Post-María Puerto Rico

Global Collaboratory 2017-2018: Final Report

Faculty Advisors: Elora Ditton, Geoffrey Heal, Phil Larocco and David Sandalow
Team Members: Rashide Assad, Eskedar Gessesse, Rodrigo Inurreta, David Maravilla, Rodrigo Paz, Alejandro Valdez and Lara Younes

Acknowledgements

The Post-María Puerto Rico team would like to express its deepest gratitude to project advisors and sponsors, including Columbia faculty Elora Ditton, Geoffrey Heal, Phil Larocco and David Sandalow, the Energy and Environment Concentration at SIPA and the Columbia Center for Global Energy Policy for their dedicated financial and knowledge-based support for the project. We are also deeply thankful to our outside advisors: Joaquín Avilés, John Humphrey and Jennifer deCesaro and local contacts Patricia de la Torre, Olga Ramos, Venus Hernández, Rosa Plá, Cecilio Ortiz, Gabriel Rivera, Mike and Marie Murphy, Mike Martin and Steve Wilson for their invaluable on-the-ground support.

Table of Contents

Tables

Executive Summary

Hurricane María destroyed Puerto Rico's power grid on September 20th, 2017. Without power, essential services such as drinkable water, sewage and hospitals were severely compromised, turning the situation into a humanitarian crisis. Seven months after the hurricane, emergency response and relief efforts have not only been late and insufficient but plagued by corruption and mismanagement scandals.

Off the Eastern coast of Puerto Rico, the municipality of Vieques is home to close to around 9,000 people. Before María hit, Vieques was served by submarine transmission power lines, making it highly vulnerable to whatever happened on the Puerto Rico mainland. For days after the storm hit, Vieques was cut off from the world, lacking power, water, medical supplies and food. Today, a portion of the island remains without electricity, but many homes and businesses are relying on their own generators while repair work on the grid continues.

Although tragic, María's devastation provides Puerto Rico with a unique chance to rethink, rather than rebuild, its power system. The territory can take advantage of its geographic position and technological advancements to focus its economic and social development around renewable energy.

Because nothing can be done to prevent hurricanes and other weather-related events, resiliency is key to enable the continuous operation of the power system, as well as expediting the return to normal operations in the presence of widespread damage. Capitalizing on the territory's renewable and distributed energy resources, particularly solar PV and wind, and human capital, could provide a path for a more resilient and sustainable electricity provision model, unlock jobs and boost social prosperity in the long-term.

With this in mind, our original Global Collaboratory proposal aimed to deliver a comprehensive action plan for the deployment of a renewables-based microgrid in Vieques Island. This project required obtaining expertise and information from several key stakeholders pertaining to the private, nonprofit and public sectors. Partners were expected to contribute with specific inputs linked to each of the project's deliverables.

However, several issues related with data availability and collection, partnerships and audience made the original project non-viable. Although none of these were unsurmountable, building on limited and outdated information would have resulted in very general -and mostly useless- recommendations. This, coupled with initial insights obtained through phone calls and e-mail exchanges with local contacts, led the team to rethink the project towards one with a narrower scope but broader impact.

Taking these into consideration, four out of the seven members of the team travelled to mainland Puerto Rico and Vieques from Sunday, March 11th to Saturday, March 17th, 2018 to i) get a better understanding of the situation on the ground; ii) assess the feasibility of establishing a solar-powered community center in Vieques; iii) identify potential sites to host the community center; and iv) firm-up partnerships and ensure buy-in of local stakeholders.

The team met with several local stakeholders and visited potential sites to host the community center throughout Puerto Rico. The main takeaways from the trip were that: i) there is a strong interest to establish a solar-powered community center; ii) there are important challenges to solar PV deployment on a medium to large scale; and iii) there's a general perception that the local government is corrupt, inept and burdensome.

With the insights and information provided by our local contacts, the new project seeks to develop the business plan for a solar-powered community center that can serve multiple purposes. During an emergency, the community center can serve as a food distribution point, a cellphone charging station, signal booster for satellite WiFi and other critical Information and Communications Technologies (ICT). Once the emergency has passed, it can host children and adult workshops and/or other side businesses, like a board game café and solar PV installation and O&M training.

To design and implement this new project, the team will rely on the expertise and guidance from Infrastructure for Sustainable Development (i4SD), the Boys and Girls Club (B&GC) of Vieques and the University of Puerto Rico at Mayagüez (UPRM). I4SD will oversee the engineering and procurement of the PV system. They will select and hire a local solar developer to install it on the rooftop of the B&GC of Vieques. The B&GC of Vieques will host the community center, run the board game café and manage the PV system installation and O&M training and energy efficiency awareness program. While the UPRM will keep provide detailed information about Vieques, encourage the replicability of the project throughout Puerto Rico and support the PV system installation and O&M training.

Considering the B&GC load, and the Tesla Powerpack system and diesel back-up generator they already own, the team estimated an additional PV system of the maximum capacity is 9.2 kW that would cost close to 30,000 USD. The proposal for financing the PV system is to have a 50/50 model where half of the investment is covered with grants and/or donations and the other half is covered with debt. The proposed strategy will allow the B&GC to benefit from the fundraising efforts organized by i4SD, in parallel with

actively contributing to the debt component of the model, spurring the sense of ownership to the community.

The cash flows obtained from the financial model show that with 11,000 USD in earnings from the board game café and the PV training, the B&GC of Vieques could pay the loan related to the total direct investment cost of the PV system, in addition to the O&M costs of the PV system and of firing the diesel back-up generator.

The net present value (NPV) of the project's cash flow, at a 12% discount rate, would be 436 USD. Additionally, the expected internal rate of return of the project is 12.4% with a breakeven point in 10 years. As a comparison, increasing the earnings from the additional sources to 13,000 USD/year, results in a NPV of 18,660 USD and an IRR of 27.2%, with a breakeven point in 5 years.

The board game café will open from 5:00pm in the afternoon, when the regular classes offered by the B&GC of Vieques end, to 10:00pm. A number of board games, chess, card games, backgammon, domino and scrabble, will be offered for rent by the hour. The café will also offer non-alcoholic beverages and a number of different snacks (empanadas, crisps, chips, etc.). In addition, both public and private events may be organized on request; *i.e.* domino tournaments or birthday parties.

On the other hand, the B&GC will provide trainings on grid-tied PV system installation, operation and maintenance. The training will incorporate a hands-on experience where the instructor(s) will provide sessions using the on-site solar system to enhance learning. Depending on demand, the trainings will be provided between 4 and 12 times a year. The partner PV system training provider will develop all of the course materials and cover the cost of instructors. The B&GC will provide the space and equipment, and it will also be charged with promoting the trainings and dealing with participants' registration.

Although the official Global Collaboratory timeline has ended, the team will move forward with i4SD, the B&GC of Vieques and UPRM with the next steps of the project. Broadly speaking, the period between May and August will be used to secure funding for the project and the period between September and December 2018 will be used to implement the project.

Background and Statement of Need

September 20, 2017: Hurricane María

Hurricane Irma hit Puerto Rico's northern coastline on September 6, 2017 as a Category 5 storm, killing three people and leaving more than 1 million residents without power. The Puerto Rico Electric Power Authority (PREPA)[1] restored service for 70% of them within one week.[2] Two weeks later, Hurricane María destroyed Puerto Rico's power grid (resulting in the longest duration power outage in U.S. history),[3] water treatment and pumping facilities, cellphone towers and banking systems. Without power, essential services such as drinkable water, sewage and hospitals were severely compromised, turning the situation into a humanitarian crisis. Seven months after the hurricane, the timeline for full restoration remains uncertain,[4] "an unprecedented outcome for a territory in the world's most advanced nation."[5]

Although most of PREPA's power plants are over 40-year old, they sustained minor damage from the Hurricane and were left almost intact. However, about 80% of the transmission and distribution infrastructure went down.[6] This, compounded with a US$9 billion debt and the following challenges, made initial recovery efforts very difficult:

1. Damage to multiple pieces of infrastructure required different skills and types of equipment. These skilled workers and heavy equipment needed to be flown or shipped to begin repair work on the island, competing for space in planes and ships with other much needed resources such as doctors, bottled water and medicines;

2. Repairing downed wires from the southern coast through the mountains and forests was also problematic because most roads were gravely damaged and needed to be repaired or rebuilt themselves;

3. Communication between repair crews to assess damage and start working once they were there was difficult with most communications infrastructure down; and

---

[1] A vertically integrated utility that supplies power to 1.4 million total customers in Puerto Rico, Vieques and Culebra.
[2] Puerto Rico Energy Resiliency Working Group, *Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico* (December 2017). Available at: https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf (last consulted: May 2018), p. 10
[3] *Ibid*, p. 11
[4] After seven months and close to US$2.5 billion, almost everybody in hurricane-ravaged Puerto Rico had their lights back on, until a subcontractor's excavator working near a fallen transmission tower got too close to a high-voltage line and knocked power to nearly every home and business across the island.
[5] Geoffrey Heal, "How to fix Puerto Rico's power system," *Politico* (December 12th, 2017). Available at: https://www.politico.com/agenda/story/2017/12/12/how-to-fix-puerto-ricos-power-system-000594 (last consulted: May 2018)
[6] Steven Mufson, "Hurricane Maria has dealt a heavy blow to Puerto Rico's bankrupt utility and fragile electric grid", *The Washington Post* (September 20th, 2017), available at: https://www.washingtonpost.com/news/energy-environment/wp/2017/09/20/puerto-ricos-power-company-was-already-bankrupt-then-hurricane-maria-hit/?utm_term=.512aa54016a2 (consulted in September 2017)

4. While hospital and water treatment facilities were powered by generators, supplying the fuel for those generators was (and remains) a logistical hurdle.

PREPA's plan for repairing the electricity grid infrastructure was unknown or limited and the local government relied on federal support for short-term, immediate emergency disaster-relief assistance to Hurricane María survivors. A couple of weeks after the storm hit, more than 19,000 federal civilian and military personnel[7] were on the ground and 22 U.S. states were supporting 69 requests for mutual aid in Puerto Rico.[8] However, even the United Nations has criticized the "absence of adequate emergency response."[9] In addition, relief efforts have been plagued by corruption and mismanagement scandals, like the Whitefish Energy[10] and Tribute Contracting[11] affairs.

Vieques Island

Off the Eastern coast of Puerto Rico, the municipality of Vieques is home to close to around 9,000 people.[12] The sugar industry, once the staple of the island's economy, declined during the early 1900s and finally collapsed when the U.S. Navy bought much of its land to serve as a bombing range and testing ground.

Apart from the U.S. Navy and a General Electric manufacturing plant, Viequenses were left with little economic opportunities, such as fishing and subsistence farming. After the bombing range and testing site was closed in 2003, there have been efforts to redevelop the island's agricultural economy and to clean contaminated areas to develop Vieques as an ecotourist destination. Still, the U.S. Census Bureau estimates median household income at US$17,500 per year (2016), with 36% of the population below poverty line.[13]

Before Hurricane María hit, Vieques was served by submarine transmission power lines,[14] which makes the island highly vulnerable to whatever happens on the Puerto Rico mainland. For days after the storm hit, Vieques was cut off from the world, lacking power,

---

[7] Including almost 1,400 Federal Emergency Management Agency (FEMA) workers.
[8] Alayna Treene, "The Puerto Rico recovery, by the numbers," *Axios* (October 9th, 2017). Available at: https://www.axios.com/the-puerto-rico-recovery-by-the-numbers-1513306055-21f2affd-cd99-4d7b-9667-b86bd782b015.html (last consulted: May 2018)
[9] United Nations Human Rights Office of the High Commissioner, *Puerto Rico: Human rights concerns mount in absence of adequate response* (October 30th, 2017). Available at: http://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=22326&LangID=E (last consulted: May 2018)
[10] PREPA awarded a US$300 million contract to Whitefish Energy, based in the hometown of Interior Secretary Ryan Zinke and which had just two employees the day the storm hit Puerto Rico, to rebuild the island's power grid.
[11] FEMA awarded US$156 million to Tiffany Brown, an Atlanta entrepreneur with no experience in large-scale disaster relief and at least five canceled government contracts, in exchange for 30 million self-heating meals for Puerto Rico. By the time 18.5 million meals were due, Ms. Brown had delivered less than 50,000. In addition, the meals had been packaged separately from the pouches used to heat them.
[12] According to interviews carried out during the team's Spring Break trip, approximately 3,000 people have left the island since September 2017. Others estimate between 300 and 900 people that left, but no official data could be found to verify any of these claims.
[13] U.S. Census Bureau, *Quick Facts: Vieques Municipio, Puerto Rico*. Available at: https://www.census.gov/quickfacts/fact/table/viequesmunicipiopuertorico/INC110216 (last consulted: May 2018)
[14] Comisión de Energía de Puerto Rico (CEPR), *Sistema de Transmisión de la AEE* (September 18th, 2015). Available at: http://energia.pr.gov/datos/transmision/ (last consulted: October 2017)

water, medical supplies and food. Today, a portion of the island remains without electricity, but many homes and businesses are relying on their own generators while repair work on the grid continues.[15]

Puerto Rico's Energy Context

Puerto Rico neither produces nor refines crude oil,[16] so about 75% of the energy used in the island comes from imported petroleum products.[17] More than 90% of Puerto Rico's petroleum imports are residual fuel, motor gasoline and distillate fuel that serve the island's transport and electric power sector.

Puerto Rico's power system includes six fossil fuel and seven hydroelectric generation sites, owned and operated by PREPA, as well as two private cogeneration plants, two windfarms and five solar farms.[18] The electric grid includes almost 2,500 miles of transmission lines, 31,500 miles of distribution lines and over 330 high-voltage substations, also operated by PREPA.[19]

The island's geography and climate, combined with the dispersion of its customers, present many operation and maintenance challenges. Most transmission and distribution lines are above ground, which makes them vulnerable to the high winds, torrential rains and landslides caused by Hurricanes Irma and María.[20]

About 70% of Puerto Rico's electricity generation capacity runs on fuel oil and diesel.[21] All of this translates into high-polluting emissions and electricity bills of 20.47 cents per kWh for residential consumers and 22.39 cents per kWh for commercial customers,[22] which is estimated to be between 80 and 100 percent higher than those of the rest of the country, curtailing growth on the island.[23]

Rethinking Puerto Rico's Power System

Although tragic, María's devastation provides Puerto Rico with a unique chance to rethink, rather than rebuild, its power system. The territory can take advantage of its geographic

---

[15] Florida Power and Light workers estimate full power on the island to be restored during the 2018 summer. Lynn Woods, "Puerto Rico Update: Vieques On the Path of Recovery," *Travel Market Report* (February 14th, 2018). Available at: http://www.travelmarketreport.com/articles/Puerto-Rico-Update-Vieques-On-the-Path-of-Recovery (last consulted: May 2018)
[16] The last of Puerto Rico's five petroleum refineries was shut down in 2009.
[17] According to the U.S. Department of Energy National Renewable Energy Laboratories (NREL), the territory uses about 8% of its shrinking GDP on fuel imports to meet its electricity needs.
[18] PREPA generates approximately two-thirds of its electricity and purchases the remaining from third parties.
[19] Puerto Rico Energy Resiliency Working Group, *Op. Cit.,* p. 7
[20] *Ibid*., p. 9
[21] It also has LNG and coal facilities that run on imported fuels. U.S. Energy Information Administration (EIA), *Puerto Rico, Territory Energy Profile Analysys* (September 21st, 2017). Available at: https://www.eia.gov/state/analysis.php?sid=RQ (last consulted: October 2017)
[22] *Ibid.*
[23] Heal, Geoffrey, *Op. Cit.*

position and technological advancements to focus its economic and social development around renewable energy.

Puerto Rico could dramatically reduce its electricity costs by switching to solar and wind, which are the least expensive ways of generating electricity in the Caribbean. Case study data collected from Puerto Rico and other islands found recent Caribbean wind energy costs ranging from 7 to 20 cents per kWh and solar from 8 to 15 cents per kWh.[24] The island possesses about 1,100 MW of solar potential, of which only 22 MW has been utilized.[25]

Capitalizing on the territory's renewable and distributed energy resources, particularly solar PV and wind, and human capital, could provide a path for a more resilient and sustainable electricity provision model, unlock jobs and boost social prosperity in the long-term. Doing so would not only cut pollution emissions, but it would also reduce electricity bills for Puerto Ricans, giving them extra money to spend on restaurants and retail, and attract more businesses and tourists to the island.

Because nothing can be done to prevent hurricanes and other weather-related events, resiliency is key to enable the continuous operation of the power system, as well as expediting the return to normal operations in the presence of widespread damage. Increasing resiliency and hardening Puerto Rico's grid requires the incorporation of modern grid technologies, equipment, protective barriers and enhanced communications, technology and operational technology systems.[26]

Solar power could also increase power resilience in the island because rooftop and land solar arrays, which are closer to end-users, minimize the need for long-range power lines. Shorter low-voltage power lines can be buried underground to further protect them from the Caribbean frequent storms. Although storage is frequently cited as an argument against intermittent renewables-based electric systems, technological innovations have been decreasing its cost, enabling its deployment in places such as Hawaii, the American Samoa, California and Australia, to name a few.

A microgrid that relies on the local solar resource and is capable of operating in parallel with, or independently from, the main grid would provide Vieques with a reliable and affordable electricity source. Microgrids' "modular and flexible architecture, together with smart technology, makes it possible for them to optimize energy collection, storage and

[24] Peter Kelley, *Renewables can help Puerto Rico keep its light on* (December 20th, 2017). Available at: https://www.evwind.es/2017/12/20/renewables-can-help-puerto-rico-keep-its-lights-on/62159 (last consulted: May 2018)
[25] National Renewable Energy Laboratories (NREL), *Energy Snapshot, Puerto Rico* (March 2015). Available at: http://www.nrel.gov/docs/fly15osti.62708.pdf (last consulted: September 2017)
[26] Puerto Rico Energy Resiliency Working Group, *Op. Cit.,* p. 12

delivery,"[27] but they are also more resilient when facing natural disasters. With less extensive networks, redundancy in sub-transmission and distribution systems can be easier, less costly and quicker to restore when damaged.

Hurricane María's damages are estimated to be around US$95 billion, including approximately US$30 billion for critical infrastructure and US$46 billion for housing.[28] Building a new power system will cost between US$10 billion and US$18 billion.[29] Although cheaper than rebuilding the current system, this investment would still impose huge costs on the island, which would in addition find it difficult to raise the necessary capital in financial capitals because it declared bankruptcy in May 2017.[30]

The federal government could jump-start Puerto Rico's power system transformation with a grant or loan to finance the new power system, but it is highly unlikely it will do so.[31] Instead, private sector and civil society initiatives are taking shape. To capitalize on them, financial incentives such as tax exemptions, could encourage independent power producers and infrastructure developments to set up renewable and distributed energy resources and more resilient transmission and distribution grids.[32]

Original GC Proposal: Description

Objective

The original project aimed to deliver a comprehensive action plan the deployment of a medium to long-term energy solution –in the form of a renewables-based microgrid- to Vieques Island, enhancing its efforts towards building resilient electricity grid infrastructure, allowing local residents to have access to reliable electricity to power households, health clinics, schools and the nascent tourism industry. The goal was to cater a scalable solution that could be replicated in other parts of Puerto Rico and the Caribbean islands.

Implementation Plan

The project built on sound methodologies to conduct energy audits and market assessments in the renewable energy field, comprising analysis of supply and demand of microgrids in Puerto Rico, as well as identifying gaps in local expertise and barriers to

[27] Jagoron Mukherjee, Joe Van Den Berg and Owen Ward, *Powering up the neighborhood grid: A strategic entry plan for the microgrid business*, PWC Strategy (August 19th, 2016), available at: https://www.strategyand.pwc.com/reports/powering-up-neighborhood-grid (consulted in October 2017)
[28] Luis Alonso Lugo, "Puerto Rico seeks $94 billion in federal aid after hurricane," *Associated Press News* (November 13th, 2017). Available at: https://apnews.com/ed2fa19863f64b8c951bea74628f2b27 (last consulted: May 2018)
[29] Depending on the source consulted, such as Geoffrey Heal and the Puerto Rico Energy Resiliency Working Group.
[30] Puerto Rican debt and pension obligations are approximately US$123 billion.
[31] President Trump criticized Puerto Rican officials for failing to do enough in the relief efforts and picked a social media fight with the mayor of San Juan, which was then followed by a tone-deaf (to say the least) visit to the island.
[32] Heal, Geoffrey, *Op. Cit.*

value chain development. The action plan for the original project can be summarized as follows:

1. Conduct an initial diagnosis and market assessment based on desk research, remote and in-person interviews with key stakeholders;

2. Develop a skill-gap analysis based on the collection and analysis of data regarding microgrid local expertise in Puerto Rico and Vieques island. Part of the team would travel to the territory to interview key local stakeholders and gain access to detailed information. This trip would also allow the team to engage local stakeholders and entrepreneurs and build a working relationship with them; and

3. Develop a capacity building program which would address the main technical and financial challenges facing local entrepreneurs interested in pursuing enterprises in the microgrid field. This program would be implemented through a partnership with local institutions capable of reaching out to a wider pool of promising entrepreneurs.

Deliverables

This project required obtaining expertise and information from several key stakeholders pertaining to the private, nonprofit and public sectors. Partners[33] were expected to contribute with specific inputs linked to each of the project's deliverables, described below.

Deliverable #1: Comprehensive energy audit and preliminary market assessment
Activity 1: Infrastructure assessment and energy audit of Vieques
Activity 2: Assessment of isolated vs interconnected micro-grid potential in Vieques
Activity 3: Feasibility assessment for micro-grids in Vieques (tech and econ)
Activity 4: Value chain assessment for micro-grid development in Vieques

Deliverable #2: Skills demand and gap analysis
Activity 1: Conduct research on skills and other resources for renewables-based microgrid development and operation
Activity 2: Conduct skill gap analysis looking at existing expertise in the renewables-based value chain in Puerto Rico

Deliverable #3: Capacity building training program for local entrepreneurs
Activity 1: Develop a technical capacity curriculum

[33] PREPA, Puerto Rico Energy Commission (PREC), Association of Contractors and Consultants on Renewable Energy in Puerto Rico (ACONER), Association of Producers of Renewable Energy (APER), University of Puerto Rico, Government Development Bank of Puerto Rico, Banco Popular de Puerto Rico, U.S. Department of Energy, Rockefeller Foundation, and Rocky Mountain Institute (RMI), and Tesla were considered and reached out to for collaboration.

Activity 2: Develop an entrepreneur capacity curriculum
Activity 3: Facilitate the implementation of the capacity building program

Deliverable #4: Action Plan for Microgrid Deployment in Vieques
Activity 1: Review of policies and regulations to support solar microgrids
Activity 2: Prepare draft action plan
Activity 3: Circulate for peer review and finalize the action plan
Activity 4: Present the findings of the action plan

Obstacles to Implementation

Several issues made the original project non-viable. They can be categorized into: i) data; ii) partnerships; and iii) audience.

i. Data: The energy audit and preliminary market assessment required detailed information on Viequense household and hotel electricity load and consumption patterns. However, there is only limited and outdated publicly available information for mainland Puerto Rico and none specific to Vieques.

ii. Partnerships: The team's initial engagements with potential partners were misleading in most cases and outright nonexistent in some others. Two other related problems were i) making sense and accommodating their different agendas, priorities and schedules into one single project; and ii) getting the inputs required from each in a timely and consistent matter.

iii. Audience: Although the overall project was comprehensive, and each deliverable built into the previous one, having different audiences for each deliverable made the whole endeavor extremely complicated and seemingly incoherent.

While it is true that none of the above were unsurmountable obstacles, building on limited and outdated information would have resulted in very general -and mostly useless- recommendations. This, coupled with initial insights obtained through phone calls and e-mail exchanges with local contacts, led the team to rethink the project towards one with a narrower scope but broader impact.

Spring Break Trip Summary

Four out of the seven members of the team travelled to mainland Puerto Rico and Vieques from Sunday, March 11th to Saturday, March 17th, 2018 to:

1. Get a better understanding of the situation on the ground;

2. Assess the feasibility of establishing a solar-powered community center in Vieques;

3. Identify potential sites to host the community center; and

4. Firm-up partnerships and ensure buy-in of local stakeholders.

The team met with several local stakeholders throughout Puerto Rico, including local solar developers, potential investors and donors, representatives from the Vieques Conservation and Historical Trust and the Rotary Club of Vieques, professors from the University of Puerto Rico in Mayagüez, representatives of the Boys and Girls Club of San Juan and Vieques, as well as Vieques High School personnel. While in Vieques, the team also conducted site visits to the Vieques en Rescate Cáncer Center; the Vieques Lighthouse; Tropical Guesthouse; and Plaza de Vieques Kiosk.

The main takeaways from the trip were that:

1. There is a strong interest, both from the community and from potential hosts, to establish a solar-powered community center;

2. Although there is increased awareness of the potential benefits of solar, there are important bureaucratic, financial and skills-related challenges to solar PV deployment on a medium to large scale; and

3. All potential stakeholders warned against working with the government, since it is seen as corrupt, inept and burdensome.

New Project: Description

Objective

The new project seeks to develop the business plan for a solar-powered community center that can serve multiple purposes. During an emergency, the community center can serve as a food distribution point, a cellphone charging station, signal booster for satellite WiFi and other critical Information and Communications Technologies (ICT). Once the emergency has passed, it can host children and adult workshops and/or other side businesses, like a cyber café.

Implementation Plan

This project relies on the expertise and information provided by our main partners, who belong to the private, nonprofit and public sectors. Below is a description of each partner, as well as of their roles and responsibilities.

Infrastructure for Sustainable Development (i4SD)

Description: Guided by the U.N. Sustainable Development Goals, they combine traditional master planning, Internet of Things (IoT) technologies and public-private partnerships to deliver sustainable infrastructure projects based on inclusive community development, sustainability and smart and resilient systems.

Role: Oversee the engineering and procurement of the PV system. They will select and hire a local solar developer to install it on the rooftop of the B&GC of Vieques.

Boys and Girls Club of Vieques

Description: Local chapter of the Boys and Girls of America organization. It provides after-school programs for children and young adults, focusing on leadership skills, good character and citizenship. They currently serve 225 children.

Role: Host the community center, run the board game café and manage the PV system installation and O&M training and energy efficiency awareness program.

University of Puerto Rico at Mayagüez

Description: The University of Puerto Rico is a well-established and mature institution, with a total enrollment of over 69,000 students. The Mayagüez Campus is fully accredited by the Council of Higher Education of Puerto Rico and is a member to the Oak Ridge Associated Universities (ORAU), a non-profit consortium of 65 colleges and universities that acts as management and operating contractor for the U.S. Department of Energy.

Role: Provide detailed information about Vieques, encourage the replicability of the project throughout Puerto Rico and support the PV system installation and O&M training

PV System for the B&GC of Vieques

Determining Value

In the U.S. market, the value of solar energy is determined by three factors: i) electricity consumption rates; ii) additional incentives (rebates, investment tax credits, etc.); and iii) solar radiation. However, assessing the value of the PV system for the proposed community center requires a different approach than the methodology commonly used in the industry for the following two reasons:

1. Under regular conditions, the value PV systems increases as owners can offset part of their grid load with solar. The higher the electricity rates, the higher the incentives to switch to solar. However, electricity provision to the B&GC of Vieques is subsidized

by the local government. Strictly speaking, this means that the energy provided by the PV system will not translate into monetary savings, unless compared with the cost of traditional backup generators (in this case, fueled by diesel).

2. In some U.S. states, many projects get financed through tax equity: a third party owns the system and is eligible to claim the corresponding tax benefits, while the user gets access to the energy generated by the system. Unfortunately, this scheme is not an option for this project because there are no Investment Tax Credits (ITCs) in Puerto Rico.

Although in this particular case a PV system might not have a readily quantifiable monetary value, it does have value in terms of the resilience it can provide during times of emergency. This was demonstrated in the aftermath of Hurricane María, where most solar installations on the island remained standing and functioning in spite of the Category 4 winds because they were tilted closer to a 10 degree angle.[34]

The model outlined in the next sections aims to determine the: i) maximum output a PV solar system installed at the B&GC of Vieques could generate; ii) costs of such system with storage; and iii) financial options to acquire and operate the system.

System Size

The first thing in trying to determine the size of the PV system was to understand and calculate the B&GC's load. Next, with the average radiation on the island and the available surface on the site, taking into consideration the Powerpack and solar panel system provided and installed by Tesla,[35] the power output and final size of the complementary PV system were determined.

Assumptions

1. Site consumption: The B&GC of Vieques has a demand of 21kW with an average consumption of 60.2 MWh/year (charge factor: 33%).[36]
    - Currently, the 10 kW PV system provided by Tesla produces 26% of the total consumption (15.8 MWh/year);
    - The B&GC has a 22-kW diesel back-up generator that can be run whenever it is needed. To stress the analysis, it was estimated that the generator would be

[34] This was verified during field visits during the Spring Break trip.
[35] This system has a generation capacity of 10kW and a storage capacity of 250 kW/ 500 kWh and can run "the Vieques facility 70 percent of the time at 100 percent capacity." Governor Ricardo Roselló, speaking at local radio station 1320. Fred Lambert, "Tesla deploys 6 battery projects in order to power two islands in Puerto Rico, more to come," *Electrek* (December 5th, 2017). Available at: https://electrek.co/2017/12/05/tesla-solar-battery-powerpack-puerto-rico/ (last consulted: May 2018)
[36] Information collected directly from the B&GC of Vieques.

needed 50% of the time,[37] even when the power transmission is restored. This means that the club would consume 22.2 MWh from the back-up system. This is our "target load to meet."

- Radiation: Solar radiation for PV panels at a fixed tilt for San Juan, Puerto Rico (18° 43' N; 66° 00' W), according to the Solar Radiation Data Base from the National Renewable Energy Laboratory (NREL),[38] is shown in Table 1, below:

Table 1. Solar Radiation for PV panels at a fixed tilt

Tilt		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0°	Av	4.30	4.90	5.70	6.10	5.80	6.10	6.10	6.00	5.50	4.90	4.30	4.00	5.31
	Min	4.00	4.70	5.20	5.40	4.40	5.30	5.50	5.20	4.80	4.30	3.70	3.40	4.66
	Max	4.60	5.30	6.20	6.50	6.60	6.80	6.50	6.50	6.10	5.40	4.90	4.50	5.83
Latitude -15°	Av	4.50	5.10	5.80	6.10	5.70	6.00	6.00	6.00	5.60	5.00	4.50	4.10	5.37
	Min	4.10	4.80	5.30	5.50	4.40	5.20	5.50	5.20	4.80	4.40	3.80	3.50	4.71
	Max	4.80	5.50	6.30	6.60	6.50	6.70	6.40	6.50	6.20	5.50	5.10	4.80	5.91
Latitude	Av	5.10	5.60	6.10	6.10	5.40	5.50	5.60	5.80	5.70	5.40	5.10	4.80	5.52
	Min	4.70	5.30	5.50	5.40	4.20	4.90	5.10	5.10	4.80	4.70	4.20	4.00	4.83
	Max	5.60	6.10	6.60	6.50	6.20	6.20	6.00	6.30	6.30	6.00	5.90	5.70	6.12

*/_The yearly average radiation for the 0° latitude was taken to make the analyses.

To size the PV system, the yearly average radiation was taken at 5.3 kWh/m^2/day, which is 230 W/m^2 (2.6 peak sun hours).

With the previous assumptions, and considering loses of 30%, the size of the system needed by the B&GC of Vieques is:

$$\frac{60.8\ [kWh/day]}{2.6\ [PSH]} \times 1.3 \approx 30\ kW$$

However, since the B&GC of Vieques has approximately 45 m^2 of free surface to install the system,[39] the maximum capacity is 9.2 kW.

Feasibility Analysis

Once the size of the PV system was calculated, a benchmark was made to have a sense of the investment costs needed. The following data was used to feed the model that helped determine the feasibility and sustainability of the project.

[37] This was calculated based on (unverified) comments from locals that the submarine transmission line will be out of service for at least two years.
[38] "Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors," *National Solar Radiation Data Base*. (Online). Available: http://rredc.nrel.gov/solar/pubs/redbook/. (Accessed: 03-May-2018).
[39] Information provided by the B&GC of Vieques.

1. Benchmark:

Table 2. Benchmark Commercial PV Systems[40]

		Windmar 10kW	Windmar 5kW	Custom Local
Number of modules	***(#)***	33	17	31
Nameplate Capacity	***(Wp)***	300	300	300
Installed Capacity	***(kW)***	10,000	5,000	9,250
Annual Production	***(kWh)***	15,330	7,670	14,800
Useful Life	***(years)***	25	25	25
Annual Degradation	***(%)***	0.5%	0.5%	0.5%
Net Capacity Factor	***(%)***	17.5%	17.5%	17.0%
Area	***(m^2)***	60	30	45
Installation Period	***(months)***	2	2	2

2. Fixed O&M costs: By taking the residential fixed O&M Costs from the U.S. solar benchmark from the NREL, 21 USD/kW/year plus a risk markup of 9 USD/kW/year,[41] the developers claimed that no additional expenses would be needed.

3. Investment costs: The total direct investment cost was separated between the engineering, procurement and construction of the development costs, as seen in Table 3.

Table 3. PV System Total Direct Investment Costs.

		Windmar 10kW	Windmar 5kW	Custom Local
EPC				
PV System*	*(USD)*	21,500	11,500	19,400
Storage Equipment	*(USD)*	7,080	3,540	6,500
Back Up Gateway	*(USD)*	700	700	700
Development Costs				
Shipping	*(USD)*	300	300	300
Permitting	*(USD)*	300	300	300
Materials	*(USD)*	950	850	800
Installation Service	*(USD)*	1,650	1,100	1,500
Total Direct Investment	***(USD)***	**32,480**	**18,290**	**29,500**

*/_Includes panels, converters and racking

[40] Benchmark information taken from quotes provided by Windmar, powered by Sunnova, and local developers.
[41] F. Ran, D. Feldman, R. Margolis, M. Woodhouse, and K. Ardani, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017," Sep-2017. (Online). Available: https://www.nrel.gov/docs/fy17osti/68925.pdf. (Accessed: 04-May-2018).

Apart from the resilience provided by the system, a way of getting a notion of its monetary value was comparing it to the cost of generating electricity with the diesel back-up generator, currently used to cover the load that the Tesla system doesn't.

For this comparison, the following characteristics of the diesel back-up generator were considered:

- Capacity: 22 kW
- Fuel consumption: 1.98 gal/hour
- Fuel price: 3.10 USD/gal[42]
- O&M Fixed Costs: 1.00 USD/hour-fired

With these assumptions, the 'savings' of generating 14,800 kWh with the custom PV system quoted by a local developer compared to generating the same amount of electricity with the back-up power generator is of 0.30 USD/kWh or 4,440 USD/year.

Development

The proposal for financing the PV system is to have a 50/50 model where half of the investment is covered with grants and/or donations and the other half is covered with debt. This financial strategy will allow the B&GC of Vieques to take advantage of products offered by local institutions[43] to boost the offtake of solar energy on the island. Therefore, the proposed strategy will allow the B&GC to benefit from the fundraising efforts organized by i4SD, in parallel with actively contributing to the debt component of the model. This will spur the sense of ownership to the community and help the non-profit expand its familiarity with finance options offered in the market.

In terms of the project's financing, the following assumptions were considered:

1. PV system: custom 9.9 kW with storage, installed by a local developer;
2. Total direct investment costs: 29,600 USD;
3. Debt/equity ratio: 50/50;
4. Installation period: 2 months;
5. Fixed O&M costs: as mentioned in the previous section (30 USD/kW/year);
6. Diesel back-up generator: as mentioned in the previous section (0.30 USD/kWh or 4,440 USD/year);

[42] Puerto del Rey Marina, Fajardo, PR on April 23rd, 2018. "Fuel prices in Puerto Rico," *ActiveCaptain*. (Online). Available: https://activecaptain.com/fuelLists/fuelIndexROW.php?co=PR. (Accessed: 06-May-2018).
[43] For example, Banco Popular de Puerto Rico offers special loans to fund PV systems ("Préstamo para adquirir solar").

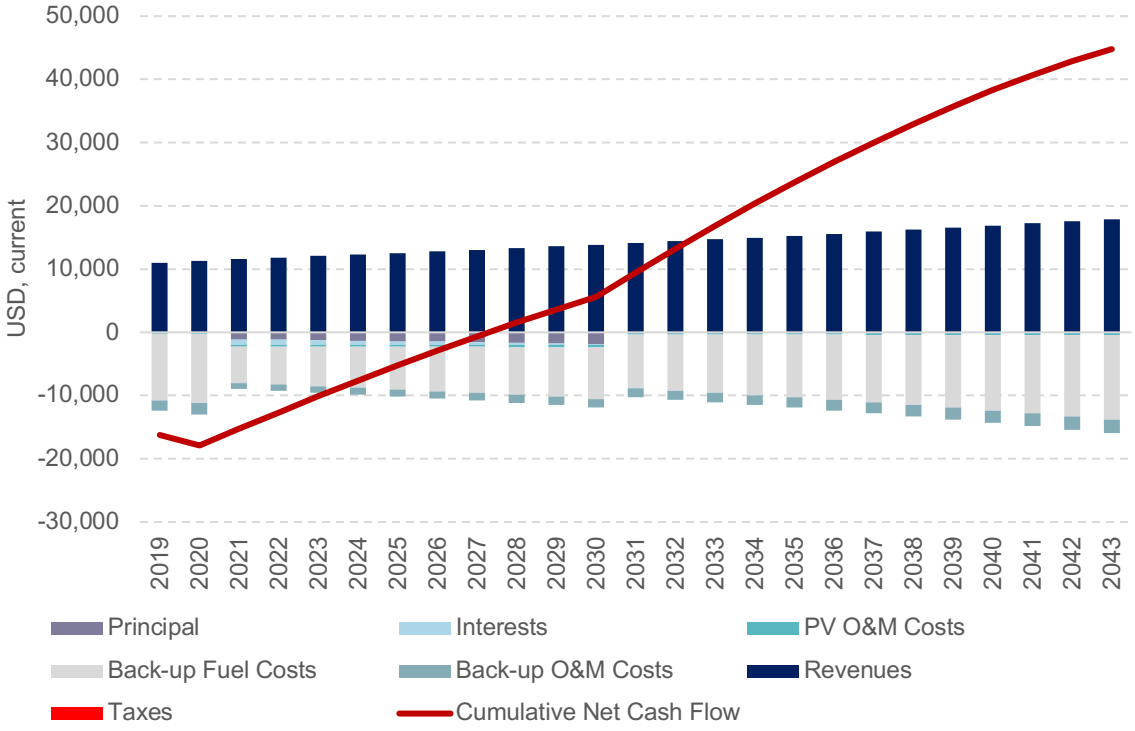
7. B&GC of Vieques load: 21 kW of demand with a charge factor of 33%;
8. Earnings from additional sources for the B&GC of Vieques: 11,000 USD/year[44];
9. Annual fixed interest rate: 1-year LIBOR (2.8%)[45] + 3.0% margin = 5.8%;
10. Repayment period: 10 years;
11. Grace period: 2 years;[46]
12. Annual inflation: 2.5% until 2020,[47] then 2.0%;[48]
13. Corporate tax rate: 20% + 5% for surtax net income;[49]
14. Depreciation: Under the Green Energy Incentives Act 83, Puerto Rico offers an accelerated depreciation of 100% first-year bonus, with the ability to carry over to subsequent tax years until exhausted;[50]
15. Discount rate: 12%.[51]

Although modeled, the corporate tax rate and accelerated depreciation were not considered in the analysis because the B&GC receives fiscal benefits and there is no case of applying an accelerated depreciation if there are no taxes payable.

The cash flows show that with 11,000 USD in earnings from the additional sources, the B&GC of Vieques could pay the loan related to the total direct investment cost of the PV system, in addition to the O&M costs of the PV system and of firing the diesel back-up generator.

[44] The 11,000 USD/year is the base case taking into consideration the business model that is presented in the following sections.
[45] T. Media, "LIBOR - current LIBOR interest rates," *Global Rates - LIBOR Rates*. (Online). Available: http://www.global-rates.com/interest-rates/libor/libor.aspx. (Consulted: May 2018)
[46] Due to the current situation, we believe that a 2-year grace period can be negotiated to wait for the submarine transmission line.
[47] "Puerto Rico - Economic Forecasts - 2018-2020 Outlook," *Exports | 2008-2018 | Data | Chart | Calendar | Forecast | News*. (Online). Available: https://tradingeconomics.com/puerto-rico/forecast. (Consulted: May 2018)]
[48] "Board of Governors of the Federal Reserve System," *FRB: IFDP Notes: The Effects of Demographic Change on GDP Growth in OECD Economies*. (Online). Available: https://www.federalreserve.gov/faqs/economy_14400.htm. (Consulted: May 2018)
[49] Although it is possible that the B&GC will receive a tax exemption, we include this to stress the model. "Puerto Rico - Taxes on corporate income," *Taxes on corporate income*. (Online). Available: http://taxsummaries.pwc.com/ID/Puerto-Rico-Corporate-Taxes-on-corporate-income. (Consulted: May 2016)
[50] "Green Energy Incentives Act of Puerto Rico," *Green Energy Incentives Act of Puerto Rico - Act No. 83 of July 19, 2010*. (Online). Available: http://www2.pr.gov/presupuestos/Budget_2012_2013/Aprobado2013Ingles/suppdocs/baselegal_ingles/035/83-2010.pdf.
[51] Grant Thornton, "Renewable energy discount rate survey results – 2017," Jan-2018. (Online). Available: https://www.grantthornton.ie/globalassets/1.-member-firms/ireland/insights/publications/grant-thornton---renewable-energy-discount-rate-survey-2017.pdf. (Accessed: 05-May-2018).

Figure 1. Cash flows vs B&GC of Vieques electricity consumption by source



The net present value (NPV) of the project's cash flow, at a 12% discount rate, would be 436 USD. Additionally, the expected internal rate of return of the project is 12.4% with a breakeven point in 10 years.

As a comparison, increasing the earnings from the additional sources to 13,000 USD/year, results in a NPV of 18,660 USD and an IRR of 27.2%, with a breakeven point in 5 years.

I4SD, which will oversee the engineering and procurement of the PV system, will select and hire a local solar developer to install it on the B&GC of Vieques's rooftop. Therefore, this first stage of the project will come to an end with the PV system ready to be operated.

Challenges and Opportunities

Challenges

1. Low financial returns: The B&GC of Vieques's PV system may not be large enough to be attractive for banks to fund it. However, the B&GC of Vieques might leverage the broader B&GC of Puerto Rico to get a loan.

2. Weariness to hire debt: The B&GC of Vieques might be reluctant to hire debt to finance the PV system. However, i4SD can provide the necessary guidance to alleviate administrative burden and help the B&GC of Vieques make an informed decision.

Opportunities

1. Greater sense of ownership: The B&GC of Vieques's financial stakes will increase the sense of ownership of the PV system, as well as ensure the top management's commitment with the overall project.

2. Sound financial strategy: Having two different and unrelated funding sources will mitigate financial risks.

3. Enhanced financial savviness: The B&GC and broader Vieques community will get familiar with specialized financial products for PV systems.

Community Center Services

Emergency Services

During emergency situations, the B&GC of Vieques has served as a food collection and distribution center, as well as a meeting center and even as a shelter. The PV system will help guarantee that these activities can be carried out for longer and under more secure circumstances, since lightning would be available. In addition, the PV system will allow Viequenses to charge their cellphones and lanterns, to facilitate communications and emergency relief efforts.

Energy Efficiency Awareness Raising Program

Throughout the Spring Break Trip, numerous interviewees mentioned the lack of responsible energy use among Viequenses. While the team does not see much opportunity for "hard" energy efficiency improvements in households or commercial venues just yet, an important first step is to raise awareness between school aged children and their parents.

Starting with their current staff members, the children they serve and their parents, the B&GC can spearhead efforts in this regard with monthly 2-hour workshops that teach them how much energy usual household appliances use and simple energy saving tips, such as turning the lights or AC off when exiting a room.

Board Game Café

The board game café will open from 5:00pm in the afternoon, when the regular classes offered by the B&GC of Vieques end, to 10:00pm. In line with the B&GC of Vieques's mission, the board game café will serve as a destination for the Vieques community to socialize, play and learn in creative ways.

A number of board games based on logic, problem-solving, strategy and trivia targeted at groups of all ages will be offered. These include chess, card games, backgammon, domino and scrabble, some of which are already popular among Viequenses. In addition, both public and private events may be organized on request; *i.e.* domino tournaments or birthday parties.

Audience

The target audience includes students and their parents, B&GC's personnel and the broader Vieques community.

Business model

The café will charge its guests for renting each board game by the hour (1 USD/hour), regardless of the number of players involved. The café will also offer non-alcoholic beverages and a number of different snacks (empanadas, crisps, chips, etc.). The B&GC of Vieques space is estimated to accommodate about 15 tables of four, for a maximum capacity of the café is 60 people.

Running the café

The inventory required includes tables, chairs, speakers, board games and card decks. A bar will also be included in the space where drinks and light snacks will be served. This requires coffee makers, a microwave and a refrigerator.

Usage of electricity will be required to prepare food on demand and beverages. The blow provides a quick breakdown of the estimated electricity consumption required daily to run the board game café.

The revenues and costs are calculated based on three scenarios: i) an optimistic scenario; ii) a realistic scenario; and iii) a pessimistic scenario, as described in Table 4.

Table 4. Board Game Café

		R		O		P
Assumptions						
Customers	*# per day*	17.5		35		10.5
Customers	*# per year*	2730		5460		1638
Occupation	*# tables occupied per day*	7.5		15		4.5
Occupation	*# tables occupied per year*	1170		2340		702
Orders (food and beverage)	*# per table every two hours*	1.5		2		1
Orders (food and beverage)	*# per working day*	28.125		75		11.25
Game ($/hour)	*$/hour*	10		20		6
Game ($/day)	*$/day*	50		250		30
Food and beverage ($/day)	*$/day*	60		160		24
Cost/Revenue						
COSTS						
Total costs/day	*$/day*	84.5		104.5		77.3
Total costs/week	*$/week*	253.5		313.5		231.9
Total costs/year	*$/year*	13182		16302		12058.8
Total costs at end of year 1*	*$ at year 1*	13382		16502		12258.8
REVENUE						
Total revenue/day	*$/day*	110		410		54
Total revenue/week	*$/week*	330		1230		162
Total revenue/year	*$/year*	17160		63960		8424

**Includes upfront costs of inventory*

PV System Installation, Operation & Maintenance Training Program

The B&GC will provide trainings on grid-tied PV system installation, operation and maintenance. The training will be designed to provide an overview of the fundamental of solar system components, design and application. The topics covered will include site analysis, system sizing, performance estimation and electrical design characteristics. The training will incorporate a hands-on experience where the instructor(s) will provide sessions using the on-site solar system to enhance learning.

Audience

The PV system installation training will be targeted at community members who have interest in building their knowledge of solar systems and/or those who want to pursue careers in solar system design and installation. The PV system operation and maintenance training will be targeted at the B&GC staff and community members who already have a solar system installed on their property.

Running the PV System Training Program

Depending on demand, the trainings will be provided between 4 and 12 times a year. The trainings will require classroom space large enough for 15-20 students and classroom equipment, such as tables and chairs, one computer, one projector and one screen, all of which are already available at the B&GC of Vieques.

The PV system training provider will develop all of the course materials, including slide presentation and handouts, and cover the cost of instructors. The B&GC will provide the classroom space, equipment and print handouts. It will also be charged with promoting the trainings and dealing with participants' registration.

The PV system installation training fee will be 350-550 USD/attendee,[52] and the operation and maintenance course fee will be 250-350 USD/attendee.

Table 5. PV System Installation, Operation and Maintenance Training

Activity	Costs	Revenues	Non-monetary benefits
Installation Training	Electricity, classroom space, equipment and handouts will be covered by the B&GC. Trainers' salaries will be covered by the partner.	350-550 USD/attendee; 6 trainings per year with an average of 5 attendees per training: 5,000-8,000 USD/year.	Enhance local knowledge on financial and energy related benefits of PV systems. Support local solar entrepreneurs and improve local solar workforce capacity.
O&M Training		250-350 USD/attendee; 3 trainings per year with an average of 5 attendees per training: 1,800-2,500 USD/year.	

[52] Solar Energy International PV101; Everblue Entry Level Solar Certification Training; Solar PV Tools and Techniques for O&M; and Solarigen PV Maintenance and Troubleshooting.

Beyond the Global Collaboratory

Although the official Global Collaboratory timeline has ended, the team will move forward with the next steps of the project. Broadly speaking, the period between May and August will be used to secure funding for the project and the period between September and December 2018 will be used to implement the project. Concrete next steps are:

1. Detail and sign the project proposal and formal terms of engagement with i4SD, B&GC of Vieques and University of Puerto Rico in Mayagüez;

2. Initiate and secure funding for the project through donations and crowdfunding campaigns;

3. Firm up partnership with solar training providers and review content and methodologies;

4. Install PV system and board game café. Review/ update O&M and financial plan as needed; and

5. Identify platforms/ conferences to present the key findings and development of the project to ensure replicability in other parts of Puerto Rico and the Caribbean.

Bibliography

"Puerto Rico - Economic Forecasts - 2018-2020 Outlook," *Exports | 2008-2018 | Data | Chart | Calendar | Forecast | News*. Available: https://tradingeconomics.com/puerto-rico/forecast. (last consulted: May 2018)

"Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors," *National Solar Radiation Data Base*. Available: http://rredc.nrel.gov/solar/pubs/redbook/. (last consulted: May 2018)

ActiveCaptain, "Fuel prices in Puerto Rico," (Online). Available: https://activecaptain.com/fuelLists/fuelIndexROW.php?co=PR. (last consulted: May 2018)

Board of Governors of the Federal Reserve System, *FRB: IFDP Notes: The Effects of Demographic Change on GDP Growth in OECD Economies*. (Online). Available: https://www.federalreserve.gov/faqs/economy_14400.htm. (last consulted: May 2018)

Comisión de Energía de Puerto Rico (CEPR), *Sistema de Transmisión de la AEE* (September 18th, 2015). Available at: http://energia.pr.gov/datos/transmision/ (last consulted: October 2017)

Grant Thornton "Renewable energy discount rate survey results – 2017," Jan-2018. (Online). Available: https://www.grantthornton.ie/globalassets/1.-member-firms/ireland/insights/publications/grant-thornton---renewable-energy-discount-rate-survey-2017.pdf. (last consulted: May 2018)

Green Energy Incentives Act of Puerto Rico - Act No. 83 of July 19, 2010. Available: http://www2.pr.gov/presupuestos/Budget_2012_2013/Aprobado2013Ingles/suppdocs/baselegal_ingles/035/83-2010.pdf

Heal, Geoffrey, "How to fix Puerto Rico's power system," *Politico* (December 12th, 2017). Available at: https://www.politico.com/agenda/story/2017/12/12/how-to-fix-puerto-ricos-power-system-000594 (last consulted: May 2018)

Kelley, Peter, *Renewables can help Puerto Rico keep its light on* (December 20th, 2017). Available at: https://www.evwind.es/2017/12/20/renewables-can-help-puerto-rico-keep-its-lights-on/62159 (last consulted: May 2018)

Lambert, Fred, "Tesla deploys 6 battery projects in order to power two islands in Puerto Rico, more to come," *Electrek* (December 5th, 2017). Available at: https://electrek.co/2017/12/05/tesla-solar-battery-powerpack-puerto-rico/ (last consulted: May 2018)

Lugo, Luis Alonso, "Puerto Rico seeks $94 billion in federal aid after hurricane," *Associated Press News* (November 13th, 2017). Available at: https://apnews.com/ed2fa19863f64b8c951bea74628f2b27 (last consulted: May 2018)

Mufson, Steven, "Hurricane Maria has dealt a heavy blow to Puerto Rico's bankrupt utility and fragile electric grid", *The Washington Post* (September 20th, 2017), available at: https://www.washingtonpost.com/news/energy-environment/wp/2017/09/20/puerto-ricos-power-company-was-already-bankrupt-then-hurricane-maria-hit/?utm_term=.512aa54016a2 (consulted in September 2017)

Mukherjee, Jagoron, Joe Van Den Berg and Owen Ward, *Powering up the neighborhood grid: A strategic entry plan for the microgrid business*, PWC Strategy (August 19th, 2016), available at: https://www.strategyand.pwc.com/reports/powering-up-neighborhood-grid (consulted in October 2017)

National Renewable Energy Laboratories (NREL), *Energy Snapshot, Puerto Rico* (March 2015). Available at: http://www.nrel.gov/docs/fly15osti.62708.pdf (last consulted: September 2017)

Puerto Rico Energy Resiliency Working Group, *Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico* (December 2017). Available at: https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf (last consulted: May 2018)

Ran, F. *et al.*, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017," Sep-2017. (Online). Available: https://www.nrel.gov/docs/fy17osti/68925.pdf. (last consulted: May 2018).

T. Media, "LIBOR - current LIBOR interest rates," *Global Rates - LIBOR Rates*. (Online). Available: http://www.global-rates.com/interest-rates/libor/libor.aspx. (last consulted: May 2018)

Tax Summaries, "Puerto Rico - Taxes on corporate income," *Taxes on corporate income*. (Online). Available: http://taxsummaries.pwc.com/ID/Puerto-Rico-Corporate-Taxes-on-corporate-income. (Last consulted: May 2018)

Treene, Alayna, "The Puerto Rico recovery, by the numbers," *Axios* (October 9th, 2017). Available at: https://www.axios.com/the-puerto-rico-recovery-by-the-numbers-1513306055-21f2affd-cd99-4d7b-9667-b86bd782b015.html (last consulted: May 2018)

U.S. Census Bureau, *Quick Facts: Vieques Municipio, Puerto Rico*. Available at: https://www.census.gov/quickfacts/fact/table/viequesmunicipiopuertorico/INC110216 (last consulted: May 2018)

U.S. Energy Information Administration (EIA), *Puerto Rico, Territory Energy Profile Analysys* (September 21st, 2017). Available at: https://www.eia.gov/state/analysis.php?sid=RQ (last consulted: October 2017)

United Nations Human Rights Office of the High Commissioner, *Puerto Rico: Human rights concerns mount in absence of adequate response* (October 30th, 2017). Available at: http://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=22326&LangID=E (last consulted: May 2018)

Woods, Lynn, "Puerto Rico Update: Vieques On the Path of Recovery," *Travel Market Report* (February 14th, 2018). Available at: http://www.travelmarketreport.com/articles/Puerto-Rico-Update-Vieques-On-the-Path-of-Recovery (last consulted: May 2018)

Appendix: Spring Break Trip Report

Introduction

In September 6-7, 2017 Hurricane Irma hit Puerto Rico leaving a sever damage on the island's infrastructure. Two weeks later, hurricane María devastated the Caribbean, hitting Puerto Rico with winds of over 150 mph and more than 25 inches of rain. Although most power generation facilities remained undamaged, the transmission and distribution network was devastated, leaving the whole territory without electricity. Six months afterwards, more than 15% of the power grid is still out of service.

The team seeks to develop a Community-supported Solar Nanogrid in the Island of Vieques, which is 8 miles east of mainland Puerto Rico, that can provide energy and communication services to the local population during an emergency. During non-emergency times, the community center will seek to strengthen the social tissue with skills training and entertainment services.

Four out of seven members of the team -Alejandro Valdez, David Maravilla, Lara Younes and Rodrigo Inurreta- travelled to mainland Puerto Rico and Vieques from Sunday, March 11th to Saturday, March 17th, 2018. The purpose of the trip was to:

1. Get a better understanding of the situation on the ground;
2. Gather relevant data from potential stakeholder meetings to assess the feasibility of establishing a solar-powered community center in Vieques;
3. Identify potential sites to host the community center; and
4. Firm up partnerships and ensure buy-in of local stakeholders and community residents.

The team met with a number of stakeholders throughout mainland Puerto Rico and Vieques, including:

- Local solar developers active throughout the territory: Verdifica;
- Potential investors: Steve Wilson;
- Vieques Conservation and Historical Trust Head: Mark Martin;
- Rotary Club of Vieques representatives: Mike and Marie Murphy;
- Professors from the Electrical Engineering and Capacity departments of the University of Puerto Rico (UPR) in Mayagüez: Rosa Pla Cortés, Cecilio Ortiz García;
- High School personnel
- Representatives from the Boys and Girls Clubs of Vieques and San Juan: Patricia de la Torre, Olga Ramos and Venus Hernández;

- Local residents.

The team also conducted site visits and collected data on the following locations:

- Vieques Conservation and Historical Trust
- Plaza de Vieques Kiosko;
- Vieques Lighthouse;
- Tropical Guesthouse;
- Vieques en Rescate Cancer Center; and
- High School

Day #1: Sunday, March 11th, 2018

Stakeholder meetings with:

1. Gabriel Rivera, CEO of Verdifica, a local solar developer;
2. Steve Wilson, independent US investor willing to fund solar projects in Puerto Rico; and
3. Kevin X, independent solar developer volunteering for Verdifica.

Takeaways:

- Hurricane María provided a unique opportunity to rethink power delivery systems and there is a wider recognition of the importance of solar;
- ~90% of solar systems in Puerto Rico are grid-tight and lacked batteries;
- The Puerto Rico Electric Power Authority (PREPA) allows net metering for households to sell any excess generation back to the utility. However, household systems sell back at a loss, since PREPA buys at 7.5 cents/kWh but sells at 23 cents/kWh;
- Solar systems in Vieques are not developed through Power Purchase Agreements contracts.
- Financing solar systems is generally done by grants (owned by end-users), who are put at a disadvantage because any excess electricity sold to the grid is bought by PREPA at a much lower rate than it is sold. This limited the attractiveness of solar pre-María.
- Puerto Rico has a great solar irradiation, which means that solar panels can be tilted to only 5-8 degrees. Most panels that were installed with an inclination of 10-15 degrees were damaged by the hurricane.
- In general, both diesel and solar post-María systems have been poorly designed and oversized.

- Verdifica supports emergency power delivery by providing solar kits ranging from 500 Watts to 2000 Watts to power small refrigerators, medical equipment and minimum lighting. These systems' market value is 3,000 USD, compared to Tesla's 25,000 USD. Verdifica raises money in various crowdfunding platforms and events to finance the systems, then proceeds to temporarily handed to customers in need. Verdifica gets the systems back when households have access to electricity and hand them to people still lacking power.
- Some of the main barriers associated with the installation of solar systems in mainland Puerto Rico and Vieques are:

1. Transporting solar system components to Vieques, because the ferry service is unreliable;
2. Bureaucracy and corruption;
3. The customer base is generally uneducated and/or unaware of the benefits of solar. Public perception on solar is, at best, mixed because of unrealistic expectations: people think that solar home systems (SHS) will provide them with reliable power services; however, most systems are grid-tight and lacked batteries, so when the grid went down with the Hurricane, the SHS went down as well.
4. There is limited help from Puerto Rico government to help people to adopt solar systems. In addition to this, the government is also exploring the opportunity to tax off-grid solar systems.

- Some of the main recommendations and opportunity areas are:
    1. Try to avoid working with government institutions as much as possible. It would be preferable to work on a community-owned building that is solar ready.
    2. Communities and households with unreliable or no grid access even before María are more likely to value solar.
    3. Before María, residential consumption patterns were excessive. The peak load in Vieques was 5.5 MW, most of which came from HVAC use during summer. As such, solar passive systems and energy efficiency solutions must be considered a top priority.
    4. Off-grid solar initiatives are disorganized.

Day #2: Monday, March 12th, 2018

Stakeholder meetings with:

1. PREPA Electrician (spoke on a personal note, not as a company representative)
2. Oscar Ruiz, Sailrelieg.team

Takeaways:

- Approximately 70% of Vieques already has access to electricity.
- Vieques runs on two generators and a submarine cable. However, the submarine cable is out of service and repair will take two years.
- PREPA is deploying all of its efforts to speed the process of restoring electricity in most areas.
- Three areas remain isolated and disconnected from the grid in Vieques: Monte Santo, Monte Carmelo and Verde Vieques.
- Currently, no one is paying for electricity. FEMA might be paying for it or other relief funds.
- The electricity rate in Vieques is 30 cents/kWh, higher than in mainland Puerto Rico.
- Some considerations for project development:

    1. Permitting: it takes around eight months to get all the permits. Project owners must pay a flat rate of 100 USD for permitting and additional fees (undetermined) for grid interconnection.
    2. Additional fees: 6 USD/month to maintain the grid connection (demand charge).
    3. The government is looking into taxing solar off-grid projects. In 2006, the drastic fiscal reform incentivized pharmaceutical companies to move operations away from Puerto Rico. Similarly, PREPA is expecting a "death spiral" due to the potential reduction in the customer base.
    4. Financing renewable energy projects is problematic: The Green Energy Fund, overseen by the Energy Authority, is currently inaccessible. One of the requirements to get funding for renewable projects is to be connected to the grid, which cancels opportunities for off-grid solutions.
    5. In light of potential customer default, pay-as-you-go is considered as the best business model.
    6. Puerto Rico does not benefit from federal support mechanisms such as the Investment Tax Credit. However, there is a possibility for US investors to fund a system in PR and benefit from ITC if they own the system.
    7. The main challenge is to identify appropriate financing schemes for low-income people.
    8. Bureaucracy and corruption were highlighted several times. There is a reluctance to work with government agencies.

Day #3: Tuesday, March 13th, 2018

Stakeholder meetings with:

1. Mark Martin, Head of the Vieques Conservation and Historical Trust
2. Mike and Marie Murphy, FEMA and Vieques Rotary Club
3. High School Principal

Takeaways:

- There is a remarkable lack of training in solar energy on the island. In this light, the Trust organizes solar fairs to educate and foster solar adoption among Viequenses.
- Most jobs in Vieques are generated by tourism and the GE manufacturing plant.
- A suggestion was made to address the public waste management problem with a business model relying on clean energy.
- Vieques Rotary Club could be a potential funding source for upcoming projects
- Interest from the Vieques Conservation and Historical Trust and Vieques Love to fund solar projects.
- People under treatment are ready to pay 20 USD/day to run their dialysis.
- Solar United Neighbors is a solar rooftop-oriented community.
- High HVAC needs (summer), so energy efficiency is fundamental in Puerto Rico and Vieques; however, it is not part of the general “attitude”.
- 63% of children in Puerto Rico live under the poverty line.
- Discussion about the business model of the club: a suggestion is to focus on food. Example: Subway served as a social meeting point during the hurricane for almost all Viequenses. This could ensure the generation of revenue streams.
- Expressed support and willingness to present the project proposal at the next Rotary Club Meeting.
- Only three schools remain open in Vieques after Hurricane María struck.
- The school is running on a mini back-up generator that can only power half of the school needs.
- The school operates under the supervision of the Oficina de Mejoramiento de Escuelas Publicas (OMEP), an agency responsible for overseeing school infrastructure.
- The school principal does not have the final say in infrastructure projects nor can she charge any fees for services provided in the school.
- The school has served as an emergency-relief center before.
- The principal believes the community would be willing to support the installation of a solar system in the school.

Day #4: Wednesday, March 14th, 2018

Stakeholder meetings with:

1. Venus Hernández, President of the Boys and Girls Club (BGC) of Vieques
2. Robert, Taxi driver with solar panels

Takeaways:

- The BGC has a solar system with batteries that was provided by Tesla a few weeks after María hit Puerto Rico. Tesla lent it to them free of cost for a year, after which they will have to negotiate the terms and conditions for payment. Currently, the BGC does not have a plan to pay for the system.
- The system provides for basic electricity needs and is used to purify water. It has failed in the past, and no one at the Club knows how to operate it.
- The Club worked as an unofficial relief center in the past by collecting and distributing food and arranging travel for people with urgent medical needs.
- Membership in mainland Puerto Rico is 20 USD/year, but the fee is waived in Vieques.
- The Club operates from 15h30 to 20h00 from Monday to Friday (there are occasional activities on Saturdays) and provides transportation services for its members to mitigate public safety concerns.
- Currently, the Club has 125 members in Vieques.
- The Club's main activities comprise education, leadership and community involvement training for boys and girls aged between 8 and 18.
- The Club is also looking for ways to provide teens with basic training in computer management and other technical skills that could enable them to enter the labor force.
- Robert bought solar panels and batteries right before María. The system survived the Hurricane.
- He accessed credit through Banco Popular, which has a specific unit to grant loans to expand solar in the country. Banco Popular took care of everything: permitting, assessment, installation, etc.
- In the past, he payed ~120 USD/month for his electricity bill. Now, he pays ~90 USD/month to cover the full cost of the system + the electricity bill.

Day #5: Thursday, March 15th, 2018

Stakeholder meetings with:

1. Rosa Pla Cortés, UPR
2. Cecilio Ortiz García, UPR

Takeaways:

- Puerto Rico implemented a solar program called Kioskos de Luz (Solar Kiosks) aiming to install solar systems in isolated communities. Systems are 4,000 – 6,000k each one, 10x6ft and they host a 4-panel PV system. The kiosk also includes charging stations for mobile phones, batteries to store energy and a small refrigerator to store medicines. The community oversees the small refrigerators, so it is safe to leave medicines inside. There are four kioskos installed in different municipalities across the island.
- They can provide technical expertise regarding system desing and operation, as well to support transportation of the equipment.
- Solar panels that were tilted between 10-12 degrees (instead of the usual 18 degrees) were generally able to stand stronger winds because they are almost flat.
- They want to formalize a memorandum of understanding (MOU) with Columbia to keep collaborating.

Day #6: Friday, March 16th, 2018

Stakeholder meetings with:

1. Olga Ramos, Head of San Juan's Boys and Girls Club
2. Patricia de la Torre, San Juan's Boys and Girls Club

Takeaways:

- BGC is a fundamental actor across Puerto Rico's communities and it has centers operating in the main cities of all municipalities.
- The NGO's mission is to serve youth and children; however, it also offers various family-oriented services to ensure social development.
- BGC has detailed information about its buildings' load and electricity bills, as well as basic information needed to size PV systems.
- BGC is willing to charge for services as long as the revenue stream is used to pay back the system; they are interested in developing educational services or products as this is in line with their mission.
- Their facilities can be used as emergency relief centers because they have a close relationship with the communities.
- BGC believes in the importance of providing energy services to the community. However, they feel uncomfortable with charging people for charging their phones or appliances. An alternative could be to charge subscription fees to the generation system. This way, community members could become associates of the generation system and get involved in maintaining the system.