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Solar Plus: Improving Performance in Distributed Clean Energy Systems

Peter Alstone

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Features

In Every Issue

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HUMBOLDT STATE UNIVERSITY

This fall, we are kicking off a new "Solar Plus" (Solar+) project to investigate how real-time coordination between clean energy systems can yield performance improvements that benefit both building owners and utility operations. Research and development over the past decade has successfully reduced the cost of solar arrays, batteries, building controls, and electric vehicles. Many of the emerging challenges we now face are related to the large-scale deployment and integration of distributed clean energy components. For example, electrical distribution circuit capacity is limited (in order to prevent power lines from overheating), which in turn limits the downline capacity of distributed generation systems. This Solar+ project will develop control strategies to coordinate onsite resources to reduce their combined footprint on the power system, effectively increasing the capacity of the grid to host clean energy technology.

Our pilot site is a gas station and convenience store at the Blue Lake Rancheria (BLR) in Blue Lake, California. Convenience stores typically have sizable loads, including HVAC and refrigeration, which require backup power. Many of the sites also have significant potential to host rooftop solar. By working with a very common building type (there are 12,000 convenience stores in California alone), we can design with replication in mind.

Over the next two and a half years we will design and install a Solar+ system at the BLR and measure the value of distributed energy coordination. Our project will develop: (1) a hardware design guide for integrated Solar+ packages, (2) open-source software for controlling the technology, and (3) guidelines to determine the best locations for investment, given local insolation and onsite potential for system coordination. Our outcomes will be focused on integrating solar, batteries, and advanced building controls into packages that are market ready and can make positive impacts on the future trajectory of California's built environment.

This project is funded by the California Energy Commission through the Electric Program Investment Charge (EPIC) program. Our key partners are the Blue Lake Rancheria, which owns the gas station, and Lawrence Berkeley National Lab, where a team of researchers is developing open-source "Solar+ Optimizer" software.

Project partners also include Southern California Edison, whose refrigeration system test center data is helping us to develop algorithms, and Pacific Gas & Electric, the local energy utility.

The Blue Lake Rancheria gas station and convenience store

A Message from the Director Arne Jacobson

The past year has been a very productive one for the Schatz Center, and I am grateful for all the good work that our team and partners have done to turn opportunities into successes.

I want to give special acknowledgement to everyone involved in the development and implementation of the Blue Lake Rancheria (BLR) Low-Carbon Community Scale Microgrid. The BLR microgrid project was funded by the California Energy Commission (CEC), with project leadership by the Schatz Center's Dr. Peter Lehman (Principal Investigator), Dave Carter (Project Manager), and Jim Zoellick (Co-Project Manager), in collaboration with the Blue Lake Rancheria's Tribal Government and many technical partners.

This microgrid project is now a finalist for two award competitions: the 2017 Platts Global Energy Awards and the Pennwell Projects of the Year Awards. For the Platts awards, the BLR microgrid is one of six finalists for the Commercial Application of the Year; winners will be announced in New York City on December 7. For the Pennwell awards, the microgrid is one of three finalists for Best Renewable Project; winners will be announced in Las Vegas on December 5. In addition, the Blue Lake Rancheria recently received the John D. Solomon Whole Community Preparedness award from the Federal Emergency Management Agency (FEMA), for which the microgrid was a contributing factor leading to the award. I congratulate the Rancheria, our team, and our partners for all their success so far, and my fingers are crossed for even more good news in December.

I would also like to discuss three key investments that we have been making to lay the foundation for future contributions to clean energy research and development. First, our success at the Schatz Center depends on the efforts and expertise of our faculty and professional staff. We have a talented and experienced team, and, over the past year, we have been fortunate to attract several key new members. On this front, I am pleased to announce that Dr. Nick Lam will be joining us soon as a Schatz Center Research Scientist. Nick specializes in energy access, indoor air quality, and environmental health, and he will play a leading role on our off-grid energy access team. He has a Ph.D. in Environmental Health Sciences from U.C. Berkeley, and he is currently working as a post-doctoral research scholar at the University of Illinois at Urbana-Champaign. We are excited to welcome Nick to the Schatz Center.

In addition, we hired Maia Cheli this past March for a newly created position that includes media relations and coordination of the Schatz Center's educational programs. Since joining, she has led an effort to revamp our website and expand our portfolio of public relations materials. Early next year, after the new website has gone live, she will turn some of her attention to development and implementation of our Center's education and outreach activities. We are very happy to have Maia on our team, and we have already benefited greatly from her expertise and hard work.

Among faculty associated with the Center, Dr. Liza Boyle and Dr. Peter Alstone joined us in August 2016, and both are already making substantive contributions. Liza has engaged in proposal development and in research related to the effect of particulate deposition on solar arrays, including work with an engineering undergraduate student, Merissa Coello, that will lead to a journal publication. Peter has been involved in research on innovative new strategies for management of California's electric grid. Peter is also the team lead for a new $1.5 million project funded by the CEC through their Solar+ program. Dr. Kevin Fingerman, who joined us in 2013, is the lead for a new $1 million CEC-funded project that involves developing tools for assessing the environmental impacts and benefits of biomass power plants in California. We are also very happy to welcome Dr. Sintana Vergara, who joined the Environmental Resources Engineering Department as an Assistant Professor this August and is already working with the Schatz Center team on a proposal for research involving measurement of methane emissions from biomass energy operations. As Director, it is exciting to see the growing contributions of new members as they work together with our existing team.

Second, we continue to expand opportunities for students at the Schatz Center. Since last fall, we have had 13 students working in paid positions and seven students supporting our efforts as volunteer docents. I would like to give a special welcome to students who have joined in the past few months, including undergraduates Bryce Baker, Jo Caminiti, Merissa Coello, Benjamin Kees Goldberg, Matilda Kerwin, Michael Malone, Murielle Manka, Eli Wallach, and Richard Williams, and graduate students Max Blasdel, Thalia Quinn, and Anamika Singh. Thalia and Anamika deserve special mention, as they are this year's recipients of the Schatz Energy Fellowship and the Blue Lake Rancheria Fellowship for Clean Energy Studies, respectively.

I am pleased to announce that Andrea and Don Tuttle of Arcata are establishing the Donald and Andrea Tuttle Fellowship for Clean Energy Studies. This fellowship will provide $15,000 in funding to one incoming graduate student per year in the Energy Technology and Policy (ETaP) or Environmental Resources Engineering (ERE) options of the Environmental Systems Graduate Program. The fellowship is for one year with the potential to renew for a second

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California Biopower Impact Project: Creating a Life Cycle Assessment for Bioenergy Systems in California

Kevin Fingerman

We recently began the California Biopower Impact (CBI) Project, which will investigate the effects associated with utilization of forest-derived woody biomass and agricultural residues for electricity generation. If managed properly, bioenergy can support sustainable forest management activities while advancing California's renewable energy and climate goals. However, there are legitimate concerns surrounding the climate, air quality, soil fertility, and ecosystem health implications of improperly managed bioenergy systems. Before biomass energy can be responsibly pursued as a means to achieve forest management and renewable energy goals, additional research is needed to firmly establish the climate impact and broader environmental performance of forest and agricultural bioenergy.

Woody residuals before bioenergy conversion

Our central effort under the CBI Project will be the creation of a Life Cycle Assessment (LCA) greenhouse gas emissions accounting tool that will allow stakeholders in California to evaluate the impacts of different bioenergy policy and technology pathways in the state. Along with greenhouse gas balances, the project team will address additional critical environmental impacts that can be associated with bioenergy – including altered risk or severity of wildfire, soil fertility and carbon stock reduction, changes to air quality, and potential impact on habitats and biodiversity.

Key study areas and outputs:

- Assess and map net recoverable biomass that could be utilized for electricity generation. This analysis will focus on agricultural and forestry residues, as well as drought- and beetle-killed trees in the Sierra Nevada range.
- Conduct a landscape-level probabilistic assessment of the fire risk implications of sustainable forest harvesting. Fire behavior under future climate scenarios will be simulated using the Pacific Northwest variant of the USDA Forest Vegetation Simulator (FVS) in combination with the Fires and Fuels Extension and Climate Extension modules.
- Develop and demonstrate the California Residual Biomass-to-Electricity Carbon Accounting Tool (CARBCAT). This tool will improve on existing frameworks representing California's unique bioeconomy context, offering improved spatial resolution, rigorously characterizing uncertainty, and offering a high degree of specification regarding supply chain characteristics. Users will be able to specify harvest practices, feedstock collection and handling methods, post-harvest treatments, feedstock management pathways, conversion technologies, and other characteristics.
- Characterize and report on key environmental impacts of residual biomass mobilization such as changes to soil nutrient balance and carbon stock, air quality effects from altered black carbon and criteria air pollutant emission profiles, and impacts to biodiversity.
- Assess potential to offset some harvest and supply chain costs through payments for ecosystem services and similar environmental market schemes.
- Identify best management practices to improve bioelectricity system net greenhouse gas balance as well as to optimize performance with respect to fire risk, soil health, air quality, and habitat conservation.
- Develop and disseminate science-based policy recommendations that support implementation of these practices in bioelectricity supply chains.

The CBI Project is supported by a three-year, $1,000,000 grant from the California Energy Commission. Our project partners include the HSU Department of Forestry, the Consortium for Research on Renewable Industrial Materials (CORRIM), CSU Chico, the Sierra Institute for Community and Environment, the University of Washington, and the Watershed Research & Training Center.

Project Updates

The Blue Lake Rancheria Microgrid

The Blue Lake Rancheria (BLR) renewable energy microgrid received full permission to connect to the Pacific Gas & Electric grid on July 28, 2017. Designed and implemented by a team led by the Schatz Center, this new microgrid powers critical infrastructure for the BLR tribal community and the Humboldt County region.

The BLR microgrid breaks new ground in its seamless transition between grid-paralleled and grid-islanded states and by demonstrating stable islanded operation with a high percentage of renewable energy. This project heralds the first deployment of the Siemens Spectrum 7 based microgrid management system (MGMS) and the first multi-inverter Tesla battery energy storage system (BESS) utilized in a microgrid application. The MGMS and the BESS were integrated using foundational relay control programming developed at the Schatz Center.

At 420 kWAC, the Rancheria's PV array is also the largest installed in Humboldt County. The BLR microgrid has a total of 1.92 MW of generation capacity, including the PV array, a 500 kW, 950 kWh Lithium-ion Tesla battery, and a legacy 1.0 MW backup diesel generator. By coupling renewable generation with battery storage, the BLR microgrid achieves significant reductions in both utility cost and greenhouse gas emissions. The microgrid is now saving the Blue Lake Rancheria $250,000 annually and has allowed the Rancheria to increase tribal employment by 10% with new clean energy jobs.

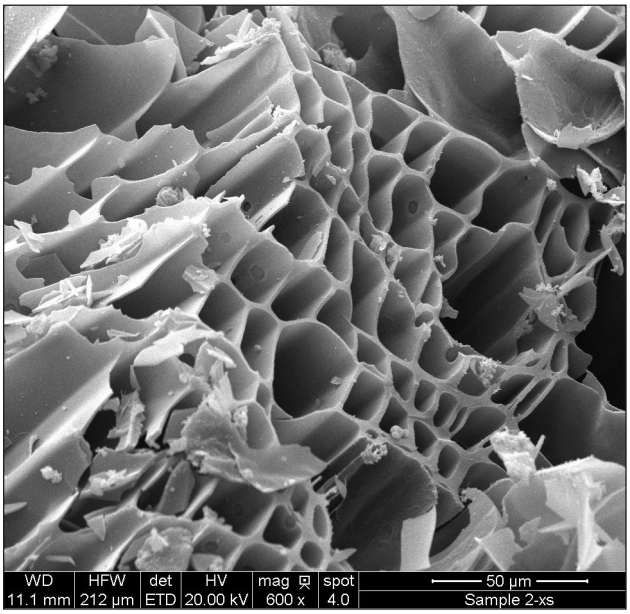
The Blue Lake Rancheria array

The Blue Lake Rancheria microgrid was developed through funding from the California Energy Commission's Electric Program Investment Charge (EPIC) program. Major partners on this project included Pacific Gas & Electric, Siemens, Tesla Energy, Idaho National Laboratory, GHD Inc., Colburn Electric, REC Solar, and Kernen Construction.

Improving a Biochar Production System in Mendocino County *Kyle Palmer & Mark Severy*

For the past three years, the Redwood Forest Foundation, Inc. (RFFI) has produced biochar from small-diameter tanoak trees collected from thinning operations in Mendocino County's Usal Forest. The Usal Forest ecosystem was disrupted by industrial logging operations throughout the 20th century. Tanoak's rapid regrowth dominated canopy light, and interfered with redwood repopulation. RFFI is selectively removing tanoak to create the natural space that redwood needs to flourish, and converting the tanoak into biochar to help fund their restoration work.

RFFI's biochar production has balanced on the edge of technical and economic feasibility due to the high moisture content of the tanoak feedstock and the labor costs required to operate the machine. In 2016, we addressed the moisture content by installing a biomass drying system that uses waste heat from the biochar machine. This year, we are working to reduce labor hours while improving safety and productivity by automating key processes on the machine.



Biochar, a blackened, solid biomass produced at high temperatures in the absence of oxygen, is used primarily as a soil amendment to increase water holding capacity, reduce nutrient leaching, and improve conditions for microbial life. Here, the highly porous structure of biochar is shown through scanning electron microscopy (SEM) at 600x magnification. This SEM image was taken by Murielle Manka and Marty Reed, using the Humboldt State CNRS Core Research Facility's FEI Quanta 250 ESEM.

In July and August, research engineers Kyle Palmer and Andy Eggink and student research assistant Murielle Manka evaluated baseline labor hours, biochar production rate, and biochar quality produced with the existing system.

Throughout these tests, real-time data were collected for gas flow, composition, and electric power demand to help develop the control schemes. Monitoring and automation equipment are currently being installed and performance improvements will be validated in the coming months.

The preliminary results from this study were presented in early September by Murielle Manka and Director Arne Jacobson at the Agricultural Research Institute's (ARI) principal investigator's meeting in Sacramento. Validation test results analyzed this autumn will quantify benefits of the automation system, including any reductions in labor, increases in throughput, and changes in biochar quality.

Murielle Manka and Arne Jacobson (left to right)

This work is supported by California State University's Agricultural Research Institute and a grant from the U.S. Department of Energy under the Biomass Research and Development Initiative program.

Energy Adoption Patterns in Uganda

The United Nations Capital Development Fund's CleanStart Programme, in partnership with SolarAid/Acumen and the Schatz Center, is conducting research on energy adoption patterns. This project seeks to determine which channels customers in rural Uganda use to finance and purchase solar systems. We are also investigating the drivers of solar product adoption, including the influence of flexible financing tools on purchasing behavior.

We have learned that the quality of existing energy services plays an important role in shaping customers' receptiveness to alternative off-grid solutions. Our research also shows that in-person marketing, "real-life" observations, interactions with sales staff, recommendations by thought leaders, and conversations with existing satisfied customers are all strongly influential in driving end-user uptake of solar energy products.

Visit schatzcenter.org/energyladder to learn more about our research methodology and results.

Schatz Center project consultant Maina Mumbi in Luwero, Uganda

A Quality Assurance Framework for Solar System Installations at Public Facilities in West Africa *Meg Harper*

The Schatz Center and the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), with support from the World Bank through their Lighting Africa program, are working collaboratively with government partners in Nigeria and Niger to develop a new approach for the procurement, installation, and long-term maintenance of off-grid solar electricity systems at public facilities, such as health clinics, schools, police posts, public offices, and water pumps.

Off-grid solar systems offer the promise of clean, renewable electricity for public facilities. However, historically, there has been a high failure rate for these systems in many countries, often caused by poor quality design and installation, or lack of maintenance and good operational practices following installation even when initially high quality system components are installed. The proposed new approach involves the innovative use of digital remote monitoring technology, along with quality standards for equipment, design, and installation, to ensure and verify the ongoing performance of off-grid solar electricity systems. Under such an approach, companies in the off-grid solar sector could enter lease agreements or extended service contracts with government agencies to provide an agreed-upon level of electricity service in return for guaranteed monthly payments. The payments could be designed to cover the capital costs of equipment and installation (or a percentage of these costs), along with the ongoing operation and maintenance costs over the projected system life. By digitally monitoring the performance of the systems, a third-party could verify that the service provider is delivering the agreed electrical service and instruct the government agency to pay the monthly fee.

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Project Updates (continued from page 5)

Spreading the cost of the systems over many years and keeping service providers engaged is expected to improve the long-term performance of the systems.

Over the next two years, the proposed approach will be developed, evaluated, and revised through research and deployment of approximately fifteen pilot systems in Nigeria and fifteen pilot systems in Niger. Our main role in this effort is to develop the quality assurance framework that serves as the basis for the approach. This includes determining a standard for service delivery that can be used to verify that the system's performance matches contractually specified targets. Our staff will conduct site visits, provide technical designs for the thirty pilot systems, and verify system performance for the first six months. Support for this effort is provided by the World Bank Group's Lighting Africa Program.

To kickoff the project this September, three team members visited sites in Niger and Nigeria to gather initial information about health clinics, schools and other public facilities. Chris Carlsen, a Center alumna and current consultant, met with officials in Niger and visited several communities to understand the country's existing infrastructure. Jimento Aikhuele, a Schatz Energy graduate fellow originally from Nigeria, and Olakunle Owoeye, a Center consultant, met Chris in Nigeria to scope out potential sites for pilot installations and learn about the energy needs of the various facilities. The team also visited sites with existing solar installations to gain insight into why well-intentioned solar systems so often fail. Our initial work in the field was fruitful thanks to the indispensable support of ECREEE, the Ministries of Energy, Health and Secondary Education of Niger, and the Ministry of Power, Works and Housing of Nigeria.

Jimento Aikhuele and Olakunle Owoeye (center to right) at a schoolyard in Nigeria

Back at the Schatz Center, we have been hard at work reviewing existing standards and determining appropriate requirements to include in the quality assurance framework. This work dovetails with projects we've conducted in the past, including the ongoing development and co-management of the Lighting Global Quality Assurance program. We are looking forward to heading back into the field to gather more information before finalizing a draft of the framework and providing recommended designs for the pilot installations next spring.

Biomass Utilization Feasibility Study for the Karuk Tribe of California *Dave Carter*

The Schatz Center is assisting the Karuk Community Development Corporation (KCDC) with a biomass utilization feasibility study. The Karuk Tribe of California (KTOC) has aboriginal territory encompassing the Klamath River and Salmon River watersheds in Northern California. These lands are heavily forested and have been adversely impacted by postcolonial land use practices such as timber production and wildfire suppression. Large, destructive wildfires have become an annual occurrence in and around Karuk territory, and there is widespread agreement among land managers that forest practices in the region need to change. The KTOC is leading this change through eco-cultural revitalization efforts that involve putting beneficial fire back on the land and restoration of traditional oak woodlands. Within this context, there is a role for utilization of biomass residuals that are removed through mechanical treatment. The Schatz Center is evaluating economic development opportunities for the KCDC to utilize forest residuals.

The overall goal of the project is to determine the feasibility of using local, renewable biomass resources that are available to the KTOC to generate power, heat, or products, while creating jobs, fostering environmental stewardship, and providing benefits to the tribe's economy. The objectives of this project are to determine the resource availability, identify technologies that could be implemented, and calculate the financial viability of potential projects.

This project is currently active and is funded by US Department of Interior Indian Affairs Energy and Mineral Development Program. We expect to complete the project by the second quarter of 2018.

For the latest project announcements and updates, subscribe to our online newsletter at: schatzcenter.org/news

Schatz History: The Trinidad Photovoltaic Array

Charles Chamberlin

From 1990 through 2016, a 9.2kW photovoltaic (PV) array located at the Humboldt State Telonicher Marine Laboratory in Trinidad, CA powered the Schatz Solar Hydrogen Project. This array provided the energy to aerate the Marine Laboratory aquaria either directly or indirectly through a Teledyne Energy Systems ALTUS™ 20 electrolyzer that produced hydrogen fuel for a proton exchange membrane fuel cell.

Located ~150 meters from the Pacific Ocean in a cool, marine climate, the array consisted of 192 ARCO M75 modules made with single-crystal silicon and rated at 48W. Prior to array installation in 1990, Jim Zoellick measured the current-voltage (I-V) curves for each module and discovered that even when new, the average peak power under full solar illumination at normal operating cell temperature was 39.9W – 14% below the 46.4W nameplate rating.

After 11 years of field exposure, Antonio Reis and Nate Coleman retested each module's I-V curve in 2001 and found that the average peak power had fallen by 4.3% to 38.1W. They attributed the drop in performance to visually observable defects in the modules, especially the delamination of the modules' ethylene vinyl acetate (EVA) encapsulant, leading to shading and corrosion of the cells and the occurrence of localized hot spots.

After 20 years of service, Marc Marshall, Mark Rocheleau, and Scott Rommel again retested each module's I-V curve in 2010, and found that the average peak power had fallen an additional 12.4% to 33.4W and that the variation among the modules had dramatically increased.

After over 26 years of field service, the array was decommissioned in 2016. All of the 192 modules were removed and tested one last time by Jacob Rada, a M.S. candidate working at the Center. He found that the average peak power had fallen 22% since 1990, with an average degradation rate of 0.85%/yr, and that the variation among the modules had increased further since 2010. Each original module was discolored and showed some degree of delamination.

Having now been individually tested four times over 26 years, these are some of the oldest carefully monitored solar modules from a working array. Of the original 192 models, 188 modules were still in service after 26 years. One module was damaged in 1996 and was replaced with a module of similar size and performance characteristics. Three other modules were later replaced due to physical damage.

In the coming year, we will be hanging seven of the modules with their corresponding I-V curve data in the staircase of our main building, as a celebration of our Center's first project and as a teaching tool for university students and visitors.

Charles Chamberlin, Tim Murphy, Peter Lehman, Gian Pauletto and Ron Reid (left to right)

Peter Lehman and Charles Chamberlin (left to right)

Visiting students role-play as molecules to learn the chemical mechanisms of electrolysis and hydrogen fuel cells

A Message from the Director (continued from page 2)

year. The selected fellow will also receive a position to work at the Schatz Energy Research Center.

Our heartfelt thanks go to Don and Andrea for their generous gift. At the Schatz Center, we are committed to expanding opportunities for students in the clean energy field as we work to develop a new generation of leaders, and support from partners like Andrea and Don Tuttle and the Blue Lake Rancheria help us greatly in making progress toward this goal.

Our third investment has been in a new 1,900 square foot "West Wing" addition, built to accommodate our growing staff and capabilities. Construction of the building is nearly complete, and we expect to move in by early December. The new facility will provide us with 14 new work stations, two offices, and a much needed second conference room. We are grateful for the generous support from Louis W. Schatz, Anne and David Katz, Peter and Carolyn Lehman, Christina and Jack West, Jamie Everett, and Joel Lehman, and grant funding from the California Energy Commission, who together made this project possible. We are also thankful to HSU Facilities Management (especially Mike Fisher and Garrett McSorley), Suarez-Kuehne Architecture, Adams Commercial General Contracting, and the many local contractors who made professional contributions to this project. Our new addition is a beautiful building that is well matched to our existing facility in both function and form, and we are excited to move in and get to work in it.

Goodbye until next time. ~ Arne Jacobson

The mission of the Schatz Energy Research Center is to promote the use of clean and renewable energy.

The Schatz Center is led by Arne Jacobson (Director), Peter Lehman, (Founding Director), and Charles Chamberlin (Co-Director). Our team of approximately 40 people includes faculty and research associates, engineers and professional staff, student research assistants, and volunteer docents. Our expertise includes design, deployment, research, and policy development in off-grid energy access, renewable energy systems, smart grids, bioenergy, and clean transportation.

Visit us at www.schatzcenter.org Email: serc@humboldt.edu