Final Technical Report (FTR)

Cover Page

a. *Federal Agency*	Department of Energy	
b. *Award Number*	DE-EE0008570	
c. *Project Title*	Developing socially and economically generative, resilient PV-energy systems for low- and moderate-income communities: Applications for Puerto Rico	
d. *Recipient Organization*	Arizona State University	
e. *Project Period*	*Start*: April 1, 2019	*End:* March 30, 2024
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Heather Clark   9/19/2024

Signature of Certifying Official   *Date*

By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate. I am aware that any false, fictitious, or fraudulent information, misrepresentations, half-truths, or the omission of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (U.S. Code Title 18, Section 1001, Section 287 and Title 31, Sections 3729-3730). I further understand and agree that the information contained in this report are material to Federal agency's funding decisions and I have any ongoing responsibility to promptly update the report within the time frames stated in the terms and conditions of the above referenced Award, to ensure that my responses remain accurate and complete.

1. Acknowledgement:

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) Solar Energy Technologies Office (SETO) under the Solar Energy Evolution and Diffusion Studies Award Number DE-EE0008570.

2. Disclaimer:

3. Executive Summary:

The nexus of energy and poverty is one of the most significant long-term challenges facing the energy and electricity sectors, with negative feedback loops between energy-related costs, risks, and insecurities, on the one hand, and diverse other social and economic insecurities, on the other, helping to undermine health, wellbeing, and resilience in low- and moderate-income communities around the US and the world (Biswas et al. 2022). The transition of energy systems to clean energy alternatives offers a potential opportunity to redesign future energy arrangements in ways that, instead, create beneficial social value for communities, reverses the energy-poverty nexus, and enhances community wellbeing (Biswas et al. 2020; Miller et al. 2018). The promise of clean energy transitions to address the energy-poverty nexus is especially significant when designed using principles of just energy transitions.

To leverage just clean energy transitions to accomplish a reversal of the energy-poverty nexus requires improvement in three capabilities:

(1) Understanding and mapping the community-scale dynamics and variability of the energy-poverty nexus, which vary considerably from community to community;
(2) Evaluating the technical, social, and economic potential for different clean energy system designs to deliver social value to specific communities; and
(3) Working collaboratively with communities to imagine and design clean energy systems solutions that meet their needs, fit their capabilities and contexts, and deliver multiple forms of community-desired social value/benefits that help reverse key facets of the energy-poverty nexus.

This project developed a portfolio of novel tools, methodological approaches, and collaborative partnerships with four communities in Puerto Rico that further the objective of building these three capabilities. Major contributions included:

- A database of the solar technical potential of residential rooftops for all households in Puerto Rico (Mooney et al. 2020; Mooney and Waechter 2020), including solar developable planes and Census Tract estimates of aggregate solar technical potential and potential solar savings (https://data.nrel.gov/submissions/144).
- An integrated suite of computational model capabilities that include a configurable model of annual hourly household electricity use based on household size and electrical devices (Campo-Ossa et al. 2023), as well as a model of social valuation of design configurations for household solar+battery systems based on PV technical potential, battery size, electricity load, and utility tariff (Gregory et al. 2023).
- Detailed assessment of the energy-poverty nexus dynamics in Puerto Rico communities (Rivera-Matos et al. in review; Biswas et al. 2022).
- Partnerships with four Puerto Rico communities to collaboratively explore and evaluate possible solar+battery system design configurations for their potential to contribute meaningful social value, combat energy poverty, and enhance resilience to electricity outages in the context of the Puerto Rico's electricity grid and solar energy innovation ecosystem (Rivera-Matos et al. 2021; Miller et al. in preparation).
- A new approach to community solar energy design that is community empowering, via both inclusion in the design process and the design of solar sociotechnical systems elements to create significant and substantial social value for the community through multiple potential benefit streams (Miller et al. in preparation), including reversing the energy-poverty nexus in communities, creating positive community feedbacks (Biswas et al. 2022), and enhancing community resilience to multi-day to multi-week electricity outages (Gregory et al. in preparation).
- A new capabilities-based framework for assessing and strengthening community resilience to energy insecurity (Gregory et al. in preparation).

Through these contributions, the project provides significant public benefit by demonstrating that (a) community-based solar energy systems have the potential to provide significant value to communities that includes but goes beyond providing clean energy to also help reduce or eliminate the energy-poverty nexus; (b) realizing this potential requires collaborative community co-design that informs solar energy system configurations based on the needs, characteristics, capabilities, and opportunities of the community, as well as the community-specific dynamics of the energy-poverty nexus; and, hence, (c) there is a need for new approaches to community solar innovation that are able to deliver tailored solar projects for communities at scale, if community solar is to emerge as a nationally and globally meaningful alternative to rooftop and utility-scale solar that not only enables access to clean energy but also delivers on the promise of providing substantial benefits to low- and moderate-income communities in line with just energy transition goals.

4. Table of Contents:

5. Background:

Since 2019, when this project commenced, large-scale deployment of community solar has emerged as a key US strategy for advancing the goals of a just energy transition, with the aim of bringing the benefits of clean energy technologies to all Americans (see, e.g., the National Community Solar Partnership, https://www.energy.gov/communitysolar/about-national-community-solar-partnership), including especially to low- and moderate-income communities and communities of color that have historically had lower solar adoption (Sunter et al. 2019) and benefitted less, financially, from solar access (Crago et al. 2023). Unfortunately, recent analysis (Xu et al. 2023) shows that, although community solar has grown somewhat in scale, several factors currently detract markedly from the above goal: community solar remains far behind rooftop and utility-scale solar deployment (~5% of US total solar deployment); community solar remains isolated to a few states with strong community solar laws (75% in just 4 states); community solar projects deliver relative few financial benefits to most participants (NPVs substantially less than for equivalently sized, owned systems, compare, e.g., to Crago et al. 2023); community solar projects currently deliver few if any other benefits beyond minimal bill savings to participants (e.g., community resilience, because most community solar projects are offsite projects that deliver electricity virtually or via the grid; see also NCSP 2023, which highlights the significantly greater benefits that flow to locally-owned and community-owned community solar projects).

For many of these reasons, this project was designed to explore the potential for what we have come to call "community empowering solar initiatives". Community empowerment is recognized as an important goal for advancing energy justice and energy democracy as part of clean energy transitions that is, unfortunately, too infrequently achieved in practice (Coy et al. 2021; Baker 2021). Part of the challenge is that community empowerment requires community engagement and involvement in envisioning and designing clean energy projects in ways that identify and advance collaborative community goals (Coy et al. 2022). At the same time, it is essential to understand how existing energy systems contribute to disempowering communities and detracting from community wellbeing and economic security (Biswas et al. 2022; Miller et al. 2018), as well as how clean energy project design configurations shape the benefits that meaningfully and realistically flow to communities from differently configured solar projects, based, e.g., on characteristics such as ownership, system and site selection, management, and other characteristics (Chan et al. 2017; Crago et al. 2023).

These factors shaped the overall design of this project around the goal of collaboratively exploring, with communities, how community empowerment might be enabled via solar energy initiatives, via (1) bottom-up, community-centered, collaborative forms of inquiry; (2) the assessment of how existing energy systems in the community undermine community empowerment, wellbeing, and economic security through the energy-poverty nexus; (3) the collaborative exploration of community-centered solar-plus-storage system configurations against community goals, needs, and contexts, with the goal of delivering substantial and meaningful benefits to communities that helped reduce or reverse the energy-poverty nexus; and (4) the evaluation of the capabilities of local solar energy innovation ecosystems to deliver community empowering solar initiatives and projects.

At the time of commencement of this project, implementing this effort entailed developing new capabilities for integrated simulation of the socio-technical system performance of households, incorporating the ability to simulate electricity loads under diverse scenarios and integrate them with modeling of the performance of distributed solar-plus-storage systems of different sizes and configurations as well as modeling of utility rate plans to enable financial analysis (levelized cost of electricity). NREL's dGEN model was subsequently modified to include similar capabilities as part of the Storage Futures Study (Prasanna et al. 2021), although our model retains greater customizability of simulated load profiles (Campo-Ossa et al. 2023) in order to enable scenario planning of desired future electricity consumption as an element of community co-design, as well as introducing resilience metrics to enable communities to understand the implications of alternative system design and use configurations for electricity availability and derived household capabilities (Gregory et al. in preparation).

We chose to pursue this project in collaboration with communities and researchers in Puerto Rico where, in the aftermath of several hurricanes (including especially but not only Hurricane María), damaging earthquakes, the vicissitudes of COVID, and other circumstances, low-income communities faced an exceptionally difficult and disempowering energy-poverty nexus (de Onis 2018, 2021) that substantially undermined health, economic security, and community wellbeing. At the same time, thanks to ongoing media coverage and public discussions, solar energy was widely viewed as a potentially powerful contributor to redesigning energy systems in ways that would enable communities to address ongoing weaknesses of the electricity grid and supply, future disasters, and persistent economic insecurity (Echevarria et al. 2022). In 2019, as a result, when this project commenced, many communities were excited about the potential for solar energy to advance goals of both community empowerment and resilience (Krantz 2020), and the Puerto Rico government passed legislation setting a goal to achieve 100% renewable electricity generation by 2050. In service of this goal, NREL subsequently conducted the PR100 study (Baggu et al. 2024), which was guided by insights and used data from this project. The results of this project are especially relevant for Scenario 2 of the PR100 study, which explored the additional potential for distributed solar deployment in service of enhancing the resilience of low- and moderate-income communities, especially in rural and remote areas (see ibid., p. xxii).

6. Project Objectives:

6. A. Impact on US National Clean Energy and Economic Benefit Goals: The project advances US national clean energy and economic benefit goals through the conceptualization and exploration of *a new approach to empowering communities via solar energy innovation and customization*. The project's approach – which we term "community-empowering solar" – offers a tool for expanding the reach and impact of solar deployment into a wide array of new communities that are not currently served by rooftop or community solar, thus potentially <u>helping to expand community solar as a third stream of US solar adoption</u>, alongside utility-scale and rooftop solar, and thus to accelerate the transition of the US electricity sector to higher penetrations of renewable energy generation. The approach expands the reach and impact of solar deployment by <u>delivering significant and substantial social and economic benefits to low- and moderate-income communities</u> who have not previously benefited significantly from other modalities of solar deployment, thus helping achieve Justice40 goals of bringing the benefits of renewable energy generation to communities experiencing energy and/or environmental injustice. The approach is able to deliver enhanced benefits to communities by <u>using community co-design practices to customize solar solutions that meet community needs, fit community contexts, and meaningfully tackle the negative impacts and burdens of existing energy systems and circumstances</u>, e.g., via enhancing economic security, community wellbeing, and/or climate resilience. The project specifically advances these goals in low- and moderate-income communities in Puerto Rico, which have suffered extensive energy and energy-related economic and human insecurities over the past decade. In Puerto Rico, specifically, the project contributes to the goals of <u>enabling</u>

Puerto Rico to achieve its target of 100% renewable energy and strengthening the resilience of vulnerable communities to climate change and economic insecurity.

6. B. Project Goals and Expected Outcomes:

- ***Objective 1****: Develop key conceptual and theoretical foundations of community-empowering solar:* The first objective of the project is to further develop and deepen key social science ideas that inform the development of solar initiatives as a tool for community empowerment, including the energy-poverty nexus, social value of energy, and community co-design, and to use those ideas to design prototype strategies for implementation of community partnerships (Objective 3).
- ***Objective 2****: Develop tools and datasets that support implementation of community-empowering solar:* The second objective of the project is to develop the tools and data necessary to analyze the potential for community-empowering solar energy to address sustainable energy needs in Puerto Rico, including the technical potential of Puerto Rico residential rooftops; the potential to customize solar solutions to provide meaningful benefits and value creation for communities that address community needs and goals; and the potential for the Puerto Rico solar innovation ecosystem to supply community-relevant solar solutions.
- ***Objective 3****: Testing and evaluating strategies for implementation of community-empowering solar in partnership with low- and moderate-income communities:* The third objective of the project is establish partnerships with four low- and moderate-income communities in Puerto Rico to test and implement strategies of community-centered solar innovation that integrate the key social science ideas (Objective 1) and tools and datasets (Objective 2) advanced by the project.
- ***Objective 4****: Improving public knowledge and skills that enable and empower communities to pursue beneficial solar energy customization and deployment:* As an important element of our community partnerships (Objective 3), the project aims to develop and share public knowledge and skills that enhance the capacity of community leaders and members to implement community-empowering solar initiatives. We also aim to enhance the capacity of diverse organizations to support communities in advancing community-empowering solar initiatives, both in Puerto Rico and nationally.
- ***Objective 5****: Developing educational resources that support training in community-empowering solar:* We will also develop educational resources that support training of students, researchers, and community organizations in the fundamentals of community-empowering solar initiatives and strategies for supporting communities in their design and implementation.
- ***Objective 6****: Advancing human resource development in science, technology, engineering, and mathematics:* Finally, the project will provide substantial training for a number of STEM students in the design and implementation of the project methods, tools, and data, as well as in the development and orchestration of effective partnerships between researchers and communities.

6. C. Significance, Innovation, and Fundamental Advances:

As described above in Section 6.A., the project aims to have impact in three principal areas: expanding solar adoption; delivering benefits from solar adoption to low- and moderate-income communities consistent with Justice40; and building capacity for community solar innovation in Puerto Rico. Here we describe how the project's significance, innovation, and fundamental advances aim to further each impact area:

- **Delivering benefits from solar adoption to low- and moderate-income communities**: The fundamental innovation of this project is to develop an integrated approach to significantly expanding the meaningfulness and impact of community solar through the ability to use community co-design methods as a tool for customizing solar solutions so that they deliver benefits that not only meet the specific needs and contexts of community partners but also that those benefits create substantial social value that directly addresses critical elements of the local energy-poverty nexus in the community. To accomplish this, the project aims to deepen theorization of the energy-poverty nexus and social value of energy and to form partnerships with communities to characterize their energy-poverty nexus dynamics and explore how customized solar solutions can be designed to tackle key elements of the community energy-poverty nexus through meaningful and beneficial social value creation. Lessons learned will be shared with organizations that support community solar development.
- **Expanding community solar adoption and access**: As noted above in section 5., community solar significantly lags other solar deployment modalities, despite extensive technical potential for community-centered solar deployment to expand solar adoption and access. Several barriers are responsible for that lag, including policy limitations that restrict options in many parts of the US. Another key barrier, however, are the limited benefits that are achievable from the currently dominant model of community solar (in which individuals subscribe to utility-scale solar projects located far from the community) which provide little incentive for communities to want to participate in or advocate for community solar solutions. Such projects do little to address common community desires, such as enhanced resilience, solar ownership and revenues that can be used for community purposes, non-energy goals such as shade or aesthetics, improved availability and affordability of energy for vulnerable community members, or other potential upsides. Instead, they provide only modest bill savings for subscribers (Xu et al. 2023) that are generally insufficient to drive market adoption without significant additional policy inducements. Our approach explores the potential for customized solar solutions derived through community co-design to significantly enhance community benefits in a way that has the potential to strengthen the benefit-cost ratio for solar projects in the calculus of both communities and investors, thus not only better justifying expensive solar investments in low- and moderate-income communities but also providing a rationale for community advocacy for projects and for utilities and policymakers to support community project development. Again, lessons learned will be shared with the community solar community.
- **Lessons, data, and capacity building for Puerto Rico's ambitions for achieving 100% renewable electricity generation by 2050**: Our project aims to provide important data, tools, lessons, and capacity building that can help achieve Puerto Rico's sustainable energy goals in a way that also significantly benefits the island's many vulnerable communities. This will include data, models, and methods that communities and their partners can use to customize solar

initiatives and solutions that help advance community empowerment and goals, fit community contexts, enhance community resilience, and tackle community energy-poverty nexus dynamics. We hope these will be especially useful as EPA and DOE grow investments in coming years in Puerto Rico solar programs.

6. D. Summary of Tasks:

Budget Period 1*:*

Task 1.0: Map the PV Technical Potential and Potential to Satisfy Energy Demand for Puerto Rico by Geography, Tenure, and Income: The team will generate spatial data on the rooftop PV technical potential and solar savings potential for Puerto Rico LMI communities at the Census-tract level, stratified by building type, tenure, and income.

Task 2.0: Evaluate the Current State of the Energy-Poverty Nexus and Solar Energy Markets, Projects, and Policy in Puerto Rico: The team will conduct research to evaluate the current state of the energy-poverty nexus and solar energy markets, projects, and policy in Puerto Rico. This research will, together with the quantitative datasets built in Task 1.0, provide a necessary foundation for subsequent in-depth, comparative research on the ability of solar energy to provide solutions to the energy-poverty nexus in low-income communities.

Task 3.0: Identify, Engage, and Recruit Communities to Participate as Case Study Research Sites for Comparative Analysis of Solar Energy Solutions for Low-Income Communities: The team will collaboratively define the comparative research data collection, analysis, and engagement to be conducted in Budget Periods 2 and 3 and identify, engage, and will recruit a set of four low-income communities willing to participate as case study research sites in that work.

Budget Period 2*:*

Task 4.0: In-Depth Analysis of the Energy-Poverty Nexus in Case Study Communities: The team will conduct thorough, in-depth research into the ways in which energy and poverty intersect and reinforce one another and the potential opportunities for and conditions that would enable innovative distributed and community-based energy solutions to address the energy-poverty nexus via a comparative analysis of four low income communities selected as case study research sites in Puerto Rico.

Task 5.0: Develop and Validate Models of Energy Demand and Financial Implications of Project Design and Ownership for Community Energy Planning: Using energy demand and financial data collected in the case study communities in Task 4.0 of Budget Period 2, models of energy demand and the financial implications for communities of project design and ownership will be built in order to predict and simulate energy demand for analyses of proposed solar energy solutions.

Task 6.0: Prepare for Community Solar Energy Planning Processes: During Budget Period 2, the team will work with community leaders and stakeholders in each case study community to design and prepare for community solar energy planning processes to take place in Budget Period 3 (Task 8).

Task 7.0: Disseminate Interim Research Results: The project will disseminate significant interim research results.

***Budget Period 3**:*

Task 8.0: Conduct and Comparatively Evaluate Community Solar Energy Planning: The project will carry out processes of community solar energy planning in each of the four case study communities and will comparatively evaluate the processes and results in order to generate generalizable insights into best practices for community solar energy planning for low-income communities.

Task 9.0: Publication and Dissemination of Final Results: The project will publish the final research findings and results of the project.

Task 10.0: Prepare Training Program for Community Solar Energy Planning: The project will prepare a curriculum for training community leaders from low-income communities to pursue collaborative, community-based solar energy planning processes.

6. E. Milestone Table:

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
1.2.1	3	Human subjects protections	Obtain Institutional Review Board (IRB) approval	Documentation	IRB approvals from ASU and UPRM submitted to DOE	Several aspects of the project involve human subjects. No protected information is intended to be collected.
1.2.2	4	Interview protocols	Questions for stakeholder interviews finalized	Documentation	List of proposed questions submitted to DOE for review	Initial round of stakeholder interviews (1.2.4) important for regulatory and solar energy market analyses (GNG-1D).
1.2.3	6	Definition of LMI for Puerto Rico	Project definition of LMI finalized	Documentation	Final definition statement submitted to DOE	To ensure proper definition of LMI, possible calibrations will be considered to address lower income than the US mainland and a range of energy insecurity challenges.
1.3.1	6	Criteria for case study selection	Project team agrees to criteria (including considerations around geographic and demographic diversity)	Documentation	Final criteria statement submitted to DOE	To ensure significant impact from the future case studies, an appropriate methodology is developed to select them; interim milestone for GNG-1C.
1.3.2	7	Candidate communities for case study research sites	10+ candidate communities identified In preparation for GNG1, identified communities should encompass a diversity of geographic and demographic characteristics, including urban, rural, flat, mountainous, more economically disadvantaged, less economically disadvantaged , close to resources/ partners, far from resources/partners, within the greater San Juan metropolitan area, and outside	Count	Information on candidate communities, in the context of prior established criteria, submitted to DOE for review.	Selection of candidate case studies allows for detailed evaluation of and early consultation with each for final selection of research sites; interim milestone for GNG-1C.

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
			the greater San Juan metropolitan area.			
1.2.4	7	Stakeholder engagement and interviews	Interviews conducted with 100+ stakeholders in Puerto Rico[1] Stakeholders must represent diverse geographies within Puerto Rico with more than half being sourced outside of the greator San Juan metropolitan area.	Count	List of completed interviews, along with descriptive information surrounding form of engagement, submitted to DOE	Interviews will generate data for assessments of energy insecurity, solar energy markets, and energy regulation in Puerto Rico.
1.1.1	9	LiDAR, building, and census data processing	Tract level estimates for LMI PV Rooftop technical potential generated	Screen share	Demonstration shared with DOE that data has been generated.	Data required for technical potential calculations for GNG-1A.
1.1.2	9	LMI energy consumption and cost data collection and processing	Tract level estimates for LMI energy consumption and cost data generated	Screen share	Demonstration shared with DOE confirming data has been generated.	Data required for estimates of LMI solar savings; interim milestone for GNG-1B.
1.3.3	10	Case study research sites	4 communities and 2 backup communities selected as case study research sites	Count	List of selected and backup communities provided to DOE, along with information on points of contact within the communities and who has the authority to sign-off on their participation.	To ensure significant impact from the future case studies, case studies selected according to methodology (1.3.1); interim milestone for GNG-1C.
1.1.3	11	Census tract LMI rooftop technical potential data review	Data passes appropriate QAQC and review tests	Documentation	Slides describing the tests performed and data validation provided to DOE.	Data validation for technical potential calculations; interim milestone for GNG-1A.
1.1.4	11	LMI solar savings data review	Data passes appropriate QAQC and review tests	Documentation	Slides describing the tests performed and data validation provided to DOE.	Data validation for estimates of LMI solar savings; interim milestone for GNG-1B.

[1] Stakeholders will be selected from among solar industry, energy industry, civic and policy leadership, community leadership, residents, small businesses, manufacturing industry, renewable energy advocates, energy researchers, etc.

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
GNG-1A	12	Dataset availability	Dataset of technical potential for solar energy generation in PR LMI communities by Census tract ready for publication.	Dataset ready to be published, loaded onto NREL data site, and awaiting only final approval from DOE to be made public.	Links to dataset submitted to DOE for final approval of publication.	Dataset is key contribution to achieving project research goal of assessing potential for solar energy to contribute to LMI community energy futures and process of selecting representative communities for further analysis and engagement in subsequent research tasks in Budget Periods 2 and 3.
GNG-1B	12	Solar economics estimated for PR LMI communities	Initial dataset of estimates completed of energy demand, energy costs, and potential solar savings in PR LMI communities by Census tract.	Documentation	Dataset provided to DOE for review.	Estimates are an important contribution to achieving project research goal of assessing potential for solar energy to contribute to LMI community energy futures and process of selecting representative communities for further analysis and engagement in subsequent research tasks in Budget Periods 2 and 3.
GNG-1C	12	Recruitment of case study communities	Four communities identified that meet selection criteria, given information about participation, engaged in discussion of participation, and agreement to participate as case study communities confirmed through signature of agreement to participate. At least 3 of the communities must be outside of the greator San Juan metropolitan area. Communities must encompass a diversity of geographic and demographic characteristics, including urban, rural, flat, mountainous, more economically disadvantaged, less economically disadvantaged , close to resources/ partners, and far from resources/ partners.	Count	Copies of four signed agreements to participate provided to DOE.	Active and collaborative community participation is essential to research tasks in Budget Periods 2 and 3.
GNG-1D	12	Analysis of Stakeholder Interview Content	Report analyzing current state of energy-poverty nexus, energy security, and solar energy projects in low-income communities and solar energy markets and policy in Puerto Rico, reviewed by 10+ stakeholders (who are pre-approved by DOE)	Documentation with third party review	Report and affirmations from reviewers that they reviewed the report and provided feedback provided to DOE.	Understanding the evolving landscape of energy insecurity, solar energy markets, and solar energy policy in LMI communities in Puerto Rico is important for designing Budget Period 2 and 3 activities.
2.4.1	13	Case study	Data collection protocol for case studies defined	Documentation	Data collection protocol	To ensure significant impact from case studies,

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
		data collection protocol			submitted to DOE for review.	rigorous data collection strategy defined for implementation.
2.5.1	14	Model definitions and capabilities	Desired capabilities of models co-defined between team and case study communities	Documentation	Statement of desired model capabilities and evidence of community review provided to DOE	To ensure models provide communities with the information they desire, discussion of model capabilities to occur prior to model development.
2.7.1	14	Solar technical potential data	Data publication	Screen share	Confirmation provided to DOE of availability of data on Solar-for-All (http://maps.nrel.gov/Solar-for-All) and data.gov websites.	Ensure public availability of data.
2.7.2	15	Disseminate solar technical potential data and findings to stakeholders	Information sheet about data and key findings circulated to 100+ energy researchers, solar industry, energy advocacy groups, communities, and other stakeholders (distribution strategy discussed with DOE)	Documentation	Information sheet provided to DOE along with distribution list/locations.	Ensure data reaches those who can use it.
2.7.3	16	Report publication (from GNG-1D)	Report published and disseminated (using same distribution lists as 2.7.2)	Documentation	Copy of report and evidence of publication provided to DOE.	Publication of key data and findings from Budget Period 1.
2.5.2	18	Model energy consumption	Model generated from energy demand data	Screen share and Documentation	Description and demo of model and performance provided to DOE.	Energy demand model necessary for simulating solar energy solutions; interim milestone for GNG-2A.
2.6.1	18	Planning for community planning initiatives	Community co-design forums held in all four case study communities to discuss potential goals and processes for community energy planning in Budget Period 3 (see 3.8.1)	Documentation	Confirmation provided to DOE of meeting, along with agenda and participant feedback.	To ensure success of community energy planning, early consultation and co-design is important; interim milestone for GNG-2C.
2.7.4	18	Publication of solar installation data	Data publication	Screen share	Confirmation provided to DOE of availability of data via NREL Open PV database (https://openpv.nrel.gov).	Improve understanding of PV landscape in Puerto Rico.
2.4.2	19	Case study data review	Evaluation of data for each case study to assess completeness and identify follow-up data needs	Documentation	Copy of evaluation and data needs assessment	Data required for analyses of energy-poverty nexus across case studies; interim milestone for GNG-2B.

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
					submitted to DOE.	
2.5.3	20	Model financial implications for communities of solar energy solutions	Mathematical/ systems model developed to enable informing community decisions by generating insights into the distribution of financial costs and benefits for the community from different ownership and project designs, drawing on data from in depth case studies (2.4.2) and using assumptions in line with best practices in Puerto Rico	Screen share and Documentation	Description and demo of model and performance provided to DOE.	Energy financial model necessary for simulating solar energy solutions as part of community energy planning processes; interim milestone for model development.
2.6.2	21	Community energy planning processes	Draft planning process design for each community submitted to at least 5 community leaders and stakeholders for review (who are pre-approved by DOE)	Documentation with third party review	Draft plans and affirmations from reviewers that they reviewed the plans and provided feedback provided to DOE.	Continued co-design of planning process; interim milestone for GNG-2C.
2.6.3	23	Community leader training	Training will be provided in community energy planning processes to at least 2 leaders from each case study community	Documentation	Agenda of training meeting and evidence of participation sent to DOE.	Leaders will help co-organize and co-lead community energy planning processes in Budget Period 3.
2.7.5	24	Journal article	Journal article drafted and submitted for review on the energy-poverty nexus and solar energy potential, markets, and policy in Puerto Rico	Documentation	Copy of draft article and submission sent to DOE	Generalizable findings from the research in Budget Periods 1 and 2.
2.7.6	24	Outreach to project funders and developers, government officials, and others involved in providing solar solutions for low-income communities in Puerto Rico	At least 50 stakeholders engaged via a presentation, webinar, conference call, or similar. At least 15 are project funders/developers and 15 are government officials	Count	Presentation materials and attendee list (with contact info) sent to DOE.	Ensure results get disseminated to relevant decision-makers in Puerto Rico.
GNG-2A	24	Models of energy consumption and financial	Models accurately forecast energy demand and simulate financial implications of solar projects, correlated with parameters that potentially affect consumption behavior, for each case	Screen Share and Documentation	Quantitative simulation and validation results provided to DOE.	Modes are important for providing short-term energy demand forecasts and distributions of financial implications of solar projects that will be

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
		implications for communities of solar project design and ownership models	study community. Average hourly energy demand model predictions validated to be no more than 20% different for a random sampling of at least 5% of the real and modeled time periods.			later used during dynamic optimization of proposed solutions during community engagement processes in Budget Period 3 (3.8.2).
GNG-2B	24	Analysis of energy-poverty nexus for LMI communities using data collected from case studies	Four analyses delivered that provide key insights into problems that solar interventions could solve to make a difference for communities. Analyses reviewed by at least 5 independent social researchers and by at least 5 community leaders, members, and stakeholders in each case study (who are pre-approved by DOE).	Documentation with third party review	Four energy-poverty nexus analysis reports and evidence from reviewers of reviews and feedback provided to DOE.	Identification of problems and agreement by communities are important for success in developing solutions during community engagement processes in Budget Period 3 (3.8.1).
GNG-2C	24	Community energy planning processes	Planning process for each of four communities is defined by project team.	Documentation	Four roadmaps provided to DOE along with sign-off by community points of contact.	Agreement on planning processes is key to success of stakeholder engagements in Budget Period 3 (3.8.1).
GNG-2D	24	Solar energy solutions for LMI communities	Inventory of potential candidate solar energy solutions for LMI communities developed and reviewed by at least 10 stakeholders (who are pre-approved by DOE)	Documentation with third party review	Inventory and affirmations from reviewers that they reviewed the inventory and provided feedback provided to DOE.	Planning processes in Budget Period 3 (3.8.1) will need an inventory of potential solutions to consider.
3.8.1	27	Initial community energy planning meetings	Community energy vision and potential solar solutions identified and deliberated in community engagement meetings	Documentation	Meeting agenda, participant lists, and summary reports of results of meetings provided to DOE.	Continued co-design and co-implementation of community energy planning; interim milestone for EOP-A.
3.8.2	30	Solution simulations	Community identified solutions simulated using models of energy demand and community financial implications and energy flow optimization capabilities of UPRM.	Screen share and documentation	Simulation results provided to DOE.	Continued co-design and co-implementation of community energy planning; interim milestone for EOP-A.
3.8.3	33	Second community energy planning meetings	Community energy roadmap or strategy developed via 2-day meetings in each case study community to discuss simulation results, revise and iterate,	Documentation	Roadmap or strategy document submitted to DOE for review.	Continued co-design and co-implementation of community energy planning; interim milestone for EOP-A.

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
			and finalize community energy roadmap or strategy			
3.10.1	33	Community solar energy training curriculum	Curriculum drafted and reviewed by at least 4 external solar energy experts (who are pre-approved by DOE)	Documentation with third party review	Draft curricula and affirmations from reviewers that they reviewed the curriculum and provided feedback provided to DOE.	Continued co-design and co-implementation of community energy planning; interim milestone for EOP-B.
3.9.1	34	Energy-poverty nexus and solar solutions	Draft report providing results of analysis submitted to at least 5 solar energy stakeholders for review (who are pre-approved by DOE)	Documentation with third party review	Draft report submitted to DOE for review and affirmations from reviewers that they reviewed the report and provided feedback provided to DOE.	Report will enable widespread circulation of lessons from energy-poverty nexus analyses and solar solutions analyses to diverse groups of stakeholders; interim milestone for EOP-C.
3.9.2	36	Outreach to project funders and developers, government officials, and others involved in providing solar solutions for low-income communities in Puerto Rico	At least 100 stakeholders engaged via a presentation, webinar, conference call, or similar. At least 30 are project funders/developers and 30 are government officials At least 50% were not in group for milestone 2.7.6	Count	Presentation materials and attendee list (with contact info) sent to DOE.	Ensure results get disseminated to relevant decision-makers in Puerto Rico.
EOP-A	36	Community energy roadmaps or strategies	Draft roadmaps/strategies reviewed by at least 5 key community stakeholders and 5 external stakeholders or researchers (who are pre-approved by DOE)	Documentation with third party review	Final roadmaps and affirmations from reviewers that they reviewed the roadmpas and provided feedback provided to DOE.	Roadmaps provide strategies for low income communities to pursue future implementation of solar energy solutions.
EOP-B	36	Community solar energy training	Training course offered to at least 15 students by UPRM	Documentation	Final training curriculum and demonstration of offering submitted to DOE.	Curriculum will enable training of stakeholders to work effectively with low income communities to advance planning for solar energy futures.

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
EOP-C	36	Energy-poverty nexus and solar solutions results	Report finalized incorporating reviewer feedback, published, and circulated to at least 100 relevant energy stakeholders (regulators, utilities, solar companies, LMI energy communities and advocates, etc.) Webinar hosted to discuss results of study. Invites sent to same stakeholder list.	Documentation	Final report and slide deck as well as list of those engaged submitted to DOE.	Report will document key findings from the project illustrating how solar energy can provide solutions to the energy-poverty nexus challenges that confront low income communities for diverse stakeholders to use to advance solar energy to the benefit of other communities.
EOP-D	36	Journal article	Journal article drafted and submitted for review on community-based solar energy planning and solutions in Puerto Rico	Documentation	Copy of draft article and submission sent to DOE	Generalizable findings from the research in Budget Periods 2 and 3.

7. Project Results and Discussion:

***Budget Period 1**: March 2019 – April 2020*

Task 1.0: Map the PV Technical Potential and Potential to Satisfy Energy Demand for Puerto Rico by Geography, Tenure, and Income

This task was fully completed by the NREL partner team, resulting in published databases of solar developable planes on residential rooftops as well as Census Tract-level estimates of solar technical potential and municipality-level estimates of the potential for rooftop solar to offset energy demand in Puerto Rico by building tenure and income (GNG 1A, 1B). Links to these databases (Mooney et al. 2020; Mooney and Waechter 2020) can be found in Section 10. Products.

Task 2.0: Evaluate the Current State of the Energy-Poverty Nexus and Solar Energy Markets, Projects, and Policy in Puerto Rico

This task was fully completed by the ASU and UPRM teams in collaboration through interviews in 2019-20 with 100+ diverse stakeholders in the Puerto Rico solar innovation ecosystem, resulting in the publication of a technical report that was reviewed by experts in the field and disseminated publicly via the project website and to the email list of 100+ Puerto Rico stakeholders with interest in community solar energy (Rivera Matos et al 2020) (GNG 1C).

Task 3.0: Identify, Engage, and Recruit Communities to Participate as Case Study Research Sites for Comparative Analysis of Solar Energy Solutions for Low-Income Communities

This task was fully completed by the ASU and UPRM teams in collaboration through a detailed quantitative assessment of potential partner communities that examined their vulnerability to risks, energy disadvantage, income, geography, social characteristics, and other data. 20 initial communities were down-selected to 10 finalists based on initial comparative data analysis. A final down-select process was carried out via a more detailed data analysis, as well as a review of the relevance of community solar perspectives and activities to key project design factors (energy-poverty nexus dynamics, social value creation, community co-design), resulting in the selection of 4 community partners, all of which agreed to participate in the project and collaboratively developed with the project team an agreed upon set of collaborative engagement and co-design efforts (as documented in exchanged emails, due to COVID restrictions; GNG-1D).

***Budget Period 2**: April 2020 – November 2021*

Task 4.0: In-Depth Analysis of the Energy-Poverty Nexus in Case Study Communities

This task was fully completed by the ASU and UPRM project teams collaboratively through detailed qualitative dialogues with community leaders and members in each community, completion of a survey of community members in each of the four communities, and conduct of detailed energy-poverty nexus research analyses for each community (GNG 2B). This task was considerably slowed from its original timeline due to the COVID pandemic which resulted, in Puerto Rico, in an extensive shut down, especially in vulnerable, elderly communities facing high infection and mortality risks. The results of this task were incorporated into a technical report (Rivera Matos et al. under revision) that was reviewed by experts in the field and community leaders. Major revisions have been completed. The report awaits addressing a few final reviewer comments, author sign-off for publication, and dissemination to the public via the project website, to the project's email list of 100+ stakeholders in Puerto Rico, and to the project's community partners.

Task 5.0: Develop and Validate Models of Energy Demand and Financial Implications of Project Design and Ownership for Community Energy Planning

This task was fully completed through the development of an energy demand model by the UPRM team and a solar-and-storage performance and financial assessment model by the ASU team. Both models were validated for accuracy (GNG 2A; see Figures 1 and 2). These two models were subsequently integrated to enable full simulation of potential solar-and-storage design configurations during community co-design incorporating energy demand scenarios, solar sizing, battery sizing, and grid electricity pricing.

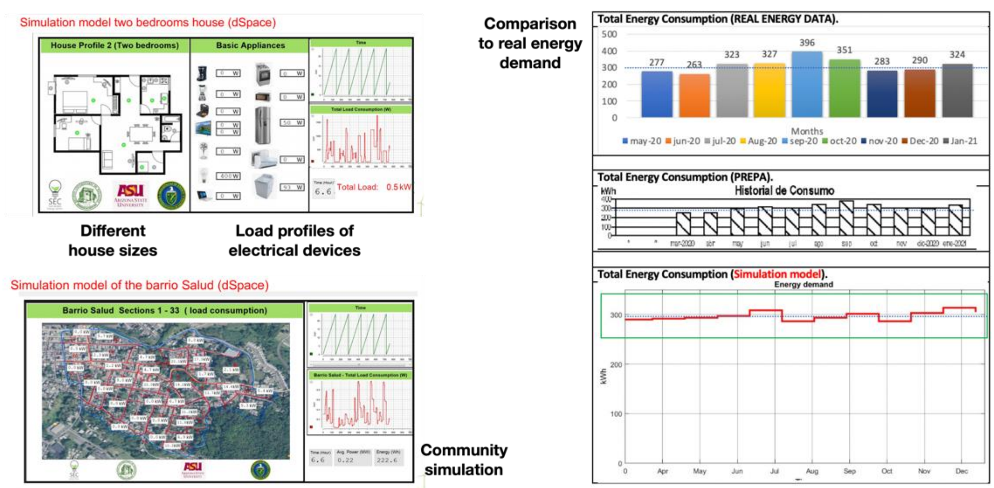

Figure 1. Validation of Community Load Simulation Demand Model

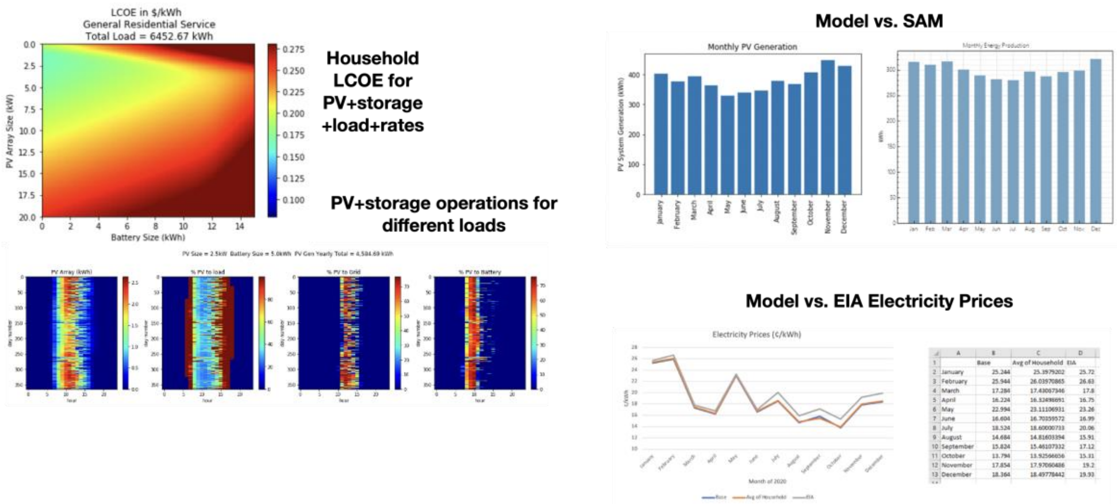

Figure 2. Validation of PV+Storage Model

Task 6.0: Prepare for Community Solar Energy Planning Processes

This task was fully completed by the ASU and UPRM teams collaboratively working with leaders in each community to plan community co-design activities. A community engagement and co-design plan was co-developed with the research team and documented and agreed to by each community via email exchange with community leaders (GNG 2C). This process was considerably slowed from its original timeline due to the COVID pandemic which resulted, in Puerto Rico, in an extensive shut down, especially in vulnerable, elderly communities facing high infection and mortality risks. An inventory of existing types of community solar projects was developed for use in community co-design conversations (Gregory et al. 2024) (GNG 2D).

Task 7.0: Disseminate Interim Research Results

This task was fully completed by the ASU and UPRM teams. A public webinar was held Dec. 17, 2020, by the research team for ~100 Puerto Rico solar stakeholders to report on the results of research to date. The presentation was subsequently published on the project website: http://cohemisferico.uprm.edu/solar2020/index.html. Based on the research results from Budget Periods 1 and 2, three journal articles were written and published (Echevarria et al. 2022, Biswas et al. 2022, and Campo-Ossa et al. 2023), and a conference paper was presented (Gregory et al. 2023).

***Budget Period 3**: December 2021 – March 2024*

Task 8.0: Conduct and Comparatively Evaluate Community Solar Energy Planning

This task was fully completed by the ASU and UPRM teams through collaborative engagement with each of the four communities in planned community co-design activities, as well as via extensive dialogues between project researchers and community leaders and members, participant observation by project researchers of community energy events, and observation and analysis of community encounters with energy. When done using co-design methodologies, with extensive community engagement and deliberation, community planning processes do not necessarily follow a replicable timeline. Nor did our partner communities start in identical places in their planning. As a result, different communities achieved different outcomes – and all four communities are continuing to do solar energy planning, three with continued support from different parts of the ASU and UPRM project teams through various means. Final reports on data and results from the project are being finalized for each community presenting and synthesizing project data and analyses for community participants (EOP-A). Once complete, we will share these reports with community leaders and offer the opportunity for a final review and discussion with each.

Task 9.0: Publication and Dissemination of Final Results

This task is mostly complete. Several publications have resulted from the project beginning to explore experiences with community co-design (Rivera Matos 2021, 2023, Echevarria 2021), as well as integrating insights from this project into higher level analyses of energy transition planning (Miller et al. 2023), as well as a conference presentation discussing strategies for using customization to accelerate solar adoption (Honsberg et al. 2023). A final project technical report on community empowerment through community co-designed solar initiatives is in preparation for dissemination to the NREL community solar community of practice and Puerto Rico community solar organizations (Miller et al. in preparation), which will be disseminated via a webinar to Puerto Rico and national stakeholders in community solar once complete (EOP-C). A final research article on the capabilities approach to solar as a resilience tool is also in preparation (Gregory et al. in preparation), and a second final research article on community co-design for solar customization is also envisioned (EOP-D).

Task 10.0: Prepare Training Program for Community Solar Energy Planning

This task was fully completed by the ASU and UPRM teams who developed a curriculum for students and community solar organizations based on the project's activities and findings. That curriculum was piloted in a 2-day workshop on May 4-5, 2023, with 22 attendees, including undergraduate and graduate students and faculty at UPRM, community solar organizations, and community leaders (EOP-B).

8. Significant Accomplishments and Conclusions:

8. A. Multiple Datasets Describing the Solar Technical Potential of Puerto Rico: A key early accomplishment of the project was to create and publish multiple datasets that describe: (1) the developable solar planes for all residential building rooftops in Puerto Rico (including geospatial location, shape, area, orientation, shading characteristics, size of deployable PV system, and annual electricity generation associated with each plane) (Mooney and Waechter 2020); (2) the annual solar technical potential generation associated with each Census tract (Mooney, Waechter, and Miller 2020); and (3) the percentage of electricity consumption within each Puerto Rico municipality that can potentially be offset by rooftop solar generation, as a function of building type, building tenure, and income (Mooney, Waechter, and Miller 2020).

These datasets provide publicly available/accessible data that can be used: (1) to analyze aggregate, high-level Puerto Rico renewable energy opportunities, strategies, and policies under diverse scenarios (e.g., this data was used as the basis for distributed solar scenario analysis in the PR100 study, Baggu et al. 2024); and (2) to conduct disaggregated, high-resolution planning of community-scale solar initiatives by locating and assessing available solar developable planes and technical potential for households within a specified geography (e.g., as we did in this study).

Analysis of this data generated several important conclusions regarding solar technical potential in Puerto Rico. For example, the total technical potential for residential buildings in Puerto Rico is 20.35 GW, with 24.55 TWh of annual generation potential. This exceeds the total system load in Puerto Rico (18.9 TWh in 2021, Baggu et al. 2024). Buildings with low- and moderate-income residents have peak generating capacity of 9.8 GW and annual generation potential of 11.9 TWh. Perhaps most importantly, across all categories of building type, tenancy, and income, available solar technical potential in Puerto Rico exceeds current electricity consumption, suggesting that rooftop solar can make a substantial contribution to Puerto Rico's future energy needs (Figure 3).

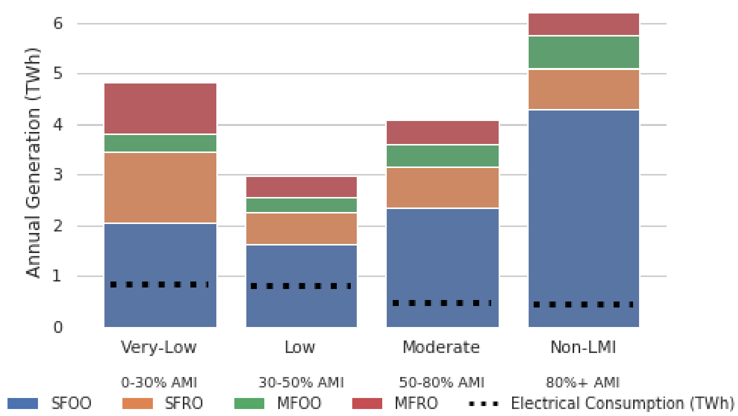

Figure 3. Generation potential of rooftop solar energy by building type, tenancy, and income in Puerto Rico (SF = single family; MF = multi-family; OO = owner occupied; RO = renter occupied) (Mooney, Waechter, and Miller 2020).

Rooftop potential also significantly exceeds electricity consumption for buildings occupied by low- and moderate-income residents across all municipalities (Figure 4).

Figure 4. Percent of electricity consumption in low- and moderate-income residential buildings that can be offset by rooftop solar generation on those buildings by municipality (Mooney, Waechter, and Miller 2020).

8. B. Development of an Integrated, Sociotechnical Systems Model Suite for Informing Community Solar Customization: the project's second key accomplishment is the development of an integrated suite of computational modeling functionality that allows for annual simulation of customizable solar-and-storage solutions, including electricity loads; PV generation, electricity storage, and electricity use; and utility electricity pricing. The value of this modeling functionality is to allow dynamic co-exploration and co-design with communities of solar-and-storage solutions under diverse scenarios (including community-generated scenarios). Specifically, the modeling suite simulates a holistic system comprised of electrical devices, the daily and annual temporal pattern of their use, solar generation, battery storage, and electricity grid supply, as well as the price of solar, storage, and grid electricity, to enable researchers and communities to collaboratively compare the value of solar-and-storage solutions under different scenarios, via analyses of what level and pattern of electrical device use service it will provide, at what cost in comparison to grid electricity, and with what gaps in the case of a grid outage.

Simulations can include any combination of loads, e.g., existing household or community electricity use, critical load electricity use during outages, expanded desirable electricity use under less constrained scenarios, or others (for details on the load simulation model, see Campo-Ossa et al. 2023). For any given load scenario, the model can simulate the ability of differently configured and sized solar-and-storage systems to meet demand, as well as patterns of electricity shortfalls and, thus, need to supplement with grid electricity. This allows communities the opportunity to see how well a given solar-and-storage solution can meet existing, critical, or desired future loads. Based on system cost, need for grid electricity supplementation, and utility electricity pricing, the model can also simulate levelized cost of electricity for ranges of solar-and-storage system size configurations, allowing for community understanding of the cost trade-offs associated with different configurations (for details on the solar-and-storage model, see Gregory et al. 2023; Routhier et al. 2021). Finally, patterns of electricity shortfall can also be analyzed to assess system resilience performance in the case of grid outages, showing communities the frequency and duration of periods where electricity would be unavailable on a daily, monthly, or annual basis – and allowing communities to explore either alternative electrical device use patterns or solar-and-storage system configurations to examine the range of possible strategies for better serving their needs under electricity outage conditions (see Gregory et al. in preparation).

As shown above in Figure 2, two of the key capabilities of this integrated model suite are to be able to: (1) analyze how any solar-and-storage design configuration performs, over an annual period, given local solar input and local electricity load, distributing power to the load, battery, and grid (lower left panel); and (2) evaluate the resulting levelized cost of electricity for the system (upper left panel). This can be done, as the upper left panel illustrates, across a full suite of potential design configurations, allowing optimization of PV and battery sizing to desired LCOE or other goals.

Based on these capabilities, the model is also able to inform resilience assessments, which are particularly important in Puerto Rico communities that face frequent grid outages. For example, Figure 5 shows how a particular solar-and-storage design configuration would perform under two different scenarios: (1) only operating critical appliance loads (as defined by the community) (top row); and (2) operating the whole house load (as currently configured) (bottom row). The critical loads scenario shows routine battery states that remain well above zero almost the entire year, with only one short “outage” (time when, if the grid was down, neither the PV nor battery would provide power). By contrast, attempting to run the whole house load on the same solar-and-storage system generates much higher frequency and duration of outages and frequent depletion of battery storage.

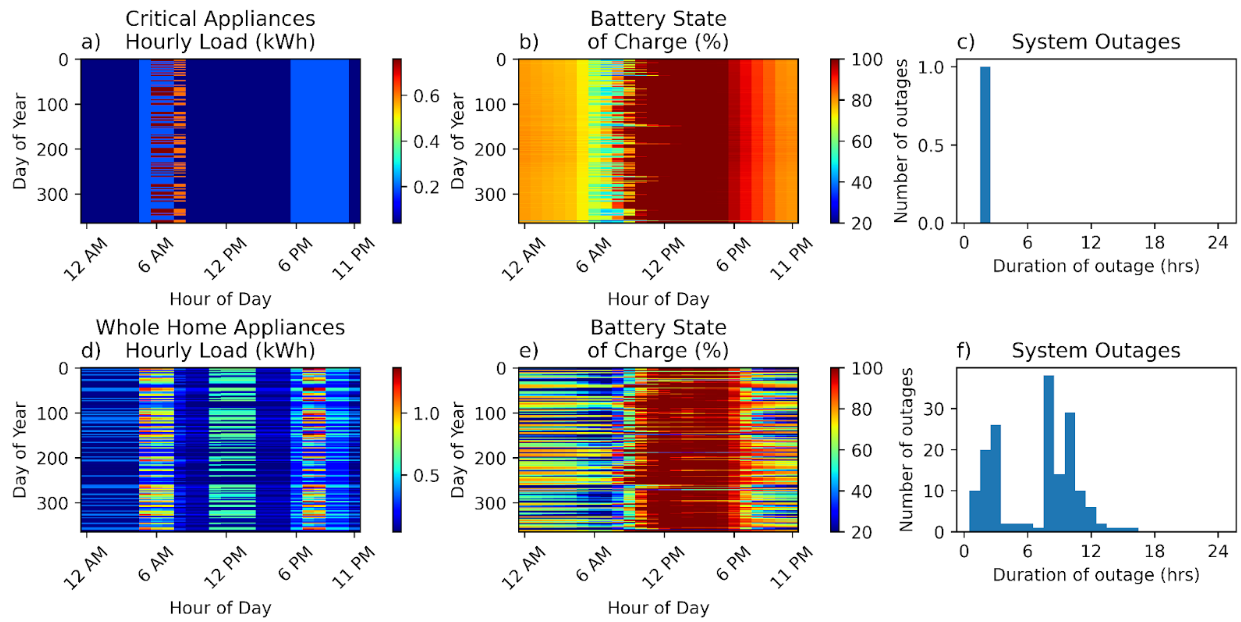

Figure 5. Illustration of the model’s capabilities to enhance understanding of resilience.

Based on these methods, the model is further able to calculate a figure of merit for resilience performance, again allowing for optimization across a wide range of solar-and-storage design/sizing configurations. We define the figure of merit (FOM) in terms of the LCOE for the system divided by its relative uptime. Figure 6 shows the figure of merit for the critical loads scenario (left) and whole home load scenario (right).

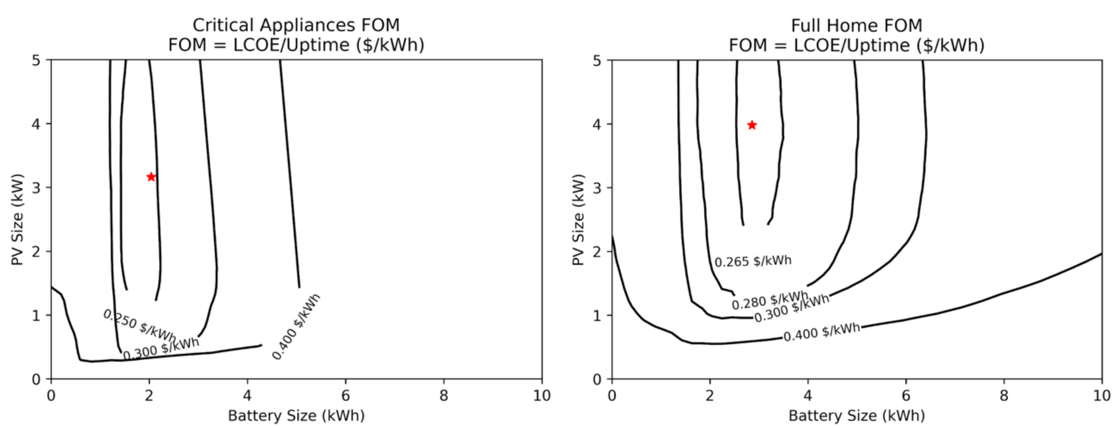

Figure 6. Evaluation of solar-and-storage system reliability vs. cost trade-offs for two scenarios (critical loads, whole home load) for a community in Puerto Rico.

8. C. Characterizing the Nexus of Energy Insecurity and Human Insecurity at the Community-Level: A third key project innovation is the theoretical conceptualization of what we term the "energy-poverty nexus" (Biswas et al. 2022) and its characterization at the community level for multiple communities in Puerto Rico (Rivera-Matos et al. in review). Under the Justice40 initiative, the characterization of energy justice and injustice is a critical element in assessing community metrics of disadvantage and defining strategies for delivering community benefits. Frequently, however, energy justice and injustice are measured using either singular metrics (e.g., energy burden, see Drehobl and Ross 2016) or multidimensional approaches (see, e.g., Mitra and Brucker 2019, although they did not include energy). Even the latter, however, tend to treat multiple aspects as poverty and insecurity as independent, stackable quantities rather than use nexus-type framings that recognize the interdependent dynamics that link multiple facets together in reinforcing feedback loops.

Our theorization of the energy-poverty nexus is meant to build on multidimensional approaches to poverty and insecurity by enabling characterization of the negative feedbacks that occur dynamically among different forms of energy, economic, health, food, and human insecurity and poverty – and thus better describing the reality of complex, interdependent challenges facing low-income communities. An important conclusion from the research carried out on this project and other closely related work is that the dynamics of the energy-poverty nexus – like the food-energy-water nexus – exhibit considerable heterogeneity from community to community (Rivera Matos et al. in review). Consequently, efforts to design clean energy solutions that aim to provide community benefits in the form of reductions in energy poverty or injustice must systematically characterize the dynamics of the energy-poverty nexus – and identify pathways through which clean energy interventions will reduce or reverse those dynamics – in order to reliably anticipate, design for, and assess the effectiveness of clean energy interventions in contributing to meeting Justice40 goals.

In Puerto Rico, for example, low-income communities experience some broad, shared facets of the energy-poverty nexus, albeit with different weighting and significance, while other facets are distinct to particular communities. Median energy burdens by Census Tract are high for Puerto Rico low-income communities (Figure 7), as a result of high energy prices and extremely low incomes (in comparison to US averages), but vary across the island, from 10% to 28%, for households below 80% Area Median Income. Some areas with the highest energy burdens (e.g., in the mountainous areas of central Puerto Rico) face additional difficulties from high frequency and long duration outages (e.g., days to weeks and even multiple outages lasting months, see Castro-Sitiriche et al. 2023) that compound energy burdens by forcing communities to pay high costs for electricity backup solutions like generators. These areas have also faced greater outmigration, both to urban Puerto Rico and the US mainland, reducing community cohesion and trust in ways that undermine the ability to coordinate community initiatives and pursue shared solutions to energy justice and resilience. Efforts to find meaningful energy solutions that address the needs and contexts of Puerto Rico mountain communities must thus grapple with a unique set of social, economic, and technological characteristics that work together to perpetuate and exacerbate poverty in the region. In other parts of Puerto Rico, different circumstances create needs for different kinds of solar solutions.

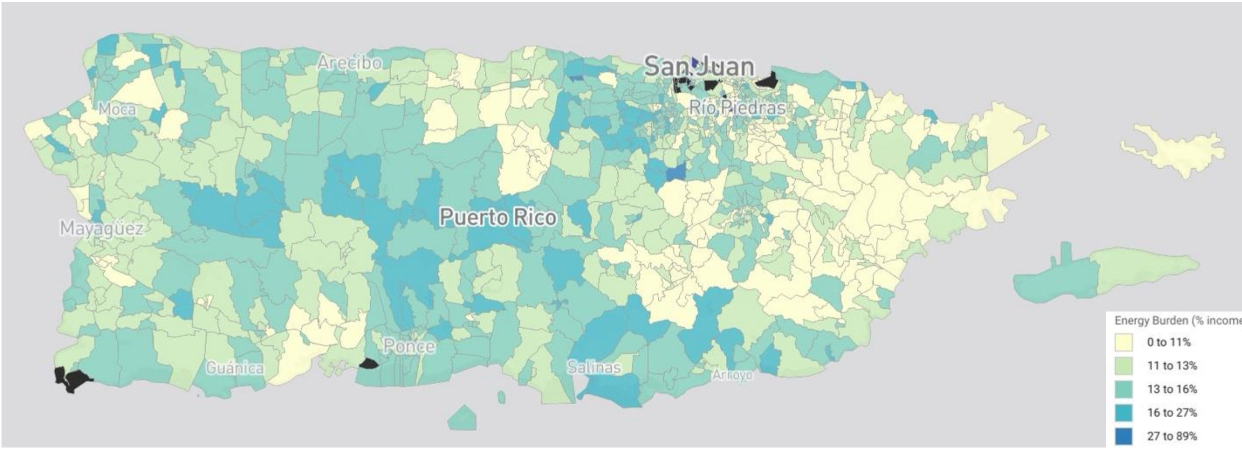

Figure 7. Median energy burden by Census Tract for households earning less than 80% of area median income. From DOE LEAD data tool: https://www.energy.gov/scep/slsc/lead-tool.

8. D. Community Customization of Solar Energy for Social Value Creation: A fourth important accomplishment of the project has been to demonstrate the potential of community customization of solar energy for social value creation (Miller et al. in preparation). The social value of energy is a user-centered theory that emphasizes the meaning and significance of energy use, for the user. The theory highlights that energy and energy systems have no inherent value, in and of themselves, unless users are able to use them to create energy services, e.g., light, heating, cooling, work, equipment charging, etc., that have value to the user (Miller et al. 2015, 2018, 2022). Techno-economic methods use levelized cost of energy calculations to evaluate the cost of energy generation and supply. By contrast, social value of energy methods seek to determine the value or benefit that the user obtains from the use of energy. This is perhaps most easily understood for a business that derives revenue from products or services that necessitate the use of energy to produce, but the same concept applies to other non-economic energy uses. If the value of energy is greater than its cost, then energy use contributes positively to improved wellbeing – but if the cost is greater than the value, then energy use undermines wellbeing.

Our project provides important evidence that, through co-design, community customization of solar energy initiatives and solutions can contribute to enhancing the social value of solar energy. Customization of community energy futures is a concept that was introduced as part of a workshop organized in part by the project team, in collaboration with the National Renewable Energy Laboratory, to capture the idea of community co-design of futures that adapt energy technologies – and therefore advance energy sustainability and justice – in ways that fit community contexts, goals, and capabilities (see, e.g., Gearhart 2021). In pursuing community dialogues around solar solutions with four partner communities, four very different conversations evolved that emphasized the different contexts, goals, capabilities of each community – grounded in the differentiated dynamics of the energy-poverty nexus experienced by that community – and the need for differently configured solar solutions to fit the different community settings. Across the four communities, preferred solar-and-storage solutions varied by ownership model, form of financing, PV size, battery size, key performance criteria and expected standards of performance, model of resilience, primary forms of social value creation, and more.

For example:

- In one remote community, which was among the most economically disadvantaged as well as the most highly impacted by frequent, long duration electricity outages, the community prioritized small emergency backup solar-and-storage systems capable of supplying participating households – as well as key community resources, such as water and communication – with electricity for critical loads. Each house had to choose to participate, however, which entailed both a financial commitment to purchase the system and a social and behavioral commitment to maintain the system and operate it within its capabilities.
- In a second community, which experienced frequent but less severe electricity outages but had a high fraction of elderly residents and a strong community organization, a different choice was made. Primary concerns included not only resilience but also under-utilization of energy and extremely high energy burdens. The community therefore decided to pursue a grant to fund a solution for the entire community that would put a whole-house solar-and-storage system on every rooftop that was sized to allow each household to expand its energy consumption and provide low-cost electricity, subsidized by the grant, with maintenance carried out by the community organization.

Interestingly, among our community partners, cost reductions on electricity bills was generally not a high priority for most community participants. One community did not have official electricity service and so paid no bills (although the community did encumber significant costs to secure an alternative electricity supply). Perhaps not surprisingly, given Puerto Rico's relatively frequent electricity grid disruptions, reliability of supply was a common objective, but the priority of reliability, the desired reliability performance standard, and the level of electricity supply varied markedly across communities. As a result, battery storage to allow electricity supply during grid outages was an essential component of all designs, although, again, the level and type of battery storage varied across visions and designs. For very low-income communities, the inclusion of batteries made overall project/system costs substantial, increasing levelized costs of electricity provided and thus reducing potential opportunities for bill savings. The one community that prioritized bill savings aimed to achieve the result through obtaining grant funds to pay for the solar-plus-storage system.

To summarize, each community identified distinct solar-plus-storage solutions as its desired approach, accompanied by distinct forms of social value creation (prospective benefits delivered to the community) that fit with (a) community needs, goals, and contexts; and (b) opportunities to mitigate key local energy-poverty nexus dynamics within the community.

8. E. Resilience as a Capabilities-Based Framework: As noted in 8.D., resilience was a high-priority objective for all our partner communities, driven by Puerto Rico's highly unstable grid. In our community survey, 25% of respondents indicated daily grid outages, with another 29% reporting weekly outages. In fact, several of the participating communities have experienced at least three outages lasting more than a month in duration over the past 5 years (Hurricane María, Hurricane Fiona, and the 2020 earthquakes). It isn't surprising, therefore, that communities prioritized resilience as a goal or identified battery storage as a key component of system configuration.

It's important to emphasize what resilience means to communities, however. In much engineering literature, resilience is defined as the ability to bounce back to normal system functionality, which, in this case, would mean grid power restoration. For communities, however, resilience meant the ability to accomplish key tasks during outages that would provide a degree of peace of mind, especially during long-duration outages. Out of dialogues with communities to co-explore this idea, we developed an important approach to resilience built around Amartya Sen's concept of *capabilities* (Sen 1990). For Sen, capabilities refer to the ability of individuals or households to create a rich and thriving life for themselves. Capabilities are, at once, therefore, a question of user knowledge and skills (what an individual knows how or has the skills to do), user access to resources and infrastructure that support the ability to exercise that knowledge, and user freedom to exercise their knowledge, using their accessible resources and infrastructure, to create a good life (in comparison, e.g., to situations where users may be prevented from using their knowledge or resources to pursue that same good life).

Taking this approach, we can assess the contribution of solar-and-storage solutions to community resilience in terms of (a) the access of communities to these solutions (only one of the four communities currently has functioning solar-and-storage systems at the household level, for some households; a second has a larger-scale solar-and-storage system for the community-managed water system, although it was broken during Hurricane Fiona); (b) what the system allows the individual or community to be able to do (e.g., how much power does the system provide, on what temporal patterns, at what cost, how does the power availability compare to the identified critical loads; see, e.g., Figure 5 and 6 above); and (c) what the individual or community knows about how to use their system(s) effectively, e.g., through proper maintenance, protection of the system during storms, appropriate use of the system, the possibility of temporal shifting of high demand device use to match high solar generation times, the protection of batteries through careful management of charge and discharge, etc.

Community solar-and-storage solutions must be compared, of course, to alternative strategies for managing electricity outages, e.g., the purchase and use of diesel generators. Generators entail costly fuel use (when fuel is available, which it sometimes is not, especially when long-term outages correspond to extreme events such as hurricanes and earthquakes that also disrupt broader supply chains) and are not intended for long-term, continuous operation – and they emit carbon dioxide at higher intensities. In our participating partner communities, many residents purchased and used generators but would prefer to purchase solar-and-storage backup systems instead, aside from the high, upfront purchase price. One community – with the highest outage frequency and duration – so valued at least minimal resilience that they tackled this challenge by collaboratively designing extremely small (2 kW, 5 kWh) solar-and-storage systems that they could afford to buy for themselves – and could train themselves to use effectively. When used properly, these systems provided key capabilities that allowed households to significantly reduce worries and concerns about outages and, instead, to know that they have critical electricity services, when needed, using a sustainable, community co-designed approach. Our integrated modeling and simulation suite (described 8.B.) is well suited to analyzing how differently designed systems perform with regard to enabling people and communities to use various devices, and various quantities and patterns of electricity, to create different kinds of social value during grid outages – and therefore for collaboratively exploring and assessing resilience with community partners.

The key contributions of this work include: (1) to complement a common technical focus on system output with a robust analysis of whether and how people are able to use the system to achieve positive impact (social value creation); (2) to provide modeling capabilities that allow for analyses of how the technical functioning of differently designed and customized solar-and-storage systems combines with different behavioral use patterns to enable or constrain household and community capabilities; and (3) to provide illustrative examples of communities using this approach successfully.

8. F. Community Empowerment: We learned a great deal in this project about the possibilities and limits of community co-design of solar-and-storage solutions as an approach to community empowerment. Our “community-empowering solar” report (Miller et al. in preparation) will provide a detailed articulation of these lessons. Here are a few preliminary conclusions:

- Community customization and co-design, when carried out using thorough engagement methods and oriented to ensure appropriate community engagement and voice, is a pathway to given communities power to imagine and shape their energy futures and to design solar-and-storage configurations that deliver meaningful social value creation and benefits to communities – often extending significantly beyond access to clean electricity.
- Successful community empowerment is as much about capacity building as it is about engagement. Communities must acquire the knowledge and skills to become effective co-designers of solar-and-storage solutions and also to become effective managers and users of solar-and-storage systems (where the latter is measured in terms of ability to maintain, protect, operate, and manage the systems).
- Community trust, cohesion, and leadership are essential and easily lost, both within the community and between communities and researchers. Vulnerable communities often lose or change leaders, which can easily disrupt co-design and implementation.
- A significant tension exists in community co-design projects between (1) situations in which communities are expected to arrive too quickly, with too little time or support to meaningfully engage in co-design processes, at a technical solution, resulting in suboptimal designs that deliver modest community benefits, and (2) situations in which community co-design processes are carried out separately and independently from financial or other support for community solar projects, thus leading to extensive community work, and often community fatigue, with little or no meaningful impact on communities and an extensive post-design struggle to (hopefully) find financing. Finding new modalities is essential that can both: (a) allow communities time for and power to shape community co-design of meaningful, customized solar solutions that deliver real community benefits, and

(b) provide communities with financial and technical support for implementation of projects that result from the co-design processes.

8. G. Power of Solar Imagination and Imaginaries to Accelerate Solar Adoption and Make It More Equitable and Just: One of the most important early conclusions of this project was the power of public imagination to accelerate solar adoption and to make it more just and equitable (Echevarria et al. 2022). This was an unanticipated finding of our work in the first year to characterize the solar innovation ecosystem in Puerto Rico. What we found was an almost universal imaginary (a theoretical idea that emphasizes collectively shared visions of the future that link technology to the achievement of improved lives and livelihoods) supporting solar energy as a tool for a just, sustainable, and resilient Puerto Rican future. The existence of the imaginary is interesting enough, sociologically, but two additional findings have the potential to help shape influential solar policy development.

The first important complementary finding is that, accompanying this imaginary, Puerto Rico has seen a rapid adoption of rooftop solar. To contextualize this finding, according to the NREL PR100 study, Puerto Rico had 680 MW of distributed solar in 2023, but this figure neglects off-grid systems, which may be significant. 680 MW amounts to ~210W per capita, which puts Puerto Rico in the top ten of states according to the Institute for Local Self-Reliance. This level of solar adoption is a remarkable achievement given four facts: first, Puerto Rico's median income is the lowest in the United States, less than 50% of the next lowest state, Mississippi; second, nearly all Puerto Rico solar systems include batteries, which dramatically raises the system cost; third, Puerto Rico does not benefit from the federal solar tax credit because residents do not pay federal income tax; and, fourth, given the cost of batteries, solar systems provide few savings for Puerto Ricans on their electricity bills. From a purely economic perspective, there is no reason to believe that Puerto Rico should have anywhere near 680 MW of distributed solar generation. Why do they? Because they collectively imagine that, by investing in solar-and-storage systems that provide resilience and other benefits (e.g., some level of independence from local electric utilities, which are not trusted), Puerto Ricans will improve their lives.

The second important complementary finding is that the solar imaginary in Puerto Rico hasn't just spurred individual households to adopt solar, it has also spurred a wide diversity of communities to explore how community solar initiatives could help address their energy poverty, inequality, and insecurity challenges. The four community partners in our project are only a few of the dozens if not hundreds of communities interested in finding solar solutions that create meaningful benefits for their residents and members.

Two key implications flow for solar policy. First, solar policy has traditionally emphasized solar costs as its primary lever for encouraging acceleration of solar adoption, either through reducing the cost of solar technologies (e.g., SunShot) or through providing subsidies (e.g., federal tax credits). But these strategies face limits, especially as adoption rises to the middle of the adoption s-curve, where fewer families can afford solar, even with tax credits (especially given recent inflation), and when technology costs fall to only a small fraction of overall installed system costs (which they have). In this new context, finding ways to stimulate positive solar imaginaries – i.e., stories that link solar adoption to collectively imagined desirable societal futures – has the potential to create significant new drivers of adoption, as it has in Puerto Rico, with people willing to invest much more in solar systems than otherwise expected.

Second, economically-grounded solar policies have traditionally failed significantly to advance solar justice, with adoption rates much higher among wealthy, white communities. Solar imaginaries that unleash community excitement and enthusiasm for solar solutions that provide meaningful community benefits, especially for vulnerable and disadvantaged communities, could help drive more inclusive solar adoption – especially if combined with policies that explicitly supported communities in building customized solar solutions that fit their needs, contexts, and goals.

In a recent conference paper, we also argue based in part on research from this project that customized solar solutions – including customized solar module design for multiple benefit streams – has the potential to be a next focus for a SunShot type initiative (Honsberg et al. 2023). Because module cost is now falling to a very small fraction of overall installed system cost, module technology improvements that enhance efficiency and reduce cost are less valuable. However, improvements that enhance multiple benefit streams (think of solar installations as more than just electron generators but creators of resilience, generators of distributed energy ownership, shade structures, cooling technologies, aesthetic enhancers of neighborhoods, etc.) can still significantly improve the benefit-to-cost ratio of the system and thus help encourage higher adoption rates. And, as argued above, if vulnerable and disadvantaged communities can be encouraged and facilitated in their efforts to put those multiple benefit streams to work for themselves through customized co-design, then accelerated solar adoption could also be more just and equitable.

9. Path Forward:

We are currently working on several follow-on initiatives that leverage and build on the work of this project. Three important ones are:

- Members of the project team continue to collaborate and partner with three of the four communities in this project and also with additional communities around Puerto Rico interested in solar solution. This includes the involvement of the project's UPRM researchers in a HUD Community Development Block Grant planning project that involves several communities, including Barrio la Salud and Villa Esperanza from this project. Project results have provided input information for those planning processes, which are wider and more inclusive than energy but certainly include energy. UPRM research team members and their colleagues have also been awarded additional research and project grants to explore community microgrids and electric vehicle charging infrastructure development, including with some of the communities in this project. Finally, the ASU and UPRM teams continue to collaborate voluntarily with the Veguita Zama community and their AMANESER partner organization in advancing the goals of that community and helping to spread the model to other communities.

- We recently submitted an NSF proposal to test the concept of community customization of solar solutions in the City of Phoenix, grounded in the idea of leveraging solar systems to address multiple urban crises while identifying and assessing models to significantly enhance deployment of non-rooftop solar within urban boundaries. If funded, the project will use the integrated socio-technical systems model suite developed by this project to assess the social and economic benefits of community solar project designs.
- Finally, we continue to work closely with solar engineers at ASU to explore further the idea of customizable solar systems as a strategy for enhancing multiple benefit flows and, as a result, improve solar benefit-to-cost ratios (Honsberg et al. 2023).

10. Products:

Journal articles:

1. Echevarria, Angel, Yíamar Rivera-Matos, Nafeesa Irshad, Christopher Gregory, Marcel J. Castro-Sitiriche, Richard R. King, and Clark A. Miller. "Unleashing sociotechnical imaginaries to advance just and sustainable energy transitions: The case of solar energy in Puerto Rico." *IEEE Transactions on Technology and Society* 4, no. 3 (2022): 255-268.
2. Biswas, Saurabh, Angel Echevarria, Nafeesa Irshad, Yíamar Rivera-Matos, Jennifer Richter, Nalini Chhetri, Mary Jane Parmentier, and Clark A. Miller. "Ending the Energy-Poverty Nexus: An Ethical Imperative for Just Transitions." *Science and Engineering Ethics* 28, no. 4 (2022): 36-55.
3. Campo-Ossa, Daniel D., Cesar A. Vega Penagos, Oscar D. Garzon, and Fabio Andrade. "Modeling, Load Profile Validation, and Assessment of Solar-Rooftop Energy Potential for Low-and-Moderate-Income Communities in the Caribbean." *Applied Sciences* 13, no. 2 (2023): 1184-1201.
4. Rivera Matos, Yíamar. "Grassroots Energy Emancipation through Solar Energy Projects: Narratives from Jayuya, Puerto Rico." *Centro Journal* 35, no. 1 (2023).

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1. Miller, Clark A., Yíamar Rivera-Matos, Angel Echevarria, and Gary Dirks. "Intentional and responsible energy transitions: Integrating design choices in the pursuit of carbon-neutral futures." In *Routledge Handbook of Energy Transitions*, pp. 353-370. Routledge, 2022.
2. Echevarria, Angel. “Encountering Energy Systems.” In *Cities of Light*, pp. 125-33. 2021.
3. Rivera Matos, Yíamar. “Aspiring Isn’t Enough.” In *Cities of Light*, pp. 163-72. 2021.

Dissertations:

1. Rivera-Matos, Yíamar. *Redesigning the Energy System through Solar Energy Innovation: Insights from Puerto Rico's Energy Transition.* PhD Thesis, Arizona State University, in preparation, anticipated 2025.
2. Echevarria, Angel. *Energy Encounters: 120 Days of Freedom*. PhD Thesis, Arizona State University, in preparation, anticipated 2025.

Conference presentations:

1. Miller, C. A., "Which Future Will We Build? The Critical Importance of Design Choices in the Decarbonization of Energy Systems," Curtin University. 2024.
2. Miller, C. A., "Catalyzing Energy Imagination and Customizing Energy Futures," Australia National University. 2024.
3. Miller, C. A., et al., "Enhancing the Social and Economic Impact of Energy Investments," Mansoura University, Egypt. 2023.
4. Gregory, Christopher, Angel Echevarria, Yíamar Rivera-Matos, Daniel D. Campo-Ossa, Alex Routhier, Clark Miller, and Richard King. "Data Driven Energy Resilience for Low-to Middle-Income Communities in Puerto Rico." In *2023 IEEE 50th Photovoltaic Specialists Conference (PVSC)*, IEEE, 2023.
5. Honsberg, C., A. Barnett, C. Miller, B. Dauksher, S. Goodnick, I. Sellers, D. Kammen, S. Kurtz, H. Atwater, "PV Opportunities Are More Than Reducing the Generation Cost," *European Photovoltaic Solar Energy Conference (EUPVSEC)*, 2023.
6. Rivera Matos, Y. "Puerto Rico's Energy Transition: Autogestión Comunitaria and Emancipation through Solar Energy Innovation." 2023 Annual Meeting on Law and Society, June 1-4, 2023.
7. Rivera Matos, Y. "Financial Mechanisms for Low-Income Communities: *Autogestión Comunitaria* through Solar Energy Innovation." Energy Ethics: Financing the Future, 2023.
8. Miller, C. A., "Equity and Justice in Electrified Communities," Large Public Power Council: Working Group on Equity. 2022.
9. Miller, C. A., "Empowering Imagination and Unleashing Sustainable, Thriving Energy Futures," CASES International Conference, University of Saskatchewan and University of Alaska. 2022.
10. Miller, C. A., "Imagining Solar Futures: Creativity and the Human Dimensions of Energy Transitions," Sowela Technical Community College. 2022.
11. Rivera Matos, Y. "Community Solar Energy Innovation: Insights from the Veguita Zama Community." Rio Reimagine Project, 2022.
12. Rivera Matos, Y. "La Energia Solar: Una Oportunidad para la Autogestion Comunitaria." Municipio de Toa Baja: Instituto de Participación Cuidadana, 2022.
13. Miller, C. A., "Ending the Energy-Poverty Nexus: An Ethical Imperative for the Low-Carbon Energy Transition?" TOMNET Center, 2021.

14. Rivera Matos, Y. "Futuros Socio-Técnicos: Una Narrativa Emergente de la Cotidianidad en la Montaña Puertorriqueña en Tiempos de Crisis Climática a través de Innovaciones Energéticas." Re-Silencio: A Mal Tiempo Buena Cara, 2021.
15. Rivera Matos, Y. "Community Solar Energy Innovation: Insights from Jayuya, Puerto Rico." Macalaster College, 2021.
16. Rivera Matos, Y. "Women and Community Energy Futures at the Grassroots: Imaginaries of Stewardship and Sustainability." Fifth Energy and Society Conference: Università di Trento, 2021.
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18. Miller, C. A., "Imagining and Designing Low-Carbon Futures: What Kinds of Futures will be Powered by Solar Energy?" University of Oklahoma, 2020.
19. Echevarria, A. L., "Enhancing Resilience Through Community Energy Grassroots Innovation and Social Value Creation," 8th Arizona Student Energy Conference, 2019.
20. Miller, C. A., "The Social Value of Energy," University of Puerto Rico, Mayaguez, Puerto Rico. 2019.
21. Miller, C. A., "Which Solar Future for Puerto Rico?" University of Puerto Rico, Mayaguez, Puerto Rico. 2019.

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1. Rivera-Matos, Yíamar, et al., *The Emerging Solar Energy Innovation Ecosystem in Puerto Rico*, Project Technical Report, Arizona State University and University of Puerto Rico-Mayaguez, March 2021.
2. Gregory, Christopher, et al., *Inventory of Illustrative Community-Based PV Systems Designs*, Project Technical Report, Arizona State University, July 2024.
3. Rivera-Matos, Yíamar, et al., *The Energy-Poverty Nexus: Case Studies from Puerto Rican Communities*, Project Technical Report, Arizona State University and University of Puerto Rico-Mayaguez, in final revision.
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Websites:

1. Can Distributed Solar Advance a Just and Sustainable Energy Transition for Communities in Puerto Rico? http://cohemisferico.uprm.edu/solar2020/agenda.html

Public events and releases:

1. Can distributed solar advance a just and sustainable energy transition for communities in Puerto Rico, public webinar, Dec., 2020.
2. Advancing community solar power: Vision and action for a resilient Puerto Rico, public workshop and training program, May, 2023.
3. Just and sustainable energy transition in Puerto Rico: A conversation with communities, 2023 Annual Meeting on Law and Society, June, 2023.

11. Project Team and Roles:

Arizona State University

- Clark Miller, principal investigator, overall project strategy, management, and oversight; ASU leadership of community co-design, community survey, energy-poverty nexus, and community resilience research, and electricity policy and innovation ecosystem analysis
- Richard King, faculty researcher, co-leadership of solar-and-storage model improvement and integration of model suite
- Christiana Honsberg, faculty researcher, co-leadership of solar-and-storage model improvement and integration of model suite
- Elisabeth Graffy, faculty researcher, initial methods development for community co-design (now at Pacific Northwest National Lab)
- Kris Mayes, faculty researcher, initial formulation of Puerto Rico electricity policy and innovation ecosystem analysis (now at Arizona Attorney General's Office)
- Yíamar Rivera Matos, graduate student researcher, implementation of community co-design, community survey and energy-poverty nexus research, and electricity policy and innovation ecosystem analysis
- Angel Echevarria, graduate student researcher, implementation of community co-design, community survey, and energy-poverty nexus research, and electricity policy and innovation ecosystem analysis
- Alex Routhier, graduate student researcher, initial development and improvement of Puerto Rico solar-and-storage model

- Christopher Gregory, graduate student researcher, initial development and improvement of Puerto Rico solar-and-storage model
- Prashamsa Thapa, graduate student researcher, preparation of community final reports

University of Puerto Rico-Mayaguez

- Fabio Andrade, faculty researcher and subcontract lead, overall strategy, management, and oversight of UPRM subcontract; leadership and oversight of electricity demand simulation model development
- Marcel Castro-Sitiriche, faculty researcher, UPRM leadership and oversight of community co-design, community survey, energy-poverty nexus, and community resilience research
- Cecilio Ortiz, faculty researcher, initial formulation of project research and case study selection criteria (now at University of Texas Rio Grande Valley)
- Marla Perez, faculty researcher, initial formulation of project research and case study selection criteria (now at University of Texas Rio Grande Valley)
- Itza Hernandez Giovanetti, graduate student researcher, defining and conducting project research, especially interviews with policy and NGO stakeholders
- Juan Colon, undergraduate student researcher, defining and conducting project research, especially interviews with business stakeholders and collection of policy documents
- Jose Frau, undergraduate student researcher, defining and conducting project research, especially interviews with business stakeholders
- Valeria Rivera Martinez, undergraduate student researcher, defining and conducting project research, especially interviews with policy and NGO stakeholders
- Arnoldo Colon, undergraduate student researcher, defining and conducting project research, especially data development regarding candidate communities
- Adrianna Torres, undergraduate student researcher, defining and conducting project research, especially interviews with stakeholders
- Daniel Campo-Ossa, graduate student researcher, implementation of electricity demand simulation model development
- Cesar Vega, graduate student researcher, solar rooftop analysis for Barrio la Salud community
- Oscar Garzon, graduate student researcher, application of electricity demand simulation model
- Geraldine Alvarez, graduate student researcher, defining and conducting project research, especially interviews with stakeholders
- William Pacheco, graduate student researcher, analysis of solar-and-storage solutions for communities

- Robert García Cooper, graduate student researcher, meter data collection in partner communities
- A significant number of UPRM undergraduate engineering students also participated in the project to help with engagement of partners communities: Javier Moscoso, Reiner Simshauser, Miguel de Jesús, Emil Santana, Alexis Burgos, Eduardo Collado Tripari, Pablo Mendez-Curbelo, Orlando Ramos Ortiz, Jean Díaz

National Renewable Energy Laboratory

- Meghan Mooney, lead researcher, overall strategy, management, and oversight of NREL contract; leadership and oversight of Puerto Rico solar technical potential analysis
- Katy Waechter, project researcher, implementation of Puerto Rico solar technical potential analysis
- Ben Sigrin, project researcher, formulation and methods design, Puerto Rico solar technical potential analysis

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