INTRODUCTION
The largest share of energy used in fruit and vegetable production is for field operations and includes diesel fuel, nitrogen-based fertilizers, pesticides, and several other inputs. The second largest energy uses tend to be in handling, refrigeration, pumping for irrigation, and packing operations. These activities are considered “headquarters” uses. This publication focuses on ways to conserve energy and increase the efficiency of its use in these headquarters activities. Greenhouse energy conservation, as it relates to fruit and vegetable production, is discussed in the fact sheet from this series “Conserving Energy in Greenhouse Operations” (9).

REFRIGERATION ENERGY
Refrigeration typically uses the most energy in the fruit and vegetable headquarters activities. Energy conservation for refrigeration is focused on two primary activities, removing field heat and refrigerated storage, both designed to preserve the quality of perishable horticultural products:

Removing Field Heat - This process 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 for each type of fruit and vegetable product. The New Jersey Commercial Vegetable Production Recommendations (7) and your local Cooperative Extension Office can provide information on the best type of cooling system and the proper storage temperature and humidity for a particular product. Historically, cooling systems have been designed to significantly exceed the maximum requirements of packing and processing operations. Today, however, energy cost savings justify systems that are properly sized for the intended use.

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 the cooler times of the day, removing the product from the field quickly, and keeping the product shaded before placing it into coolers. Energy use during cooling also occurs 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 should minimize the amount of air that can bypass the product, thereby not coming in direct contact with the product and not removing the heat. 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.

Refrigerated Storage - After the fruit and vegetable products have been cooled to the proper holding temperature they can be placed into refrigerated storage facilities. It is very important to maintain the “cold chain” all the way to the consumer once the field heat has been removed from the fruit or vegetable product. This means that the cooled product should enter refrigerated storage upon exiting the cooler, or be transported in the shade and out of the wind to a refrigerated storage room or truck as soon as possible. Topping produce with ice is also an acceptable method of keeping the produce cool after the initial field heat is removed. Iced produce should also be held in refrigerated storage and serves to prevent the heating up of the product in the middle of the box.

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 vegetable refrigerated storage rooms are designed for high humidity; they will require a larger evaporator coil to avoid icing up, 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 be designed with little more capacity than forecast needs would require, as 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 your needs and conserve energy. The Air Conditioning, Heating, and Refrigeration Institute (AHRI)
standard 550/590-2011 (1) 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 1250-2009 (2) 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 currently there are 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 walls in coolers and R-32 for freezers, and R-28 for floor insulation in freezers (8).

Other opportunities for energy conservation in cold storage rely on the same principles as building cooling – non-airtight doors are usually the best opportunity to reduce heat exchange through air loss, and doors and other construction should be designed to exclude outside air. 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 one horsepower)
- 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 designing the room to the proper size and minimizing the number of times that the room is opened.

IRRIGATION

Much fruit and vegetable production relies on irrigation, which has related energy costs, the most significant being pumping. Electrically-driven pumps can achieve up to 80% efficiency, whereas the best diesel pumps can achieve a maximum of approximately 40% efficiency (5).

Energy for irrigation can be divided into distinct “field” and “headquarters” uses. In-field pump stations are considered a headquarters use. Various strategies can improve the energy use of headquarters irrigation equipment:

- Increasing the on-off pressure differential on pump controls (e.g. from 5 – 10 psi 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 the use of electric pumps is not feasible, such as for remote locations or in operations where the source of water changes frequently, specific guidelines apply to the use of pumps driven by internal combustion engines:

- 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.

See the fact sheet in this series “Performing an Agricultural Energy Audit” (6) for further information on conserving energy used by internal combustion engines.

Variable-Frequency Drive 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 the fruit and vegetable products need to travel. Use rotating sponges and air curtains after washing the product to remove the 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 the safety of the processing 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.

Natural gas use can be beneficial to energy requirements. With current energy commodity prices, conversion of equipment, such as water heaters and room heaters fired by LP gas, to burn either biomass or natural gas, is both a cost savings and a net savings of total energy.

All lighting should use the most efficient equipment practical. While shock-resistant incandescent bulbs remain popular for task lighting use, newer lighting fixtures which are equally shock resistant and make use of 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, accommodating differing 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 located where light is needed.

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 utilize HPS and MH lamps as an efficient choice for providing the needed light levels at working height. Fluorescent lamps work well in any fixture designed to illuminate areas within seven feet or less of the fixture.

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.

The American Society of Agricultural and Biological Engineers (ASABE) Standard EP344.3-JAN2005 (3) should be followed in installing lighting systems.

**BUILDING ENERGY**

In the fruit and vegetable handling sector, the effect of equipment and needs unique to the industry must be taken into account in building envelope design. Fruit and vegetable handling is highly reliant on mechanical cooling and other heat exchange techniques, and it is important to install cooling equipment in a properly ventilated area. Generally, it is most energy-efficient to place condensers outside the building, with the benefit to proper ventilation outweighing efficiency losses from the greater length of plumbing. Placing condensers where they will be exposed to prevailing winds can help improve efficiency.

Because the needs of many New Jersey fruit and vegetable operations require use of packing facilities almost entirely in warmer months, the design of these buildings can be optimized 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, thereby reducing the energy needed to draw air into such equipment. Such plantings can also be used to shade the building or reduce some undesirable drafts.

Handling buildings often use artificial ventilation to remove heat and dust from the building. Ventilation devices must be placed so as to best create linear air flow, that is, air flow in a straight line throughout the entire structure; as well as best take advantage of 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 to eliminate places inadequately cooled by the main ventilation scheme, thereby reducing the need to increase the total volume of air moved.

For general guidelines on operating energy-efficient agricultural buildings, see the fact sheet in this series “Conserving Energy in Building Envelope Design” (4).

Well-Ventilated Condensers with Pipe Insulation
PHOTO: Z. HELSEL, NJ AGRICULTURAL EXPERIMENT STATION

REFERENCES


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