Power in Numbers:
Case Study of the Culebra Community Residential Solar Project

by

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Executive Summary

Residential solar systems, often paired with batteries for onsite energy storage, are in increasingly common use as a source of clean, reliable power for households. These systems are growing in popularity, especially among consumers who have the resources to pay for or finance the significant up-front costs of installation, who then benefit from reductions to their monthly energy bills and the increased energy resilience that comes from having an on-site renewable power system.

Residential solar systems have so far been less accessible to lower-income communities, but that is starting to change [1, 2]. Forces including lower solar prices, new public and private pathways for financing clean energy projects, expanded government climate and equity policies, and growing awareness of the climate, health, and reliability benefits of clean energy are propelling growth in programs to expand access. Many of these programs are focused on under-resourced communities that have seen limited solar uptake to date, including a commitment by the US Department of Energy in 2023 to allocate $440 million for solar energy in high-need households in Puerto Rico.

A handful of projects in the US territory over the past several years have established early track records in deploying renewables, often aiming to underpin energy reliability in communities that are especially vulnerable to power disruptions. Rapidly bringing such programs to scale requires a robust understanding of the factors that contribute to success, measures that can overcome common barriers, and awareness of recurring challenges and strategies to navigate them.

In 2019, Environmental Defense Fund (EDF) began working with residents of the Puerto Rican island of Culebra in a partnership to demonstrate how a community-centered renewable energy network can provide clean, affordable, resilient, reliable energy in an under-resourced community. Culebra – a small, semi-urban to rural island 17 miles east of Puerto Rico's main island – was hit hard by Hurricanes Irma and Maria in 2017. Those back-to-back hurricanes led to a total power outage on the island, and as the electric system was slowly brought back online, Culebra's 1,800 residents[1] went 18 months before electric power was fully restored [3]. The extreme outage put a spotlight on the linkages between energy access and resilience, and led to the launch of an EDF pilot project using a community-centered approach to renewable energy deployment to enhance electricity services on the island.

Driven by community input, the project prioritized low-income and high-need households including those reliant on electrically powered medical equipment, elderly residents, and children. Many of those households previously had limited electric reliability or service due to factors like the high cost of electricity in Puerto Rico and the unreliability of power delivery. Through consultation with community members and technical experts, a plan was developed to equip participating households with solar-plus-battery power installations. At the time of writing, installation of 45 rooftop solar systems was complete and those households were experiencing the benefits of cleaner, cheaper, more reliable power.

Throughout the community consultation, project planning, installation, and operations phases of the Culebra Community Residential Solar Project, the project team navigated expected and

[1] The 2020 US Census counts1,792 people as residents of Culebra [4]. However, local leaders dispute this figure as an overcount that does not reflect seasonal variation and partial-year residencies, and some local groups place the number of year-round residents as low as 1,000.

unexpected challenges with varying degrees of impact on project progress and results. This case study, informed by a review of project documentation and interviews with stakeholders including project managers, equipment and service providers, educators, funders, and residents from participating households, aims to capture key insights from the project's implementation.

As the deployment of rooftop solar expands in Puerto Rico to meet the needs of diverse households, solar developers can learn from this pilot-stage experience to anticipate and navigate hurdles and lay the groundwork for successful deployment. This case study identifies lessons that can inform programs for expanded solar energy access, particularly in island settings and in other remote and under-resourced communities. In this way it can inform the development and design of programs to deploy solar in Puerto Rico, across the Caribbean, and around the US, enhancing equitable access to a technology that can improve energy reliability and resilience while reducing climate-warming emissions from fossil fuel-based electricity generation.

Project participants, EDF staff, and members of the Genesis Solar installation team in Culebra, 2022. Photo by Angel Luis, courtesy of EDF.

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Methodology

This case study was initiated in 2023 at the end of the installation phase of the Culebra Community Residential Solar Project, and continued as the project team and community engaged in long-term planning ahead of the transition to self-paid operations and maintenance at the end of 2024. It was developed through an analysis of project documents, open-ended interviews with members of the project team from EDF and other organizations, a site visit to Culebra to see representative installations at several homes, and in-person, structured interviews with members of participating households.

Background interview participants included EDF personnel involved with the project who were based in Culebra, in San Juan, and on the US mainland; a manager with the solar installation company; a Puerto Rico-based electrical engineer who worked as the primary technical consultant on the project; a student from the University of Puerto Rico who developed and led a community education and outreach workshop; a project funder; and a provider of data collection and analytical services for the project.

Participant data was collected through structured interviews using an Institutional Research Board-approved list of questions (see Appendix 1). Interviews were conducted over the course of three days at two central locations in Culebra. They were conducted in English or in Spanish according to the preference of the interviewee, with an interpreter available as needed. EDF staff helped with outreach and logistics for the interviews but were not present during the discussions to ensure that interviewees could speak freely about their experiences; notes from the participant interviews were recorded and anonymized before incorporation into the case study.

While the initial research plan included analysis of household energy use data before and after solar equipment installation, barriers to collecting this data directly from households or through the utility prevented including it in the case study.

A solar-powered house in Culebra.
Photo by Jenny Mandel.

Overview and project background

When Hurricanes Irma and Maria landed in Puerto Rico in September 2017, the back-to-back storms caused devastating loss of life and damage from record-breaking winds, landslides and flooding [5]. The combined impact of the storms blocked roads, cut off cell phone service, knocked out drinking water systems, and destroyed countless homes and other buildings. Damage to the power generation, transmission and distribution systems triggered a total blackout. Official records put the death toll in Puerto Rico from Hurricane Maria at nearly 3,000, many of those due to the inaccessibility of medical care, medicines, and in-home medical equipment linked to the blackout, and a credible study suggested that figure could be as high as 8,000 [6, 7]. It was 11 months before the utility declared that power was restored to all customers [8].[2]

Long before that, though, Puerto Rico's electric utility had struggled to provide reliable power to the territory's homes and businesses. The Puerto Rico Electric Power Authority (PREPA) – now partially managed by LUMA Energy – serves 1.5 million people, more than any other public electric utility in the US, but on a per customer basis it provides less than half as much power as peer utilities on the US mainland [9, 10]. Frequent power outages and high electric rates place a heavy energy burden on residents and local industry, with customers paying higher rates than any state except Hawaii [10]. Recurring blackouts drive many customers to keep small diesel generators as backup. From an environmental standpoint the energy mix is remarkably polluting, with fuel oil, natural gas and coal accounting for a combined 97% of Puerto Rico's power generation today. And in July 2017, just two months before the devastation of its aging electric infrastructure, PREPA had filed for bankruptcy in a proceeding that continues to drag on through political and legal challenges [11].

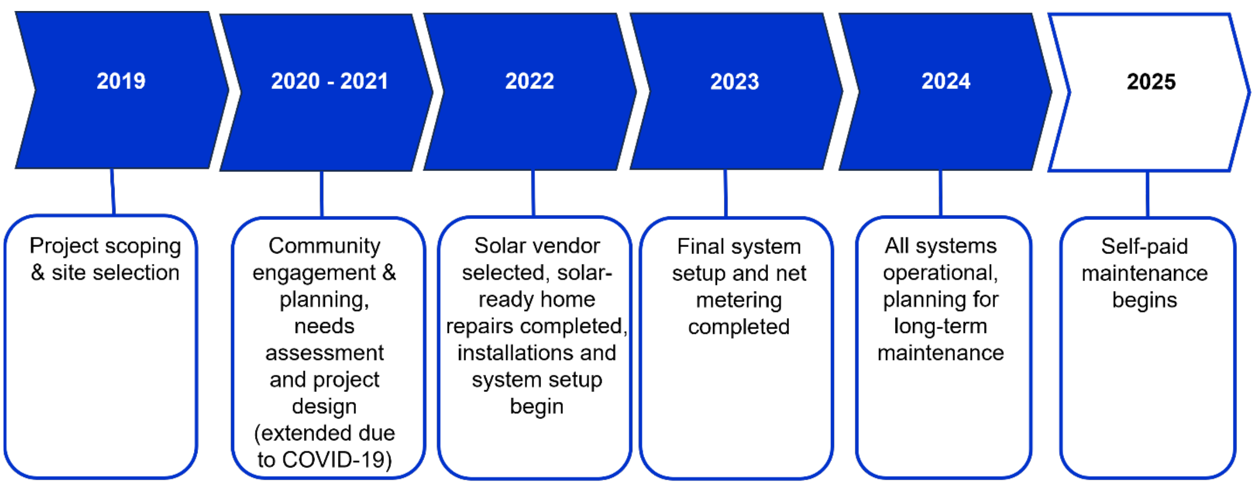
For residents of Culebra, located an hour-long ferry ride from Puerto Rico's main island, many of the challenges that exist on the mainland are intensified. The utility provides electric service via an undersea cable carrying power from the main grid, an added layer of technical complexity in an already fragile power system. High electricity prices contribute to a higher cost of living, driven by the challenges of being physically disconnected from the mainland. About three months after the hurricanes knocked out power, the US government restored electricity to Culebra via a pair of building-sized diesel generators that, when running, provided electricity to the downtown area and the slowly expanding portions of the island where power lines had been restored. This partial restoration was a significant win for the community, even as residents were frustrated by the noise and fumes caused by the heavy equipment and saw the already-limited ferry capacity available for food and other essentials cut back to accommodate fuel shipments.

Source: Google Maps

[2] The utility declared that service was fully restored in August 2018, however it was not until March 2019 that an undersea cable bringing electricity from the main island to Culebra was reconnected, allowing Culebra to switch off the large-scale generators that had powered the island for months.

Against this backdrop, in 2018 EDF began working with interested funders to scope a pilot project that could use renewable energy technology to provide a cleaner, more reliable, more resilient source of energy at the community level. The project set out to establish a model for using advanced renewable technologies to meet community goals and demonstrate the role for clean energy in transforming Puerto Rico's electrical system to become more resilient and reliable. The EDF team evaluated 10 possible project sites and considered factors including community size, interest from community leaders, unmet energy needs, and the potential for local renewable energy siting. The organization selected the island of Culebra – with its population of less than 2,000 year-round residents, community interest in clean energy, supportive mayor, and strong community-based organizations – to pursue a project.

The EDF team and local leaders undertook a process to engage the community in assessing its needs (see timeline below). Eventually the project team settled on a plan to install rooftop solar systems with battery storage at 30 or more homes across the island of Culebra, prioritizing households that were low-income, included elderly or very young residents, and had residents with electricity-dependent medical needs such as electric wheelchairs or refrigeration-dependent medicines. Residents had to own their home or get approval from their landlord to participate, and the system would become property of the homeowner upon installation.



In 2021 EDF brought on a full-time staff member in Culebra to manage the project, working with two full-time staffers based on the main island of Puerto Rico, a larger team on the US mainland, and various consultants and other project supporters.

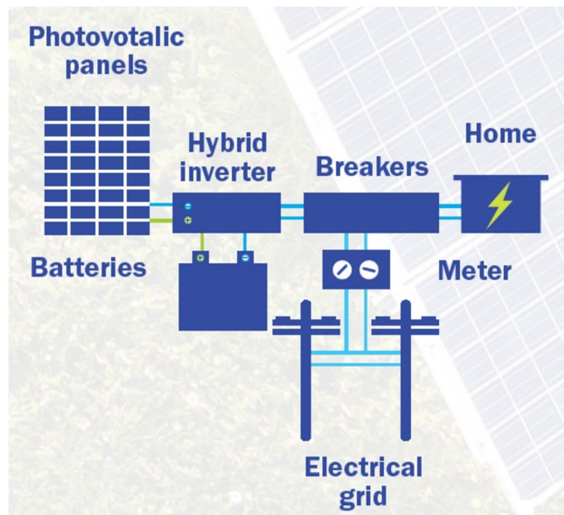
From 2019 through 2023, the project team conducted community outreach and engagement, developed an implementation plan, invited competitive bidding to supply the project, and oversaw the installation of solar and storage systems for participating households. As the project evolved and with additional funds raised, it eventually grew to serve 45 households, including several that had not previously been grid-connected due to limited grid services and other issues.[3]

[3] In general, houses had to be grid-connected to be eligible for system installation, but several households were able to participate in the project following grid extensions completed by the utility in 2022. One interested community member, an elderly resident who had gone for years without electricity, remained off-grid at that point and the community decided together to prioritize their participation. That home was wired to use a solar and storage system in an off-grid configuration.

A key milestone in the project came in 2022 when the EDF project team, in consultation with members of the community, signed a contract with Puerto Rico-based Genesis Solar to supply and install the solar systems for the project and provide the first two years of basic maintenance services [12]. The proposal by Genesis was selected from submissions by five solar companies, through a process in which a group of participants reviewed anonymized summaries of company bids and provided input on their strengths and weaknesses.

For participating households, the project covered installation of a grid-connected rooftop solar system with a battery for energy storage. Two system sizes were available depending on the household's energy use patterns: a small system with 3 kW of solar capacity and 6 kWh of battery storage, or a large configuration with 4 kW of solar capacity and 10 kWh of battery storage. Systems would be grid-connected and households would participate in the electric utility's net metering program, receiving bill credits for excess electricity offered back to the grid.

System controls and battery for the solar and storage system installed at a house. Photo courtesy of EDF.



Schematic of the basic system configuration used in the project. Source: UPRM Guidelines for the Residential Solar Energy Pilot Project on Culebra, Puerto Rico

As of the time of writing, all 45 systems were installed and operational, with 44 of them configured to sell excess power to the local grid through net metering agreements that reduced household electric bills, in many cases to a minimum monthly charge of less than $5. The individual components of each system are warrantied by the manufacturer under terms specific to the component, and each system is covered by an operations and maintenance contract with the installer through December 2024, at the end of which households will become financially responsible for maintenance and repairs.

A project participant on her front porch.
Photo by Nicolás Gómez, courtesy of EDF.

In interviews, participants universally described being pleased with their systems, with the power staying on during frequent power outages that affect their neighbors. Several described their shock at seeing how little they owed for electricity once their system was configured for net metering, dropping from around $100 per month to the minimum fixed charge. One elderly participant said she was considering getting a small room air conditioner to help manage the extreme summer heat, something she had previously written off as too expensive due to the energy it would use. Another participant said she was happy she could help her neighbors in a future blackout, reciprocating assistance that they had offered her over the years.

As of early 2024, the community of project participants was exploring options to cooperate in managing future maintenance and costs when the initial 2-year operations and maintenance contract concludes in December 2024. The options under consideration include forming a community-based organization or cooperative structure and scheduling shared service visits.

The community participation model used in the Culebra pilot project seeks to address the energy needs of a group of residents in a way that mitigates barriers that can be more pronounced in lower-income and vulnerable communities, including more limited influence in local decision-making, lack of financial resources for building upgrades and energy equipment, and less exposure to solar technologies. By anticipating and planning to address barriers and enhancing integration across the financing, planning, installation and management aspects of the project, this approach aims to reduce disparities in access to clean and reliable energy services.

A community workshop in Culebra. Photo courtesy of EDF.

Implementation Insights

The Culebra community-centered solar project was launched to provide renewable energy-based resilience to at least 25 low-income households on the island, while establishing a model for successful community partnership in this remote, underserved setting. Among the project learnings are a number of insights with particular relevance to meeting the needs of underserved, vulnerable, and low- and very-low-income households, and how to design for project success in communities that face challenges due to remoteness or workforce limitations.

The larger installation configuration can power the basic needs of a household with two or more people. Photo courtesy of EDF.

Phase 1: Community Consultation

Allocate time for community outreach and input

When EDF and funders first began scoping out a renewable energy project in Puerto Rico, they planned from the start to connect with community groups and use outreach to set the stage for long-term community buy-in. During project site scoping, Culebra stood out due to its strong network of community leaders who shared a vision of powering the island with solar energy, despite limited resources and solar deployments up to that point. The EDF team spoke with local leaders and a community group composed of health experts, teachers, environmental scientists, and non-profit organizations about their needs and challenges to gain insight that would shape the project.

Consulting with local residents to understand their needs was critical to validate the project plan and intended outcomes. The project team worked with locally based organizations including Mujeres de Islas, Fundación de Culebra, and Foundation for a Better Puerto Rico, as well as Fundación Comunitaria, an organization based on the main island which was in the process of developing a federally funded project on Culebra. At the start of EDF’s engagement, project planners anticipated that the community would benefit from a renewable virtual power plant system in which a group of clustered homes and businesses could generate renewable energy and feed that clean power to the local grid. This technology solution was identified based on the best assessment of experienced energy analysts and general knowledge of the challenges present in Culebra.

Early community meetings on the island, however, uncovered that this concept did not align with community priorities. Participants in these meetings said that serving a tightly clustered group of downtown residents and businesses did not address key challenges faced by a community in which energy-poor households are scattered across a wide area, and they were concerned that there was not sufficient technical expertise available on the island to keep it operational. Rather, residents were interested in identifying a resilient source of electricity that could be available to remote community members with particular vulnerabilities such as the elderly, children, and those with electricity-dependent medical needs.

Because project planning was not locked into a predetermined output, EDF was able to revise the preliminary strategy and propose a technology solution that aligned with community input. Taking into consideration the goals of addressing remote and dispersed households and the range of household sizes in the community, a new plan was developed and fine-tuned to offer two different sizes of rooftop solar plus battery storage with the goal of meeting the critical power needs of participating households, wherever they might be located on the island.

The process of soliciting and incorporating community input at the planning stage requires time and forethought. Not uncommonly, projects aiming to serve low-income and disadvantaged communities do significant planning and operations work before reaching out to the people whose needs they are trying to meet. This can stem from factors including high confidence in the technical solutions under consideration, requirements tied to planned funding or financing arrangements, limited contacts within the focus community, or a desire by project planners to be as well prepared as possible for the unknowns of community engagement. However, in waiting to engage with participating communities, projects run the risk of struggling with avoidable obstacles and misalignment with the needs and priorities of those they aim to serve. This can lead to low commitment by project participants, and to projects falling into disrepair or disuse once the sponsor's attention has moved on. As EDF's community engagement lead explained, "You need to be partners -- not build a project, plop it down, and say you're welcome."

Consulting from the start with local leaders who are familiar with the community, and inviting community input throughout project development, are important to make full use of available resources with technology systems that meet real needs and are embraced and maintained for the long term.

Invest in community capacity-building

From the start of project scoping, through installation and into the operational phase of the Culebra project, empowering community members to be active stakeholders was a core strategy to meet community needs and build a long-lived technical solution. That process included holding workshops and other educational events to establish a shared understanding of solar technologies, partnering with the community to select a technology vendor, building a bridge with the contracted technical support team, and supporting a transition to long-term community management of the project.

At the start of EDF's engagement in Culebra, the community already featured a number of strengths that put collaboration on a good footing: local organizations like Mujeres de Islas, Fundación de Culebra and Foundation for a Better Puerto Rico were active on the island; residents of the island shared a culture of creating resilience outside of government programs; several residents and the local public school had already installed solar systems, reflecting the community's long-standing interest in clean energy (though the school's solar panels were no longer functioning); and a number of residents had experience with small-scale solar systems from the context of their use on fishing boats. Still, there were challenges that included limited solar installations on the island, minimal familiarity with the technology among many residents, and people having limited bandwidth to focus on improving energy service systems.

Knowledge transfer and community-building were important goals of community engagement for the project, and several project participants described participating in the many community meetings as a highlight of participation. One interviewee said, "I loved the meetings. We were able to ask lots of questions and … feel more knowledgeable." Another described how fellow participants offered to help her navigate the phone-based system controls as her system usage data began to flow in, and two participants mentioned the process of collectively reviewing the bids to supply equipment for the project as particularly empowering.

Training on the Genesis Solar system management app. Photo courtesy of EDF.

A coordinator with Genesis Solar said the group structure of the project helped with customer education. "For individual sales, people have a lot of questions but maybe there's still something they don't understand. In a group, they help each other understand and they feel free to ask more questions."

Community capacity-building serves the clear need of building up the knowledge base of people who will be responsible for owning and managing new energy systems. But community gatherings, educational events and collective decision-making also establish trust among community members, foster long-term commitment to the selected technology solutions, and equip the community with the tools and contacts to advocate for their energy needs over time.

Anticipate diverse communication and language needs

Communicating with community members in Culebra required using multiple communication channels, both to effectively contact people with diverse technology preferences and schedules, and to build trust by demonstrating a commitment to the convenience and preferences of the community. That trust and open flow of information were essential to effectively navigating technical and logistical challenges during project implementation.

The Culebra project used communication tools including in-person meetings and workshops, zoom meetings, email, text, office hours, home visits, and flyers. Each format offered different strengths and use cases.

- **Community meetings and workshops:** Good for sharing general information and educational materials, useful for building trust in early project stages, support community cohesion and shared decision-making.
- **Zoom meetings**: Potentially accessible to different participants than in-person meetings, including those with mobility constraints, and can be recorded for participants with scheduling conflicts.
- **Email**: Good for sharing updates and materials in writing, especially detailed information and material that community members might want to process individually before or after a group meeting.
- **Text**: Preferred by some individuals with limited email use, helpful for coordinating site visits and equipment installations.
- **Office hours**: Good for building connections between project developers and participants and providing opportunities for people to ask questions or clarify individual circumstances in a semi-private setting.
- **Home visits**: Good for addressing individual needs, especially for those with mobility or other constraints, and for understanding site constraints.
- **Flyers/take-home materials**: Good for complicated materials and for issues requiring community decision-making. Also helpful for sharing information among multiple stakeholders within a single household, for sharing information with community participants who aren't present at meetings, and for supporting people to independently review and engage with materials.
- **Phone calls**: Useful for one-on-one conversations, detailed explanations, and collecting sensitive information required for project development.
- **Facebook**: Good for event announcements, early-stage outreach, and process updates.

In Culebra, conducting work primarily in Spanish was most effective. In instances where visitors or other stakeholders preferred to work in English, interpretation was arranged to ensure full access. Written materials were provided in both Spanish and English because some community members preferred reading in English.

Assessing communication and language needs at the outset of the project, with input from community leaders, is important for full participation and inclusion. That, in turn, enables project participants to take full ownership of their involvement and have the information and community support needed for long-term success. Project managers should be prepared to adapt as the project progresses if additional language barriers emerge with expanding community engagement. New language and communication needs can be identified by maintaining two-way dialogue with participants and noticing where limited engagement could be a sign of communication barriers.

Phase 2: Project planning

Anticipate the need for building upgrades to prepare older homes

Once a solar system design was determined, EDF project staff and an electrical engineer conducted preliminary site visits to assess whether the homes of interested community members would be suitable for installation. During these visits, they encountered a wide range of construction materials and conditions and a similar range of electrical wiring standards. In Culebra, where construction specialists are in short supply, building materials are expensive and difficult to obtain, and damaging storms are common, homes are often built or added onto over time by those living there and repaired resourcefully using a range of materials and techniques. Electrical work also reflected a range of standards, sometimes installed to code by licensed electricians and at other times cobbled together by homeowners and the people in their personal networks.

As a result of these varying building conditions, some houses required preliminary work before solar panels and battery equipment could be installed. For solar panel installation, houses needed to have a strong roof large enough for the intended number of panels and unshaded by trees or other vegetation. For the battery, they needed at least one wall made of concrete or a similar material strong enough to support the battery and related equipment. While electrical wiring did not necessarily need to meet the most recent code requirements, there was a minimum required threshold of wiring safety and functionality, and the wiring needed to support the separation of critical and non-critical loads for times when the battery would power the house while the grid was down.

Some homes, like the one above, required structural reinforcements to accommodate solar panels on the roof. Photo courtesy of EDF.

Due to funding constraints, households that wanted to participate were responsible for making any necessary upgrades to the building.[4] In most such cases, the residents found ways to complete the work. In a few cases, residents withdrew from participating for reasons related to those requirements, such as a household that was waiting on a pending application for federal hurricane-related damage compensation before making building repairs. In one other household, the owner did not want to proceed with the proposed site modifications and decided to drop out of the project.

In one case, the project team worked around the timing of an electrical wiring upgrade to allow a household to participate. That house required electrical upgrades but there was not a qualified electrician available in Culebra at the time. Installation of the solar system proceeded, but system setup was delayed until an electrician was available to do the work.

In retrospect, an EDF manager noted, the preliminary inspections did more than just catalogue home construction conditions and building needs. It also provided the project team with a glimpse into the home lives and decision-making factors of individual residents, helping them cooperate to solve problems as issues arose over the life of the project.

[4] The only exception to this requirement was the case referenced above in the project background section, the unelectrified home for which EDF and the community worked together to organize funding for structural upgrades.

Simplify equipment configurations

A key aspect of EDF's approach in Culebra was to design a small set of system configurations based on information provided by the community early on about their energy needs and consumption patterns. This offered consistency across installations that would support community members learning from and supporting one another with the technologies while limiting the challenges associated with obtaining parts and technical support.

Genesis Solar, in winning the installation and service contract for the Culebra project, proposed using two installation sizes of the same solar panels, with two associated battery sizes, and other equipment standardized as much as possible across the project. That standardization was useful to the project team when it came to providing informational materials about the systems, since the equipment was common to the entire community of participants.

Genesis Solar, engineering students from the University of Puerto Rico at Mayaguez, and EDF partnered on a series of training workshops and leave-behind materials in English and Spanish that explained how the equipment worked and how to manage the systems (see Appendix 2). In interviews, some residents described the commonalities in system design and installation as helpful because they could consult with fellow project participants when they had technical questions. Others, though, leaned mainly on project personnel when they had questions.

A site coordinator with the Genesis Solar team said that in addition to the streamlining that resulted from repeated equipment use, technicians found that using the simplest, most robust equipment possible was important in the project, even when more sophisticated options were available. For example, the coordinator said that some home energy systems require a continuous high-speed internet connection, but that wasn't reflective of the internet services available in Culebra so a simpler model was chosen.

The vendor also considered the affordability of different equipment options. "Doing a project with a community that doesn't have a lot of economic resources, we had to study that carefully," she said. "We tried to look for simple equipment, because I know it's hard for people to [afford to] replace something if the equipment breaks or is damaged."

Streamlining project equipment requires additional upfront planning and diligence to meet the core needs of participants but can pay dividends during installation and operations.

Phase 3: Installation

Plan for logistical challenges unique to the setting

Genesis Solar, as a Puerto Rico-based solar installer, had experience with the technical and utility landscapes in the territory before winning the Culebra project contract. Nevertheless, Genesis managers found that the logistical difficulties of operating in Culebra were more challenging than anticipated, largely related to the island's remoteness and weak infrastructure.

Geographically Culebra is just a short distance from the main island of Puerto Rico, but the island has a history of disconnection from the mainland, in part because the US military controlled the island and dominated local decision-making until 1975 [13]. As a lingering result, Culebra's transport and other infrastructure are not on par with those of the mainland. The primary means to travel between Culebra and the mainland are via ferry, commercial flight, private boat, or private aircraft, and transit requires weighing the high cost of flying against unpredictability of the ferry service.[5] For energy service providers transporting equipment, the low cost of ferry service makes it preferable to flying but imposes planning constraints.

Culebra also has other logistical challenges related to its geographic isolation. Hotel capacity on the island is limited, which in light of the difficulty in getting there, is a hurdle to efficiently completing large work projects. Hardware supplies are also limited to those carried by the few small shops on the island, meaning that project suppliers must bring in all the supplies that they reasonably anticipate needing and, if complications arise during an installation, progress may be stalled until the necessary parts can be obtained from the main island. Finally, in addition to the planning and cost implications of these issues, goods and services that are available in Culebra are often higher priced than they would be on the mainland, reflecting the costs associated with running a business there.

A manager with Genesis Solar said the company learned from the pilot project in ways that will inform their future work in Culebra, pointing especially to transportation, lodging, and materials. Faced with those constraints, advance planning was critical to complete as much work as possible during each visit to the island, she said.

The Genesis Solar manager highlighted homeowner schedules as another unexpected logistical challenge. Some of the project participants work two or three jobs and are available at home only at limited times. This constraint may be more common among low- and middle-income solar customers than in higher-income customer groups.

The Genesis manager pointed to the community education and organizing that took place before installation began as important advantages that helped offset the logistical difficulties. "I was really surprised because [the participants] knew a lot about the system. They already had education about …what they were going to get," which streamlined installation, she said. She expects the extensive community engagement about how to operate and maintain the systems will also help contain costs going forward.

The logistical challenges that complicated this pilot project will impact other solar projects in Culebra, and may also apply to installations in some parts of the Puerto Rican mainland and on the island of Vieques. Some of these hurdles could also apply to projects at locations that are isolated in other ways, such as solar installations in rural areas or on some tribal lands.

Anticipate infrastructure barriers

As the project in Culebra proceeded, it became apparent that the local grid infrastructure did not meet minimum performance standards in ways that caused problems for the new solar equipment. The most problematic issue was frequent voltage dips and spikes that made systems unable to connect to the grid or in some cases damaged the equipment. The voltage problems were outside the control of project engineers and have required extended troubleshooting among the installation team, the manufacturer of the main affected piece of equipment, the utility, the project team, and affected participants.

[5] The ferry, which runs between Culebra's main port and the city of Ceiba on the mainland, is scheduled to run several times per day but is prone to last-minute schedule changes due to weather and other factors. In addition, demand for the service often exceeds capacity, leading to both lengthy wait times before scheduled departures in order to secure tickets, and unpredictable delays for passengers who are turned away during boarding.

Problems with feeder equipment in some neighborhoods caused connection delays and operational issues. Photo courtesy of EDF.

Early in the installation timeline, when solar and battery systems had been installed on several homes, technicians discovered a problem during system configuration. At some homes, when the technicians tried to connect the systems to the grid the equipment identified overly high or low voltage levels and activated a protective feature that blocked connection. Through discussions with the utility, it was determined that utility personnel needed to update the feeder – a piece of equipment that controls electricity provision to a small group of homes in a neighborhood – in order to better control the voltage. Working with the utility to address each of the houses where this challenge was present took considerable time and resources.

Later in the project, a number of homes that had previously been grid-connected and successfully operating experienced equipment failures in the central connection equipment. Investigations involving project personnel, the homeowners, the installer, and the equipment manufacturer found that the equipment had likely been damaged by an under- or over-voltage event. The manufacturer replaced the equipment under their warranty terms and has since worked closely with the team in Culebra to better understand the issue and how they can prevent problems on the grid from causing damage to their systems. Project engineers have worked in parallel to look for technical solutions that can be added to the base configuration and avoid this problem.

The problems with the Culebra power grid that have translated to extended installation timelines and equipment replacements are an example of how infrastructure problems over which a project has limited influence can affect outcomes. The fact that multiple households experienced similar problems and were able to advocate together for solutions has been helpful in drawing the necessary attention and resources to fix it. However, such problems will continue to occur as the Puerto Rican utility works to improve performance on the grid, and project developers should be aware of how such issues can affect system performance for individual households.

Be mindful of workforce gaps

A major challenge for power projects in Culebra – as well as across Puerto Rico and all of the US – is an acute shortage of electricians relative to the need [14]. It is well documented that Puerto Rico faces a lack of trained workers and has experienced a trend of population loss dating back to the 1990s as long-time residents have moved away [15]. A rapid scale-up of solar energy deployment will quickly run up against the lack of trained workers.

Interviews with project leaders and Culebra residents suggest the island has between one and three certified electricians. For the Culebra community solar project, the solar installer brought all labor from the mainland, requiring employees to commute between their homes and Culebra for days at a time and incurring additional travel and lodging costs. If more projects began to run in parallel, the demand for electrical workers from off-island and capacity to host them in Culebra could quickly become a bottleneck.

More broadly, as long as pay scales, cost of living and professional opportunities continue to favor the mainland US, Puerto Rico will continue to struggle with worker shortages. Federal data suggests the shortage of electricians will become more pronounced in the coming years. O*NET OnLine, a federal occupation data portal, forecasts a 21% increase in employment opportunities for electricians in Puerto Rico from 2020 to 2030, far above the 6% job growth rate for electricians across the US from 2022-2032 [16]. The tight timeline of spending on renewable energy projects, especially through the Department of Energy's Puerto Rico Energy Resilience Fund, means that solar installations can expect to encounter similar and even intensified shortages of electricians and other trained workers over the coming years.

There are efforts underway in Puerto Rico to address this challenge, including a program launched by the electric utility in 2023 and private-run programs like one through the non-profit GRID Alternatives [17, 18]. However for the foreseeable future, project developers should consider this systemic barrier in project planning and not assume that workers will be available locally or from nearby jurisdictions when establishing project timelines.

Phase 4: Steady-state operations

Transition system owners to appropriate technical support contacts

The EDF project team was closely involved in all aspects of the work in Culebra through the consultation, planning and even installation phases, but knew from the start that they would not be available for solar system support through the life of the technology. With this in mind, the team prioritized ensuring that participants could confidently seek customer support and technical assistance from the installer, with whom each household had an initial two-year operations and maintenance contract with the potential for longer-term extension.

Many participants built up trust and comfort with the EDF project leads – especially the Culebra-based project manager – over the early stages of the project, and laying the groundwork for a transition required advance planning. As soon as Genesis Solar was selected as the equipment provider, the EDF team introduced their staff during community meetings to speak about the solar systems and installation process. While participants at that point already had EDF contact information, informational materials began to consistently reflect the contact information for the solar company as well, and participants were supplied with take-home information about the system warranties and pathways for support, all reflecting the solar company's technical support process.

As of late 2023, some participants were consistently going straight to Genesis Solar when they encountered technical issues with the solar system or the phone app for system management. Others, especially some of those who were less comfortable navigating the phone app, continued to contact EDF staff first. The Culebra-based program lead sees the community coming together and increasingly looking to each other and to the formal support system as time goes on. "It's complicated," EDF's community outreach lead said of the handover. "The goal is to have enough of a network in Culebra that it's much more than just EDF. … Success would look like EDF being a welcome partner at the table but not necessary."

Genesis Solar and EDF personnel plan in Culebra.
Photo by Angel Luis, courtesy of EDF.

Plan for long-term maintenance

An important but often overlooked aspect of rooftop solar is ensuring that system users are able to access maintenance and repair support for the full life of the system.[6] The Culebra project integrated this consideration even before the technical plan was in place through engagement and shared decision-making that laid the groundwork for long-term community ownership. In the final phase of the project, EDF has partnered with residents to explore formal structures for community coordination and resource-sharing that will allow system owners to manage their costs by jointly negotiating service rates and coordinating scheduled service visits.

Early in the project, preparation focused on ensuring that the project was a good match to local needs and that participants understood the systems they were getting. Later, the focus shifted to ensuring that households realized the expected financial benefits from the system by managing their electricity use and benefiting from the utility's net metering plan. Strategies included efficiency measures like turning off unused lights and other appliances, planning energy-intensive activities to draw from real-time or stored solar production, and maximizing the amount of solar power available to be sold back to the utility. The project team emphasized how operating the system to yield savings would provide households with extra cash flow that could be applied to future maintenance needs.

Once the solar systems were fully operational and households had passed through the early operations learning curve, the project team began a series of discussions and planning meetings about long-term management of the systems. EDF obtained follow-on financing to facilitate community consultations about possible governance structures, looking to other places in Puerto Rico where infrastructure like drinking water systems and electric microgrids are locally owned and managed, and considering which models were most promising to build from.

[6] There are cases, especially among renewable energy programs in low-income communities, of technology being installed in a community under grant programs with limited or no follow-up only for it to fall into disrepair. Another issue, exacerbated by recent high business turnover in the solar industry, arises when solar systems are "orphaned" when warranty service providers go out of business [19, 20].

A core group of project participants sees promise in a collective approach to managing ongoing operational expenses, leveraging the shared system configurations and community network to bring down individual household costs.

The project's community outreach lead, who is helping facilitate the ongoing discussions, noted that arranging for long-term financing after the installation stage was completed may be counter-intuitive, but can be necessary in a community with limited trust that projects will deliver what they promise. "Ideally you'd want to create a community governance structure before the pieces are in place," she said. "We could have done it that way, but we probably would only have half as many people. They needed to see and feel the project before they were ready to engage."

Community members review solar materials at an informational meeting. Photo courtesy of EDF.

Putting it together: Considerations for large-scale deployment

The Culebra pilot project surfaced a number of important lessons for deploying residential solar and storage in a remote community and working with households that have not traditionally had ready access to the technologies. Many of the takeaways have important timeline implications.

It is useful to divide the lessons learned into two groups – those that respond well to advance planning and management – *challenges to manage* – and those that are systemic and more difficult to address through individual solutions – *challenges to monitor*.

The key **challenges to manage** arose during the community consultation, project planning, and steady-state operations phases:

- Allocate time for community outreach and input
- Invest in community capacity-building
- Anticipate diverse communication and language needs
- Anticipate the need for building upgrades to prepare older homes
- Simplify equipment configurations
- Plan for logistical challenges unique to the setting
- Transition system owners to appropriate technical support contacts
- Plan for long-term maintenance

The more intractable **challenges to monitor** arose particularly during the installation phase:

- Anticipate infrastructure barriers
- Be mindful of workforce gaps

As programs to expand solar access are scaled to larger numbers of households on faster implementation timelines, it will be important for planners to address the manageable challenges. Equally important will be working creatively to address the systemic challenges with stakeholders like state, territory and federal government agencies, utilities, workforce training providers, and educational institutions.

A project participant during the installation of solar panels on his roof. Photo courtesy of EDF.

Conclusion

The Culebra Community Solar Project was successful in equipping a group of under-resourced and vulnerable households with reliable, affordable, clean electricity, and illustrates the tremendous potential for community-centered renewable energy deployment. Before system installation, participating households faced elevated health and welfare risks and cost burdens associated with both routine power outages and long-term power loss from the tropical storms that are common in the area. Today, solar-and-storage energy systems support resilience not only for the participating households, but also within their communities for the extended families and neighbors who have new anchors of energy reliability.

There are a number of insights and lessons that can be taken from this pilot project to support the success of future efforts with similar goals and approaches. In particular, project developers and communities can partner to maximize factors that contribute to success, overcome common barriers, and navigate systemic challenges. This is especially valuable as Puerto Rico launches into a major scale-up of solar energy deployment for low-income households with federal funding and to meet its 2050 goal of fully transitioning to renewable electricity generation.

Every community working to rectify inequitable access to energy services, financial resources or local control has a unique history and brings its own strengths and barriers to the task. Understanding where enhanced planning is needed and how to activate community connection and community resources as tools to overcome those barriers will be critical to expanding access to clean, reliable, affordable energy for all.

View into the harbor in Culebra. Photo courtesy of EDF.

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Appendix 1: Interviews

Two categories of interviews provided data for this case study: open-ended interviews with project staff, consultants and other partners, and structured interviews with members of participating households..

Open-ended interview participants were conducted with:

- Johanne Cubero Rodríguez, Sales and Service Coordinator, Genesis Solar
- Maria (Baby) Jaunarena, Executive Director, Fundación Colibrí
- Rachel Jenkins, Director of Operations, Pecan Street Inc.
- Abimarie Otaño Cruz, Project Manager, Environmental Defense Fund
- Jose Roman Morales, Consulting Electrical Engineer
- Javier Moscoso Cabrera, Electrical Engineering Student, University of Puerto Rico, Mayagüez
- Amalia Saladrigas Malaret, Community Outreach Manager, Environmental Defense Fund
- Dan Whittle, Associate Vice President, Environmental Defense Fund

For structured interviews with members of households participating in the project, the below Institutional Research Board-approved questionnaire was used.

Interview questionnaire:

- How long has your solar home system been up and running?
- What size solar system do you have?
- Does your system run reliably? Please explain.
- How has your energy use changed as a result of being in the solar program?
- How have your energy bills changed as a result of being in the solar program?
- Looking back on the information that you received and the conversations that you had with project staff before your system was installed, how well prepared were you for the installation process and for operating it once it was hooked up?
- How does the solar system and your energy service now compare with what you were expecting when you joined the program?
- Looking back on the program so far, what are the best parts of the program? Are there things you would want to be different?
- What are you most happy about with being in the program?
- What is difficult or frustrating about being in the program?
- If there are openings for new households in the program, would you advise a friend or family member to sign up?
- Looking ahead to when the free service from the installer (Genesis) ends for your system, how do you feel about the transition to paid service visits? Do you have concerns about when program-paid maintenance services end?
- In this program Abimarie, who has been living in Culebra for 10 years, is available to help address problems and coordinate with the installer, the utility (LUMA), the electrician, and other people who are involved with the solar installations. How important is it to have a local program representative? How would the experience be different without a local contact for support?

Appendix 2: Community solar system guide

CULEBRA SOLAR

Environmental Defense Fund

fundación COLIBRÍ

PROYECTO LUZ VERDE

GENESIS SOLAR

GUIDELINES FOR THE RESIDENTIAL SOLAR ENERGY PILOT PROJECT ON CULEBRA, PUERTO RICO

Content drafted by Alexis Ramiro Burgos-Rivera and Javier A. Moscoso Cabrera

Students from the Electrical Engineering Department, University of Puerto Rico - Mayagüez

What is a photovoltaic (PV) solar system?

Electrical components that transform the energy received from the sun into useful electrical energy for the electrical consumption of appliances and electrical equipment, such as: lighting, refrigerators, freezers, telephone chargers, computers, fans, radios, televisions, water pumps and other household appliances. In this case, the solar photovoltaic system installed in homes on the island of Culebra, Puerto Rico, is a **backup system**, which supplies energy to the appliances or the artifacts that are considered most important **(a critical load)** in the home.

How does a photovoltaic solar system work?

A solar system does not consist only of photovoltaic (PV) panels. In order to harvest energy, four main elements are necessary.

Photovoltaic (PV) panels
They receive energy from the sun in the form of radiation.

Charge controller
It regulates the energy received from the solar panels and the charging and discharging of the batteries. For this reason, it is often considered the "brain of the system." The most recommended type of charge controller is Maximum Power Point Tracking (MPPT), which maximizes the amount of energy received by the PV panels. In modern systems, the charge controller can be found integrated into the inverter.

Batteries
Their function is to store the energy generated by the photovoltaic panels.

Inverter
Receives the energy from the battery in **direct current (DC)** and transforms it into **alternating current (AC)**, the one most commonly used type of electricity current used in homes.

Microinverter
Like the inverter, it converts DC to AC but locally, behind the solar panel. One microinverter is connected to each PV, and then all microinverters are connected together (in parallel) and combined in junction boxes to run the connection to the home distribution panel. It provides power optimization and allows for each solar PV panel to be monitored individually.

To see what these parts look like for a system like the one installed in your home, see the picture in the next page for an example of a system installed in Culebra.

COMPONENTS OF A PHOTOVOLTAIC SYSTEM

Rapid shutdown system

The switch used to shut down the solar system in case of emergencies

Connection to the distribution panel or breaker box

Provides power to critical household appliances.

IQ or Enphase enpower system controller

Controls and ensures a safe connection between the home and the grid, the batteries and the solar system. Detects outages in the grid and facilitates the transition to backup power.

IQ Enphase combiner box

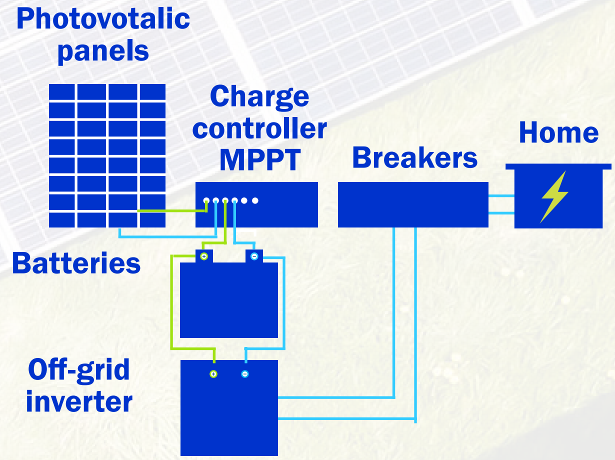
Consolidates the interconnection and communication equipment.

Enphase encharge battery

Solar energy storage system which provides backup power for household appliances.

DIFFERENT TYPES OF PHOTOVOLTAIC SYSTEMS

Off-Grid system

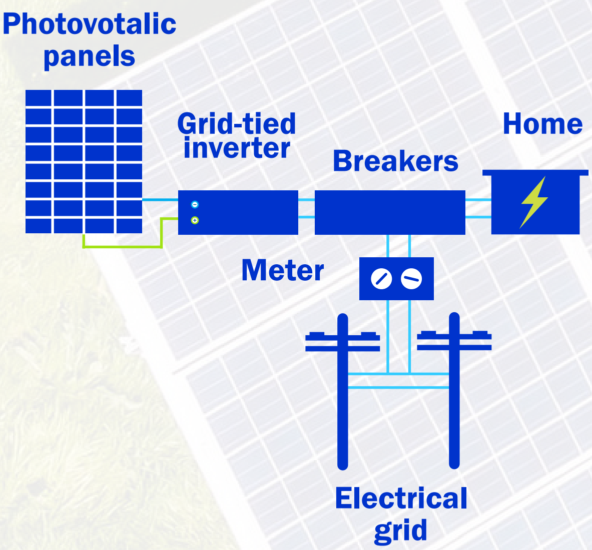


An **autonomous, off-grid** or **stand-alone PV system** is one that is disconnected from the grid. This means that people with this type of system in their homes should be aware that their energy consumption must be limited to whatever load the size of the PV system can supply.

Advantage: Convenient design for remote locations, where grid interconnection is difficult or unlikely. Consumers will have reliable power as long as they do not exceed the storage capacity of the system.

Disadvantage: It is very expensive to install and run a completely off-the grid (they tend to be quite large).

Grid-tied system

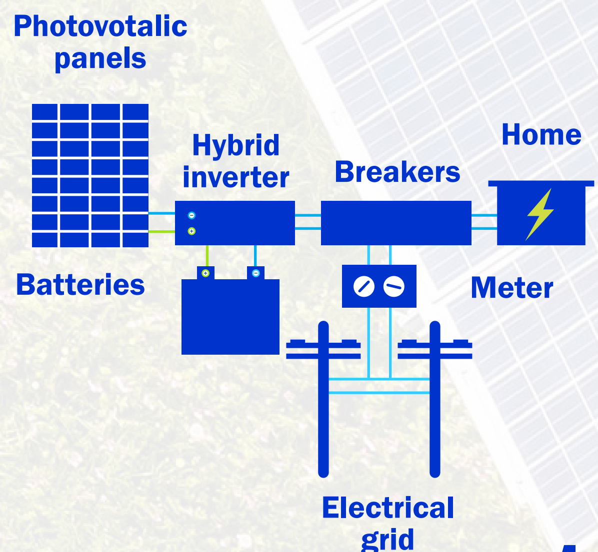


A **grid-tied PV system** is made up solely of solar photovoltaic panels (without batteries) to supply household energy consumption during the day and is interconnected so that it can export any excess energy to the electric grid. In these cases, bi-directional meters are used to measure the amount of energy generated by the system, the amount of energy consumed in the home, and the amount of excess energy exported to the grid.

Advantage: Cheaper than an off-grid or hybrid system.

Disadvantage: If the electrical grid stops working or there's a power outage, the system will also stop working.

Hybrid system



A **hybrid PV system** is interconnected to the grid and has its own energy storage (batteries). It is possible to benefit from the energy coming from both the grid and the PV system through different configurations and preferences with a hybrid inverter.

Advantage: The hybrid system is more reliable and versatile than other configurations.

Disadvantage: It is more expensive than a grid-tied system.

COLLABORATIVE SOLAR PROJECT BETWEEN EDF AND RESIDENTS OF CULEBRA

Project objectives and expectations

As part of Environmental Defense Fund's efforts in the archipelago, a collaborative residential project has led to the installation of rooftop solar PV and storage systems in more than 40 homes on the Island Municipality of Culebra in Puerto Rico. These **hybrid systems** (see previous section), connected to the electrical grid, aim to supply critical household needs and also provide backup power to support families in Culebra during prolonged power outages. The systems were designed in a fairly uniform manner to facilitate their operation and maintenance in the short, medium and long term.

These PV systems were designed in two sizes, taking into consideration the current needs and particularities of each household. They are based on the power generation capacity of the photovoltaic panels **(3 kW and 4 kW)** and the energy storage capacity of the Enphase batteries **(6 kWh and 10 kWh)**.

What size is my system?

Your system is a **hybrid system** with ____ kWh in solar panels (monocrystalline), and ____ kWh of storage capacity (lithium batteries).

RECOMMENDATIONS FOR SYSTEM USE

What can I do in my home now that I have a solar + storage system?

These solar systems provide additional resilience for the home by supplying enough energy to meet basic household energy consumption needs (the critical loads of the home) in "normal" times and allowing these loads to continue operating even in the event of a blackout. The system has the capacity to supply energy to:

- Fridge and freezer, 24 hours a day
- Light bulbs (preferably LED)
- TVs, radio, fans
- Chargers for cell phones, laptops, tablets, etc.
- Small, energy-efficient appliances

The number of appliances you can keep turned on and the amount of time these can be used for, depend on the household's electricity consumption, the solar production of the day, and the amount of energy stored in the batteries. The system will, therefore, work according to the resident's consumption pattern and may vary among different households. The performance of a system of the same size, with the same storage capacity, can vary from one family to the next. It is advisable to monitor and know the limits of your solar system as much as possible, and to be efficient and conservative with energy use in the home to ensure the batteries are charged for any emergency situation that may arise.

In the event of a power outage, as long as the power is coming solely from the batteries, remember not to plug in or turn on:

- Air conditioners
- Electric stoves
- Microwaves
- Hair dryers
- Electric dryers
- Equipment or appliances that consume more than 20 A (this information can be found on each appliance's label).

FREQUENTLY ASKED QUESTIONS

What kind of maintenance does my system need?

One of the great advantages of solar PV systems is that they do not require extensive maintenance. However, it is always important to:

- Check the roof's surroundings to ensure that there is no shade over one or more of the solar panels.

- Monitor the *Enphase Enlighten* application regularly to ensure that the batteries are performing as they should.

During the first **two years** after the system is installed, Genesis Solar will arrange a technical visit twice a year to perform routine maintenance on the system and to check the integrity of each component (the anchors, the panels, etc.). This is part of the operation and maintenance service included in the contract between EDF and Genesis Solar. After the first two years, residents must decide what type of routine maintenance service they prefer for their system.

What do I do if I see an error in the application or if I notice a decrease in the system's performance?

If you think that there is a part of your system that is not working properly, **call the Genesis Solar Customer Service number included at the end of this booklet.**

A decrease in the system's production capacity can happen due to several reasons; one of the more common ones is dust accumulated on the panels which does not let the panels generate the same amount of energy.

If you wish, you can clean the panels using a clean microfiber cloth (just the cloth, no water or soap). It is **NOT RECOMMENDED** that residents climb on the roof to handle or manipulate the system, as it has delicate electrical components and may also pose a physical risk.

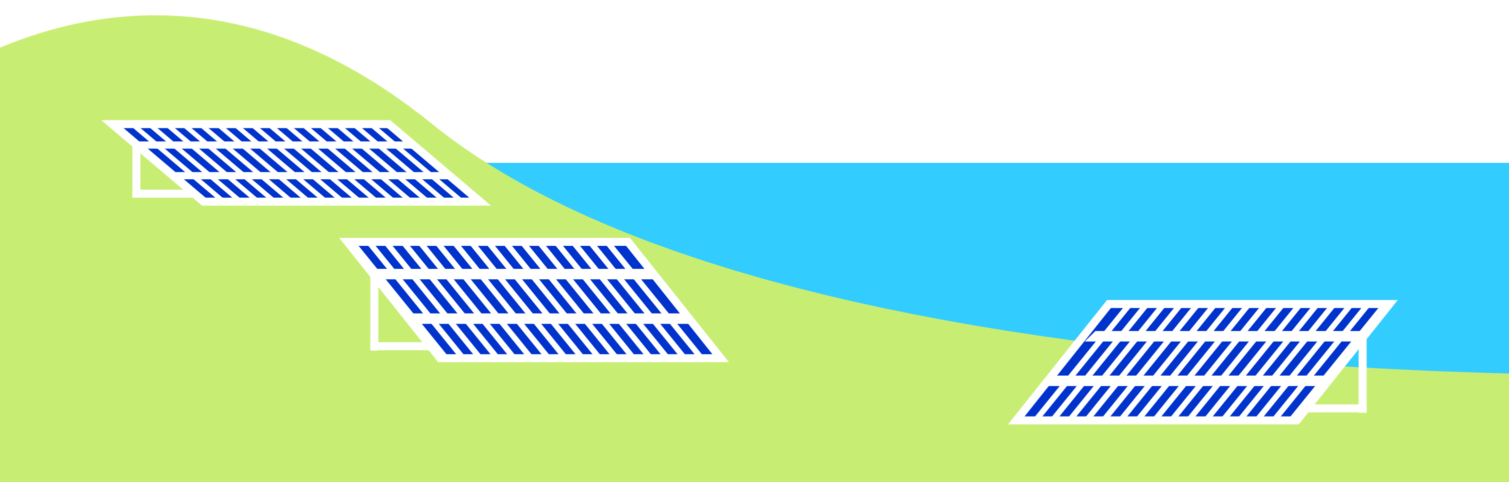
What should I do with my panels and system in the event of a hurricane?

It is important to consider the implications for the different parts of the system when facing a hurricane. The battery and all the other components of the system are designed to be located outdoors and prepared to withstand wind and rain.

Genesis Solar **DOES NOT RECOMMEND** removing or lowering roof panels in the event of a storm or a hurricane. Solar panel mounts are tested to sustain high winds, and the engineering codes were revised after Hurricane Maria (2017). These codes are modeled based on residential structures in optimal conditions. Therefore, it is recommended that routine home maintenance and repairs to the roof (i.e., roof sealing) be part of the practice to prepare for hurricane season.

If you would like to add additional protection for the anchoring of the solar panels, **call the Genesis Solar Customer Service number included at the end of this booklet** so they can give you the best recommendations for your system and your home.

You cannot control what may fly, bump or damage the panels. One of the advantages of the system installed in your home, is that even if one panel loses some or all its capacity (for example, if a solar panel is hit by a flying debris), the microinverters will allow the other panels to continue to operate.



WHAT SHOULD I DO IF I NOTICE AN ISSUE WITH THE BATTERY?

Even if there is a problem with the Enphase battery, **your first call should be to the Genesis Solar Customer Service number** included at the end of this booklet. The Genesis Solar team will be able to determine whether it is a problem they can solve remotely, if a technician's visit is needed, or if they should refer the situation directly to Enphase.

The most common problems that may arise with the battery are due to a complete discharge of the battery or lack of internet coverage. The internet connection facilitates both the sending of "real time" information to the *Enphase Enlighten* application and the regular battery updates (which occur remotely).

WHAT WILL HAPPEN IF I LOSE INTERNET CONNECTION?

It is very important that the system is always connected to the internet. This connection allows battery updates to occur as soon as they are available, which in turn helps to keep the system operating efficiently and compliant to the warranty.

If connection to the internet is lost for a short time, there is no problem! The information you will see in the *Enphase Enlighten* app will be the last information the system recorded prior to the loss/interruption of connectivity, but it does not mean that the panels and the battery are not working. The app is simply displaying the most recent information available. As soon as the drop in coverage is resolved, the system will resume normal operation.

If the interruption in internet connectivity seems to go on for a long time, **call the Genesis Solar Customer Service number** so they are aware of the situation. If a problem arises with the system once the internet connection is restored, they will be able to assist you more easily.

WHAT HAPPENS IF THE INVERTER TRIPS/STOPS WORKING?

This can occur when the consumption exceeds the capacity that the solar system was designed for when there are more elements connected to the equipment/system, and these entail a greater consumption or load than the system can supply. The capacities of these solar systems are given by the power (in **Watts, W**) that they can supply.

This can also be due to the battery not being sufficiently charged. Typically, inverters have an internal low voltage switch, which acts as a protection mechanism when a voltage is detected below the expected range. To resolve this situation, the batteries should be allowed to charge again (without being relied upon or used).

If a problem with the inverter arises, the warning will also show up in the system for the Genesis Solar team, who can address the situation remotely. If you find that the inverter is slow in returning to normal, you can **call the Genesis Solar Customer Service number** included at the end of this booklet to follow up on the issue.

HOW LONG COULD MY SYSTEM LAST?

It is important to keep in mind that, within a photovoltaic system, each component has a particular lifespan or useful life. Good maintenance and monitoring can extend the performance of the system for several years. It should be noted that the ***lifespan*** of the system's components is not the same as their ***warranty***.

Typically, **warranties** cover a shorter time period than what the equipment can continue working for (the lifespan of the equipment). For example, solar panels typically have **lifespans** of 25 to 30 years. Batteries, depending on their use patterns (charge/discharge cycles) and type of chemical composition, can last from 3 to 10 years. Depending on the model, microinverters can last around 25 years.

It is important to take these factors into consideration since, over the lifespan of the solar panels, it may be necessary to replace some of the other parts in the system. The warranties on the components of the equipment installed by Genesis Solar cover **mechanical malfunction** of the parts (Table 1).

TABLE 1:

System components installed by Genesis Solar, including the years of warranty for each.

General specifications on photovoltaic systems					
Component	**Maker**	**Model**	**Warranty**	**Capacity (per unit)**	**Amount**
Solar Panel	Q-Cells	Q-Cells Duo XL-G10.d	25 years	480W	7 o 9
Microinverter	Enphase	1Q 7A	25 years	366 W	7o 9
Battery	Enphase	Encharge10	10 years	6 kWh o 10 kWh	1

DO SOLAR PANELS STILL WORK ON CLOUDY DAYS?

The answer is yes. The solar panels still generate electricity, but it will not be at the same intensity as on a sunny day. Therefore, it is even more important to be aware about household energy consumption and to monitor the system and the batteries in the app to make sure enough energy is stored in case of a power outage.

IS MY SOLAR SYSTEM COMPATIBLE WITH AN ELECTRIC GENERATOR?

Yes, you can connect a backup electric generator and it could even charge the batteries of your system. This is possible as long as you follow safety regulations, such as including a "transfer switch." **We recommend contacting Genesis Solar** for guidance if you are interested in acquiring and connecting a generator: the Genesis Solar team will be able talk through the proper placement of the "transfer switch," and to confirm that your generator is compatible with the specifications of the solar system installed on your home.

WHAT IS NET METERING AND WHAT DOES IT MEAN?

It is possible to enter into an agreement where you are allowed to export excess generation (if there is any) from your solar system to the grid and receive a credit on your bill from the company that manages the electric grid.

Once the agreement goes into effect, the net metering process begins, where the flow of electricity is measured in both directions: the electricity coming from the grid and the electricity supplied by the solar system. If the energy exported or "sold" by your system to the grid exceeds the energy used directly from the grid, you will see a credit reflected on your monthly bill.

Useful concepts and definitions:

Voltage (V)
Work required to move an electric charge through a circuit.

Current (A)
Flow of electrically charged particles through a medium (conductor, wire, etc.) in a circuit.

Power (W)
Rate at which work is done to transfer current through a circuit at an instant of time.

Load (W)
An element, within a circuit, that consumes power.

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DETAILS AND WARRANTIES FOR THE COMPONENTS OF THE SOLAR SYSTEM

Equipment	Details	Warranty
Hanwha Q, Peak Duo XL-G10.3 (480W)	Nominal power:480 Watts 10 years (power): 93.5% 20 years (power):86% Dimensions: 7.27'x3.42'x.11'	25 years
Enphase IQ7A-72-2-US	Interconnectable: yes Output voltage: 240 VAC Maximum voltage: 96.5% Nominal power: 349 Watts	25 years
Unirac Solarmount racking system	Kind: rail Color: silver Finish: mill finish Material: aluminum	25 years
Enphase Encharge T 3.36 kwH	Capacity: 52 Ah Nominal voltage: 67 VCD Charge and discharge type: 1.28 KVA Nominal dimensions: 1.21' x 2.54' x .62' Nominal weight: 108 lbs	10 years
Enphase Encharge T 10.08 kwH	Capacity: 156 Ah Nominal voltage: 67 VCD Type of battery: Lithium iron phosphate Charge and discharge type: 3.84 KVA Nominal dimensions: 4.21' x 2.54' x .62' Nominal weight: 316 lbs	10 years
Enphase Enpower	Nominal voltage: 240 VAC / 100-310 VAC Maxiumum continuous current: 160A Nominal frequency: 60HZ /56-63 Hz Nominal dimensions: 1.64' x 3' x .66' Nominal weight: 85lbs	10 years
Enphase IQ Combiner 3C	System voltage: 120/240 VAC, 60 Hz Maximum continuous current (output to the grid): 65A Nominal dimensions: 1.63' x 1.23' x .55' Nominal weight: 16.5 lbs	10 years
Installation	Installation and electrical connection	6 months with Genesis Solar

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