Solar Energy Applications for Small Farms and Home Gardens

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The University of Florida Institute of Food and Agricultural Sciences, Extension Orange County, maintains a 3-acre demonstration area called the “Exploration Gardens,” containing seven themed horticultural gardens. Among these is a quarter acre Small Farm and Home Demonstration Garden. Vegetable growing techniques for both commercial and home applications are on display including raised beds, grow boxes, floating raft, vertical stacked, and nutrient flow technique (NFT) hydroponic systems, as well as square foot and container gardens. The vertical and NFT hydroponic systems require electricity to provide daily fertigation. The nearest electrical box is 700 feet away, so it was decided to add solar electric panels to power the recirculating pumps. The vertical stacked (Verti-Gro® and Hydro-Stacker™) systems receive intermittent fertigation requiring an alternating current (AC) timer, charge controller, inverter and battery. The recirculating NFT systems use direct current (DC) power with the solar panels connected to a DC marine bilge pump with only a small charge controller in between. The NFT system operates continuously during sunlight hours. These systems will be described in detail. One NFT system was placed over an aquaculture tank in an onsite greenhouse and is receiving water and supplemental nutrients from the fish tank. Results of heirloom tomato and mini-cucumber variety trials in the greenhouse NFT aquaponic system will be discussed. Solar power offers opportunities for growers to produce hydroponic vegetables “off the grid,” with easily applied setup and maintenance techniques and provides Extension Agents a resource for teaching renewable energy applications.

The agricultural extension service of the United States is reported to be the world’s most successful change agency (Rogers 2003). Classroom education can only go so far in increasing knowledge and understanding of plant science concepts. Demonstrations are a way to motivate farmers and gardeners to try out new innovations by showing how the new method works in practice (Van Den Ban and Hawkins, 1996). Demonstrations must be well integrated into Extension education programs to be successful. Hands on demonstrations of new innovations completes the picture, increasing understanding and retention of classroom concepts.

Small Farm and Home Demonstration Garden

The University of Florida/Institute of Food and Agricultural Sciences, Extension Orange County, Orlando, maintains a 3-acre demonstration area called the ‘Exploration Gardens’, containing seven themed horticultural gardens including a quarter acre devoted to the Small Farm and Home Demonstration Garden. This area demonstrates traditional in-ground and alternative vegetable growing practices including raised bed/square foot gardens, container gardens, self-watering containers, and floating hydroponic gardens.

The demonstration garden received donations of two vertical hydroponic systems (Hydro-Stacker™ LLC, 7308 Verna Bethany Road, Myakka City, FL 34251; and Verti-Gro®, Inc., 15000 S.E. U.S. Hwy. 441/27, Summerfield, FL 34491.) in 2013. These systems grow many vegetables in a small foot print. They are ideally suited to be included as a demonstration because of their small size and high production capacity providing an alternative method of growing vegetables for small farm and home gardeners that have poor soil and/or limited space for growing their own food.

The 3–5 stacked pots that make up the vertical hydroponic systems are provided a water/nutrient solution from a reservoir tank several times a day for a few minutes at a time. These growing systems require electrical power for the irrigation timer and pump that moves the water/nutrient solution from the reservoir to the vertically mounted containers. This Demonstration Garden is located about 700 feet from the nearest electrical power panel. To provide electrical power from the commercial source would require a very long and hazardous extension cord or a very costly installation of underground cable and associated breakers and electrical outlets. A third option was considered as this is a relatively low power requirement—electrical energy from the sun.

Photovoltaic (PV) Alternating Current (AC) System. Photovoltaic systems have been providing water pumping solutions to remote farm sites for several decades (Helikson, H.J., et al 1991). These systems are relatively passive in that they power the pump for water when the sun is shining. They are relatively inexpensive and very reliable. The situation in the Demonstration Garden is a little more complex in that the water/nutrient solution must be provided to the plants on a regular intermittent schedule whether the sun is shining or not.

In the early 1950s, Bell Laboratories developed the photovoltaic (PV) cell about the time they invented the transistor. Their solution was to take two layers of highly purified silicon and “dope” them with phosphorous or boron so each layer would contain an excess or deficiency of free electrons or free holes. When bombarded by high speed particles of sunlight (photons), some electrons
were “knocked loose” to create a voltage difference between the two layers. The voltage difference in a silicon cell is > 0.5 volts. However, when several cells are connected together in a module and then several modules are connected into a solar panel, one can obtain sufficient energy for useful purposes. The PV cells are electron pumps and do not store electrical energy for future use.

To store energy in a PV system, deep-cycle batteries are used. In a small application such as the one at the Demonstration Garden an “RV” or “Marine” deep-cycle battery works very well and should provide good service for 2–3 years. To ensure adequate service, the battery is usually sized for the system to provide 3–4 days of energy should there be that many days of inclement weather that would prevent the sun from shining on the solar panel.

Since PV cells are electron pumps, they may overcharge and damage the battery if connected directly to it. There are devices called “charge controllers” that protect batteries from overcharging and prevents discharging the batteries from reverse current passing through the PV cell at night. The current from the battery is not in a form that can be used by the irrigation timer and the water/nutrient reservoir pump. A device called an “inverter” converts the direct current (DC) from the battery to alternating current (AC) that is useful to the timer and pump. There are different types of inverters. The best ones to consider for this application are called “true sine wave” inverters. They are a little more expensive but provide the most stable form of AC for the timer and pump. The system schematic is illustrated in Fig. 1.

The largest expense for the PV system in an open site like the Demonstration Garden may be the environmental enclosure or garden shed (Fig. 2A). It must be sturdy enough to keep rain away from the battery, charge controller and inverter as well as the associated wiring and circuit breakers to provide over current protection of the PV system (Fig. 2B). The enclosure must also provide sufficient ventilation for hydrogen gas—a byproduct from the battery—to escape. All circuits within the PV system should be connected to a good earth ground such as an 8-foot copper clad rod driven into the ground next to the environmental enclosure.

**PV Pitfalls.** If this is the first venture into PV system construction and installation, a very good understanding of electricity and electrical components is a must. Otherwise, consult with someone who is knowledgeable. There are several types of solar charge controllers but only the MPPT (Maximum Power Point Tracking) type adjusts the system voltage and current from the PV panel as close as possible to the maximum power point to get the most available energy from the sun. Inverters also come in many forms. The choice should be to use an inverter with a true sine wave output because the vast majority of electric plug in products and appliances work well with commercial utility power which is a true sine wave. Batteries are probably the weakest link. RV or Marine Deep-Cycle batteries are a good choice for a limited duration project. True deep-cycle batteries such as absorbed glass mat (AGM) batteries, are specifically designed for energy storage and deep-cycle service. They tend to have larger and thicker plates and are ideal for renewable energy systems. AGM battery cells can hold roughly 1.5 times the amp hour capacity of a similar size RV or Marine Deep-Cycle battery due to their higher power density. The low internal resistance allows AGM batteries to be charged and discharged much faster than other types. AGM batteries function well in colder temperatures and are highly resistant to vibration.

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Fig. 1. Schematic of solar energy parts and pathways for PV Alternating Current (AC) System.
**PV Direct Current (DC) System.** A solar powered nutrient flow technique (NFT) hydroponic system was also setup in the Demonstration Garden as part of a statewide Extension Enhancement grant in 2010. The system components are light enough to be portable and have been moved to various small farm conferences as a demonstration (Fig. 3A). The system consists of sloped aluminum roofing panels with the low end able to drain into a reservoir tank. A DC marine bilge pump in the nutrient tank is directly connected to a solar panel and pumps a nutrient solution through a hose to the high end of the panel where it gravity feeds back to the tank. A small charge resistor should be spliced in-line to the positive (red) wire to moderate electron flow during peak sunlight hours to avoid damaging the pump if the voltage and current operating range of the solar panel is higher than the pump specifications. If the pump and panel are within similar operating ranges no resistor is required. The system runs continuously when the sun shines on the solar panel and shuts off during cloudy days or at night. This system does not use a battery and relies on direct current from the PV panel, not alternating current.

After several successful seasons of outdoor use, the solar NFT system was brought into a greenhouse at the Demonstration Garden and mounted on top of a 1200-gal (6 x 12 x 2.5 ft) aquaculture tank producing tilapia and koi fish (Fig. 3B). Ongoing variety trials have been conducted using this aquaponic system (Tyson et al., 2012). The NFT system is solar powered while the aquaculture system continues to use local electric grid power to run recirculating and air pumps 24 hours per day.

**Aquaponic Trial Methods.** The most current replicated vegetable variety trials from this aquaponic system consist of 1) three mini-cucumber greenhouse varieties and 2) six heirloom tomato varieties. Each were arranged in the NFT aquaponic system in a completely randomized block design with four replications. Cucumber plants in trial 1 were transplanted into rockwool blocks and placed into the NFT roofing panels on 9 Aug. 2012. Harvesting occurred from 18 Sept. thru 24 Oct. 2012. Tomato plants in trial 2 were transplanted into rockwool cubes and placed into the NFT panels on 16 Nov. 2012. Harvesting occurred from 4 Feb. 2013 through 24 May 2013. Plants in both trials were trellised and
pruned to a single stem. Additional fertilizer was added as needed based on visual observations and soluble salt concentrations to the rockwool cubes and to the aquaculture tank to supplement the nutrients in the fish effluent which was pumped past the plant roots. Total dissolved solids in the aquaculture tank water were maintained between 500–800 ppm and pH between 7.0–8.0.

Cull fruit in the cucumber trial were removed from the plants early as they appeared and so were not included in the yield results (Table 1). The variety ‘Manar’ was the highest yielding cucumber variety followed by ‘Jawell’ and then ‘Decaster’. Most cull fruit were allowed to develop in the heirloom tomato trial since no clear marketable standards exist for heirloom tomatoes and their shapes, sizes at maturity, and color vary considerably. The highest marketable yields occurred with ‘Japanese black’, ‘Cherokee purple’, and ‘Moskvich’ (Table 2). Yields of all heirloom varieties could be improved by harvesting at the breaker to pink stage since softness and stem end shoulder splitting increased at maturity.

### Summary

The solar energy setup and applications described for providing electricity to small hydroponic reservoir pumps could be used for other applications on small farms and gardens by gearing up as needed for the power requirements with more solar panels and batteries. Power needs requiring 24-hour operation will use the PV system with a battery and charge controller to power direct current (DC) devices such as the marine bilge pump. The addition of an inverter will provide alternating current (AC) for powering devices that need house current to run. Daylight power needed to power only DC devices can use the less expensive and simpler PV system providing DC directly from the solar panels with the understanding that there will be days when overcast conditions will result in no power generation from this system. Now we are producing vegetables “Off the Grid” since electrical power from the local utility is too far away to feasibly connect to. Solar PV systems provide opportunities for growers and home gardeners to access electricity with easily applied setup and maintenance techniques and provides Extension Agents a resource for teaching a renewable energy application.

### Literature Cited


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Table 1. Aquaponic cucumber variety trial.

<table>
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Table 2. Heirloom tomato variety trial using aquaponic production.