PORTABLE SOLAR POWER FOR A HIGH TUNNEL HOOPHOUSE:
POWERING HYDROPONICS, IRRIGATION, AND COMMUNITY GARDENING

INTRODUCTION

High tunnels are season-extension structures that can be installed where they are needed for food production. They protect specialty crops from the elements for much of the year and, in the summer, the sides can be rolled up. High tunnels freeze during cold winters, but crop plans are designed with this in mind. Sometime cold tolerant crops are used or the hoophouse is not used in winter. High tunnels are highly flexible. They are placed where space and terrain allow although sometimes in sites where electricity and water may not be available. Using renewable energy is a key part of sustainable food systems and can be used to power hoophouses.

At Appalachian State University, students from the Department of Sustainable Development (SD) devised a portable solar charger to provide electricity and operate hydroponics and other systems in a high tunnel hoophouse in the SD Civic Garden, a garden on campus.

Sustainable Development graduate Kiernan Presler-Marshall ('23) built a portable solar charger with a 200-watt panel in 2022. Presler-Marshall created the solar charger in his shop and transported it to the garden for installation. Graduate Nelson Gonzalez Jr ('23) modified the hydroponic system for seasonal (summer) production and installed a separate irrigation system for the hoophouse.

Design Goals for the solar charger and hydroponic system

- Mobile, weatherproof & sturdy solar power unit capable of powering a small water pump indefinitely
- Use as few new parts as possible
- Portable charger; with wheels if possible
- Space-flexible
- Create an affordable and functional hydroponic system
- Adaptable to an unheated space

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FIGURE (2) LAYOUT OF MAJOR COMPONENTS OF PORTABLE SOLAR SYSTEM.
SEE FIGURE (6) FOR DIAGRAM OF ENTIRE SOLAR SYSTEM.

Cost Breakdown

- 200 watt panel: donated
- Solar controller: $40
- Batteries $90
- DC-DC converter $20
- Assorted wire and connectors $30
- Low Voltage cutoff: $10
- Cart wheels $65
- Tote to protect outdoor equipment (Craftsman 20 gallon) $20
- Inverter DC to AC $69
- General hydroponic growing chambers 8 ft long (3; donated)
- Pump (Submersible EcoPlus ECO-264): donated
- Net Cups: $22
- Tubing for water pump $12
- Water reservoir food-safe 27-gallon $12
- Water pressure booster pump $69

Total $459 + donated parts

Technical Details

Solar charger

- Power Storage: 24 × 8ah sealed lead acid batteries (200ah rated capacity)
- System Voltage: 24v battery system, step-down to 12v
- Solar Controller: EPever 50A MPPT Controller
- Safety Features: Waterproof containment unit, wind load bracing, fully fused and protected electrical system, low voltage cutoff to protect batteries.
- Inverter DC to AC: 24VDC input 120VAC

Hydroponic system

- ECO Plus Pump: ECO-264 Model - 290 Gallons/Hour
- Water Capacity: ~50 gallons including reservoir

Irrigation system

- Water pressure booster pump 70 PSI 110VAC

FIGURE (3) AUTOMATED HYDROPONIC SYSTEM BUILT WITH PVC PIPES, RESERVOIR, AND PUMP.
FIGURE (4) HOOP HOUSE DURING GROWING SEASON. CROPS GROWN INCLUDE PEPPERS, KALE, AND TOMOATOES.

MATERIAL SOURCING

Materials were salvaged or reused whenever possible. The metal for the construction of the solar unit and support for the runs for the hydroponic system were all salvaged. The batteries are repurposed from retired UPS systems, purchased from Nathan's Battery in Wilkesboro, NC. The solar controller was purchased used, as the previous owner upgraded to a newer model. The solar panel was donated. A few of the materials had to be purchased new.

IRRIGATION SYSTEM

The solar unit also powers an automatic irrigation system. There is no piped water supply in the hoophouse; however, students periodically fill a 50-gallon barrel with a garden hose. Gonzalez connected the barrel to soaker hoses in the raised beds and an overhead water line for hanging plants. He installed an electric water pressure booster pump. A battery timer is used to water automatically once per day. During the winter, the irrigation is closed down and plants are watered by hand as needed from the barrel.

HIGH TUNNEL LAYOUT

The high tunnel is 10 ft wide and 16 ft long.The hoophouse was designed by Jim Dees with the Office of Sustainability and built by Dees and students in 2020. Its base is built into the side of a hill. The uphill side is a rock wall (dry stack) and the downhill side is a wood frame half wall. After construction, Nelson Gonzalez Jr and students designed and led the installation of two raised beds that run lengthwise and are two feet wide, with a one-foot walkway between them. On the uphill side, Presler-Marshall placed the hydroponic system at waist height above the rock wall to make good use of the space.

LEARNING OUTCOMES

Presler-Marshall commented: "**The solar unit, while utilizing skills I've had a chance to work with previously, gave me a good opportunity to practice forming a complete design around a limited number of set components; namely the solar panel, the tote used for components, and the wheels I had on hand.**"

FIGURE (5) - SOLAR SYSTEMS ARE ALSO BENEFICIAL IN TROPICAL AGRICULTURE SETTINGS, PROVIDING A SUSTAINABLE POWER SOURCE FOR ELECTRONIC DEVICES USED IN MONITORING CROPS, MANAGING IRRIGATION SYSTEMS, AND COLLECTING DATA FOR PRECISION FARMING.

APPLICATION

This largely student-built and -designed system is used for community gardening. Students and volunteers start seeds in a separate greenhouse (active solar thermal, Ferrell J. C.) in late winter. In late spring, workers transplant seedlings into the raised beds in the high tunnel. Through succession planting of spring, summer, and fall crops, crops are grown most of the year, except for December, January, and February. Organic production methods are followed for crops, including soil fertility, pest and disease control. The Frontline to Farm program, a training program for military veterans and other beginning farmers based at App State, has also adopted the renewable energy hoophouse and hydroponic system as a model for the future Victory Garden.

CONCLUSION AND FUTURE PLANS

The solar charger, hydroponics, and irrigation system demonstrate that low-cost, off-the-grid technology is possible in high tunnels and useful in areas with cold winters to extend the season.

Monitoring of environmental conditions in the hoophouse is needed.

When the plastic cover for the hoophouse is replaced, we plan to install a double layer of plastic.

We intend to supply natural nutrients to plants in the hydroponic system (i.e. effluent from biogas production).

High-tunnel hoophouses are generally more accessible to small farmers than expensive greenhouses, and they are highly flexible for local food production.

CITATIONS AND NOTES

Presler-Marshall, Kier 2022. Appalachian State University Energy Summit Boone, NC, poster session

Ferrell, J. C. and A.C. Fanatico. 2018. Urban Farm-to-Table Development and Technologies for Research, Education, and Community Engagement. Innovation Scholar Grant Proposal, Appalachian State University, Boone, NC

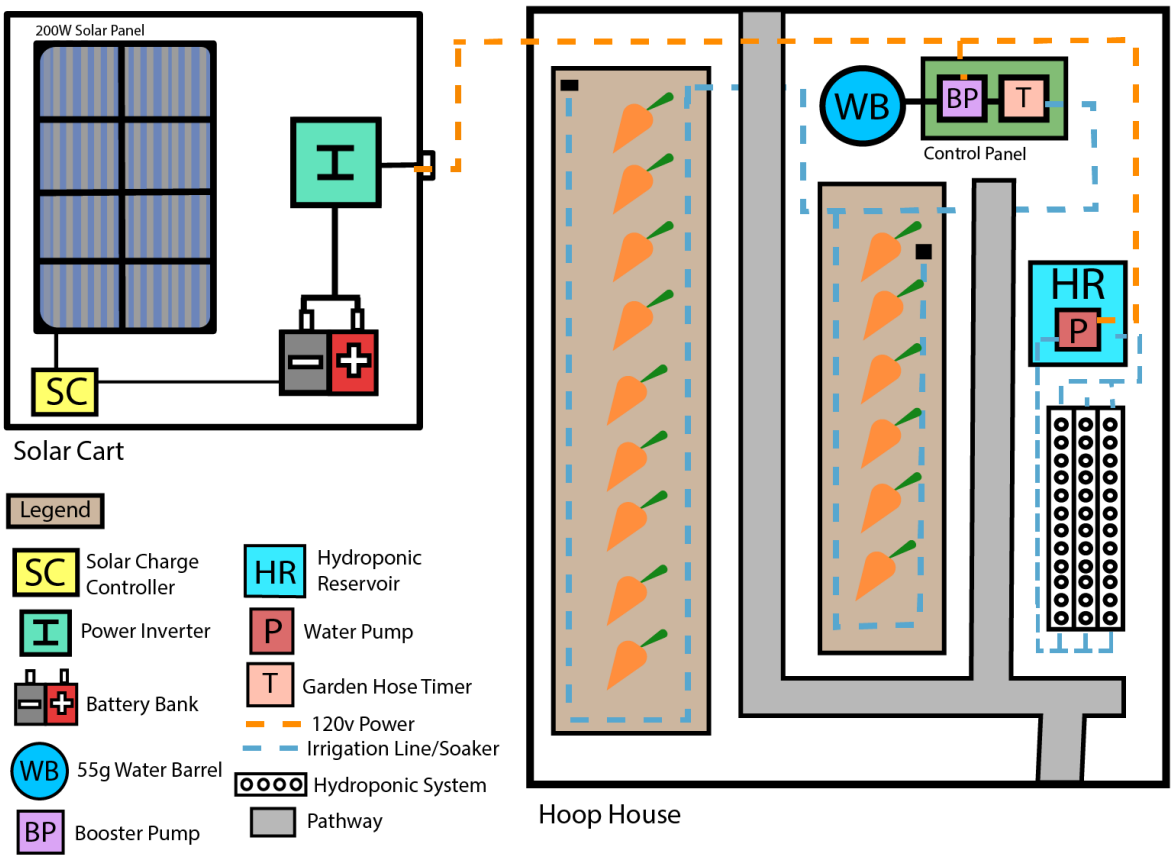

Figure (6) - Diagram of solar system, automatic drip-irrigation, and hydroponic system.

Figure (7) - Sustainable Development students (left to right) Kiernan and Nelson working on the solar panel system.