Energy Conservation in Direct Farm Markets

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INTRODUCTION

Direct market farms use energy in many different applications; the type and amount of energy used depend highly on the character of the operation. Often the largest energy use in direct market farms is for field operations in the form of diesel fuel, nitrogen-based fertilizers, and pesticides. Other large energy uses may include refrigeration, lighting, heating and cooling, off-site transportation, irrigation pumping, and processing and packing operations. Direct market farms with greenhouses may also have high energy use associated with these facilities.

REFRIGERATION ENERGY

Refrigeration often represents the largest electrical energy use in direct market farms. Energy conservation for refrigeration focuses on two primary activities, removing field heat and refrigerated storage, both of which are designed to preserve the quality of perishable products

REMOVING FIELD HEAT

Removing field heat brings produce to the proper storage temperature as quickly and efficiently as possible with minimal stress to the product. Techniques include hydro-cooling, vacuum cooling, and forced air cooling. The best and most efficient technique used to remove field heat is specific to each type of fruit and vegetable product. The New Jersey Commercial Vegetable Production Recommendations (Ghidui, et al) and local Cooperative Extension Offices can provide information on the best type of cooling system and the proper storage temperature and humidity for particular products. Cooling systems should be sized to cool crops adequately, taking into account the economic and energy impacts of large mechanical cooling systems.

Keeping the produce as cool as possible before it enters the cooling equipment will reduce the energy needed to remove field heat. This can be done by harvesting during cooler times of day, taking the product from the field quickly, and keeping the product shaded before placing it into coolers. Energy is also used during cooling processes when air comes in contact with cooled water in various stages of the process. Therefore, a well-designed cooling system will minimize the amount of outside air that enters the cooling chamber and be well insulated on the outside to minimize loss of cooling energy through the walls. Forced air cooling tunnels can maximize the amount of air coming into direct contact with the product and, hence, heat removal. Produce boxes in a forced air cooling tunnel should be stacked to avoid open air gaps. The tarps used to cover the boxes should also be free of holes and in close contact with the boxes.

Hydro-Cooler with Air Exclusion Flaps
SOURCE: W. KLINE, NJ AGRICULTURAL EXPERIMENT STATION

REFRIGERATED STORAGE

Once field heat has been removed, fruit and vegetable products should remain at storage temperature until they reach the consumer. Refrigerated storage rooms should have evaporator coils (the heat exchangers that are mounted behind the fans) that are sized properly for the desired temperature and humidity level of the room. Because most fruit and vegetables are stored at high humidity, refrigerated storage rooms require oversized evaporator coils to prevent icing, which leads to energy inefficiency.

Optimizing energy efficiency of the mechanical cooling components is generally the same for both product coolers and refrigerated storage systems. In both, systems should not be oversized because mechanical cooling is most efficient when equipment is run at or near its maximum duty cycle. Additionally, cooling equipment must be properly insulated and in good mechanical condition. Check the system regularly for leaks and pressure, adding refrigerant as necessary to achieve the manufacturer's suggested charge levels. A well-qualified refrigeration contractor can design a system to meet the cooling needs efficiently. AHRI (Air Conditioning, Heating and Refrigeration Institute) Standard 550/590 (AHRI 2011) provides guidelines for the design and installation of refrigeration equipment.

Refrigerated storage can be made more energy efficient by using single, large coolers where feasible. If multiple small cool storage structures are due for replacement around the same time, significant energy savings can be realized by replacing them with a single, larger unit. ANSI/AHRI Standard 1250 (ANSI 2009) outlines testing and rating requirements for certifying walk-in coolers. ENERGY STAR has requirements for commercial refrigerators and freezers based on maximum daily energy consumption. The U.S. Department of Energy is proposing procedures for testing walk-in coolers and freezers but there are currently no accepted standards and few available ratings. In the absence of comparative data for commercial refrigeration equipment, ensuring adequate insulation is the most important single consideration. AHRI recommends minimum R-values of R-25 for cooler walls and R-32 for freezers, and R-28 for freezer floor insulation.

Other opportunities for energy conservation in cold storage rely on the same principles as building cooling–doors and other openings should be airtight to the extent possible. Energy efficiency measures for coolers and freezers include:

- Automatic door closers
- Strip doors or spring-hinged doors where appropriate
- High efficiency fan motors (use electronically commutated or three phase motors for motors under 1 hp)
- Energy efficient lighting (at least 40 lumens per watt)
- Occupancy sensors for lighting
- Improved defrosting technology
- Air economizers
- Properly designed drains that prevent outside air from entering the room
- Heat recovery from the refrigeration compressor for room heating

Controlled Atmosphere (CA) storage is another method of refrigerated storage that is commonly used to store fruit for extended periods of time. In CA storage, it is very important to have an airtight seal for the room to keep the atmosphere inside at the proper levels of carbon dioxide, oxygen, humidity, and temperature. In addition to the steps outlined above, energy conservation can be achieved with CA storage by sizing the room properly and minimizing the number of times that the room is entered.

IRRIGATION

On direct market farms, irrigation can represent a significant energy use. Electric pumps can be up to 80% efficient, whereas the best diesel pumps can achieve a maximum of approximately 40% efficiency (Schneider Electric, 2012). Various strategies can improve the energy use of irrigation equipment:

- Increasing the on-off pressure differential on pump controls (e.g., from 5 – 10psi to 10 – 20 psi).
- Using multiple small pumps instead of a single large pump
- Using pumps properly sized for the flow and pressure characteristics of the system.
- Using variable frequency drive (VFD) on larger motors that have varying loads.

Where internal combustion engine driven pumps are used, as in remote locations or in operations where pump must be moved, specific guidelines apply:

- Use diesel engines where possible

- Install a mechanical governor on all engines; replace spark cut-out governors with mechanical type
- Ensure the proper mechanical condition of engines and pumps, including performance of seals, timing, cylinder compression and balance
- Replace all filters and fluids at the manufacturer's recommended intervals or more frequently
- Ensure that pick-up screens are appropriately sized and remain clean.

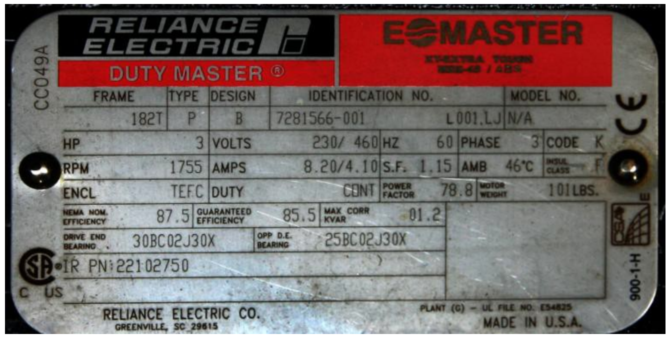
Variable Frequency Drive-Controlled Irrigation Pump
PHOTO: USDA

WASHING, GRADING AND PACKING EQUIPMENT

Energy-efficient operation of washing, grading and packing equipment requires proper design and specification of machinery, as well as proper lighting and maintenance. New and replacement electric motors should be NEMA-certified "Premium Efficient" products specified for the intended application. Use motors with Totally-Enclosed Fan-Cooled (TEFC) or Totally-Enclosed Air-Over (TEAO) frame design in dusty or otherwise harsh environments. As with irrigation pumps, a Variable Frequency Drive may provide significant energy savings for motors that cycle on and off often or that operate at variable speeds or variable loads, such as grading belts.

To maximize energy efficiency and product quality, processing and packing lines should be designed to minimize the distance that products need to travel. Use rotating sponges and air curtains after washing the product to remove excess water efficiently. Control packing equipment electronically to the greatest extent possible. This allows parts of the packing machine to shut down when not in use to conserve energy. Place shut-off switches in readily accessible locations. This improves safety line and allows machinery to be shut off easily when not in use.

Where an energy audit shows that energy use in washing, grading, and packing equipment is a significant portion of the operation's total energy use, examine the nameplate data of all equipment to identify excess capacity in motors, immersion heaters, and ventilation drives. Infrared imaging can be helpful in identifying equipment and structures that are poorly insulated or leaking heated or cooled material.



Motor Nameplate Data

PHOTO: T. MANNING, NJ AGRICULTURAL EXPERIMENT STATION

LIGHTING

Grading tables should be well lit with energy efficient lighting that provides the proper color and light level for efficient grading to occur. The color of lighting needed for packing and grading lines is usually as close to natural light as possible–especially important when sorting fruit and vegetables by color and when looking for blemishes on the surface of the product, such as what is done on tomato packing lines. Light levels needed for packing lines are high compared with many other task lighting levels because workers need to easily identify color, size, blemishes, and other markings during the grading process. Light levels from 200 to 450 foot-candles are recommended in this application (ASABE 2005). Natural lighting can supplement artificial lighting for packing lines, but there is typically limited success because of lighting variability due to cloud cover and packing during the darker time of day.

Many direct market farms require areas with task lighting to provide sufficient light for workers. Task lighting for areas other than those used for packing and grading should be lit to approximately 50 foot-candles (Ghidiu, 2012). Because processing operations may entail different activities in the same building at different times, movable and semi- permanent lighting fixtures can help improve lighting energy efficiency. Small fixtures mounted to pedestals can be used to light small areas and machinery. Larger areas can be lit with semi-permanent fixtures hung from chains and powered by flexible cords, which can be moved throughout the building as necessary.

Lighting that remains on for significant amounts of time should use the most efficient equipment practical. While shock-resistant incandescent bulbs remain popular for task lighting use, newer light fixtures which are equally shock resistant and use fluorescent or Light Emitting Diode (LED) lamps are now available. Permanently installed lighting should also use lamp technologies other than incandescent, such as high pressure sodium (HPS) or metal halide (MH) lamps. As with all agricultural buildings that accommodate different activities, new lighting systems should be installed with as many zones as practical, so that unused fixtures can always be shut off independently of fixtures that are located in higher-use areas.

Lighting systems should be designed to provide an adequate light level at the working height of the tasks they illuminate. In the fruit and vegetable handling sector, buildings that have relatively high ceilings can use HPS, pulse-start metal halide or high bay LED or fluorescent fixtures as an efficient choice for providing the needed light levels at working height. Where possible, use natural light, as it uses relatively little energy compared to other light sources. There is often a slight energy cost in using natural lighting, associated with the increased energy losses through glazing in conditioned spaces. Properly placed skylights and southwest facing windows can admit up to half the light needed for handling tasks. When possible, skylights should be placed close to the center of areas needing light during a majority of time the building is in use. Follow the American Society of Agricultural and Biological Engineers Standard EP344.3-JAN2005 (ASABE 2005) when installing lighting systems.

BUILDING ENERGY

Buildings that are used mostly during warmer months can be designed to optimize for efficient cooling and ventilation at the expense of efficiency in heating. Such buildings should use the lightest-colored roof and sheathing practical–stucco, white siding, or tar that has been painted white is excellent. Additionally, well-placed plantings of tree rows can be used to channel prevailing winds into ventilation intakes and refrigeration condensers. Such plantings can also be used to shade the building or reduce undesirable drafts.

Handling buildings often use artificial ventilation to remove heat and dust from the building. Ventilation devices should be placed so as to create consistent airflow throughout the entire structure and to take advantage of prevailing winds and naturally occurring convection currents. Because packing facilities usually have one or more large openings at ground level, the most efficient placement of fans and vents are at a high location either on the roof or near the roofline, opposite from most of the large doors. Placement of several smaller vents around the roof can help eliminate places inadequately cooled by the main ventilation scheme, thereby reducing the need to increase the total volume of air moved.

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This project supported by the Northeast Sustainable Agriculture Research and Education (SARE) program. SARE is a program of the National Institute of Food and Agriculture, U.S. Department of Agriculture. Significant efforts have been made to ensure the accuracy of the material in this report, but errors do occasionally occur, and variations in system performance are to be expected from location to location and from year to year.

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