WINTER STORAGE RESOURCE- FEB 2010

CASE STUDY: NEW CONSTRUCTION, STAND-ALONE COLD STORAGE WITH FREE AIR

Prepared by

GDS Associates, Inc

For

CISA (Community Involved in Sustaining Agriculture)

Contact: Claire Morenon, Program Coordinator

One Sugarloaf Street South Deerfield MA 01301

413.665.7100

www.buylocalfood.com

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INTRODUCTION

The intent of this guide is to provide general information regarding the design of winter root crop storage facilities. The guide is presented in two parts:

1. General design considerations that should be reviewed prior to the initiation of a cold storage project. Proper planning, including review and understanding of the various design and construction requirements of a cold storage facility, is critical to the success of any project.

2. A sample case project based on a stand-alone storage facility designed for a set of storage crop assumptions, including an energy use and financial analysis evaluating the impact of different system types.

This document should be used in guiding the decision-making process and cost analyses. The authors note that this guide is not intended to represent a full and complete reference for the design and construction of cold storage facilities. Cold storage facilities are subject to local building code requirements and mechanical refrigeration systems should be designed and installed only by qualified professionals. It is the intention of this document to provide interested parties with an introduction to options and considerations associated with cold storage.

CROP CONSIDERATIONS

The primary consideration of any cold storage project is the type of crops to be stored - different types of crops require varying levels of temperature and humidity for optimal storage. This guide focuses on root crops including topped carrots, beets, rutabagas, parsnips and turnips, which have similar storage temperature and humidity requirements[1] of approximately 32.5 °F and relative humidity of 98-100%. A complete list of other vegetables with similar storage temperature (32.5°F) and humidity (98% RH) requirements is available in the ASHRAE Refrigeration handbook[2].

It is important to note that vegetables with different temperature and/or humidity requirements need to be stored in separately controlled environments. Other crop considerations include:

- The time of year the crops will be harvested as this affects field temperature
- The total volume (pounds) of crops to be stored
- Potential sequencing of harvest and storage loading. Will the entire crop be harvested and loaded into storage at one time, or will the harvest and loading occur incrementally over a period of time? The sequencing of loading can affect the sizing of the cooling system.
- The timing of removing crops from storage. Will all crops be unloaded simultaneously or incrementally? How late into spring will crops be stored?

Different types of crops also have specific cool down requirements after harvest. For example, potatoes have a multi-step cool down and humidity level acclimation process. The rate at which field heat must be removed from the crops and the total mass of crops to be cooled directly impacts the sizing of the cooling equipment.

For more detailed information about crop storage temperature, humidity, temperature drawdown, and post-harvest handling, refer to the ASHRAE Refrigeration Handbook.

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1 Massachusetts Farm Energy Program, Cultivating Solutions report by GDS, June 2009

2 ASHRAE Refrigeration handbook 1998 chapter 23 Vegetables p 23.5-23.14

STORAGE FACILITY LAYOUT

The type of storage facility is another important consideration in the planning process. Some options include standalone facilities, cold storage within an existing building, or facilities partially or completely buried within the ground to reduce heat loss. Additional considerations for the arrangement of storage are the size and configuration of the facility, which will be dictated by the type and volume of crop to be stored, the plan for loading and unloading the crop, and the potential need for segmented storage to accommodate varying demands for temperature and humidity controlled environments. Related to the issue of size and configuration are considerations regarding the number, size, and placement of doors and other access points into the cold storage room. Access should be provided to facilitate loading and unloading and should take into account space required for maneuvering of any equipment. It is strongly recommended that a detailed plan for loading and unloading produce be developed during the planning process as these considerations will inform the final facility layout.

For the building entrance, we recommend two 14' x 14', roll-up, insulated, overhead doors with automatic controls for operation to maximize the usability of the interior space, though other options may be appropriate based on unique circumstances of each application. The door placement must be carefully considered to maximize crop storage space, optimize air flow, and facilitate product removal over the winter months.

Among the most critical considerations is the selection of a method for insulating the facility. Effective insulation will minimize heat transfer to the exterior and reduce operating costs. The recommended cold storage building envelope (shell) insulation value is R-30 in the walls and R-40 for the roof[3]. In the case of new construction, the slab should be insulated to R-20. In existing or retrofit buildings, the potential savings from added slab insulation does not warrant replacing the slab just to insulate under it. The recommended method of insulation is polyisocyanurate (Polyiso). Polyiso has an R value of approximately 7.7 per inch of insulation, so a minimum of 4 inches of Polyiso is recommended for walls and 5 ½ to 6" in the roof.

A final key consideration in planning a cold storage project is the location and functionality of the cooling system, which are discussed in detail below.

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3 ASHRAE Handbook of Fundamentals 1993

STORAGE ARRANGEMENT

When storage bins are used, the cooling and humidity system should be arranged so that cold air is supplied into the forklift openings at the base of the pallet bins and allowed to travel through the openings where it is drawn back towards the recirculation vent (when in refrigeration mode) or the exhaust air damper (when in outside air cooling mode). (See page 7 for more information related to the two cooling modes).

There are two main considerations for the loading and stacking arrangement of the pallet bins. First, the pallet bins should be stacked with the forklift openings and the pallet skids in line, which will allow air to pass freely beneath the pallet bins and up through the produce[4]. If a single pallet bin is improperly oriented, it can restrict airflow to downstream areas of the storage. Secondly, air gaps must be maintained on all sides and the top of the pallet bins to allow proper air circulation. NRAES-22[5] recommends maintaining 8"-10" air gaps between storage and the wall opposite the evaporator (and/or the outside air fan) and 4"-6" air gaps on the sides of the storage space.

The arrangement of storage within the room requires planning. Consideration should be given to the order in which the product will be introduced into storage, and the need to access the various products for washing and sale. GDS strongly recommends that a plan for loading and storing the product be developed prior to consultation with the vendor or design-building contractor who will finalize the mechanical system design; the arrangement of storage will absolutely impact the layout of the system components. Once the cold storage room is constructed, it would be helpful to mark the locations of pallet bins on the floor to ensure that the actual loading is consistent with the design layout.

Generally, the mechanical equipment inside the cold storage area should be mounted near the ceiling to help provide the maximum floor space for crop storage and loading and unloading the room.

STORAGE CONTAINERS

Hardwood storage bins with internal dimensions of 4'L x 4'W x 3'H are considered industry standards[6]. These bins will hold an estimated 1,250 pounds of topped carrots or equivalent

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4 Ontario Ministry of Agriculture Food and Rural Affairs. Long Term Storage of Carrots. December 1998. http://www.omafra.gov.on.ca/english/engineer/facts/98-073.htm

5 Northeast Regional Agricultural Engineering Service (NRAES), Refrigeration and Controlled Atmosphere Storage for Horticultural Crops (NRAES-22), Cooperative Extension. 1990.

6 Ontario Ministry of Agriculture Food and Rural Affairs. Long Term Storage of Carrots. December 1998. http://www.omafra.gov.on.ca/english/engineer/facts/98-073.htm

and can be stacked five high. Plastic pallet bins are also being used at a somewhat higher cost, as they last longer and are easier to clean between harvest cycles. Bulk storage is another option, though it is more difficult to uniformly cool crops in this arrangement, and it is more difficult to incrementally remove crops from storage for sale.

COLD STORAGE

COOLING SYSTEM CAPACITY

The type and capacity of the cooling system is critical to the successful operation of a cold storage facility. This section describes the key considerations to be accounted for when sizing a cooling system, and describes different types of available cooling systems.

The cooling system must be sized appropriately to accomplish two key tasks; first, the system must have sufficient capacity to initially cool the crop from the field temperature to the desired storage temperature. Variables include the temperature at the time of year of harvest, the volume (pounds) of crop to be stored, the desired storage temperature, and the time period in which the desired storage temperature must be reached. A second key task accomplished by the cooling system is to maintain the desired temperature during the storage period, which involves accounting for the heat of respiration of the crop and heat gain through the building envelope. In most instances, the initial cooling period represents the largest cooling load and is the driving factor in the sizing of the system.

The references cited in this document stress the importance of cooling root crops from field temperature to storage temperature in a matter of a few hours to maintain product quality. This prevents moisture loss and reduces damage caused by crop respiration. One way to achieve this rapid cooling is to size the cooling system to handle the peak cool-down load, which in most commercial cases requires a cooling system with a capacity of at least 5 $tons_{AC}$[7] or 60,000 Btu/hr.

Depending on the outside air temperature at harvest time, it may be possible to use natural outdoor cooling to reduce the product temperature before it enters storage, thereby limiting the amount of mechanical refrigeration. One possible arrangement is to store the harvested crop in a pallet bin covered with a layer of clear plastic to help retain moisture. Outside temperatures lower than 40°F should be sufficient to cool the product. This approach was not discussed in any of the literature reviewed and should be used cautiously, if at all, to assess the impact of this method on product quality and storage viability.

An alternate approach would be to use ice for the initial cooling, which would allow for a smaller cooling system. This approach would require (a) that an estimated 6-8 inches in the top of the bins be allotted for the ice and (b) managing the logistics of transferring the ice to

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7 One ton_{AC} of refrigeration is an archaic unit unique to the industry and equals 12,000 Btu/hr and has nothing to do with ton_{crop} of produce.

the field or the storage facility and leaving the pallet bins outside long enough for the ice to melt and drain off. GDS has not researched this method in detail. There may be certain challenges with introducing water to the product, as well as other unanticipated effects. As such, it is recommended that this method be undertaken only experimentally, if at all, on a limited portion of crop to test the impact of this method on storage crops.

COOLING SYSTEM TYPES

Mechanical Cooling

Mechanical cooling that uses commercially available refrigeration equipment is the most common and reliable method of achieving and maintaining proper storage temperatures, though it is also the method with the highest operating costs. For most facilities it is recommended that the system consist of two equally sized cooling systems, each capable of bearing 50% of the cooling load. This provides a degree of redundancy and allows for more efficient operation during periods when full capacity is not required. Typically, a control system is utilized to maintain the desired temperature during the storage period. Once the crop has been initially pulled down to the desired temperature, the cooling load will be lower and the control system will utilize only a single refrigeration unit thus resulting in lower operating costs. If a single, larger system were utilized, the system would tend to "short cycle", meaning that it runs for a short period of time at higher capacity then shuts off. The smaller systems run more efficiently at lower capacity. If ice is used for the initial cool down, a smaller cooling system (e.g. two ½ ton_{AC} units) should be sufficient to maintain temperature.

Free Cooling Option

When the outside air temperature is less than 28°, outside air can be used in lieu of mechanical cooling. When outside air temperatures are above 28°, free cooling is generally not a viable option. Due to the unreliability of outside air temperatures, it is recommended that free cooling be used to supplement a mechanical refrigeration or geothermal system, but not as the sole cooling source.

Outside air cooling systems – or outside air economizers - typically use a series of dampers and a ventilation fan that brings cool outside air into the storage facility and expels warmer exhaust air. This is accomplished using an integrated system of dampers, ventilation fans, sensors and controls. The sensors monitor inside and outside temperature and when the outside temperature is less than 28°, the controls configure the dampers and fans to provide cooling using outside air.

The system will generally include a minimum of two dampers: one set of damper that controls the inflow of outside air, and one that controls the release of exhaust[8]. Dampers along the exterior boundaries of the thermal envelope should be designed to be as airtight as possible to limit air flow and heat transfer to the exterior. Motorized dampers have less air leakage than gravity dampers, which generally allow more infiltration.

The outside air fan will run only when outside temperatures are favorable for free cooling. The necessary fan size (Motor horsepower/HP, cfm) will depend on the final arrangement of the system, primarily the size and configuration of the air components. The fan must provide sufficient velocity and static pressure to deliver cold air beneath the pallet skids to the opposing exterior walls to achieve adequate ventilation and to effectively change out the air through the exhaust damper.

Geothermal Cooling Options

Geothermal cooling can be one of the most efficient cooling systems available. Geothermal cooling systems can typically reduce the operating cost by nearly half but have significantly higher start-up costs. For seasonal crop storage the typical paybacks can be over fifteen years. For more detailed information and specific design consideration reference ASHRAE Fundamentals and refrigeration handbook.

COOLING SYSTEM OPERATION (SYSTEMS USING OUTSIDE AIR)

Cold storage systems utilizing a combination of mechanical refrigeration and outside air cooling will operate in two active modes; mechanical refrigeration and outside air. In mechanical refrigeration mode the outside air damper is closed and the outside air fan is not in use. Evaporator fans circulate the air internally, and the mechanical refrigeration equipment removes the heat from the space to maintain the desired set point. Mechanical refrigeration is necessary when the outside air temperature is above 30^{0}F to 32^{0}F, and for the initial cool down of product.

When outside air temperatures are below 28° and the control system calls for additional cooling to maintain the desired set point, the system can utilize the free cooling mode. In this mode, the outside air (inlet) damper and exhaust dampers are open, and the outside air fan operates to draw in cold outside air and distribute it though the space and the product. The warmer air is forced out through the exhaust damper. The ceiling-mounted evaporator unit and outdoor condensing unit should not run in this mode.

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8 NRAES-22 Northeast Regional Agricultural Engineering Service cooperative Extension "Refrigeration and Controlled Atmosphere Storage for Horticultural Crops" Figure 12

In both modes, the humidifier will likely need to run to maintain the high level of humidity necessary for effective storage. The evaporator that runs during refrigeration mode removes moisture from the air, which must be replaced by the humidifier in order to maintain 98% relative humidity (RH). Outside air is generally cold and dry, so humidification may be required in outside cooling mode as well. The control system, which monitors the humidity level, activates the humidifier when necessary. Considerations for controls and sensors are discussed in Section 2.7 below.

HUMIDITY CONTROL

Most root crops require storage at 32.5° F and 90% to 95% relative humidity (RH). Effectively maintaining a high RH within the cold room is critical to maintaining the crops in good condition and limiting desiccation (water loss), which results in drying and shrinkage of the crop. Both the mechanical refrigeration and outside air cooling modes will remove moisture from the cold room, thus lowering the RH. Humidifying at a temperature so close to freezing precludes the use of systems that introduce water at or near the storage temperature, because the heat of vaporization will cause the water temperature to drop below freezing and the systems will produce snow.

The recommended type of humidification system is centrifugal. It offers the least operating costs and has been in use for many types of crop storage facilities. If a centrifugal humidification system is selected, the evaporator or cooling coil will need be designed for a 1^{0}F-2^{0}F temperature difference across the coil to help reduce the potential for icing.[9] Consideration should also be given to steam humidification using a fuel-based (oil or propane) steam generator for economic reasons.

The water supply line should be designed for freezing conditions. We recommend that a hydrant with buried pipe be used to bring water to the cold storage building and that water lines which are exposed to ambient conditions be heat taped and insulated.

To reduce maintenance on the boiler and the steam distribution system, particularly the nozzles, a water de-ionizer should be installed to remove minerals in locales where water hardness is an issue. Humidification sprayers must be located so that water is not allowed to drip on stored produce.

CONTROL SYSTEM

A central control system is critical to the proper operation of this cold storage design. For this project, at a minimum, the control system will be responsible for:

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9 Triver, Doug, Agri-book Magazine/Potatoes in Canada 1996

- Monitoring temperature within the conditioned space, and at selected locations inside the bins;
- Monitoring humidity within the conditioned space;
- Monitoring temperature outside the enclosure;
- Configuring the system dampers to take advantage of cold outside air cooling (e.g. free cooling);
- Operating the system components (evaporator fans, outside air fans, humidifiers) as necessary to achieve and maintain desired space conditions;
- Running the defrost cycle on the evaporator coils.

The design of the control system will be unique to each project and required consultation with a design professional. It is important to place multiple temperature and humidity probes within the cold room at various locations, including high, low, near walls, and within the bins to get accurate readings throughout the space.

SAMPLE CASE

This section details a sample case for storage to illustrate some of the technical and financial aspects in more detail. The sample case is based upon the following design assumptions:

- Root crops (such as carrots, beets, parsnips, turnips, etc.)
  - Requires storage temperature of: 32.5°F.
  - Requires relative humidity: 98 to100%[10].
- Harvest time: late October through early November.
- Initial cool down to be accomplished from field temperature to 7/8 of desired temperature in 24 hours.
- Storage period: five to eight months.
- Stand-alone cold storage building with an interior space 16 feet wide, 32 feet long and 20 feet high (plus any rafter/peaked roof height).
- Washing and packing areas are external to the facility, and are not included in the financial analysis.

STORAGE LAYOUT

The figure below illustrates an effective storage layout for this sample design. The prototype storage facility, at 16'W x 32'L x 20'H, will store 72 pallet bins if arranged 4 x 3 x 6 as shown. At 1,250 pounds of product per bin, the facility will hold 90,000 pounds or 45 $tons_{crop}$ of product.

The open aisle on the right side of the figure allows for the maneuvering of equipment so that the pallet bins shown can be picked up from any side. If the building is equipped with doors at either end, the first product stored can be the first product removed. If the ice initial-cooling method mentioned above is used, the pallet bins will have less than the estimated 1,250 pounds of produce unless the bins are topped off after cool-down and before being moved into the storage facility.

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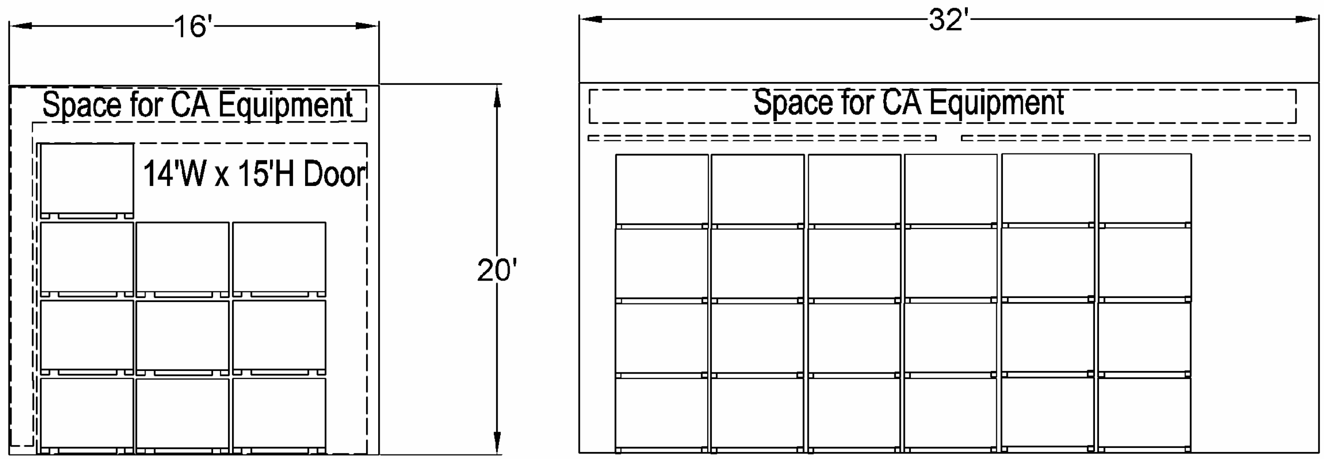
10 ASHRAE Refrigeration handbook 1998 chapter 23 Vegetables p 23.7

Note the open spaces between the pallet bins and the walls of the cost storage on all sides. This free open space allows air to circulate completely around the pallet bins, thus more efficiently cooling the crop. When utilizing pallet bins for storage, an air gap should always be maintained between the bins and the walls to allow for free air movement.



Hardwood bins are 4'W x 4'L x 3'H inside dim
Stack 4H x 3W x 6L = 72 bins
1250 pounds of crop per bin
90,000 pounds or 45 tons of carrots
Note: These bins may be stacked 5 high

Based on "Long Term Storage of Carrots" Factsheet by
Ministry of Agriculture & Rural Affairs, Ontatrio, 12/98

GDS Associates
CISA Project
16' x 32' x 20' cold Storage Shed
Pallet Bin Arrangement

COOLING SYSTEM ARRANGEMENT AND CAPACITY

For the purpose of the sample case, the cooling system is assumed to consist of a combination of mechanical refrigeration and natural outside air cooling. The primary components of the cooling system are the evaporator/condenser unit, the outside air fan, the humidifier, and motorized dampers.

In sizing the mechanical cooling equipment, there are three potential sources of heat that must be considered as discussed below:

- Heat gain through the building envelope on the warmest winter day.
- Based on R30 walls and R40 ceiling as recommended, the maximum rate of heat gain is estimated to be 2,675 Btu/hr.
- Heat of respiration of the carrots. The carrots respire and release heat throughout the storage period; this heat gain must be accounted for in the calculations. It is important to note that a crop's rate of heat respiration varies with temperature such that the heat of respiration is much higher at initial harvest than once is has been brought down to its desired storage temperature.
- The heat of respiration of carrots at 60 F is estimated at 11,220 Btu/24-hr per toncrop, or 21,000 Btu/hr for the 90,000 lbs of crop assumed in the sample case. At the storage temperature of 32.5° F, the heat of respiration drops to 3,500 Btu/day-toncrop of product, or just over 6,500 Btu/hr for the entire crop.
- The initial cooling of the carrots from field temperature to the desired storage temperature represents the most significant cooling load for the system and is typically the factor that drives the sizing of the equipment. The calculation involves several variables such as the initial field temperature of the crop, tonnage of crop to be cooled, time duration to reach desired storage temperature, and the desired storage temperature:
- The initial cooling load for this sample case has been estimated at 38,000 Btu/hr assuming that the entire 90,000 pounds of carrots will be cooled from a field temperature of 55°F to 7/8 of the desired storage temperature of 32.5°F in a period of 24 hours.

Evaporator/Condenser Set

The primary function of the refrigeration unit is to cool the product from the field temperature (assumed to be 55^0 F) to the storage temperature (32.5^0 F)11.

To determine the required cooling capacity, NOAA[12] hourly weather data for Worcester, MA was utilized. The sample analysis was based on a worst case scenario of cooling the entire 45 $tons_{crop}$ of product from the field temperature to 7/8 of the desired temperature of 32.5^0F (e.g. 35.3^0F) in 24 hours. In reality, the product will be brought into cold storage in stages over a period of days, so the actual daily volumes to be cooled will be significantly lower. The constant loading of product during this period will, however, result in additional cooling load because of the open door during loading. Sizing the refrigeration system for cooling the total volume of product within 1-2 days is intended to provide a conservative estimate for system sizing that takes into account variables such as fluctuating harvest $tonage_{crop}$ per day.

The analysis indicates that the refrigeration system must be capable of providing approximately 60,000 btu/hour of cooling (5 ton_{AC} capacity). Defrosting the evaporator coils is a significant concern that must be addressed by the installing contractor. The evaporator coils will be operating at a temperature below freezing in an environment with extremely high relative humidity, so a regular defrost cycle accomplished using hot water, electric heating, or hot gas will be required to keep the evaporator coils in working condition.

Installing the evaporator(s) at the ceiling of the cold room appears to be the least complicated arrangement and is typical of many cold storage rooms.

Humidification

The sample case assumes a centrifugal type humidification system. The evaporator or cooling coil will need be designed for a 1^0F-2^0F temperature difference across the coil to help reduce the potential for icing.[13] The water supply line would have to be designed for freezing conditions.

To reduce maintenance on the boiler and the steam distribution system, particularly the nozzles, a water de-ionizer should be installed to remove minerals in locales where

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11 ASHRAE Refrigeration handbook 1998 chapter 23 Vegetables p 23.7

12 NOAA TMY2 Weather data for Worcester, MA

13 Triver, Doug, Agri-book Magazine/Potatoes in Canada 1996

water hardness is an issue. Humidification sprayers must be located so that water is not allowed to drip on the stored produce.

Peak humidification load for the prototype facility has been estimated at 10 gal per hour.

Outside Air System

The outside air system consists of an economizer fan, motorized damper, exhaust damper, and controls system. The controls system monitors interior and exterior temperature, and when outside conditions are suitable for cooling it turns on the outside air fan, turns off the evaporator/condenser unit, and opens the exhaust damper so that cool outside air is injected into the storage area and warmer stale air is expelled. For the desired storage temperature of 32.5°F, 28°F is the warmest outside temperature at which free cooling is an option. For this application, at an outside temperature of 28°F it is estimated that a maximum flow rate of 1,700 Cubic Feet per Minute (cfm) would be required for effective cooling[14]. 1,700 cfm would require a ½ HP fan at an assumed static pressure of 1" Water Gauge (WG). This assumed fan sizing has been utilized in the financial analysis below.

FINANCIAL ANALYSIS

This financial analysis is based on the design assumptions stated above, and considers a 5-month storage period and an 8-month storage period. Outside temperatures, on average, are warmer for the 8-month scenario than the 5-month scenario and thus influence the amount of electricity needed to operate the systems.

The table below illustrates the potential savings for three types of efficiency measures:

- High efficiency evaporator/condenser sets
- Use of natural outside air cooling
- Use of ice for assisting in field heat removal

The savings and installed costs in the table below reflect incremental savings and costs compared to a standard refrigeration unit with an Energy Efficiency Rating (EER) of 8. In this "base-case" of a mechanical refrigeration unit with an EER of 8, no outside air cooling and no ice usage is assumed.

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14 Based on bin hour calculation and information from both the NRAES-22 Northeast Regional Agricultural Engineering Service cooperative Extension "Refrigeration and Controlled Atmosphere Storage for Horticultural Crops"

Electric savings represent the difference in electricity used to operate the energy efficient system compared to the base case system. Similarly, the installed costs stated in the table represent only the incremental cost of the efficient system compared to the base case system. The base case cold storage cost estimate is based on evaporator sized for a 2^{0}F temperature difference The 2^{0}F temperature difference is a requirement to help the humidification system operate at optimum conditions and to help reduce the drying of the crops and to prevent icing during the humidification process. The standard system costs are estimated at $33,000 (less the cold storage building) and result in an estimated annual operating cost of $1,100 (5 months) to $2,200 (8 months). All operating costs are based on a fully blended electric rate of $0.15/kWh, which includes transmission, distribution, taxes, and customer charges.

In the case of utilizing ice for the removal of field heat, the reduction in initial cooling load allows the mechanical cooling system to be downsized from 5 tonsAC to 1 ton resulting in lowered project costs. The cost for the ice is estimated at $2,000 /year[15], but since using the ice allows for cost savings due to the downsizing of equipment, no cost has been shown in the table.

ID	Energy Efficiency Measure	Electricity Saved Annually (kWh/yr)	Operating Cost Savings ($/yr)	Installed Cost ($)	Simple Payback (years)
COLD STORAGE MEASURES					
CS1	High Efficiency Equipment (5 Months of Storage)	1,238	$186	$797	4.3
CS2	High Efficiency Equipment (8 Months of Storage)	2,788	$418	$797	1.9
CS3	Free Cooling Mode 8 months of storage	3,420	$513	$2,225	4.3
CS4	Free Cooling Mode 5 months of storage	3,744	$562	$2,225	4.0
CS5	Utilizing Ice for Field Cooling Down	4,375	$656	$0	0.0
	Total - All Utilities	**15,565**	**$ 2,335**	**6,044**	**2.6**

EMISSIONS CONSIDERATIONS

The following table shows the potential emissions savings from using high efficiency equipment or implement free cooling when the weather conditions are favorable.

15 Transportation costs not included.

ID	Energy Efficiency Measure	CO_2 (lb/yr)	CH_4 (lb/yr)	N_20 (lb/yr)	CO_2E (lb/yr)
COLD STORAGE MEASURES					
CS1	High Efficiency Equipment (5 Months of Storage)	1,125	0	0	1,133
CS2	High Efficiency Equipment (8 Months of Storage)	2,534	0	0	2,552
CS3	Free Cooling Mode 8 months of storage	3,108	0	0	3,130
CS4	Free Cooling Mode 5 months of storage	3,403	0	0	3,427
CS5	Utilizing Ice for Field Cooling Down	3,976	0	0	4,004
	Totals	**14,147**	**1**	**0**	**14,246**