Date: June 30th, 2022

Summary

Jack's Solar Garden is the largest commercial research site for agrivoltaics in the United States in large part thanks to the Colorado Water Conservation Board (CWCB). Jack's Solar Garden is a 1.2 MW single-axis tracking solar array that is privately held and owned by Kurt and Byron Kominek on their family's farm in Boulder County, Colorado. Electricity from Jack's Solar Garden is sold to more than 50 residents, 5 companies, and 2 local governments. Jack's Solar Garden leases land beneath its 4 acres of solar panels for free to researchers from the National Renewable Energy Laboratory (NREL), Colorado State University (CSU), and the University of Arizona (UoA). Jack's Solar Garden's largest lease is to Sprout City Farms that cultivates crops underneath our solar panels in order to maximize the utility of our space and provide local food back into our community. The grant funding provided by the CWCB enabled Sprout City Farms, the UoA, and Byron Kominek's cooperative space with WishGarden Herbs to successfully cultivate a variety of crops underneath our solar panels initially during the 2021 season and now in the 2022 season.

Our idea for Jack's Solar Garden is to showcase how the solar industry can incorporate various agricultural practices within a solar array to keep the land beneath their solar panels functional and productive. This practice of agrivoltaics – agriculture occurring underneath and within solar energy infrastructure – is not a new idea, but is relatively new in the United States. Researchers from around the country, and large parts of Europe, had only been studying crop growth under solar arrays that were 10-30kW in size. At 1.2 MW, the Kominek family allows for researchers to test a variety of ideas and learn about the microclimates underneath a scaled-up solar array as a means of giving back to our community and helping to usher in a new method of solar array development.

Benefits of agrivoltaics include: reduced heat stress on crops and animals, reduced evaporation from soils due to shading, a likely reduction in irrigation needed for crops due to shading, an extension of the growing season for particular crops, protection for crops from damaging winds and hail, and potentially an increase in electrical production due to a cooling effect vegetation beneath the panels can have on the solar array infrastructure. All these benefits are being researched at Jack's Solar Garden so that the public institutions with which we work can funnel this information back into society.

The agrivoltaics research project as laid out for the CWCB included 4 tasks: 1) the construction and energization of Jack's Solar Garden undertaken by the Kominek family, which was completed in November 2020; 2) the procurement and installation of the irrigation system at Jack's Solar Garden, for which CWCB was requested to provide funds to build that was namely completed by September 2021 and further work continued through mid-June 2022; 3) the planting, management, and harvesting of crops at Jack's Solar Garden conducted by Sprout City Farms that occurred in 2021 and continues in 2022; and 4) the monitoring and analysis of water savings from agrivoltaics by research partners at NREL, CSU, and UoA that began in 2021 and continues through 2022. Tasks #1 and #2 have been completed while #3 and #4 are on-going.

Project Report by Task

Task #1:

Jack's Solar Garden was built in 2020 by Namaste Solar, who was contracted by Jack's Solar Garden, LLC to complete the work. Namaste was able to energize the 1.2 MW solar array on November 1st, 2020. Namaste is under contract to provide operations and maintenance support to keep the Jack's Solar Garden functional enabling the Kominek family to earn revenue while leasing the land beneath our solar panels for free to the nonprofit / academic organizations learning about agrivoltaics on our land. Byron Kominek, co-owner of Jack's Solar Garden, conducts on-going simple maintenance of the solar array to keep O&M costs down. As of the end of June 2022, Jack's Solar Garden has been producing electricity for 20 months.

The main challenges during the operation of Jack's Solar Garden occurred from June to August 2021 when the solar array went offline for two weeks due to a mechanical malfunction in the main switch gear, and, once repaired, our inverters shutdown every afternoon for two months losing ~$20k in revenues. The voltage tolerances of the inverters were set too narrow causing afternoon outages as neighbors in our area switched on air conditioners in the hot afternoons. This voltage tolerance issue was finally remedied after Xcel Energy better understood the problem and relayed that to our O&M team and on to the inverter manufacturer who remotely adjusted our inverters' voltage tolerances. Other on-going challenges include soiling of our solar panels from agricultural operations underneath our panels as well as that of conventional agricultural practices on lands to our west.

Task #2:

CWCB grant funding was used to hire Loveland Environmental Resource Development Corps (LERDC) to design, plan for, permit, procure, and install a drip irrigation system as well as build a retention pond to store Colorado-Big Thompson water. LERDC was contracted in April/May 2021 to undertake this work. Between May and July 2021, LERDC procured and installed a drip irrigation system beneath our solar panels that includes 17 valves creating 17 zones of irrigation, over 1,000 ft of lay flat pipe, miles of drip tape, a three-chamber filtration system, and a 3HP submersible variable frequency drive pump. From July to September, LERDC planned out, excavated, and built a retention pond capable of holding 108,000 gallons of water. Due to the delay in building the retention pond, a temporary connection was built out to connect to a fire hydrant on the Jack's Solar Garden property to deliver water to the irrigation system to get the 2021 growing season going.

Challenges with the irrigation were numerous from the improper sizing of valves, starting off at 1.5" and being reduced down to 1", to labor difficulties that delayed the earthworks around the retention pond, to the retention pond not sufficiently holding water during the initial season, to the pressure reduction from the fire hydrant being difficult to maintain without causing damage to the irrigation system. These challenges were in 2021. To remedy the valve sizes, 1" valves were procured and installed in 2022. To investigate the challenges with retention pond, LERDC was hired to conduct tests on the clay with different spray foams meant to increase water retention time of the clay during the winter 2021/2022. The investigation concluded that spray-on foam would not aid in retaining water meaning a pond liner or application of bentonite is needed for long-term water holding.

At the beginning of the 2022 season, the Boulder and Lefthand Irrigation Company that supplies ditch water to Jack's Solar Garden was taken off priority in April/May due to a lack of water / drought. This meant that leasing C-BT water from the City of Boulder, or the St Vrain Water Conservancy District, would be delayed and that water would not be flowing in the spring to help us irrigate our crops. In order to remedy this, we devised a plan to install a more permanent connection to our local fire hydrant to supply more regular water and a reduced pressure. LERDC was to be contracted to install this system, however, in April, LERDC ended its relationship with Jack's Solar Garden. This event put all plans for making changes to the irrigation system into question. Other irrigation professionals were contacted, however, due to it being the spring, all other potential contractors were fully employed. In early May, LERDC was hired briefly by our research partners to restart our irrigation system using water from the Kominek home on-site to kickstart Sprout City Farms' ability to grow leafy greens under the solar panels. LERDC was being contracted to continue supporting irrigation needs, but abruptly ended relationships again in mid-May. From April through May, Byron Kominek spent significant time finding, contracting, and consulting with the company, WilWater. Byron also undertook the repair, maintenance, and sudden winterization and re-starting of the irrigation system in May and June of 2022. WilWater was contracted at the end of May and in early June to procure and create a more permanent and safer interconnection between the installed drip irrigation system and the local fire hydrant. With the hydrant connected by June 10th, Sprout City Farms and the UoA research team were able to continue their research project for the season. To avert future delays in repairing the irrigation system, Jack's Solar Garden procured spare 3" lay flat pipe and fittings to have on hand for future eventualities.

Task #3:

In 2021, Sprout City Farms hired a full-time farm manager and a part-time farm assistant for the 2021 growing season. This farm labor worked with Byron Kominek to prepare almost 3 acres of land beneath the solar array for crop production. Byron spent over 40 hrs ripping and tilling the former hay field in order for the farm manager to create 3ft wide beds within the solar array. The farm labor laid out miles of drip tape within the solar array and planted (as of July 1st 2021) on about an acre of land of about 25 different market garden crops with multiple varieties of each, including: beans, squash, radishes, turnips, arugula, lettuce, tomatoes, garlic, kale, eggplant, carrots, peppers, etc. From July 1st to the middle of October, they grew over 8,000 lbs of food on that acre of land. The farm labor learned about the benefits of the solar panels providing them shade in the morning and later afternoon while they worked. They saw a longer soil moisture retention because of the solar panels' partial shade. They showcased how squash prefer being outside of the solar array than underneath the panels and that squash at the morning drip edge became diseased and pest ridden. They saw how the leafy greens within the solar array grew extremely well and did not bolt as early as leafy greens grown outside of the solar array helping to extend their growing season.

In 2022, Sprout City Farms had challenges with farm labor losing both employees from the previous year due to burnout. Sprout City Farms decided to scale back efforts to regroup for 2023 and, with funds from the UoA, hired one farm manager without an assistant to specifically cultivate leafy greens and select crops for the UoA to study underneath the solar panels. More than 400 linear feet by 9ft wide of leafy greens were planted in mid-May. Once the new fire hydrant connection was made in early June, more crops specifically for the use by researchers from the UoA were planted including varieties of: beans, tomatoes, potatoes, radishes, beets, peppers, etc. The 2022 season has just begun and more full results of this season will be available by the early winter.

Task #4:

Researchers from NREL, CSU, and UoA have been at Jack's Solar Garden since 2020, after the completion of the solar array construction, taking measurements to better understand the microclimates created by our single-axis tracking system.

CSU teams are studying the ecosystem services provided by the shade of the solar panels by 1) learning more about CO2 emissions from the soils, 2) measuring soil moisture retention in grasslands, 3) studying water stress, photosynthesis efficiency, and thermal stress on grasses, and 4) cutting grasses to study biomass production underneath the solar panels. The main information available to date is how the soil moisture retention changes from underneath the solar panels to in between the rows of panels – where soil moisture is highest at the drip edges of the solar panels while lowest directly underneath the middle of the solar panels.

NREL prepared land beneath our panels to monitor wildflower and pasture grass growth. Both of these research projects are still underway.

The UoA studied five crops growing underneath the solar panels in the 2021 season but had inconclusive information due to the small amounts of crops that they had access to studying, including difficulties with on-site staffing and monitoring equipment. Now, in 2022, UoA hired a more full-time research assistant, along with Sprout City Farms farm manager, to monitor plant growth in a more rigorously designed research project. UoA is studying how various crops as listed in Task #3 will grow at different spacings underneath the solar panels and applying half as much irrigation to half the number of crops to see how much irrigation is truly needed to cultivate crops in our soils.

Challenges for the researchers have been access to water, labor, and the slowness in donor organizations providing funds to purchase research equipment in the 2021 season. All of the challenges the researchers were experiencing in 2021 have largely been addressed now in the 2022 season and will be less and less challenging in coming years.

Matching Funds Committed

This is a confirmation that matching funds were provided by our various partners.

Jack's Solar Garden not only committed $1.7 million in the construction of our 1.2 MW solar array, but an additional $300k in development expenses during the planning and startup of the project. On-going costs include more than $50k in annual operations costs. Jack's Solar Garden also covers on-going electricity needs for collaborators as well as the provision of drinking water.

Sprout City Farms did hire a full-time farm manager and a part-time assistant farm manager for the 2021 season though they did not hire part-time apprentices. Throughout the 2021 season, they purchased farm equipment, built a cool-bot and wash station, compost, plant seed and starts, and incurred costs for delivering food to the OUR Center in Longmont (a local food distribution nonprofit). In 2022, Sprout City Farms has incurred costs of cover crop seeds, labor for cover cropping, and plant starts and seeds. UoA is covering the cost of the farm manager for this season. Sprout City Farms has incurred close to $100k in costs over the past two seasons.

Researchers from NREL have spent approximately $35k on measurement devices, the purchase of wildflower seed and pasture grass seed, the payment for the use of fire hydrant water, and the hiring of

interns to support research activities at Jack's Solar Garden. These funds were provided by the International Irrigation Consortium based at CSU.

The UoA received $75k in National Science Foundation funding and has since received further funding from the US Department of Agriculture to procure microclimate monitoring equipment as well as funding the salaries of their on-site research assistant and the 2022 farm manager for Sprout City Farms.

CSU has spent over $90k on graduate student salaries and equipment to study microclimates and ecosystem services at Jack's Solar Garden and have received further funding to continue studying agrivoltaics at soon-to-be built sites in Fort Collins.

Conclusion

Jack's Solar Garden has become an inspiration for agrivoltaics not just in the USA but around the world. In May of 2022, the Department of Energy released an RFP worth $8 million for 4-6 projects to be funded to essentially replicate the work being done at Jack's Solar Garden. Photos of Jack's Solar Garden were used in the RFP and they are looking for projects of our same size to grow vegetables as we are. Jack's Solar Garden helped inspire successful legislation in 2021 in Colorado to support research into agrivoltaics to the tune of $150k while proposed legislation in 2022 that would have provided funding for an agrivoltaic project in the San Luis Valley failed in the House this past May. Byron Kominek and collaborators at Jack's Solar Garden are sought out to be speakers to help influence policy in other states, e.g., New Jersey, New York, New Mexico, Arizona, to support agrivoltaics. Collaborators at Jack's Solar Garden have attended the 2022 World Agrivoltaics Conference in Italy to share information about our work. All this is owed in part to the CWCB being willing to support the rollout of our drip irrigation system to showcase how crops can be grown at scale within a 1.2 MW solar array.