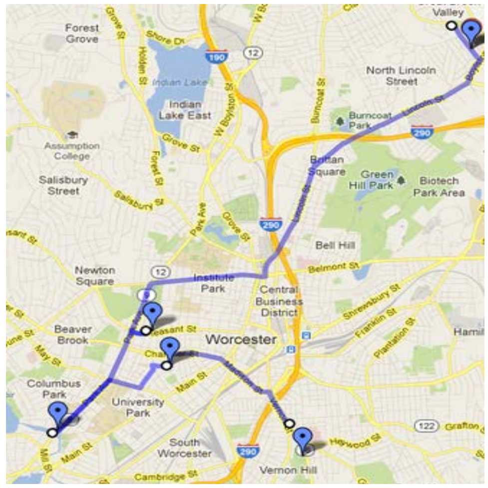


Figure 10: Tuesday stops for the REC

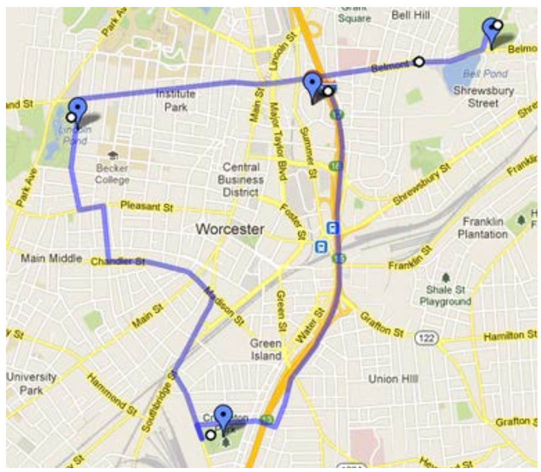


Figure 11: Thursday stops for the REC

The figures above display the routes of the Mobile Farmers' Market, on both Tuesday and Thursday. The majority of these stops service low-income neighborhoods, such as the Belmont Towers. Some also service the elderly, such as Seabury Heights Apartments. We can compare these stops to the USDA food desert track for Worcester, which can be seen in Figure 5 above, and we find that a majority of these stops are within a walking radius of the recognized food deserts.

Chapter 3: Methodology

The goal of our project is to help the REC improve access of healthy food to low-income communities in Worcester by creating a more attractive and well-designed Mobile Farmers Market. . The mobile market can easily reach any part of the city and provide nutritional and healthy food to its residents, but it is an ongoing experiment to address the problem of food insecurity. We have developed the following objectives in order to achieve our goal:

1. Identify key design parameters for the mobile farmers market van through collaboration with REC staff
2. Design a solar powered refrigeration system to increase the range of products for sale on the mobile farmers markets van
3. Develop design options to optimize the interior space of vehicle that accommodates freezer, refrigerator, produce and other things required in the van

Identifying key design parameters

Having a clear understanding of the mobile farmers' market's operation was vital to our project. We needed to know the number of days it was operating, the number of stops where they sold food, and the location of those stops. We also needed to know what kind of food it sold, and the size of vehicle. In order to have a better understanding of all these parameters, we drove with the mobile market van during one of its days of operation. After riding on the van we were also able to observe how the food is stored in the van, and how they setup and displayed food at each stop.

In addition to driving with the van, we made multiple visits to the Elm Park stop, which is closest to WPI, as well as to the REC office and conducted interviews with the REC staff. They provided us with more information about the mobile market, including which farms they source the produce from, the location of farms, and when and how they pick up the food. In addition to the current operational information, they also explained their future plans sell meat and dairy products, their desire to have a solar powered refrigeration system, and the budget they have for such a system. After gathering this information we had clearer view of what the design parameters were for our project.

Designing the solar power refrigeration system

The REC wanted to start selling meat and eggs to diversify their product line, and better serve their low income customers. To do this, they wanted to add a refrigeration system to keep these new products fresh, and they wanted to use solar energy to power it. To begin the design we started looking for freezers and refrigerators. The size of the van and the volume of products REC estimated to store in them determined their sizes. Keeping the determined sizes in mind we searched for the products from different manufactures. We also had to keep price and style in mind, to ensure we stayed under the REC's budget and gave them the style they preferred. Using these parameters, we selected a freezer and refrigerator.

The freezer and refrigerator were to be powered by solar energy. To generate solar power, we needed to find solar panels, which convert the sun's light into electricity. We did extensive research on solar panels to determine what panels would best meet the REC's needs. The research taught us about solar panels as well as how they can be used. The research revealed that the basic components required to use a solar power system are a solar panel(s), a charge controller, a battery or batteries and an inverter, which gave us the basis for our design. We were not familiar with these components, which led us to do more research on each of these components to learn what they are used for and what parameters are to be considered while selecting them. The research introduced us to various electrical terms and equations that were parameters for each component, such as battery capacity. We performed various calculations using the equations found through the research to determine how to maximize the battery life of the solar power system, while staying under the REC's budget.

Designing the interior layout and placement of the refrigeration units

After the solar powered refrigeration system was finalized, we needed to determine where each component would be placed. We measured the inside layout of the van to create accurate drawings of it. The drawings were then used to determine the best placement of the components of the solar power system inside the van. We created scaled SolidWorks drawings of the van's interior and the components of the solar power system based on their respective data sheets, to determine where to place them. These drawings were then used to experiment with the placement of the components. The drawings made it very easy for us to move around each component inside van and have an idea of how much space would they occupy.

In addition to the SolidWorks drawings, a scaled wooden model was created that helped visualize it. These drawings and the wooden model were taken to REC, where we consulted with the REC employees on where the components should be placed. After we finalized the inside layout of the van, we consulted with a professional of an auto body shop to check if it was possible to implement the design we have finalized, and how much it would cost.

Selecting the grill and the portable sink

As part of the Share our Strengths Cooking Matters, the REC wanted to have cooking demonstrations for the customers at the mobile market stops. For this we needed to research a grill that can be fueled with a standard propane canister. The grill needed to be portable because the staff member needs to be able to take it to all the stops. It also needed to be small enough to not occupy a lot of space inside the van. This led us to look at the size and cost of grills to select one.

Massachusetts law required the market to have an onsite sink if they wanted to hold onsite cooking demonstrations and give out samples at the market. Therefore, we searched for a portable sink. The criteria for selecting the sink included the portable size, cost, and supply of water. Like the grill, this sink had to be small enough to fit in the van. The portable sinks could either hold water in their own tank, or require an outside water source, like a hose. We analyzed each of the stops to see if they will have access to a hose. Based on this, we decided on the type and the size of the sink.

Designing an easier and efficient way to setup and display their products

We wanted to help the REC staff to save time while setting up the market at their stops. Therefore, we designed a system that would be easier and faster to setup. Another considered function was to make the setup attractive and appealing to customers. We researched various mobile farmers' markets throughout the country, and found that each market had very distinctive ways of storing and displaying their produce. We analyzed the possibility of adapting some of the designs found in those markets to the current REC mobile market vehicle. We used inspiration from those designs which seemed feasible to create new designs for the mobile market. The size of the vehicle and the characteristics of the stops were key parameters we considered while developing the designs.

We also held a focus group to discuss our ideas and gain new ideas and new views to improve the designs. We showed the participants pictures of existing mobile markets and explained our designs to them. We asked for their opinions and concerns with the designs we had chosen from other mobile markets and designs that we came up with. We also asked if they had ideas for any alternative designs, or entirely new ideas. We recorded the focus group on video to analyze and share their responses later. After we determined the possible designs, we presented them to the REC.

4. Findings

In this chapter we first discuss current mobile market operations and then examine the new initiatives the REC is planning for the upcoming season, such as more neighborhood stops and a more diversified product line. Our findings identify appropriate design options for the mobile market to help the REC accommodate these changes, including a solar powered refrigeration system.

4.1 Design parameters

How the Mobile Farmers Market operated played an integral part in shaping our design. Our design is meant to work with the different aspects of the operation including the products sold, the operating schedules, and the locations where the van parks.

In the first year of operation the market only sold vegetables and fruit. However, customers wanted additional products. To address this issue, the REC will sell meat and dairy in the upcoming year. This addition requires an onboard refrigerator and freezer. The placement of these additions had to make access to the products comfortable of the worker. Our definition of comfortable is any movement that can be done without complex or strenuous movements of the body.

In the first year of operation, the Market followed a weekly schedule that allowed the market to run for two days every week during the season. The schematic of this can be seen in Figure 10. The market first picked up the produce at all four farms on Monday afternoons or Tuesday mornings. If pickup was on Monday, the produce is stored at the Worcester Senior Center and picked up on Tuesday morning. On Tuesdays, the market stopped at a set of five different locations for an hour and a half at each stop. All produce that was not sold was taken back to the senior center and picked up again on Thursday. The market stopped at a different set of four locations for Thursday for the same amount of time. After the market has gone to all the stops, all unsold produce is donated to the food pantry. The schedule is represented in Figure 10 below

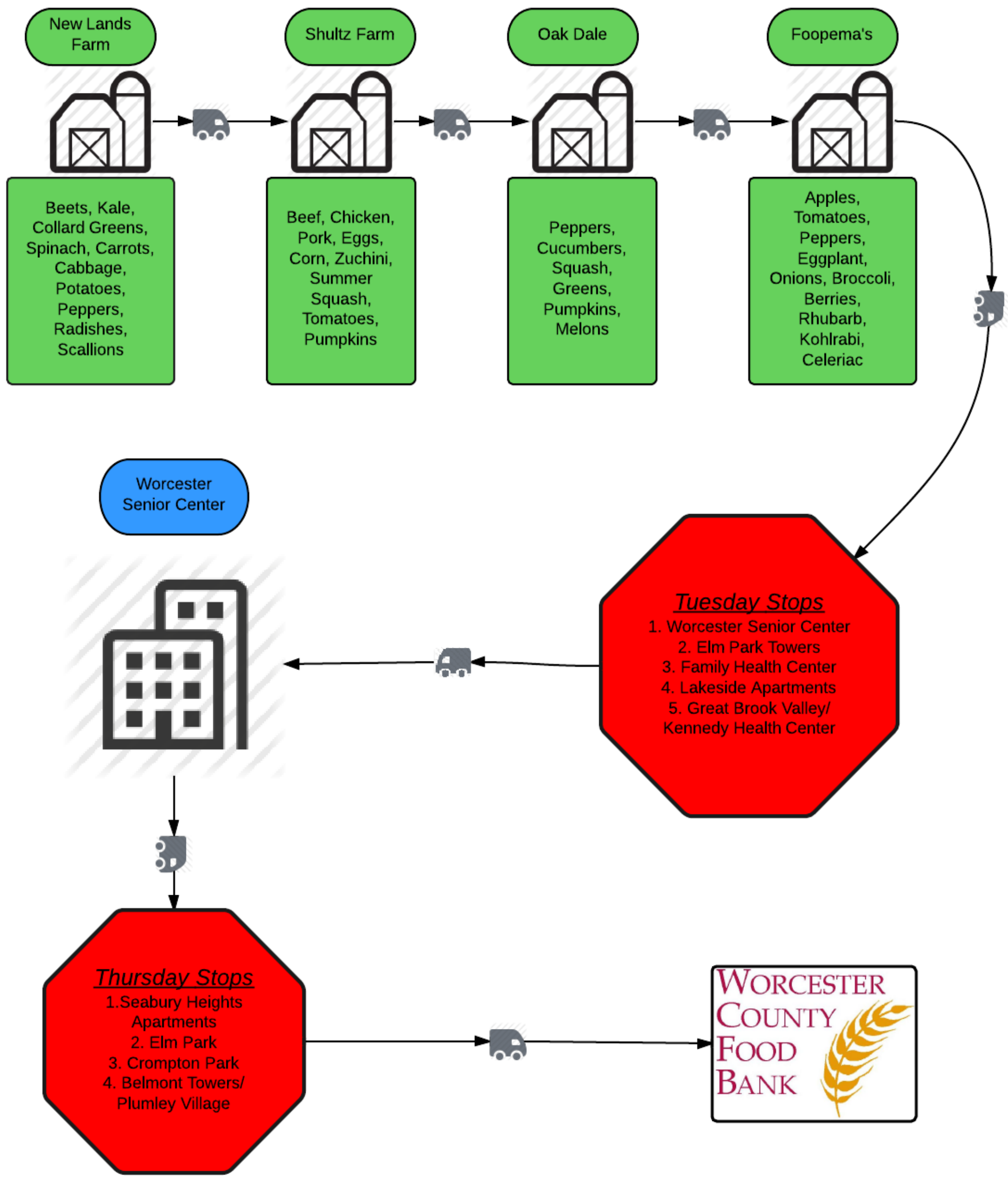


Figure 12: First Year of Operation Schedule

Operation in Year 2

In the first year, the market did not run on Wednesday, which required the use of the senior center. By adding in the third day of stops, the market will need to spend less time on transporting the produce, meat and dairy products to the senior center. To make the process easier, the goal of the market is to eliminate the use of the senior center to store the produce. To help attain this goal, as we describe in more detail below, the new design of the power system allows for the refrigerator and freezer to be used over the extended amount of time. This allows the market to be used throughout all three days.

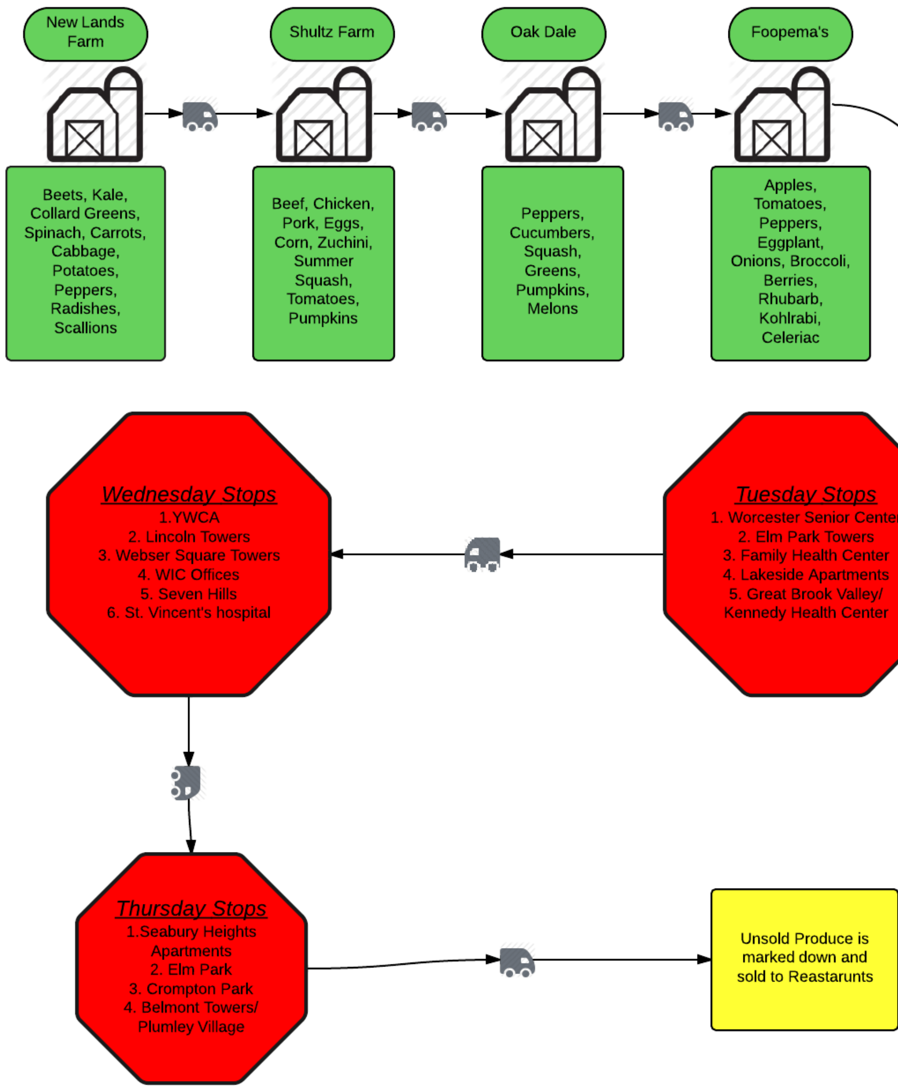
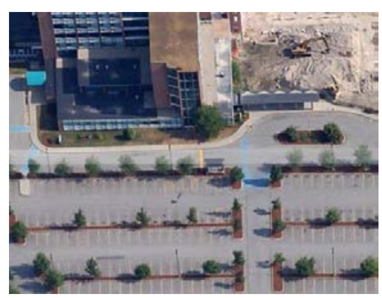


Figure 13: Second Year of Operation

In order to determine the best design for the market, we needed to analyze the sites in which the market sold the produce. A majority of the stops were at locations where the van is parked on the street. This fact restricts any use for the side of the van facing the street because the customers will have to stand in the street, which causes a hazard to their safety due to traffic. This limits the use of the pull out features initially planned as referred in the method chapter. We analyzed all sites and some new sites they intend to add. The sites from 2012 can be seen in Figures 8 and 9 in Chapter 2.

The following table depicts the sites that the market stopped in its first year of operation:

Market Stop	Parking Lot	Street Parking	Design Parameter	Picture of site
Worcester Senior Center	X		Walk on system is restricted	
Elm Park Towers	X		Restricts exterior use of van	
Worcester Family Health Center	X		Open parking lot allows for complete use, but not guaranteed.	
Seabury Heights	X		Complete Use	

Belmont Towers/Plumley Village	X		Limited space, little van use	
Lakeside Apartment		X	Restricts exterior use	
Elm Park		X	Restricts exterior use	
Crompton Park		X	Complete Use	
Great Brook Valley Health Center			No use of the van	

Table 2: First Year Market Stops Characteristics.

As seen in Table 7, the stops are either on the street or in a parking lot with the exception of the Great Brook Valley Health Center. At the Worcester Senior Center, Elm Park Towers, Family Health Center, Seabury Heights, and Belmont Towers, the van is parked in a parking lot. The van has limited use on the side if the parking lot has other cars parked next to it. At the Lakeside Apartments, Elm Park, Crompton Park, and Great Brook Valley Health Center, the van is parked on the side of the street. If the market is to use a pull out system or side display that faces the street, a danger to the customer's safety is created because they may stand in the street.

At the Worcester Senior Center, the elderly make up most of the consumer base. To reduce the amount of effort the elderly use to make it to the market, the van is backed up as close as possible to the center. This allows for the elders to have easier access to the van stop. With this being a concern, the elderly will have even more trouble walking onto the van to by produce. For this reason, a walk-in system is not ideal for the market.

At Great Brook Valley Health Center, the van is parked in the parking lot. The produce is taken out and displayed at center stage of the complex, so there is no van use. This is similar to the Belmont Towers/ Plumley Village stop. Here, the van is parked in the parking lot, and there is usually a limited amount of parking space. The produce is taken out of the van and set up in an open area, so use of the van is not prevalent.

At Crompton Park, the van is currently parked on side of the street, and the produce is moved to park. The market plans to sell at the pool for next summer. Here, the van has an open parking section. This will allow for the van to have complete use. At Seabury Heights, the van is parked in a spot where they have two spaces available. This makes it possible for complete use of the van.

Added Sites for Second Year of Operation

As mentioned before, the market intends to add five more stops onto the market. The stops are Lincoln Towers, 150-160 Webster Sq. Towers, Seven Hills, WIC office, St. Vincent's Hospital and the YWCA. At the YWCA, the exterior of the van has limited use. The van will be in a location where there is thru traffic. At Lincoln Towers and 150-160 Webster Square towers, the exact spot the van is placed at is unknown. At the WIC office, the REC is unsure if they will be in the parking lot or on the main street. Parking on the street limits use as the same as the others spots. At Seven Hills, the van will be in an open parking lot. This will allow for full use of the van. At St Vincent's Hospital, the van will most likely will be in a parking lot and set up by sidewalk. This depends is the hospitals gives permission to the REC.

A special stop the market will make on Thursdays during the season will be at Worcester commons as seen in Figure 13. This stop is made for the Out to Lunch Program. The van will be allowed to park on the Worcester common, which will allow for complete use of the van.

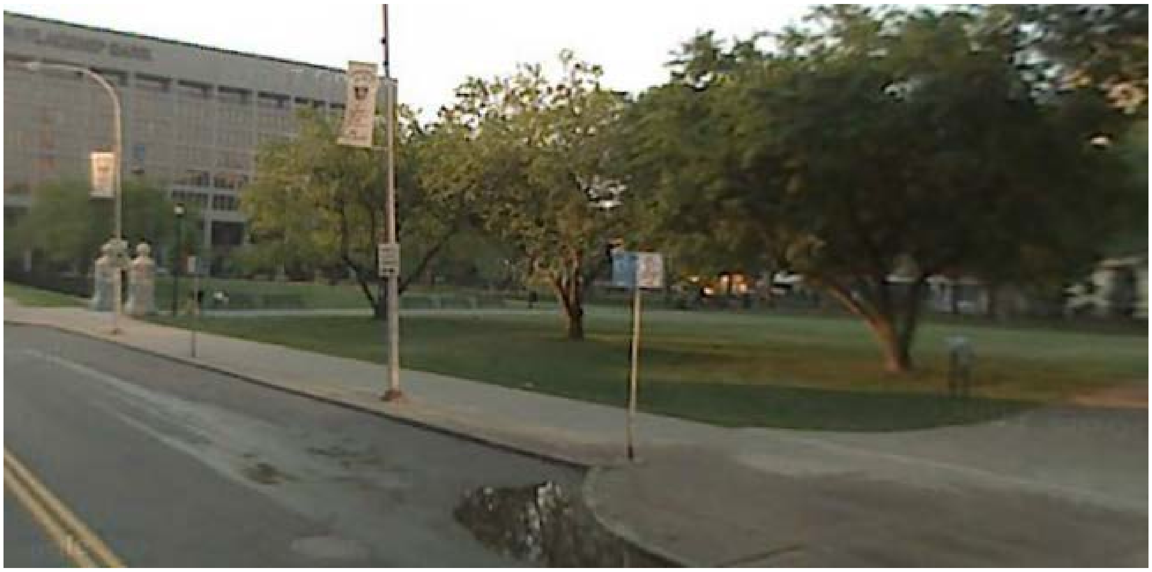


Figure 14: Worcester Commons

2013 Mobile Market Stop Schedule

Stops	Times
Tuesday	
Senior Center	9am-10:30am
Elm Park Towers	11am-12:30pm
Family Health Center	1pm-2:30pm
Lakeside Apartment	3pm-4:15pm
Great Brook Valley	4:30pm-6pm
Wednesday	
Lincoln Towers	10am-11:30am
150-160 Webster Square Towers	10am-11:30am
Seven Hills (every other week)	12pm-1:30pm
WIC office	2pm-3:30pm
St. Vincent’s Hospital	3:45pm-5pm
YWCA	5pm-6:30pm
Thursday	
Seabury Heights	9am-10:30am
Out to Lunch	11am-2pm
Crompton Park	2:30pm-3:30pm
40 Belmont/Plumbley Village	4pm-5:30pm

Table 3: Stops and locations for REC 2013 Season.

4.2 Appropriate Technologies

Determining the power demands of the solar powered cooling system

The REC wants to add meat and dairy to their selection of available products. This is to make the mobile market a true mobile grocery store, which can sell each of the healthy food groups and better promote a healthy diet. To sell these new products the REC would like a refrigerator for dairy and a freezer for meat because they will receive the meat frozen, and would like to sell it that way. The refrigerator and freezer would be solar powered to allow them to run while the van is off, as well as to remove the added load of refrigeration from the van's electrical system.

The beginning of our research showed us the basic components required for any vehicle-mounted solar power system. Solar panels, being the obvious first component, are required to generate electricity for the system. Photovoltaic cells generate electricity by using photons from the sun's rays to excite electrons, raise their energy level, and generate a flow of electrons, also known as electricity. A solar controller is needed to regulate the voltage and current from the solar panel/s. This controller connects to the battery or batteries to charge them. If the appliance being used runs on AC power, such as a typical household electronic device, an inverter is needed to convert the battery's DC power to AC power. A diagram of a simple solar power system is shown below.

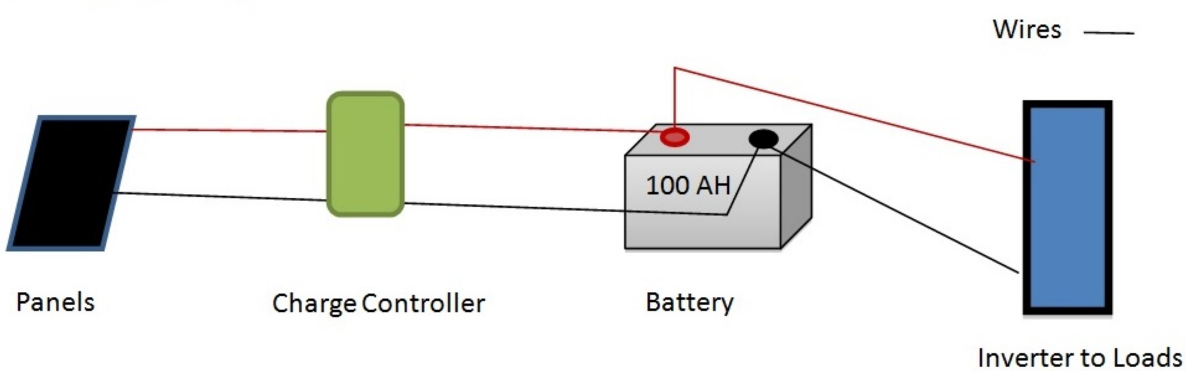


Figure 15: A sample setup for a solar power system

One key aspect of the design was to identify the appropriate refrigerator and freezer and to determine the amount of power they require. These are the loads on the system, and dictate how much power is needed from the solar panels, what rating the solar controller needs, what capacity the batteries need to be, and the rating of the inverter.

We began the search looking for the refrigerators and freezers with an appropriate capacity for the REC's needs. This seemed to be approximately 5 ft^3 for the refrigerator, and 7 ft^3 for the freezer. Talking with REC staff, it seemed they preferred a chest style freezer, and had more meat than dairy. They could not give us exact figures for what they expected, but they seemed very optimistic. Chest style freezers are more efficient, and their contents are more comfortably accessed than freezers with a door on the front. They plan to stock many different types and cuts of meat, so the freezer needed to be of descent size, while still fitting inside the market. We looked at many different models online to get an idea of what capacities were available. We considered a cost of $400 or less to be reasonable, due to the REC's $3,000 budget for the solar powered refrigeration system. Solar panels and batteries cost around $400 as well, which meant getting a $400+ freezer would result in a system costing nearly $3,000 without labor. With the cost of $400 in mind, 7 ft^3 was the largest freezer we could find. Others were 5 ft^3 or less, which based on the REC's estimates seemed too small. Looking for more expensive freezers led us to freezers 10 ft^3 or more. At this size, the freezer would be too large to comfortably fit on the van. It seemed 7 ft^3 was suitable for the amount of meat the REC planned to have, and would meet their budget.

	<= 5 ft^3	**6 to 7 ft^3**	**>= 10 ft^3**
Size	Good for space used on the van. May not hold enough meat.	Still good for space used on the van. Will hold more than 5 ft^3.	Too large to place on the van.
Cost	$350 Maximum, most closer to $200	$430 Maximum, most closer to $300	$490 Minimum

Table 4: Freezer Criteria

For the refrigerator we had fewer size options. We again considered a refrigerator should cost less than $400, due to the REC's budget. There are only 3 classes of refrigerators we could find, including traditional kitchen size refrigerators around 18 ft^3, miniature refrigerators around 4 ft^3, and extra small refrigerators between 1 and 2 ft^3. Chest style refrigerators were not widely available, and were above the REC's budget for a refrigerator. We decided to go with a 4.4 ft^3 refrigerator, because it was as large as we could find without getting a kitchen sized refrigerator.

	<= 2 ft^3	~4 ft^3	18 ft^3
Size	Too small to store gallons of milk or many dozen eggs. Would fit well on the van.	Larger capacity than 2 ft^3. This would fit well on the van.	Much larger capacity. This would not fit well on the van.
Cost	$200 Maximum, most around $110 or less	$300 Maximum, most around $200	$500 Minimum

Table 5: Refrigerator Criteria

After finding the size and style of the refrigerator and freezer, we needed to find ones that list their power rating. Unfortunately, many appliances do not list their actual power ratings in watts, and instead simply list whether or not they meet an Energy Star or equivalent power rating. As nice these ratings are, we needed to know exactly how many watts these units would require, in order to adequately design this system. We were only able to find a handful that gave power ratings in terms of watts. The refrigerator we decided on requires 90 watts, and the freezer requires 150 watts, amounting to a combined power requirement of 240 watts. Preferably, the solar panels claim to output more than 240 watts, because their rating is always higher than their real world performance.

Solar Panels

First we researched what kinds of solar panels there are and which kind is more efficient. Most solar modules are currently produced from silicon photovoltaic cells. These are typically categorized as monocrystalline or polycrystalline modules. There have been many advances in both monocrystalline as well as polycrystalline technology and neither can be regarded as superior to the other. Our system required 290 watts to power the refrigerator, the freezer, and the sound system. Therefore, our solar panel or panels needed to output at least that much power. However, the power rating should have been above 290 watts to account for real world performance.

The criteria we used to select the solar panels were size, weight, voltages, and cost. The size of the solar panels mattered because they cannot be larger than the van. These panels went on the roof of the van which meant their dimensions have to be smaller than the roof. Similarly, they could not be very heavy. The next parameter was voltage which is fixed for any given panel. Voltages are fixed but the current varies depending upon the amount of sunlight and the product of voltage and current determines the power generation. Solar panels come in many varieties of voltages ranging from 1V to 42 volts, as well as many different power outputs. One very important reason that we needed 12V solar panels is because of the battery we will be using. To recharge any battery, the voltage from the panels must be regulated to at least its own voltage. We used two 12V batteries in series, so the panels had to charge a 24V battery bank. Therefore, the solar panels had to output 24V. Two 12V solar panels were able to charge two 12V batteries. A more detailed description of the battery is given in next section and Appendix A.

The following table shows the results after considering all the parameters we discussed.

Parameters	Panels Less than 12V	12V panels	Panels greater than 12V
Power	Don't generate enough power	Generate enough power	Generate enough power
Voltage	Not enough voltage	Enough voltage	24V is enough voltage. Greater than 24V ruins battery
Size	Small	Fits within the area of rooftop	Some fit but most are too large.
Weight	Light weight to appropriate weight	Appropriate	Very heavy
Cost	Inexpensive	Affordable to Expensive	Expensive to Very expensive

Table 6: Options we had for the solar panels

We found that any solar panels below 12V were not powerful enough to provide the required power of at least 300 watts. The 24 volt or higher panels were very heavy and not within the size parameter of roof top of the mobile market van. They were also very expensive. We did find some single 12 volt panels which output enough power on their own, but they were also too expensive, too large and too heavy. 12V solar panels are typically used in RVs to recharge the 12V car battery. Therefore most 12V solar panels are sized perfectly to fit on top of a vehicle. It was clear multiple panels were needed, so we found some 155 watt, 12 volt panels within the REC's budget.

Batteries

For our goal to help provide product diversity to the mobile market, we chose a refrigerator and freezer, as well as solar panels to power them. Solar panels generate energy, but only while they are receiving sunlight. For example, if the mobile market parks by a building blocking the sun, or under a tree's shade, the light will be gone. Once the light is gone, no power flows from the panels. Batteries were needed to store the energy from the panels, so a constant supply of power was available to the refrigerator and freezer.

There are many different types of batteries but the kind we were interested in were very high capacity ones. The most commonly used high capacity batteries are 12 V lead-acid batteries which are used in cars. It is natural to think of using car batteries for this power system, since the mobile market is a van and it already has a lead-acid car battery. However, regular car batteries are SLI (starting, lighting and ignition) which were not ideal for our purpose because they could not be discharged more than 25% of their total charge. However, there are deep cycle batteries which are meant to be used as backup power systems for households and small commercial places. Deep cycle batteries can provide constant current and voltage, and discharge up to 80% of their total charge. Deep cycle batteries are the better choice to run appliances like refrigerators and freezers which require high current for long periods of time.

A battery's specifications include its voltage rating, maximum current rating and capacity. Understanding the capacity is very important because we need to make sure the batteries do not die after a few hours of operation. Capacities of batteries are rated in Amp-Hours (AH). Please refer to Appendix A to learn what this means and how to use it.

We performed various calculations with different amounts of voltages, AH and watts required for the system. These calculations can be found in Appendix A. First we started with a 100AH @ 8 hrs12V battery before any calculations. However, this was not enough power, so we gradually progressed to meet the requirements. These calculations do not include the power that will be supplied from the solar panels as it is very difficult to calculate the exact amount of energy produced by solar panels. The purpose of this calculation is to have batteries that will last at least a day without any power from the solar panels. The following table shows what our research taught us and the process of how we reached the final decision.

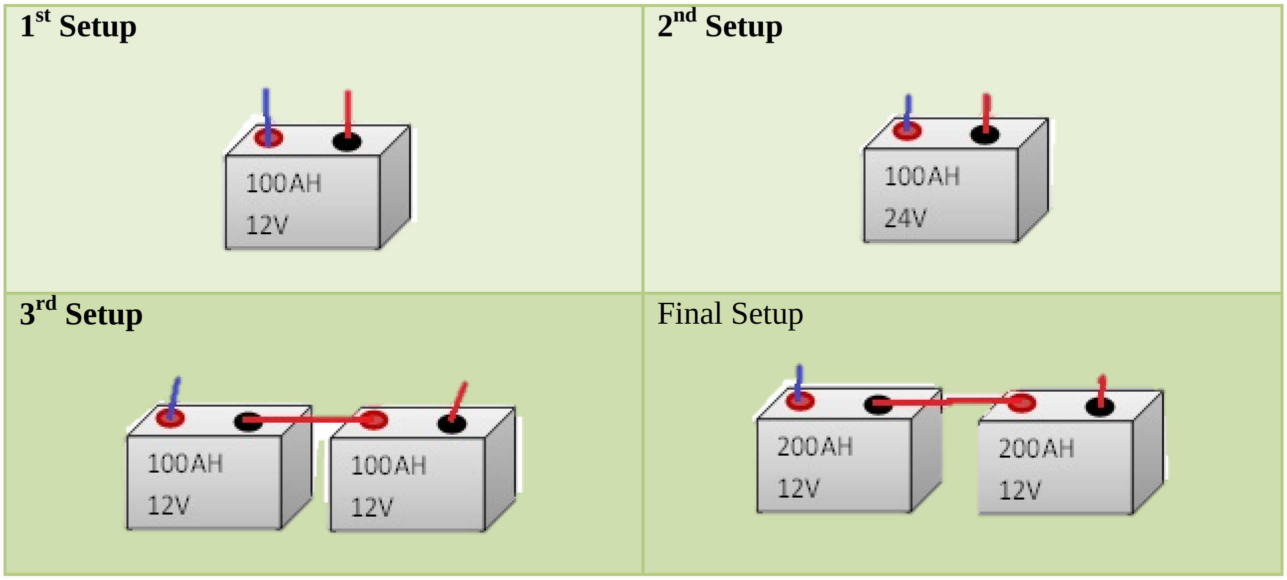


Figure 16: Different battery design option considered

Criteria	1st Setup	2nd Setup	3rd Setup	Final Setup
Voltage of battery	12V	24V	12V	12V
Number of Batteries	1	1	2	2
Capacity of each battery	100 AH	100AH	100 AH	200 AH
Total capacity of batteries	100 AH	100 AH	200 AH	400 AH
Required Capacity	600 AH per day	335 AH per day	335 AH per day	335 AH per day
Cost of each battery	$ 200	NA	$ 200	$ 350
Total cost of batteries	$ 200	NA	$ 400	$ 700
Additional comments	Not enough capacity.	24V high capacity battery not found.	Not enough capacity.	Enough capacity, meets all requirements.

Table 7: Description of various battery options

The use of two 200AH batteries will give us a total of 400AH. This covers the required AH for at least 24 hours. Deep cycle batteries should not discharge more than 80% of their total charge. 335 AH is about 83% of 400AH. This ensures the operation of the system for more than 24 hours without any power from the solar panels. This is the best scenario for using this kind of system because the REC will be running the market for 3 consecutive days. This means that if either Wednesdays or Thursdays are overcast with little sunlight, the batteries will still have enough power to run the refrigerator and freezer. Each 200AH battery costs about $350 which makes a total of $700 for the batteries. Therefore, we concluded with using two 200AH batteries will give total of 400AH. Two UPG UB-4D AGM Sealed Lead Acid Batteries fulfilled all these requirements.[1]

Inverter

The battery is a direct current (DC) power source and the freezer and the refrigerator require an alternating current (AC) power source like the wall outlet of our home. The appliances will not work with the battery directly. Therefore an inverter is required which takes in DC and converts it into AC. Inverters are very common. They can be found in voltages of 12 or 24 volts with various power ratings ranging from 50 watts to 1500 watts. The system requires about 300 watts so keeping a good, safe margin of a 600 watt inverter would sufficiently power both the refrigerator and the freezer. Beside power another requirement for the inverter is that it needs to output pure sine wave not modified sine wave. We also found out that most inverters are only 85% to 90% efficient. We had to consider this inefficiency while calculating the capacity of batteries for the system. Inverters have regular wall outlets which makes them very easy to use. We chose a

Figure 17: Chosen Inverter

[1] An important piece of information that should be kept in mind is that solar panels should never be plugged directly into the batteries. Damage can be caused to the batteries if the current supplied to them is not properly controlled, due to overcharging or negative current. A device called a charge controller exists that takes care of all these cases, and regulates the voltage and current so the battery gets charged properly. This will add an additional $135 for a charge controller to the cost.

Samlex product because it has decent efficiency at a reasonable price. The following table shows the inverter options we had and what we chose.

Criteria	Power	Efficiency	Cost	Input V	Wave	Chosen?
Samlex PST60S24A	600W	87%	$210	24V	Pure Sine wave	Yes
Power Bright APS600-24	600W	85%	$165	24V	Pure Sine wave	No
Go Power SW600-24	600W	89%	$330	24V	Pure Sine wave	No

Table 8: Inverter Options

Solar Power System

Final design

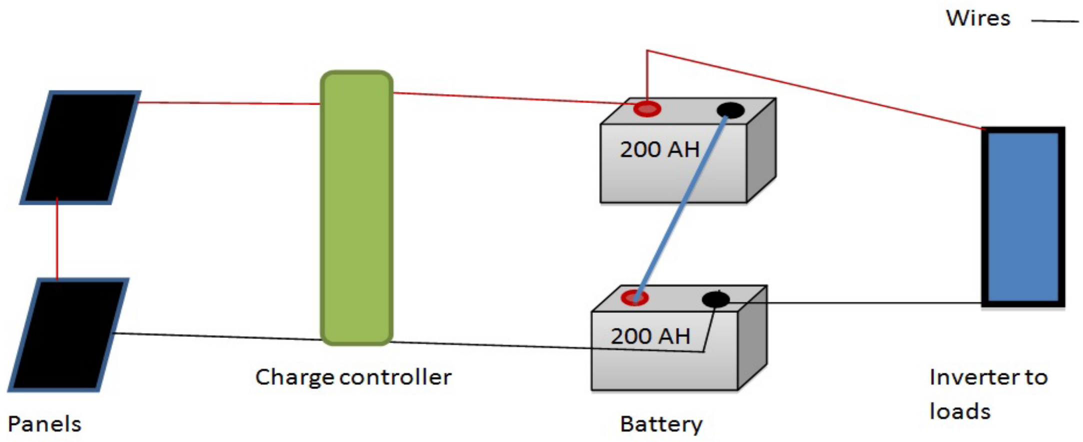


Figure 18: Final Solar Charging System Design

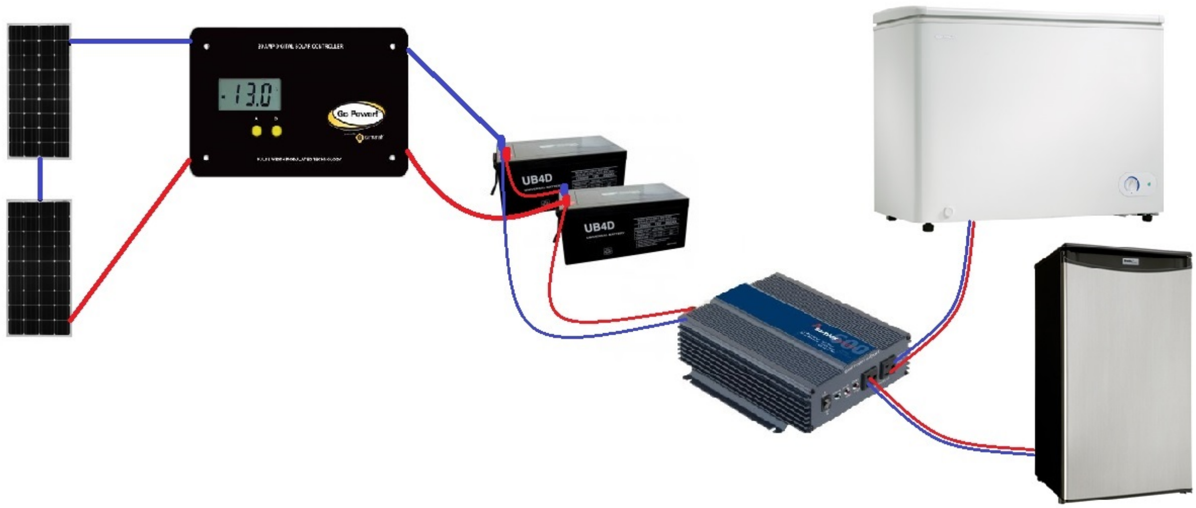


Figure 19: Components for the solar power system connected

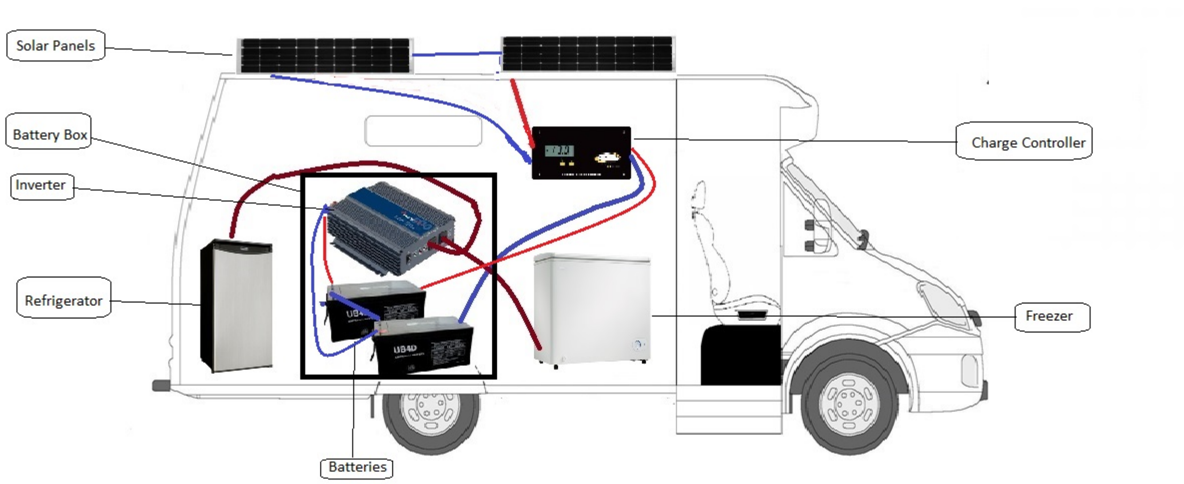


Figure 20: Placement and connection of each component (not to scale)

Initially we designed a system that included one 100AH battery, 1 charge controller and 1 solar panel. After we figured out that this system will not meet the requirements we began looking for new components specially batteries then came up with parallel charging design. Parallel charging design was a system that charged each battery individually which required two separate charge controller for each battery. To get around the extra expense of additional charge controller, we changed design to charge both batteries together. Our final design uses two 12 volt, 155 watt solar panels wired in series, attached to a single charge controller. From our calculations we found out that two 12V batteries with 200 AH @ 20hrs in series would provide at least 24 hours of operation of both the refrigerator and freezer. A battery bank is just a series of batteries considered as one. In this case we will have a battery bank of 24V and 400AH @ 20hrs. More detailed explanation about why and how we decided on final design is discussed section below in technology research. We chose a 600 watt, pure sine wave inverter to ensure the best signal. The figure below shows a schematic of our system.

Sanitary Needs

In order for the market to hold on site cooking demonstrations, Massachusetts Law requires the market to have an onsite sink (Mass. Gen. Laws ch. 94, § Section 305A, 2009). The sink will be used to wash any produce the customers want as well and washing produce before cooking demonstrations. Because the market for portable sinks is small, our options were very limited. However, we found two different sinks based on the size and ease of use to propose for the market.

Figure 21: First Considered Sink

Our first option is a portable outdoor sink that can be disassembled so that every component fits inside the sink. This will also allow for the sink to be stored on the shelf or floor between stops. The disadvantage of this sink is that it must be connected to a garden hose or faucet, which may not always be nearby or useable. A major advantage of this sink is that it may be adjusted to 36 inches in height, so it can be placed next to the grill during demonstrations.

Figure 22: Second Considered Sink

Our second option was the HandyMan Motor Series 12 Volt Sink. We recommend this sink. This sink can be attached to any vertical surface, so our proposed placement for this sink is to be attached on the doors. This sink is also detachable so it can be placed on any horizontal surface. The disadvantage with this option is it has a maximum water storage capacity of 2.5 liters. This requires the operator to refill the sink when it is empty.

4.3 Interior and Exterior Designs

Interior Design

The interior design of the market needed to be meet three requirements. First it needed to allow for proper storage of the produce, meat, and eggs. Second a chair, properly fastened, is needed so a second employee can travel with the market. Third, space needs to be open for the transportation of the sink, grill, and table.

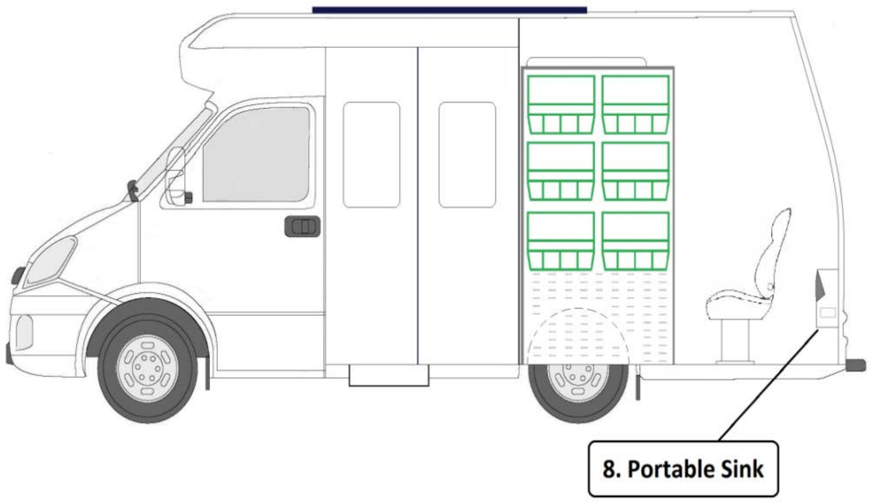


Figure 23: Final design of the interior right side of van

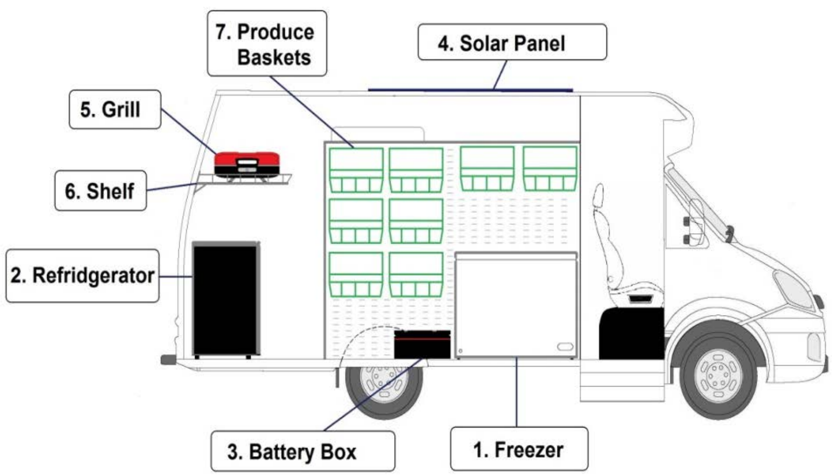


Figure 24: Final design of the interior left side of van

Storage

The REC wanted to diversify its product line, which led us to redesigning the storage systems. This meant we needed to find a proper storage design that will not take up too much space on the van. A small refrigerator and freezer needed to be considered so that moving around the market is comfortable for the worker. These designs can be seen in Figures 22 and 23 above. The REC staff currently keeps their products in shelves on the wall of the market, and takes them down to put them on the table they bring with them. We researched other markets to see how they store their products and display for sale, to determine new designs for the REC's market.

Maximize use of space within van

Figure 25: Van interior of right side

Figure 26: Van interior of left side

To fully utilize the space on the market, we proposed to install a shelf on the back end of the van above the refrigerator. By adding shelves inside the van, which will allow for the market to carry more items and organize the storage space in a seamless manner, and goods can be easily categorized and put in different shelves for better management of the space and faster delivery. We proposed for the shelves to be built with stainless steel rails in order to help secure items put on it. Our proposed use for this shelf is for grill or sinks storage. Our chosen area to install the shelves is in the back because there is a free, usable overhead space of two feet. The shelf can be installed in a similar manner as the bin shelving already on the market. It will be bolted on the back and on an adjacent side. This will allow the shelf to withstand up to hundred pounds of force.

We also measured the inside of the van and made a layout of where the refrigerator, freezer and other additions would go. Using the measurements of the refrigerator and freezer from their manuals we figured out how much space each would occupy. Then we made scaled SolidWorks models of the inside of the van, refrigerator, freezer, bins, and the shelves they have inside the van. They currently have a seat inside which they intend to use. It could not be removed, so the freezer and refrigerator were put on the other side. The batteries and inverter would be put inside a wooden box that we reference as the battery box. This box will hide batteries and wires and only the wall outlets of the inverter and switch of the inverter will be exposed through a cut window.

Additions for Cooking Demonstrations

An important mission for the market is to educate the public on proper cooking methods for the food. In order to accomplish this mission, the market will hold cooking demonstrations as part of the Share Our Strengths Cooking Matters program. All the equipment needed for the demonstrations needs to be able to fit in the van, so the grill chosen needed to be small enough for easy transport. Also, the grill cannot be fueled by charcoal for sanitary issues concerning the storage of the produce. It is also against Massachusetts's law for any mobile food cars to have a propane fuel tank. To address this issue, we chose a grill that is that can be fueled by a standard CRL propane fuel canister.

For the grill to be used at a comfortable height, we also set a requirement to for the grill to have a mechanism that will allow for the grill's height to be adjusted. This will allow for the demonstrations to be used on any nearby surface. The Cuisine Petit Gourmet Portable Gas Grill was chosen because it met all of our requirements. The grill has a detachable telescoping stand, so it can be changed to reduce the volume size to store on the market.

Walk On Design

When we were exploring the use of the van, the walk-on system was considered. Markets, such as The Farm Bus, used buses and removed the seats to add counters and shelves to place their products on. The customers would simply walk onto the market from one end, shop, and walk out the other end of the bus. These tended to be box trucks capable of large storage. Our idea for our market would have been similar to the Farm Bus, but instead of counters, the produce will be on the walls. The customer would be able to pick what they want to buy and exit then pay at the end of the van.

Some markets used trailers, sometimes custom made, to carry their products. This type of feature was considered for the mobile market. However, after measurements were taken, we saw limited space for free movement with the storage. This will make it uncomfortable for people to move on the market, and it causes a burden on the elderly.

Figure 27: Recommended Grill

Display Designs

Figure 28: REC current set up to sell

The REC wanted the market to attract more customers, which led us to determine outside display options. When we began the project we found many different formats to store and display products, each of which was based around the vehicle being used. Initially, we based our design off of the Baltimore Mobile Farmer's Market, which would have an extension or platform rolling out of the back of the van or the side. The platform would be empty, and baskets would be placed on the platform form inside the van.

To promote more involvement, we brainstormed a few ideas to have a chalkboard on side of the van. This could act as an advertising tool to show what produce they had in the van as well as their prices. Chalkboards could also be entertainment for kids as they could draw on them while their parents are shopping. We had to restrict most of our options for the REC because of cost, limited space around the van, and street side parking.

Figure 29: Richmond's Farm to Family, The Farm Bus

The REC's market is a van, which is smaller than most of the markets we found. Therefore, all the designs we found needed to be examined to determine what could be scaled down to work with the REC's market.

To help address the street side issue, we examined the possible use for a side display. One market, The Fulton Fresh Market, had a unique display system, which was simply a shelf bolted to the side of the vehicle, allowing them to place baskets of their products on the market. We designed a similar system for the REC, which could allow them to place the shelves they have inside the market on the outside, providing them more display space. However, because of the widows and the installed awning, the shelf will only have a display area of about 1.5 square feet.

Figure 30: Fulton County, Georgia's Fulton Fresh market

5. Recommendations

Recommendation 1: Assess the effectiveness of the solar powered refrigeration system, and possibly upgrade to a more efficient refrigerator and/or freezer.

We designed a solar powered refrigeration system for the mobile market, so the REC could start selling meat and dairy products. Before designing the system, we considered how the system would be used. We considered the possibility of the REC keeping the meat and dairy on the van overnight, between operation days. If they were able to do this, they would not need to add extra time for packing and unpacking these new products. We decided the system should be able to hold a full charge for one week before needing to be recharged. With this goal in mind, we designed the system with the goal of maximizing the system's battery life.

With our solar power system design the REC may need to move the meat and dairy products off the market if there are multiple days of inclement weather. This would increase the time to load and unload the market, which would require the employees to work longer days and possibly delay their arrival time to the first stop. Ideally, the meat and dairy would stay on the market during the week to reduce the time spent packing and unpacking the market. Our research has found products that would help increase the life of the solar power system.

We designed and optimized the solar power system for the REC with their $3,000 budget. However, during our research we found high-efficiency freezers and refrigerators which would greatly increase the battery life of the system, and make the system simpler by eliminating the inverter. The Sundanzer company makes these high-efficiency refrigerators and freezers, which operate on DC power rather AC power. This would allow the REC to remove the inverter, which would decrease the chances for component failure in the system, as well as further increase the system's efficiency by eliminating the power lost through the inversion process.

The Sundanzer products are highly efficient. The normal refrigerators we used for our design use almost 350AH per day with a 24V power supply. The power usage ratings for Sundanzer products are from 65AH to 80AH using a 12V supply. Considering the worst case scenario of the refrigerator and freezer running constantly, the system would use 160 AH per day with a 12V supply. The Sundanzer products use only one-quarter of the power consumed by the regular freezer and refrigerator. This means the life of the system could be up to 4 days with the Sundanzer products, compared to the 1 day our system provided.

The reason these high-efficiency refrigeration systems are recommendations rather than included in our designs is their high cost. A single Sundanzer product costs a minimum of $699 for a 1.8 ft^3 unit which can operate as either a refrigerator or freezer. For the REC's space needs, they would need the $1,149, 4.7 ft^3 upright refrigerator, and the $1,189, 5.8 ft^3 chest freezer. Both of these products would total $2,338, which would be 77.9% of the REC's total budget for the solar powered refrigeration system. This would not leave enough money for solar panels, batteries, and a controller. Therefore, we recommend the REC look into buying these products when more funds are available to improve this system. The following table shows the approximate total of our final design and design using Sundanzer product.

	Solar panels	Charge Controller	Batteries	Inverter	Refrigerator and freezer	Total
Final design	2@ $335 each	$135	2@ $350 each	$240	$200 and $300	$ 2295
Design with Sundanzer	2@ $335 each	$135	2@ $350 each	$0	$1,149 and $1,189	$ 3843

Table 9: Comparison of the cost of our system and the cost of Sundanzer system.

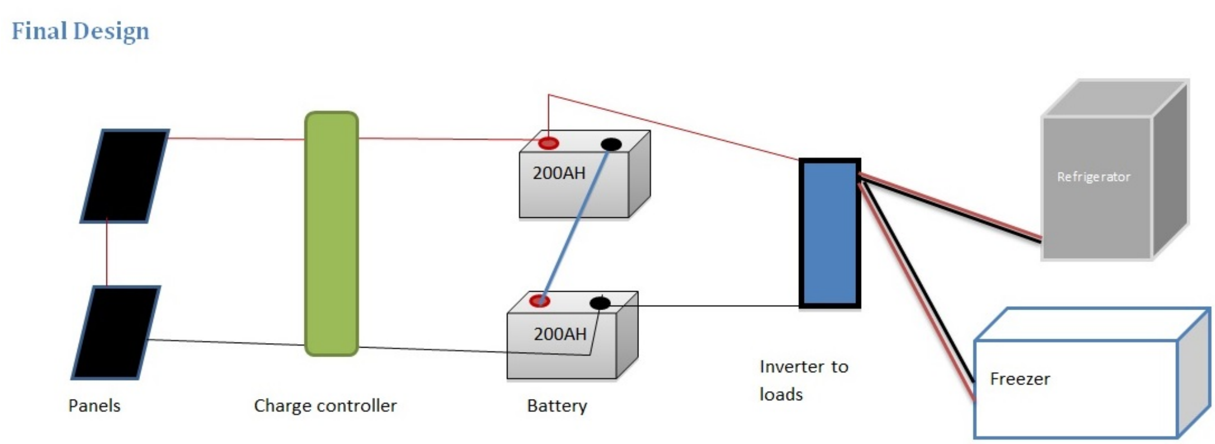


Figure 31: Final design costing $2,295

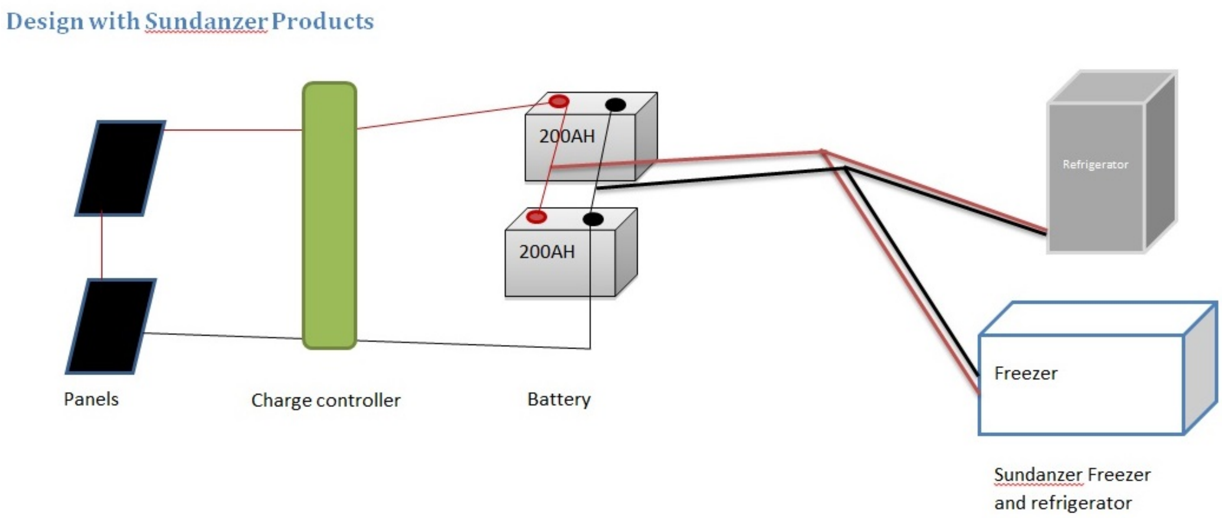


Figure 32: Solar power system design with Sundanzer products costing $3,843.[2]

Recommendation 2: Using Cool-bot technology, build a freestanding refrigerator to store produce and add flexibility to the mobile market's operations

The mobile market is currently sharing space in the walk-in freezer located at the Worcester Senior Center. The produce that has not been sold by the end of the day is taken to this walk-in refrigerator and stored until the next morning day. Senior Center is about 1.5 miles away from the REC. Having a refrigerated unit would allow the mobile market to purchase a larger amount of produce and store it for sale at a later date. This would decrease the mobile market's dependency on the Worcester Senior Center and get around the limited space available while sharing. Furthermore, if the location of this storage is closer to the REC, it would save some time each day if staff does not have to travel to store the produce.

A Coolbot based cooling system is an alternative to an expensive walk-in cooler compressor. It requires an insulated room, a window-type air conditioner and a Coolbot device used to keep the temperature low. The produce does not need to be frozen and it does not need to be less than 35-36 degrees Fahrenheit to keep fresh. A Coolbot could easily achieve each of these criteria. A detailed description of the Coolbot can be found in Appendix **X.**

This product is cheaper than a regular walk-in refrigerator. A Coolbot device costs $300 and requires an air conditioning unit, which might cost around $400 to $500. Installation of a

[2] It should be noted that these costs do not include taxes, labor and installation, and other parts such as wire or mounts. These estimates only include the bare essential components. The final cost would be much higher, because labor alone cost $700 to $800.

Coolbot does not require special training. To build the structure to house the Coolbot, the REC could simply use lumber and insulation. The cost of lumber for an 8ftx8ftx7ft shed would cost approximately $60, based on pricing from Home Depot. Insulation is more expensive, at approximately $1,000. However, this depends greatly on the type of insulation used, and bulk pricing, if it is available. This product is highly recommended if there is a need for larger storage and the space is available. By contrast, the total costs of a walk in cooler amounts to some $4,000, which includes, a compressor $2,500, as well as $1,200 dollar for installation by professionals.

Recommendation 3: Use the Mobile Market to help launch other direct food marketing initiatives, such as a community supported agriculture scheme and buying clubs.

The Mobile market only ran two days a week during its pilot year. For the upcoming year the plan is to run three days, and attend the Out to Lunch Concert Series on Thursdays. The Out to Lunch Concert Series is an event by the City of Worcester, which takes place on the Worcester commons. Free, live performances accompany local food vendors, now including the REC's mobile market, to provide downtown residents and workers to relax during their lunch hour.

Our Recommendation is to use van all 5 weekdays, as well as Saturday if possible. More revenue can be earned if the van operates throughout the week, provided there is enough supply to sell. If the market could run additional days, the REC could target other neighborhoods and groups of customers as well and potentially use this revenue to cross-subsidize it work in low-income neighborhoods.

If the market wishes to not add more stops to the market, there are alterative options that utilize the van. For one, the market can provide a home delivery option for selling their produce. This will create a specific buying club for the REC because the consumers can order a specific type and amount of food they want. The ordering process can run throughout the week until a designated day, which will be before the produce is picked up from the farmers. The REC can designate the days the market is not selling at their stops to make the deliveries.

The delivery option can also work with the farmers by launching a CSA model. The CSA model can vary, but the program will work directly between the farmer and consumer, and the Mobile Market can be used to deliver between the farmer and the consumer. The market can set a specific amount to make the delivery from each farm to the drop-off point or even to specific homes.

One factor limiting the increase in operation of the van is staffing. The market does not have enough money in their budget to hire another member. We suggest that the REC could work with local colleges to recruit students to help run the van and use the experience as an unpaid internship for college credit.

Recommendation 4: Design an attractive trailer that could be pulled by the mobile van to increase the availability of products.

During the course of our research we came across the idea of using a trailer. A trailer can serve many purposes. One of these purposes could be as a second mobile farmers' market, which is towed by either a car or other passenger vehicle. This second market could travel to areas the mobile market does not already go, to reach a larger number of communities. For example, Eliot Coleman has built a handmade trailer, which he takes to various stops. The trailer allows him to easily setup his market, sell his produce, and pack up the market to go to the next stop. As can be seen in Figure 32, Mr. Colman has his products on shelves, which fold out of the trailer, awnings to provide shade and protection to these products, and a checkout station. Another purpose of the trailer would be to act as extra storage for the regular mobile market. A trailer could be attached to the van and can be driven around along with the mobile market. Furthermore, a closed trailer could be insulated and equipped with a Coolbot and solar power. This would turn it into a mobile cooler with plenty of storage. If the funds and sources are available, it is recommended the REC consider trailers as additional storage or an additional mobile market.

Figure 33: Eliot Coleman's Mobile Farm Stand

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Appendix A

This appendix gives definitions to basic electrical terms that are required to know while designing a solar powered system. This appendix can also be used as a guideline to design a similar solar powered system.

Electrical Terms

Power is the amount of energy used over a certain period of time. In electrical systems, the power is the product of voltage times current. The unit of measurements for power is watts.

A series connection is a setup of electrical elements. This connection is when the positive terminal of one element is connected to the negative terminal of another element. Similarly, a parallel connection is setup when all positive terminals are connected together and all negative terminals are connected together. The solar panels and batteries could be connected in series or parallel. When these systems are connected either in series or parallel, they can be treated as a single unit.

A battery bank is a setup of multiple batteries connected in either series or parallel connections.

The capacity of a battery is rated in milliamp-hours (mAH), amp-hours (AH) or kiloamp-hours (kAH). Miliamp-hours are typically used for small batteries like standard AA or cell phone batteries. Kiloamp-hours are very rare, but if the unit is expressed then typically it is a rating for entire year. Amp-hours (AH) are very common but even AH vary. Most of the time rating of AH is followed by an @ symbol and some number of hours, for example 50 AH @ 8h. This type of rating means how long a battery can operate if a certain amount of current is extracted from it. We performed various calculations with different amounts of voltages, AH and power required for the system. For our example of 50AH @8h; if 6.25 A is extracted from the battery at a constant rate, the battery will last 8 hours.

Calculations

Technical Details

Brand Name	Danby
Model Info	DAR125SLDD
Item Weight	73.5 pounds
Product Dimensions	21.5 x 20.5 x 33.1 inches
Item model number	DAR125SLDD
Capacity	4.4 cubic_feet
Refrigerator Fresh Food Capacity	4.4 cubic_feet
Installation Type	free standing
Part Number	DAR125SLDD
Form Factor	Stand alone
Color	Black/Stainless
Voltage	120 volts
Wattage	90 watts
Defrost	Automatic
Door Hinges	Reversible
Door Material Type	Steel
Lighting	incadescent
Shelf Type	Glass
Shelves	2
Certification	energy_star
Material Type	steel
Included Components	Can Dispenser
Counter Depth	21.5 inches

Spec sheet of freezer

Technical Details

Brand Name	Danby
Model Info	DCF700W1
Item Weight	101.5 pounds
Product Dimensions	20.5 x 39.8 x 32.9 inches
Item model number	DCF700W1
Capacity	7 cubic_feet
Freezer Capacity	7 cubic_feet
Installation Type	free standing
Part Number	DCF700W1
Form Factor	Chest
Color	white
Voltage	120 volts
Wattage	150 watts
Defrost	none
Door Material Type	Steel
Shelf Type	Wire
Material Type	steel
Counter Depth	20.5 inches

Spec sheet of refrigerator

Specification sheets from manufactures usually state the power consumed by their products. The figures above are the sections of specification sheets of the freezer and refrigerator, which states their power consumption is 90 watts and 150 watts, respectively. So the total power consumption of both units is 240 watts. We will refer to them as loads. Similarly, the specification sheets of solar panels list the maxmium rated power output for solar panels. However, it is not guaranteed to generate the maximum power all day so we gave ourselves some margin to ensure that the generation of power is always greater than comsumption. The solar panels we chose had the rating of 155 watts of power. We used two solar panels which gave us a total power generation of 310 watts.

Now we can calculate the capacity of the battery required for the system. The load of the system is 240 watts, which is in AC not DC. We wanted the system to run atleast 24 hours without any power from the solar panels. First we tried using a single battery and did these calculations. The calculations proved a single battery cannot power this system.

Using Single battery of 12V:

AC load = 240 watts ÷ 120 V (AC) = 2 Amps @ 120 V (AC)

DC load = 2 Amps × 120 V (AC) ÷ 12 V (DC) = 24 Amps @ 24V (DC)

Factoring the inefficiency of the inverter

DC load = 24 Amps ÷ .87 ≈ 27.5 Amps

Total daily load = 27.5 Amps × 24 Hours/day ≈ 662 AH per day

This led us to use higher capacity batteries and higher voltage by connecting the batteries in series.

Using battery bank of 24V:

AC load = 240 watts ÷ 120 V (AC) = 2 Amps @ 120 V (AC)

DC load = 2 Amps × 120 V (AC) ÷ 24 V (DC) = 10 Amps @ 24V (DC)

Factoring the inefficiency of the inverter

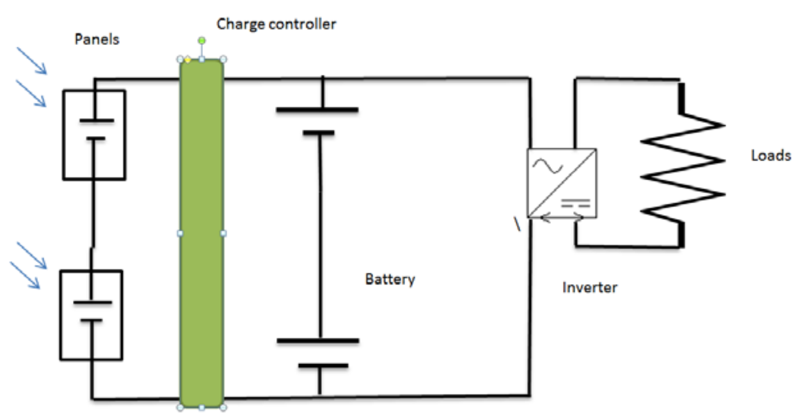
DC load = 10 Amps ÷ .87 = 11.49 ≈ 11.5 Amps

Total daily load = 11.5 Amps × 24 Hours/day = 275 AH per day

The calculations showed that the batteries need to be of at least 275 AH. There is one more thing that needs to be considered. The deep cycle batteries should not discharge more than 80% of their total charge. Constantly going below 80% will shorten the life of the battery. To have a safe margin we decided to use two 200AH batteries. 80% of 400 AH is about 320 AH which ensures that the batteries do not discharge more than 80% after 24 hours of operation.

When selecting a charge controller, it needs to be of the same voltage as the solar panels and batteries. Our design has 24V solar panels which are charging a 24V battery bank. Therefore, the charge controller we picked had to be of 24V. In same way, the inverter needs to be of 24 volts. The inverter also should be able to handle the power of the system. The total power of our system was 240 watts so we chose 600 watts.

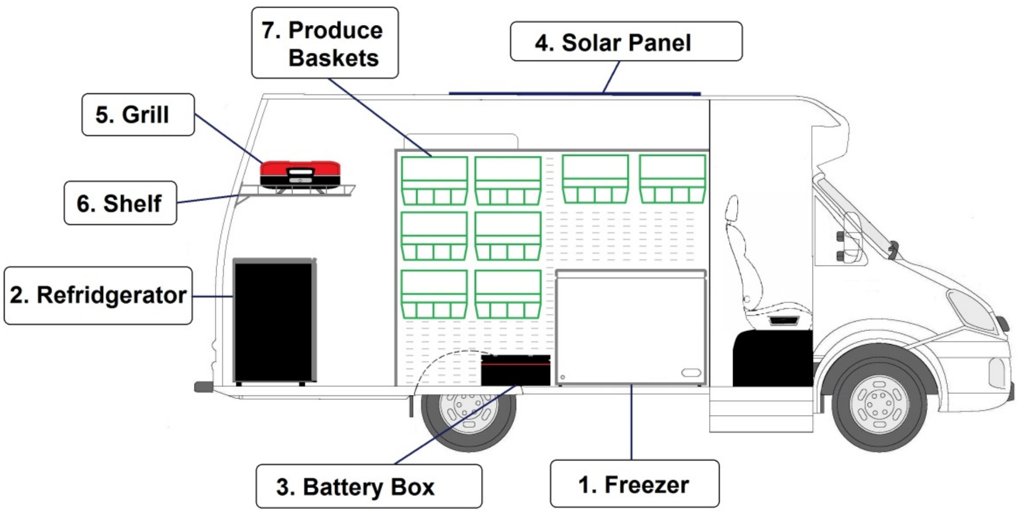
The figure below shows the electrical schematic to setup the solar powered system.

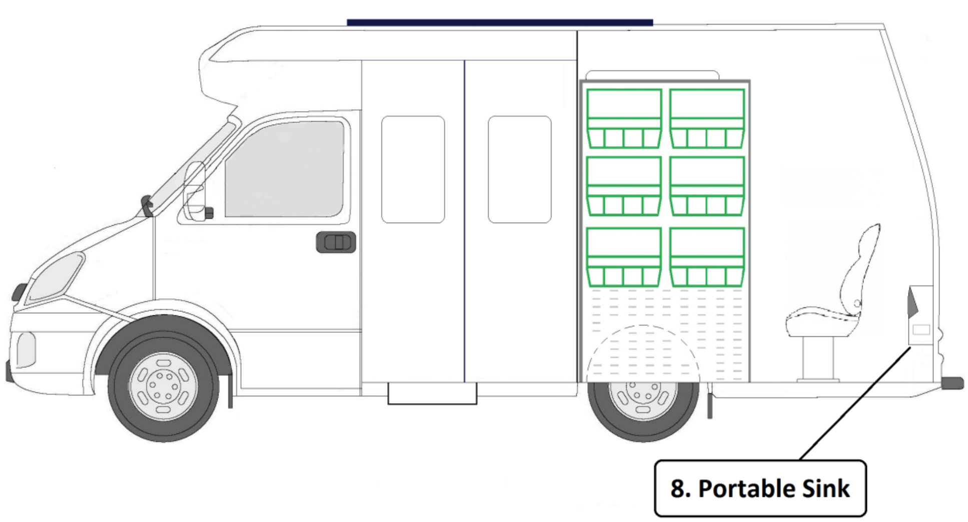


Appendix B

This appendix includes the design packet that was presented to the REC before this final report was prepared. This design packet includes each components, their functions, costs and links to websites to buy them.

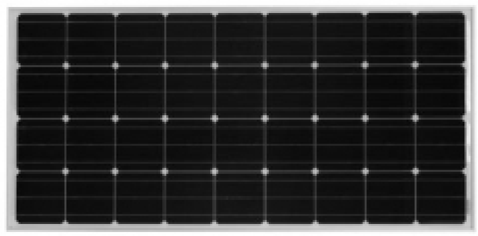
Mobile Market Designs





Detail Descriptions

Solar Panel



Model: Carmanah CTI-155

- 155 watts
- 8.61 amps
- 27” x 59”
- 12 volts
- $335 from RV Solar Electric

The solar panels requirements are:

- Combined power greater than 300 watts
- 12 or 24 volts
- Low cost

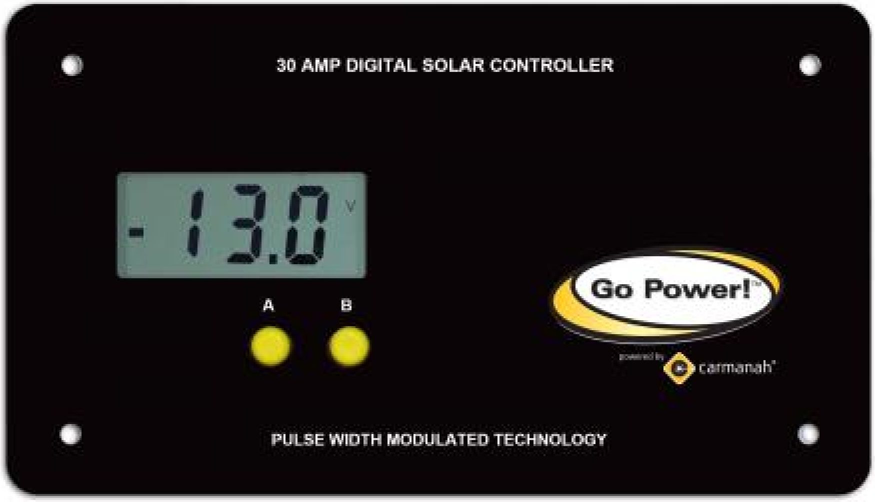
Two of these will be mounted to the roof, and used to generate power to charge the battery bank. They will be wired in series and connected to the solar controller.

This can be purchased from this site:
http://www.rvsolarelectric.com/index.php?route=product/product&path=30&product_id=68

Or the Worcester Carmanah distributer can be contacted at this number: 1-800-999-7824

The website seems to have the best price, but shipping costs could make buying locally worthwhile.

Solar Controller



Model: GP-PWM-30 Solar Controller

- 12 or 24 volts
- 25 amps
- 4.25” x 7.5” x 1.38”
- Maximum wire gauge of 6 AWG
- $135

The requirements for the controller are:

- 12 or 24 volts
- Pulse Width Modulated charging

The solar controller protects the batteries from over charging by limiting the current to the battery. The leads from the solar panels plug into the controller, as do the leads of the batteries. This can be mounted on the wall or ceiling using the screw holes in the corners.

This can be bought at this site:
http://www.rvsolarelectric.com/index.php?route=product/product&path=32_35&product_id=94

Or can be purchased from the Worcester Carmanah distributer at this number: 1-800-999-7824

Batteries

Model: UPG UB-4D AGM Sealed Lead Acid Battery

- 12 volts
- 200 amp-hours
- 20.75” x 9.65” x 8.11”
- $718 for 2
- 123.46 lbs. each

The requirements for the batteries are:

- 12 or 24 volts
- 200+ amp-hours
- Deep cycle
- Low cost

The batteries hold the power generated by the solar panels. This allows the power to be both regulated and available when there is no sunlight. They will be wired in series to create a high voltage battery with a larger capacity, to elongate the battery life of the system. These will be housed in a battery box built on the floor of the market, between the refrigerator and freezer.

The best price we have found is at this site: http://www.batteriesinaflash.com/sealed-lead-acid/12v/200ah/2x-12v-200ah-sealed-lead-acid-battery-upg-ub-4d-agm-for-solar-systems

Inverter

Model: Samlex America PST60S12A 600W Pure Sine Wave Inverter

- 600 Watts
- Pure sine wave signal
- 120 volt output
- 3.3” x 11” x 9.3”
- 5.4 lbs.

The requirements for the inverter are:

- Power output greater than 300 Watts
- Pure sine wave signal
- 2+ outlets

The inverter plugs into the battery bank and converts the DC power to AC power. The AC power is output through standard indoor wall outlets to run appliances. This can be mounted within the battery box to protect the electrical connections.

The inverter can be bought at this site: http://www.amazon.com/Samlex-America-PST60S12A-600W-Inverter/dp/B003FWNWN2/ref=sr_1_5?s=automotive&ie=UTF8&qid=1361492982&sr=1-5&keywords=pure+sine+wave+inverter

Freezers:
Danby DCF700 7 cubic feet freezer.

- Height 33”, Width 40”, depth 52”
- Weight 114.6 lbs.
- Capacity of 7 cubic feet
- For storing meat
- $300
- This can be bought online at

http://www.amazon.com/Danby-DCF700W1-cu-ft-Chest-Freezer/dp/B001CWDZYI/ref=sr_1_1?ie=UTF8&qid=1360203265&sr=8-1&keywords=chest+refrigerator
Or
http://www.homedepot.com/p/Danby-7-0-cu-ft-Chest-Freezer-in-White-DCF700W1/202521030

Refrigerator:
Danby 4.4 cu.ft.

- Height 33”, Width 20”, depth 22”
- Weight 78 lbs.
- Capacity of 4.4 cubic feet
- For storing milk, eggs etc.
- $200
- This can be bought online at

http://www.amazon.com/Danby-DAR125SLDD-4-4-cu-ft-Refrigerator/dp/B0052F5NB4/ref=pd_ybh_7
Or
http://www.walmart.com/ip/Danby-4.4-cu-ft-Refrigerator-Spotless-Steel/16621129?findingMethod=rr
Or
http://www.homedepot.com/p/Danby-4-4-cu-ft-Mini-Refrigerator-in-Black-DAR440BL/100673961

Both of these will be powered by the solar panels and the battery bank. The inverter will be connected to the power source and it will have two wall outlets. The chords from these will connect directly to the wall outlets of inverter.

Grill:

Cuisinart Petit Gourmet Portable Gas Grill with VersaStand

Distributor: Cuisinart

- 12 x 30 x 31 inches (WXHXD)
- 145-square-inch grilling area
- Detachable telescoping stand
- Weighs 17 lbs.
- $128.88

This is a gas grill that can be used for onsite demonstrations for the public. It is small enough to fit on the inside shelf near the back. It can be fueled by any standard CRL propane fuel canister.

Sink Options

Option 1:

Portable Outdoor Sink GSS501
Distributor: Generalsputerstore JBV International

- 12 x 27 x 8 inches (WXHXD)
- Adjustable 33-36" in height
- 15 lbs.
- 2 spray settings, 5 ft. drinking safe water
- Connects to garden hose or faucets/spigot
- Cost: $400.00

This sink can be connected to any garden hose or faucet. It has a 2-spray setting that will allow for washing of produce. The adjustable height will make it comfortable use.

Link:
http://generalsuperstore.com/outdoorsink.html

Option 2:

HandyMan Motor Series 12 Vold Sink

Distributor: New World Technology

- Closed: 11.8 x 12.8 x 6.9 inches
- Open: 11.8 x 12.8 x 12.8 inches
- 6.61 lbs. - empty
- 11.7 – Full: 2.5 liters of water
- Holds dirty water
- $193.00

The can hold 2 liter is useable water, and it will also hold the dirty water. It can easily be dumped and refilled. It can be attached inside or outside to any vertical surface of the van. Can be placed specifically to the inside of the entrance doorway of the van, and it can be taken out for the market use.

Website order Link:
http://vangadgets.co.uk/handyman-motor-series-12-volt-sink.htm

Projected Cost

Component Expenses		Price	Quantity	Component Total
Carmanah CTI-155		**335**	**2**	**670**
Samlex 600W Inverter		**200**	**1**	**200**
UPG battery		**350**	**2**	**700**
GO POWER GPM-30		**135**	**2**	**270**
Refrigerator		**159**	**1**	**159**
Freezer		**269**	**1**	**269**
Wires		**50**		**50**
Inline fuse		**20**	**1**	**20**
Waterproof Sealant		**50**	**1**	**50**
Sink		**193**	**1**	**193**
Gas Grill		130	1	130
Total	**$ 2711**			
Other Expenses				
Labor		**$ 800**		
Total	**$ 3511**			

Website Order Links

Unit	*Website Links*
Carmanah CTI-155	http://www.rvsolarelectric.com/index.php?route=product/product&path=30&product_id=68
Samlex 600W Inverter	http://www.amazon.com/Samlex-America-PST60S12A-600W-Inverter/dp/B003FWNWN2/ref=sr_1_5?s=automotive&ie=UTF8&qid=1361492982&sr=1-5&keywords=pure+sine+wave+inverter
UPG battery	http://www.batteriesinaflash.com/sealed-lead-acid/12v/200ah/2x-12v-200ah-sealed-lead-acid-battery-upg-ub-4d-agm-for-solar-systems
GO POWER GPM-30	http://www.rvsolarelectric.com/index.php?route=product/product&path=32_35&product_id=94
Refrigerator	http://www.amazon.com/Danby-DAR125SLDD-4-4-cu-ft-Refrigerator/dp/B0052F5NB4/ref=pd_ybh_7
Freezer	http://www.amazon.com/Danby-DCF700W1-cu-ft-Chest-Freezer/dp/B001CWDZYI/ref=sr_1_1?ie=UTF8&qid=1360203265&sr=8-1&keywords=chest+refrigerator
Wires	http://www.rvsolarelectric.com/index.php?route=product/product&path=31&product_id=89
Sink	http://vangadgets.co.uk/handyman-motor-series-12-volt-sink.htm
Gas Grill	http://www.sears.com/shc/s/p_10153_12605_07104799000P?sid=IDx01192011x000001&kispla=07104799000P&srccode=cii_17588969&cpncode=31-94524076-2

Design Packet

Solar Charging Options

Parking:

We recommend parking at the YMCA to maximize the time the solar panels are in the sun. This will allow the system to remain charged, so food can be left on the market between operation days. We understand the possibility of burglary with the market left in the open, but based on our research the YMCA area should be safe. You could move the products and turn off the refrigerator and freezer if you like after the last day of operation each week to preserve the battery life over periods time longer than a couple days, but as long as the panels are in the sun during the day the system will continue to run.

Parking at Clark would ensure the safety of the market, but would require the refrigerator and freezer to be turned off after the market is parked. This means all products need to be moved off the market between days of operation. At the beginning of each operation day and before any products are loaded into the refrigerator and freezer, they each need to run for one hour before they are at their proper operating temperatures.

System Options for Optimal Battery Life:

1. Using high voltage batteries

Pros: This allows for low Amp-Hours required in the batteries, which correlate to longer battery life. We may only need 1. With 12V batteries we need 27 Amp-Hours per hour which gives us about 650 per day. Using 24V batteries required Amp hours comes down to 14 Amp-Hours per hour and 335 Amp-Hours per day.

Cons: Charging of batteries requires a higher voltage than what they can output. Typically 12V needs at least 14V. Higher voltage panels are difficult to find and much heavier. Simply wiring multiple panels in series is not recommended. Batteries higher than 12V are difficult to find. One or two were found which cost start in thousands.

Other Thoughts: We're still looking into it, but this doesn't seem to be a good option right now.

2. Using multiple batteries in series

Pros: Most battery banks use multiple batteries. This will act as higher voltage battery. Adding another 100A-H battery will provide us with 24V with 200A-H capacity.

Cons: This requires a second charge controller. Beside that even with two batteries, the required capacity is not enough which is 335A-H. This will add about $135 for additional charge controller and $200 for additional battery.

Other Thoughts: This calculation does not include the power that will be supplied from solar panels. Power of solar panels is affected by various factors like its efficiency, area of panels, angle of panels with sun, loss in wiring, insolation etc. It is very difficult to calculate every single factor but it can be said definitely that 150 watt panel will not be able to provide 150 watts from dusk to dawn. However it will generate significant power during the summer. Also financially this is little more affordable.

3. High capacity batteries

Pros: Use of two 200A-H batteries will give us total of 400A-H. This covers the required A-H for at least 24 hours. Deep cycle batteries should not discharge more than 80% of its total charge. 335 A-H is about 83% of 400A-H. This ensures operation of system for more than 23 hours without any power from solar panels. This is best scenario for use of this kind of system.

Cons: Each 200A-H battery cost about $350 which makes total of $700 only for the batteries. The estimated cost for the battery went up from $200 to $700, and increase of 250%. Also an additional $135 for charge controller is to be considered. Total cost for all components totaled about $2400.

Other Thoughts: This is very expensive and might not cover for labor charge. However, this is the recommended setup.

4. Managing operation time

This option can involve both moving food off the market when it is not being sold, as well as only turning the refrigerator and freezer on selectively.

Pros: This could allow for fewer batteries and lower initial costs for components.

Cons: Products have to be moved off the van at night and back onto the van in the morning. The refrigerator and freezer will also need to be restarted in the morning, which could take at least an hour.

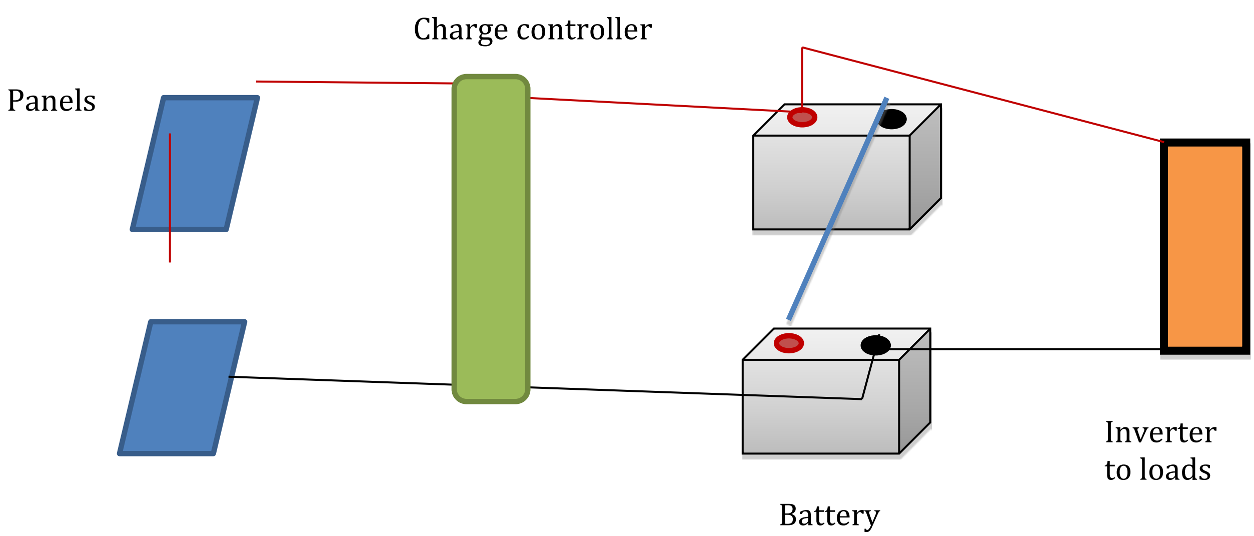
Other thoughts: This is the easiest from a technical standpoint, but not ideal logistically due to the time it takes to start the freezer and refrigerator.

Daily Usage:

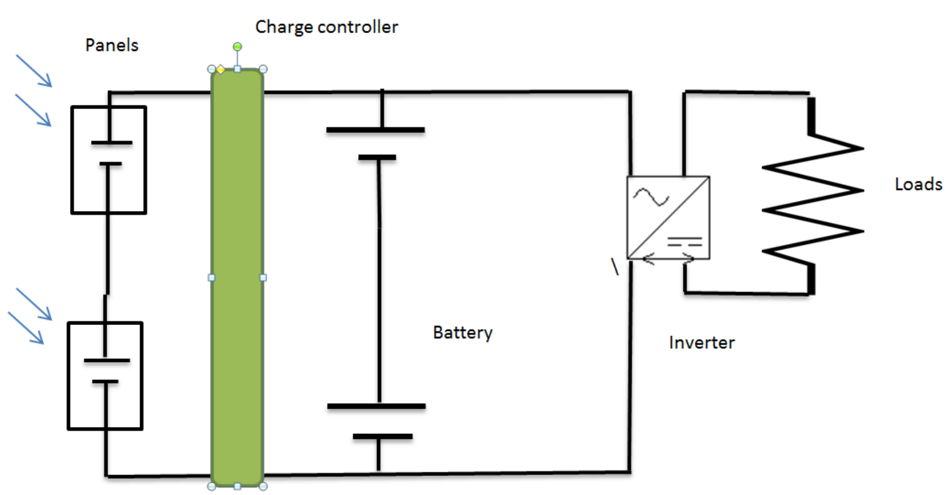
We recommend option 3 from the previous section because it forms a compromise between expensive high voltage and high capacity batteries, and the low battery life of single or double low capacity batteries. If parked at the YMCA, this system will stay charged between days of operation, allowing the products to be kept on the market. You will not need to turn off or restart the refrigerator or freezer, because the system will keep a sufficient charge to keep them running while the market is parked. If the solar panels get no sunlight, the system can still run for 24 hours before the batteries are depleted. You may still do turn off the refrigerator and freezer at your discretion, however. For example if you know there will be multiple days of rain which prevent the system from charging, you can turn off the refrigerator and freezer to ensure there will be enough power to run them the next time the market is running. This would require arriving at the market an hour early to turn them back on before loading any products.

Therefore, on the first operation day of the week you only need to load the products into the market, with no need to restart the refrigerator or freezer. The products can be left there until the next day of operation, after which the products can be removed.

Pictorial Setup



Schematic



Coolbot

Coolbot is an alternative to an expensive walk-in cooler compressor. It requires an insulated room, a window-type air conditioner and a Coolbot. The price for a Coolbot is about $300 and

AC has to be purchased separately. It works by tricking the AC to keep on cooling until the desired temperature is reached. Normal AC does not output full power once it reaches about 60F but Coolbot tricks the AC and doesn't let it know its 60F. Therefore the AC keeps outputting at maximum power until the Coolbot says it is cold enough. Coolbot is not just a thermostat but it uses multiple sensors and programmed micro-controllers to direct AC to operate in low temperatures without freezing up. Coolbot can easily achieve 35-36F but it cannot keep things frozen.
The size of the AC is proportionally related to the size of the room. Bigger the room, bigger AC is required. The size of AC is measured by BTU rating of certain AC. The table below shows the required size of AC for required size of room.

Dimensions of the Walk-In Cooler	Size of Air-Conditioner
6' x 8'	10,000 BTU
8' x 8'	12,000 BTU
8' x 10'	15,000 BTU
8' x 12'	18,000 BTU
10' x 12'	21,000 BTU
10' x 14'	24,000 BTU

(Air-conditioner vs. room size for CoolBot Systems @ 38F)

http://www.storeitcold.com/howitworks.html

Coolbot won't work if the AC is old without a Digital display. Almost all name brand manufacturers have moved to digital controls by now. Frigidaire still has a couple knob-type models out there, but so far all known brands like LG, Samsung, Toshiba and Kenmore have all upgraded by now.
It is very important that the room is well insulated. It is suggested that room should be insulated with industry standard which is at least 4" of Styrofoam in walls, ceiling and floor. The idea is to trap cold air in the room so that it keeps getting colder and holds that cold temperature for longer time. If the room is not insulated, the cold air leaks out and does not hold the temperature. Similarly it is not ideal solution if the door has to be opened frequently because the air leaks from door and in large amount. It is perfect solution for someone who needs to load/unload only few times a day.

http://www.storeitcold.com/testimonials.html

The video in the link below goes over the steps to install the Coolbot.

http://www.storeitcold.com/installation.html

Sundanzer

Sundanzer refrigerators and freezers run directly on DC current. These high efficiency refrigerators and freezers have exceptionally low energy consumption requiring smaller, less expensive power systems and low operating expense. It also eliminates the dependency on inverter. Inverters are also only 90% efficient so use of a Sundanzer increases the efficiency. The specification sheet of the Sundanzer products states that every product only uses 14 to 20 AH per day which is extremely efficient.

However only 4.7 cubic feet refrigerator costs $ 1149 and 5.8 cubic feet freezer costs $1189. Compared to regular refrigerator ($200) and regular freezer ($300) Sundanzer products are very expensive. This is recommended over regular freezers and refrigerator if it’s under budget.