IMPROVED PERMITTING AND INTERCONNECTION PROCESSES FOR ROOFTOP PV SYSTEMS IN PUERTO RICO

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Cover Photo (by one of the authors):

Rooftop PV system in Casa Pueblo, Adjuntas, PR. A collaboration involving Casa Pueblo (a community-based NGO), UPR-Mayagüez and the local PV company Solartek. This was the first net metered system in Puerto Rico, and earned the “Outstanding Electrical Engineering Project” Award from the Puerto Rico State Society of Professional Engineers and Land Surveyors.

Back Cover Photos (by the authors):

Residential rooftop PV system owned by one the authors.

Houses with rooftop PV systems in Villa Turabo (Caguas), the first PV Community in Puerto Rico (40 houses with net metered PV systems).

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CHAPTER 1

INTRODUCTION

As of February 2013, Puerto Rico depended 99% in fossil fuel for electric power generation (approximate values: 60% oil, 23% natural gas, and 16% coal). The remaining 1% came from renewable sources (e.g., hydroelectric, wind and solar photovoltaic). This energy portfolio shows a significant dependency on oil-based fuels. The Puerto Rico Electric Power Authority (PREPA) is the only electric utility in the island. PREPA is a vertically-integrated electric utility providing transmission and distribution of electricity as well as most of the generation in Puerto Rico. More than two thirds of the overall cost of electricity in Puerto Rico comes from fuel costs, being oil the largest contributor due to its high cost and price volatility. There is a direct link between the cost of electric energy and any variation in the price of the barrel of oil. Average cost per kWh sold in Puerto Rico during 2012 was 27.78 cents in 2012, more than twice the average electricity price in the U.S. according to the Annual Energy Outlook 2010 data. Considering these facts, public awareness needs to be increased on the availability of local renewable energy sources and the feasibility of their use to decrease the Island’s dependence on fossil fuels. The best renewable energy resource in Puerto Rico is solar energy. Photovoltaic (PV) technology has been studied and implemented in Puerto Rico for decades. The first PV system that was integrated to the electric power grid in Puerto Rico began operating in 1987 in Juana Diaz. After successful tests in collaboration with PREAA, the system was dismantled. At the time, costs were high and the necessary policies and incentives were not in place to support the growth of PV in the Island.

Even though the state energy office was created in 1978 (Act 128), it was not until 1993 that an energy policy was formally approved through an executive order signed by the Governor of Puerto Rico. The Energy Policy of 1993 represented an important step in providing a framework to guide energy issues in Puerto Rico. However the lack of resources prevented the energy office (renamed the Puerto Rico Energy Affairs Administration that same year) to properly carry out its mission of revising and overseeing compliance with the energy policy mandates. On the other hand, various organizations and entities kept insisting on the need to change Puerto Rico’s energy sources, technologies and practices. The University of Puerto Rico-Mayagüez (UPRM) has been an energy leader in the Island for many years. UPRM researchers have delivered seminal work on renewable energy sources and technologies, for example the first distributed generation (DG) studies in Puerto Rico. DG refers to the operation of power generation close to the points of use (at the distribution level), contrary to the dominant energy model where electric power is generated in large power plants, then delivered to customers using transmission and distribution lines. Figure 1.1 shows part of the DG work carried out at UPRM which entailed the analysis of a DG source integrated in a rural distribution feeder operating at a voltage of 13.2 kV. The impact of the operation of DG can be observed in Figure 1.2, where the fault current increases with the presence of the DG source. The DG source was modeled as a synchronous generator, however the impact of inverter-based DG is much less than depicted in Figure 1.2. Further studies at UPRM proved that point through interconnection studies of PV systems.

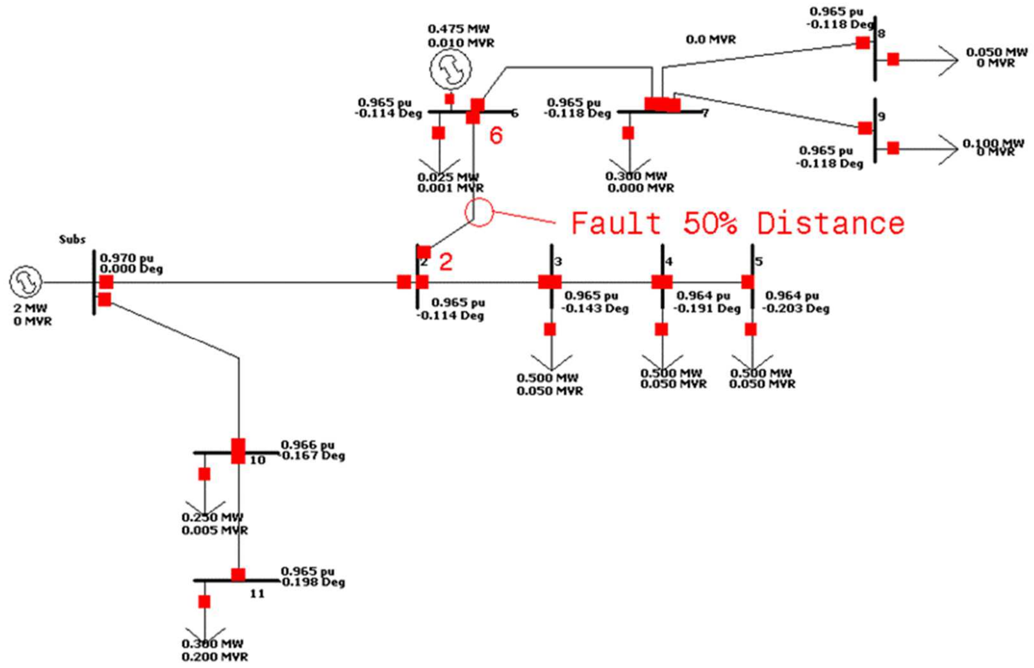


Figure 1.1: The simulation of a fault between buses 2 and 6 in a 13.2kV feeder with a DG in bus 6. (Reference: Doeg Rodríguez, E. O’Neill-Carrillo, UPRM, 2002. Funded by the National Science Foundation)

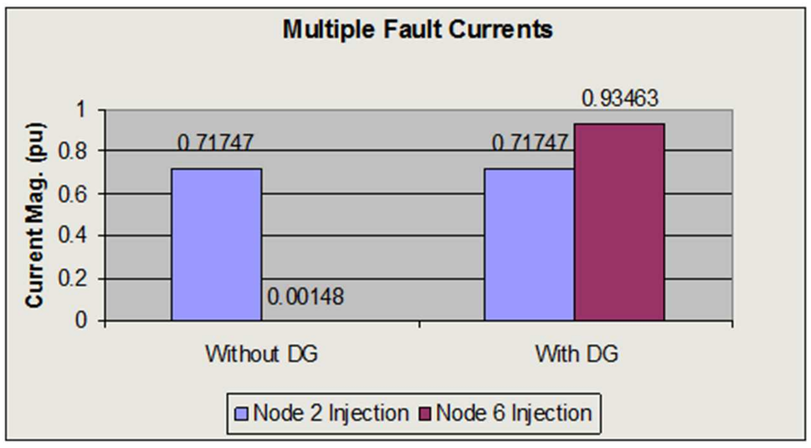


Figure 1.2: Effect of DG on fault currents (Source: Doeg Rodríguez, E. O’Neill-Carrillo, UPRM, 2002. Work funded by the National Science Foundation)

Just nine years ago, in 2004, the reaction to the idea of DG in Puerto Rico was mainly skepticism. Many argued that for DG to succeed, net metering needed to be established. Under net metering a person that owns a small DG system could sell the excess generation to the utility at the same rate that the utility charges the customer for utility power. Most people agreed that PREPA would not welcome net metering. On August 16, 2007 the Governor of Puerto Rico signed Act 114, mandating PREPA to establish a net metering program in Puerto

Rico, including required standards and rules, within one year. Earlier that year, on January 2007, the Institute for Tropical Energy, Environment and Society (ITEAS by its acronym in Spanish) was founded with the objective of studying Puerto Rico's challenge from the holistic perspective of sustainability. The participation of ITEAS in the public hearings held by PREPA in 2008 regarding net metering and DG interconnection rules proved to be essential to ease the many restrictions the utility wanted to impose on DG interconnection. On August 16, 2008 net metering officially began in Puerto Rico. To this date, the authors feel this is the most important milestone in the electric energy industry in Puerto Rico since 1941 (the creation of PREPA), because it heralded a new era in which the dominant, central energy model was not the only electric energy alternative in the Island. Incentives for renewable energy installations were put in place to support the new net metering effort.

Between 2008 and 2009, UPRM researchers, working with support from the Puerto Rico Energy Affairs Administration (PREAA), completed the first comprehensive study of the renewable energy potential for electricity generation in Puerto Rico. The "Achievable Renewable Energy Targets" (ARET) project showed and quantified the Island' abundant renewable energy alternatives for electric power generation. Figure 1.3 shows one of the main results from the ARET study, the average insolation in Puerto Rico. This was obtained by combining results from various measurements studies (shown as blue dots in Figure 1.3) previously done in the Island and creating a visual tool with common units.

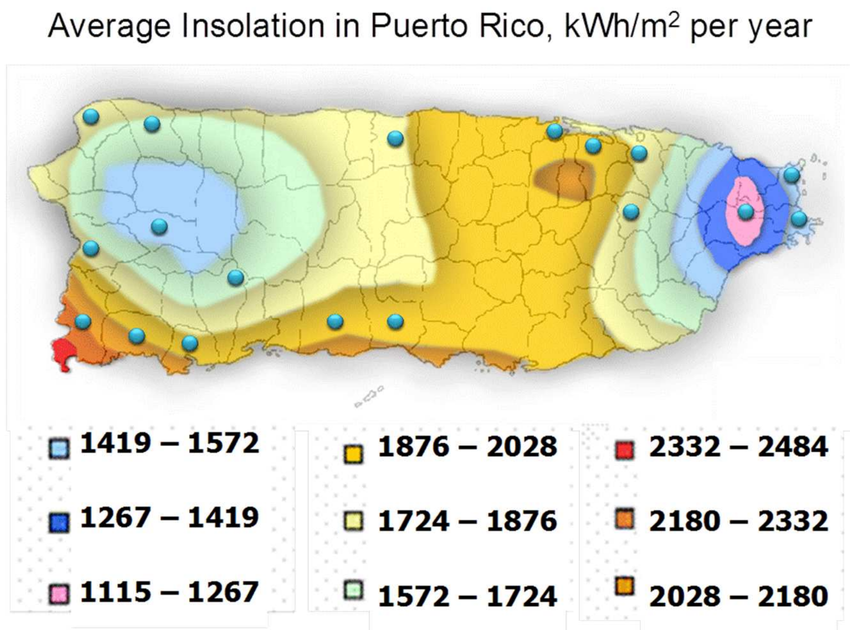


Figure 1.3: The first visual tool for insolation in Puerto Rico (Work funded by the PREAA, 2008-2009. Reference available at http://www.uprm.edu/aret)

From Figure 1.3 one can estimate that 70% of the population lives in areas with an excellent solar resource. On average Puerto Rico receives 2,000 kWh per square meter (m^2) compared to Germany's 1,000 kWh per square meter. This comparison is important because Germany is the world leader on PV systems. If that solar potential were to be realized, then using only 65% of residential rooftops in Puerto Rico all the electric energy used could come from PV systems, as shown in Figure 1.4 (based on 2006 energy demand levels). There are technical and social limitations to achieve this, however the potential for an increased use of PV exists, and is available on residential rooftops in Puerto Rico (with an area of 180,814,184 m^2). Thus, there is no need to use scarce land in the Island for PV systems, and the energy policy should foster the use of residential, commercial and industrial rooftops. Rooftop PV systems, connected as DG sources and under net metering also have less impact on electric power grid operation because of their size and geographically dispersed nature. Furthermore, PV systems can be purposely integrated to distribution systems in ways that account for variations of the solar resource, and thus reducing the impact to the power grid (H. Ladner, *Design of PV Systems using K_t Distributions*, M.S. Thesis, December 2008, UPRM). In 2010 the Governor of Puerto Rico signed Act 82-2010, mandating for the first time a renewable portfolio standard (RPS) in the Island. An RPS is a policy instrument that establishes goals that strive to increase the levels of renewable energy used in a jurisdiction. Act 82-2010 established 20% as the renewable energy goal to be achieved by the year 2015. Tied to Act 82-2010, a Green Energy Fund (GEF) was established through Act 83, also signed in 2010. This fund supports yearly incentives in two tiers, tier 1 for systems up to 100 kW, and tier 2 for larger systems. The GEF substituted the incentives that were created in 2008.

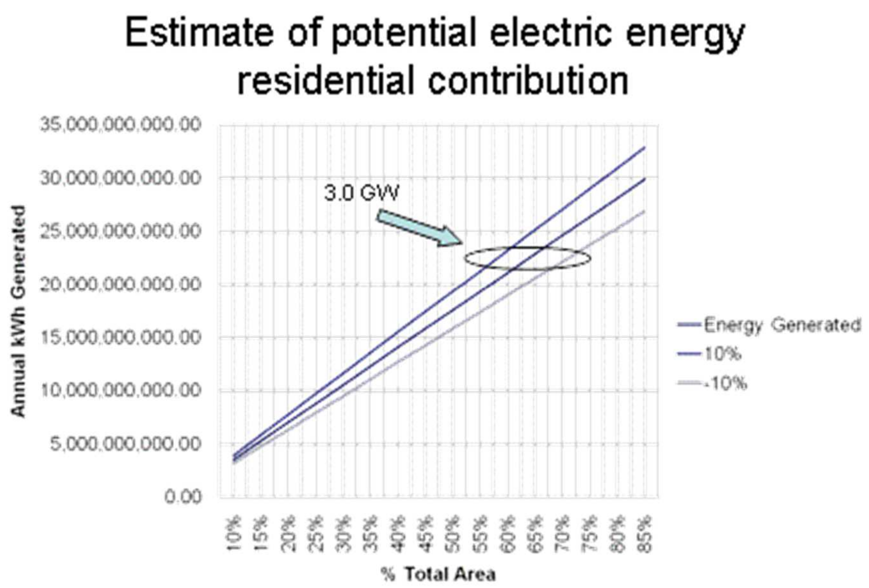


Figure 1.4: Potential of electric energy generation from the Sun as a function of percentage of residential rooftops with PV systems. (Work funded by the PREAA, 2008-2009. Reference available at http://www.uprm.edu/aret)

A final example of the technical work that proves the feasibility of DG systems in Puerto Rico, comes from graduate work at UPRM. This work proved that higher distribution voltages and well-planned, distributed placement of DG allow for increased levels of integration of DG (*Evaluation of Photovoltaic Distributed Generation on the Voltage Profile of Distribution Feeders*, M. Irizarry, Masters project, May 2011, University of Puerto Rico – Mayagüez). Figure 1.5 shows simulations for a 2.5 MVA load in 4.16 kV feeder and the effect on voltage profile of different levels of DG penetration and location. Even distribution along the feeder allows high DG penetration, up to 70% of feeder load. However, just 10% penetration located at the end of a feeder infringes the ANSI maximum voltage level in steady state. This is due to the increase in current towards the substation in segments of the feeder that have larger impedance. On the other hand, increased levels of DG can be integrated as one gets closer to the substation as the larger feeders have smaller impedances. Simulations in a 13.2 kV feeder with a load of 11 MVA were also performed. This higher voltage allows more DG capacity to be interconnected at all locations in the feeder. Furthermore, better voltage profiles and loss reductions are attained when DG is distributed along the feeder. Thus, it would be a sound energy policy to design and build distribution systems to support the maximum use of DG possible.

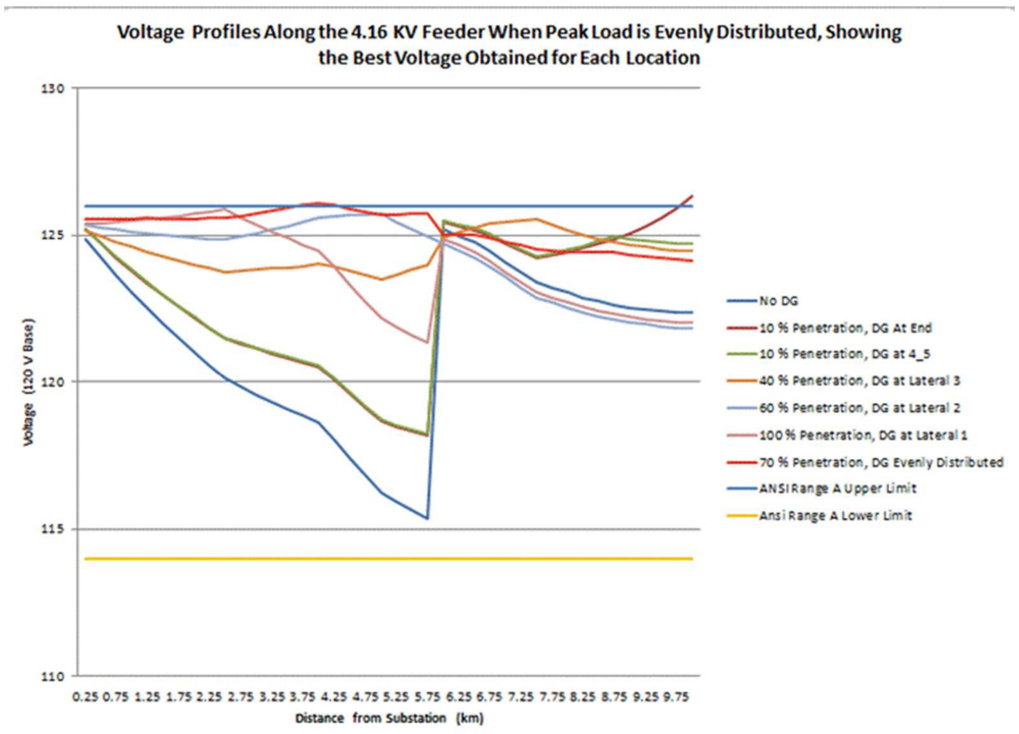


Figure 1.5: Voltage profiles with various levels of DG penetration in a 4.16 kV feeder. Source: *Evaluation of Photovoltaic Distributed Generation on the Voltage Profile of Distribution Feeders*, M. Irizarry, Masters Thesis, May 2011, University of Puerto Rico – Mayagüez. (Figure used with permission of the author)

In the five years after the beginning of net metering in Puerto Rico in 2008, the Island have made more progress in the renewable energy arena than in the previous forty years (1973 marked by the oil embargo, which sparked important efforts that were not continued once oil went back to acceptable prices in the early 1980s). But still many persons contend and question why Puerto Rico is not doing more on the renewable energy area. If Puerto Rico has the solar resource, the experience, the expertise, evidence of technical feasibility for an increased use of PV systems, why is the Island not using more solar energy? The answer is complex, but it can be summarized with the following: this challenge IS NOT a purely technical problem. Conservation and efficiency rarely are included in the discussions of Puerto Rico's energy portfolio, because they involve human and social elements not easily grasped or understood by the mainly "technical" people that work on energy issues. There is also a tendency to view the electric energy challenge only as one of supplying the demand for electric energy of customers, thus conservation and efficiency are not considered as important energy alternatives. Furthermore, the dominant energy model is one that favors a central, hierarchical organization of the electric industry, with little (if any) public participation. That dominant energy model also favored one way of planning and operating the electric infrastructure owned by the people of Puerto Rico. These legacy practices have come under close public scrutiny in recent years due to high electricity costs, and problems related to PREPA's finances.

Although the comparison with Germany, cannot be a one-to-one comparison, much can be gained from evaluating their path to an increased used of PV energy. Key findings from an evaluation of German utilities actions related to PV are:

- Renewable electricity output has priority in grid management – the system operator manages non-renewable units around the integration of renewable electricity, which has priority in the system integration.
- Customer satisfaction is important and "customers want utilities to embrace renewables, not just accept them."
- German utilities must interconnect all renewables to the grid and the rules are very clear.
- External disconnects and system inspections are not necessary. German utilities used to require external disconnect switches but do not any longer. Since there are so many PV systems on their grid, it would be a burden to the utility to utilize and manage them all.
- Ease of integration is inherent to the less litigious nature of Germany and the assignment of no-fault as long as the specific rules were followed.
- Clarity and transparency – there are no surprises or uncertainties regarding processes and therefore all stakeholders can plan accordingly.
- German utilities want PV to stay on the grid during disturbances to provide grid support.
- Large ground mount systems are a relatively small and decreasing part of the overall German solar market.

- As long as a structure is built to code, no permits are needed for residential PV. The only requirement is to register the PV system with Germany's energy agency (1 page long, 15 minutes to fill out online).

Germany has shown that it is possible to address obstacles and foster an increased use of solar energy. There are key social factors such as institutional barriers, social acceptance, stranded costs among others that need to be addressed in a holistic way before one can see a more sustained and orderly growth of PV systems in Puerto Rico.

DOE's Rooftop Solar Challenge

A contribution towards addressing part of the challenges facing PV energy is to study and propose alternatives to reduce the time and costs related to PV administrative processes, interconnection, as well as addressing planning and zoning issues. This book summarizes work on those areas completed through a U.S. Department of Energy (DOE) project, under the Rooftop Solar Challenge program of the SunShot Initiative. This DOE program required:

- Partnerships among relevant stakeholders to improve market conditions for rooftop PV in major regions of the USA.
- Focus on grid-connected rooftop PV in the residential and small commercial sectors (less than 300 kW).
- Emphasis on streamlined and standardized permitting and interconnection processes.
- Meaningful, measurable results through broad stakeholder participation.

UPRM led this Rooftop Solar Challenge project, with the administrative support from the PREAA. The project aimed to identify, analyze, and provide best practices that could overcome processing and planning obstacles that impede a faster growth of rooftop PV systems. The final deliverable was a proof-of-concept framework that could improve process predictability and standardization while dealing with many of the local rooftop PV market barriers. The proposed framework for PV deployment includes streamlined, organized, lean permitting and interconnection processes for the safe and fast installation of residential and small commercial PV systems.

Appendix A shows a summary and brief description of the milestones and tasks that were completed for this project. The following chapters summarize the work and present the final recommendations from the project on rooftop PV standards, financing, planning and stakeholder engagement.

CHAPTER 2

NET METERING AND INTERCONNECTION STANDARDS

Freeing the Grid

The Network for New Energy Choices (NNEC) publishes the Freeing the Grid report which was studied and its recommendations adapted to Puerto Rico. The report presents a survey and comparison of nationwide standards and best practices. A comparison of the "Freeing the Grid" Report of 2011 and the 2010 edition was also completed. There were no major differences from one year to the other, especially in the areas proposed to address in the Island. This task required stakeholder input, which was obtained during two kick-off meetings in San Juan and Mayagüez, and two focus group meetings also in San Juan (PREAA) and Mayagüez (UPRM) all held during May 2012. Details of these meetings can be found on Chapter 6. The Freeing the Grid Report identifies common mistakes regarding interconnection and net metering. The following list most closely applies to Puerto Rico, followed by a potential approach proposed by UPRM researchers to address each mistake.

1. Limiting program eligibility based on the size of individual renewable energy systems. *Proposed solution for Puerto Rico:* The size of a system should be determined only by a customer's load and by the nature of the grid (the point of interconnection).

2. Capping the total combined capacity of all customer-sited generators. *Proposed solution for Puerto Rico:* Limit must be set based on engineering criteria in a way that does not affect the grid's reliability.

3. Requiring unreasonable, opaque or redundant safety measures, such as an external disconnect switch. *Proposed solution for Puerto Rico:* Do not require external disconnect for inverter-based systems such as the ones used in PV systems.

4. Creating an excessively prolonged or arbitrary process for system approval. *Proposed solution for Puerto Rico:* Create a mechanism to ensure the interconnection application takes the least amount of time possible.

5. Failing to promote the program to eligible customers. *Proposed solution for Puerto Rico:* Encourage rooftop PV among residential customers

The report also gives net metering grades depending on the following scales:

- A: full retail credits with no subtractions. Rules actively encourage use of distributed generation (DG).

- B: Generally good net metering policies with full retail credit, but there could be certain fees or costs that detract from full retail equivalent value.
- C: Adequate net metering rules, but there could be some significant fees or other obstacles that undercut the value or make the process of net metering more difficult.
- D: Poor net metering policies with substantial charges or other hindrances.
- F: Net metering policies that deter customer-sited DG
- "–": No statewide policy exists."

Net metering refers to a commercial transaction where a customer that owns DG can sell excess power to a utility at the same rate as the utility sells its electric energy to the customer. Figure 2.1 gives a pictorial overview of net metering grade distribution in the U.S. The figure shows a grade of 'B' for Puerto Rico, but the project's initial analysis shows a more correct grade would be 'C'.

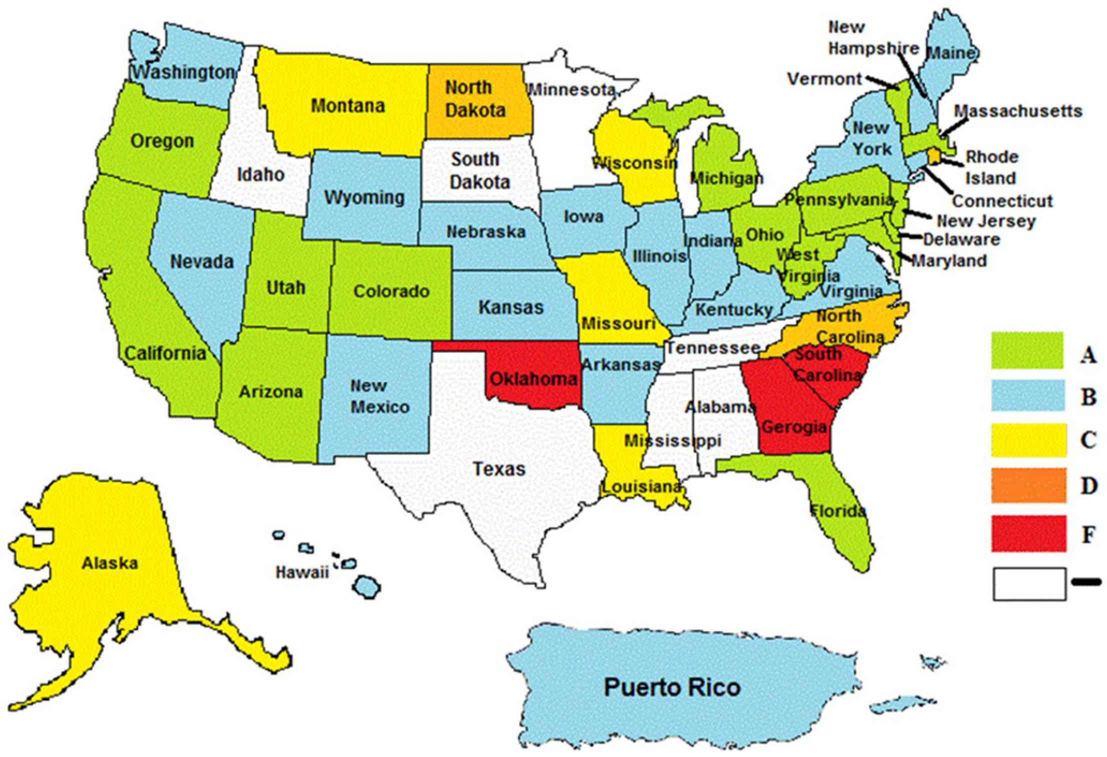


Figure 2.1: NNEC's Net Metering Grades in the United States (adapted by: Vivian Rodríguez, UPRM)

The best net metering practices common in many states are:

1. Adopt safe harbor language to protect customers-generators from extra, unanticipated fees.

2. Remove systems size limitations to allow customers to meet all on-site energy needs.
3. Increase overall enrollment to at least 5% of peak capacity.
4. Specify that customers-generators own their RECs.

Table 2.1 shows net metering practices that are common to states with grades of 'A' that were used as guide for the recommendations in Puerto Rico.

Table 2.1: Best Practices in States with Net Metering Grade of 'A'

Eligible Renewable/Other Technologies	Solar Thermal Electric, Photovoltaics, Landfill Gas, Biomass, Hydroelectric, Geothermal Electric, CHP/Cogeneration, Hydrogen, Biogas, Anacrobic Digestion, Small Hydroelecric, Fuel Cells using Renewable Fuels, Wind, Tidal Energy, Wave Energy, Ocean Thermal, Anaerobic Digestion, Microturbines, Waste Gas and Waste Heat Capture or Recovery.
Applicable Sectors	Commercial, Industrial, Residential, Nonprofit, Schools, Local Government, State Government, Fed. Institutional, Agricultural, Multi-Family Residential.
Applicable Utilities	All utilities (some exceptions for small municipal utilities) or Investor-owned utilities, electric co-ops, solar, wind, biogas, full cells, alternative electric suppliers.
System Capacity Limit	System must be sized to meet part or customer's entire electric load and may not exceed 125% of customer's total connected load. Systems must have between 1MW-60MW approximately.
Aggregate Capacity Limit	5% of peak demand (utilities may increase limit) or no limit specified.
Net Excess Generation	Credited to customer's next bill at retail rate; excess reconciled annually at avoided-cost rate.
REC Ownership	Customer owns RECs (must be relinquished to utility for 20 years in exchange for incentives).
Meter Aggregation	Virtual meter aggregation on multi-family affordable housing allowed. Allowed for IQU customers. Allowed at same or adjacent location. Group net metering allowed.

The *Freeing the Grid* report also provides a grading system for interconnection practices in the U.S.:

- A: No restrictions on interconnection of DG systems that meet safety standards.

- B: Good interconnection rules that incorporate many best practices adopted by states. Few or no customers will be blocked by interconnection barriers.
- C: Adequate for interconnection, but systems incur higher fees and longer delays than necessary. Some systems will likely be precluded from interconnection because of remaining barriers in the interconnection rules.
- D: Poor interconnection procedures that leave in place many needless barriers to interconnection.
- F: Interconnection procedures include many barriers to interconnection. Many to most DG systems will be blocked from interconnecting because of the standards
- "–": No statewide policy exists.

Interconnection refers to the physical connection and operation of a DG in parallel with the utility's electric grid. Interconnected systems can be either under net metering or not. Figure 2.2 gives a pictorial overview of net metering grade distribution in the U.S. Puerto Rico obtained a grade of 'F'.

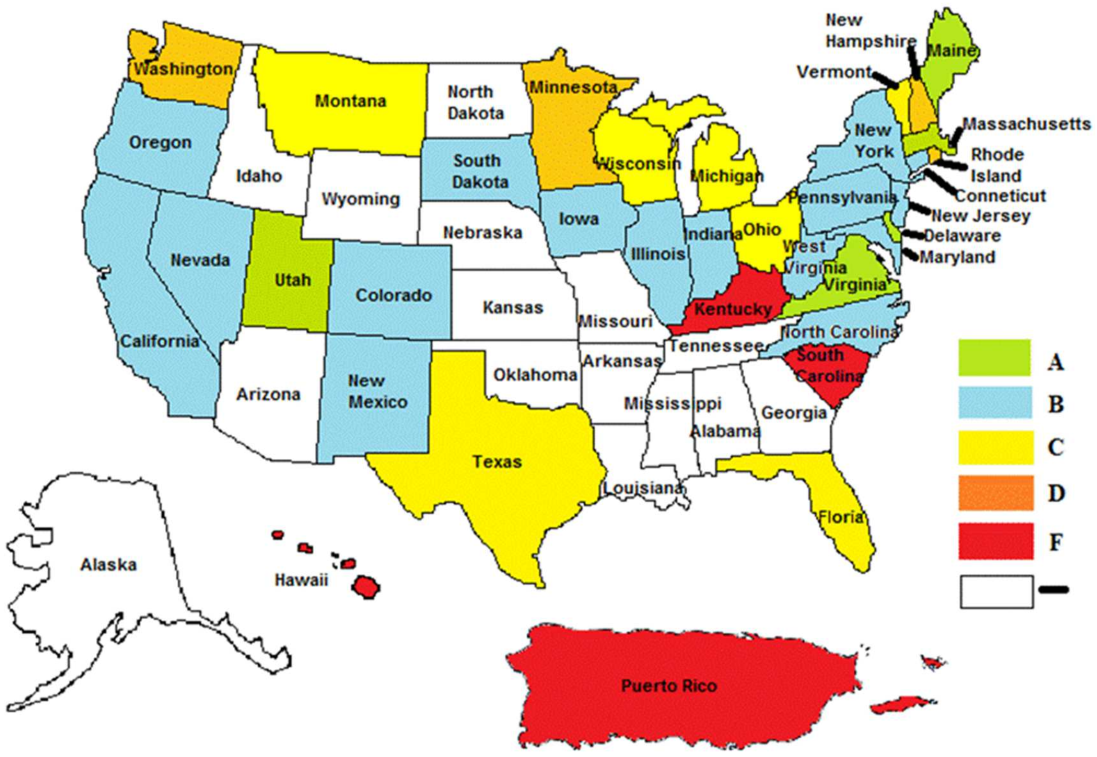


Figure 2.2: NNEC's Interconnection Grades in the United States (adapted by: Vivian Rodriguez, UPRM)

The best interconnection practices common in many states are:

1. Remove system size limitations to allow customers to meet all on-site energy needs.
2. Provide more clarification on the dispute resolution process.

3. Prohibit the use of redundant external disconnect switch.
4. Prohibit requirements for additional insurance.
5. Prohibit external disconnect switch requirements for all inverter-based systems.

Table 2.2 shows interconnection practices that are common to states with grades of ‘A’ that could were as guide for the recommendations in Puerto Rico.

Table 2.2: Best Practices in States with Interconnection Grade of ‘A’

Eligible Renewable/Other Technologies:	Solar Thermal Electric, *Photovoltaics*, Landfill Gas, Biomass, Hydroelectric, Geothermal Electric, CHP/Cogeneration, Hydrogen, Biogas, Anacrobic Digestion, Small Hydroelecric, Fuel Cells using Renewable Fuels, *Wind*, Tidal Energy, Wave Energy, Ocean Thermal, Anaerobic Digestion, Microturbines, Waste Gas, and Waste Heat Capture or Recovery, Other Distributed Generation Technologies, *Other Sources of Renewable Energy*.
Applicable Sectors:	Commercial, Industrial, Residential, Nonprofit, Schools, Local Government, State Government, Fed. Institutional, Agricultural, Multi-Family Residential,
Applicable Utilities:	All utilities, Investor-owned utilities, All Transmission and Distribution utilities,
System Capacity Limit:	10MW, 20MW, 80MW approximately
Standard Agreement:	Yes
Insurance Requirements:	Additional liability insurance not required for systems that meet certain technical standards. Vary by system size and type
External Disconnect Switch:	Required for systems lager than 25kW or no required
Net Metering Required:	***No***

Besides the *Freeing the Grid* report, the following references were studied to identify best practices:

1. Review of the suite of standards from IEEE 1547. This is a set of standards which provided the main foundation for most of the best practices for the safe interconnection of distributed generation (DG) to the electric power grid. The Energy Policy Act of 2005

(EPAct 2005) required all regulatory bodies and unregulated utilities (such as PREPA), to state whether they would accept DG or not and why. The IEEE 1547 was mentioned in that federal law as a model to follow. In Puerto Rico PREPA followed the IEEE 1547 when writing Puerto Rico's interconnection standard. However, some of the interpretations given to 1547's requirements were somewhat inflexible in Puerto Rico's standard. Furthermore, many of the best practices from the Intestate Renewable Energy Council (IREC) and NNEC are more aligned to the goal of increasing PV usage in Puerto Rico. One should remember that 1547 was written under the premise that DG penetration would not reach 10%. Thus, strict alignment to 1547 is not necessarily the best approach in the context of Puerto Rico.

2. Various technical papers from conferences and journals. For a sampling of papers studied see Appendix J.

3. Reports on software tools for interconnection analysis. For example, HOMER (http://www.homerenergy.com) was used in the project for integrated analysis of PV interconnection. Other tools that were used for the project, developed by NREL, can be found in http://www.nrel.gov/analysis/analysis_tools_market.html.

4. IREC's 2009 *Model Interconnection Procedures* and *Model Net-Metering Rules*

Key ideas for net metering include that the rated capacity of the PV system can be as much as the customer's service entrance capacity. Another rule is the retention of RECs unless those were explicitly contracted in a separate transaction independent of Net Metering or interconnection (e.g., as is the case with the incentives of the Green Energy Fund). If interconnection has been approved, the utility shall not require further tests except those required by the manufacturer of the equipment in the system. These ideas were studied and aligned to the Puerto Rico Rooftop Solar Challenge project.

Regarding the model interconnection processes, it was encouraging that the IREC report includes an Online Application Requirement as a model practice. This was well-aligned and provided further support to the project's work on an online system to expedite PV administrative processes. Another important model studied was FERC's four levels listed below:

- Level 1 Screening Criteria and Process for Inverter-Based Generating Facilities Not Greater than 25 kW
- Level 2 Screening Criteria and Process for Generating Facilities Not Greater than 2 MW
- Level 3 Screening Criteria and Process for Non-Exporting Generating Facilities Not Greater than 10 MW
- Level 4 Process for All Other Generating Facilities

Since the project was focused on systems up to 300 kW, only the first two levels were considered. However, a recommendation is given to PREPA to evaluate the possible use of the other two levels as this would create a more supportive environment for renewable energy and would allow Puerto Rico's grades in the NNEC's standards to improve.

Recommendations

Based on the references read, stakeholder input, and UPRM's analysis of the Puerto Rican context, specific recommendations were developed for changes to net metering and interconnection practices in Puerto Rico. Since PREPA has control over the net metering and interconnection Standards, the work was divided between areas that will be more difficult to change and areas easier to implement (i.e., with lower resistance).

These are the specific recommendations for the revision of *net metering standards* in Puerto Rico:

- Allow net metering system size limits to cover large commercial and industrial customers' loads as systems at the 2 MW level are no longer uncommon.
  - Best practice: Increase size allowed to 2 MW for systems connected to 13.2 kV feeders
  - Near term: Preliminary study of potential users of 1-2 MW systems at 13.2 kV
- Do not arbitrarily limit net metering as a percent of a utility's peak demand.
  - Best practice: Revise language in rules and regulations to ensure interpretation of a more flexible capacity limit
  - Near term: Determine rational limits
- Allow monthly carryover of excess electricity at the utility's full retail rate (unlimited).
  - Best practice: Accept the recommendation as an energy efficiency and conservation strategy, with reasonable ceilings to protect PREPA's finances.
  - Near term: Accept the recommendation up to a reasonable percentage at least for residential customers.
- Allow customer-sited generators to retain all renewable energy credits for energy they produce.
  - Best practice: Accept the recommendation and develop explicit rules.
  - Near term: Study feasibility and ways to account for customer-generated RECs (especially residential and small commercial).
- Protect customer-sited generators from unnecessary and burdensome red tape and special fees.

- Best practice: Web-based system implemented will help reduce red tape.
- Near term: Clarify all gray areas. Compliance with the intent of Act 114-2008.

As previously discussed, the recommendations have both the best practice and more realistic, near term actions to deal with obstacles or direct the PV market towards achieving the best practice. These recommendations were developed with the help from PV stakeholders in the focus groups and were furthered reviewed in small group meetings during July 2012 (details on Chapter 6). The goal was to provide technical support for each net metering recommendation, so that the Puerto Rico grade in net metering goes up to ‘B’. For example, as shown in Appendix B specific practices in Hawaii (island system like Puerto Rico), and Delaware (grade of ‘A’ in net metering) were compared and analyzed.

These are the specific recommendations for revision of *interconnection standards and practices* in Puerto Rico:

- Set fair fees that are proportional to a project’s size.
    - Best practice: No fees for processes done on-line. Begin an Island-wide effort to characterize feeders, so that number of supplementary studies is minimized (begin with 13.2 kV feeders).
    - Near term: PREAA and OGPE (permitting office) should make available a certification database (no charge for on-line copies), and accept National Labs certification for new equipment with minimum evaluation (no fees or minimum). PREPA should publish details and costs related to studies that might be needed.
- Ensure that policies are transparent, uniform, detailed and public
    - Best practice: A Web-based system must comply with these characteristics
- Prohibit requirements for extraneous devices, such as redundant disconnect switches. Apply existing relevant technical standards, such as IEEE 1547 and UL 1741.
    - Best practice: Do not require external disconnect for all rooftop PV Systems below 300 kW (or system with a 200 A service entrance).
    - Near term: Do not require external disconnect for systems below 25 kW (including small commercial systems)
- Do not require additional insurance.
    - Best practice: Do not require for all residential systems and small commercial systems below 25 kW.
    - Near term: Ensure the existing PREPA administrative order (waiver for residential customers) is included in PREPA’s rules and regulations.

- Process applications quickly; a determination should occur within a few days. Standardize and simplify forms.
    - Best practice: Web-based system must address this. Ideally everything should occur within a month (interconnection & net metering).
    - Near term: PREAA-based system, OGPE and PREPA use the system's software tools.
- Screen applications by degree of complexity and adopt plug-and-play rules for residential- scale systems and expedited procedures for other systems.
- Best practice: Improve interconnection conditions based on:
    - Level 1 Screening criteria and process for inverter-based generating facilities not greater than 25 kW
        - Plug-and-play rules for residential-scale systems below 10 kW
    - Level 2 Screening criteria and process for generating facilities not greater than 2 MW.

The recommendations for changes in *interconnection* have both the best practice and more realistic, near term actions to deal with obstacles or direct the PV market towards achieving the best practice. These recommendations were developed with the help from PV stakeholders in the focus groups and were furthered reviewed in small group meetings during July 2012. An important stakeholder recommendation was to increase to 300 kW the current limit for commercial systems to go through PREPA's "simple application process". Technical justifications were developed to support these recommendations. The goal was to provide technical support for each of the interconnection recommendations so that the Puerto Rico grade in interconnection goes from 'F' to 'C'. For example, as shown in Appendix C UPRM researchers compared and analyzed specific practices in Hawaii (island system like Puerto Rico), and Delaware (improvement from 'F' to 'A' in interconnection).

Technical Justifications for Recommendations

The proposed best practices require justifications in order to accept them as policies that ensure safety for the people working on the electric lines and for the grid while improving PV market conditions. Many states are allowing a maximum capacity for net metering to 2 MW. This has become the minimum standard. Large loads such as government buildings, hospitals or universities could use 2 MW. Thus standards should permit systems that are sized to meet such large loads. Puerto Rico should increase net metering system allowed capacities from 1 MW to 2 MW. Recently system capacities up to 5 MW were approved for Puerto Rico if connected to sub-transmission voltage (in Puerto Rico that is 38 kV). However, for voltages up to 13.2 kV the limit remains on 1 MW. There are technical reasons to continue the 1 MW limit for voltages under 13.2 kV, however an increase to 2 MW for systems connected to 13.2 kV feeders must be considered. In discussions with PREPA it was stated that in practice there are no clients that would connect over 1 MW at 13.2 kV. A preliminary study is recommended to identify potential users of 1-2 MW systems at 13.2 kV to justify the best practice.

Interconnection procedures should be less stringent for small, simple systems and more stringent as system size increases. Fast track processes should exist for small generating facilities. Examples of best practices include California where small systems pass certain “screens” such as: capacity less that 2 MW, fault current is less that 10% of total fault current and not exceeding 87.5% of distribution equipment and protective devices rating. FERC has also established four screen levels, and thus it was recommended a careful examination for possible adaptation in Puerto Rico of the first two levels.

Plug-and-play rules are recommended for residential-scale systems below 10 kW. These systems are small enough to justify simple interconnection and net metering rules. Furthermore, commercial systems up to 25 kVA should have expedited procedures that reduce the time and money required for their installation and operation.

It has been concluded that the utility-accessible external disconnect switch is redundant and unnecessary for residential and small-commercial inverter-based PV systems. Eight state public utility commission (i.e., Arkansas, Delaware, Florida, Maryland, Nevada, New Jersey, New Hampshire, and Utah) have reached this conclusion and eliminated their external disconnect switch requirements for systems that meet criteria, and nine state public utility commission have decided to leave the external disconnect switch decision up to individual utilities. In the states with utility choice, at least five utilities have eliminated the external disconnect switch requirement. Some factors that help in the process of eliminating the external disconnect requirement are:

- Increasing utility experience with grid-connected PV systems that demonstrates the effectiveness and safety of UL -listed inverters
- Re-evaluation of safety practices and rules in light of technological advances and regulatory changes
- A need to eliminate the administrative burden and associated cost of requiring utility-accessible external disconnect switch.
- Growing pressure to remove barriers to entry to meet growing state-level targets for PV installations.

Using these guidelines, it is recommended that the redundant disconnect switch requirement be eliminated for inverter-based systems that follow comply with IEEE 1547 and UL 1741. This recommendation is given for all rooftop PV Systems below 300 kW (or 200 A service). In the near term, the requirement should be lifted for systems below 25 kW (including small commercial systems).

These recommendations were well-received by stakeholders and their feedback used to refine this work. Further justifications are mentioned below for each best practice:

- Prohibit requirements for extraneous devices, such as redundant disconnect switches. Apply existing relevant technical standards, such as IEEE 1547 and UL1741.
  Best Practice: Do not require external disconnect for systems for all rooftop PV below 300kW.
  - Justification: OSHA requires to check to be sure the circuit is dead, to ground the circuit conductors, and to wear gloves. OSHA procedures, also, explicitly require the line section to be verified as de-energized prior to all service actions. In addition the inverters with IEEE and UL standards pass the unintentional islanding test. Since all workers must perform the OSHA procedure before any work done on a line, a line considered de-energized cannot become energized by an inverter without the utility applying voltage to the line (Sheehan, 2008).
- Screen applications by degree of complexity and adopt plug-n-play rules for residual scale systems and expedited procedures for other systems.
  Best Practice:
    - Level 1 screening criteria and Process for inverter based generating facilities not greater than 25kW.
    - Level 2 screenings criteria and process for generating facilities not greater than 2MW
  - Justification: In practice, there is rarely a need for state procedures above 10 MW of capacity since larger systems typically follow FERC-jurisdictional transmission lines. However, since FERC does not have jurisdiction in Puerto Rico, it is recommended that PREPA uses FERC procedures as guidelines to improve their interconnections requirements for larger systems, adapted to the Island's particular physical restrictions.
- Process application quickly, a determination should occur within a few days. Standardize and simplify forms.
  Best Practice: Web-based system will be developed to this end. Ideally everything should occur within a month.
  - Justification: Barriers of time and expense brought about by requiring multiple departments to review the same application severely inhibit the timely and efficient construction of new PV systems. The majority of residential PV systems share many similarities of design, which allow for national standardized expedited permit process for small-scale PV systems. (Expedited permit process for PV systems). Standardization may be beneficial for installers who learn to navigate well in a single process throughout the state, lowering installation costs and time. A web-based system increases the number of complete and quality applications and installations, saves time by lowering reviews and repeated back and forth between the

installer and the municipal staff. At the same time when the simple application is launched with an on-line submittal system it may flag missing information and may aid the installer of what information is necessary and why it is needed.

- Set fair fees that are proportional to a project's size.
  Best Practice: No fees for processes done on-line. Begin an island-wide effort to characterize feeders, so that number of supplementary studies is minimized.
  - Justification: A fair fee system rewards good-standing customers and does not subsidize the less responsible (suggestion from the Sierra Club). In addition it helps bring system costs down.

Non-PREPA Policies and Regulations for PV systems in Puerto Rico

In Puerto Rico there are regulations that allow certain actions to be petitioned as exemptions to environmental compliance, as long as it complies with RETDA. The actions mentioned are exempted from these requirements since their processes are deemed as an everyday routine and predictable and do not wonder off the environmental compliance policies. Among those regulations, there is one from the state Permits Office (OGPe) "Resolución Sobre Exención Categórica" that is relevant to PV systems. Renewable energy has an important advantage, mentioned as a "Category Exclusion". The resolution mentions that any renewable energy source with a nominal capacity up to 1 MW in rooftops of houses or existing buildings and its property for the purpose of generating and supplying electric energy may be installed with use of this Exemption of environmental reporting and construction permits. This does not mean that the proponent of the system is exempt from complying with applicable dispositions (other than those explicitly exempted) found in OGPe or other government agency regulations.

Puerto Rico enacted net metering legislation in August 2007. This law allows customers of the Puerto Rico Electric Power Authority (PREPA) to use electricity generated by solar, wind or other renewable-energy resources to offset their electricity usage. This law applies to residential systems with a generating capacity of up to 25 kilowatts and non-residential systems up to one megawatt in capacity. Customer net excess generation is carried over as a kilowatt-hour credit to the following month, but the credit is limited to a daily maximum of 300 kWh for residential customers and 10 megawatt-hours for commercial customers. Figure 2.3 compares Puerto Rico to Delaware, a state with an "A" classification that was used as reference for best practices (from *Freeing the Grid* report).

Renewable energy credits (REC) is part of the financing work explained in detail in a latter chapter. The following recommendations regarding RECs are included in this chapter in support of the interconnection and net metering recommendations presented earlier. Currently RECs from residential systems are not allowed. Some guidelines exist on Puerto Rico's Act 82-2010 regarding the Island's renewable portfolio standard, but only for large generators. Puerto Rico currently does not have clear REC rules, thus it received a -1 in the PV Market evaluation as this is not addressed. Some recommendations from the California rules that should be adapted for processes in Puerto Rico are:

1. Fully bundled, non-tradable RECs: This kind of RECs is essentially an accounting tool. This type of REC distinguishes a megawatt-hour of renewable electricity apart from any other megawatt-hour of conventionally generated electricity. By using RECs in this manner, it should be easier to establish a tracking and verification system that ensures the various parties engaged in the business of electricity generation and supply do not account for renewably generated electricity multiple times, and so avoid a distorted picture of the use of renewable.

2. Unbundled, fully-tradable RECs: If RECs are unbundled and traded separately from the associated electricity, they become as tradable certificates which memorialize the positive environmental attributes of renewably generated electricity. When fully unbundled from the associated electricity and sold, tradable RECs allow a generator owner to receive a direct monetary value for the green benefits resulting from their renewable production. Also, the environmental benefits may be traded or sold to another party who may not otherwise want, or be in a position to purchase the actual electricity.

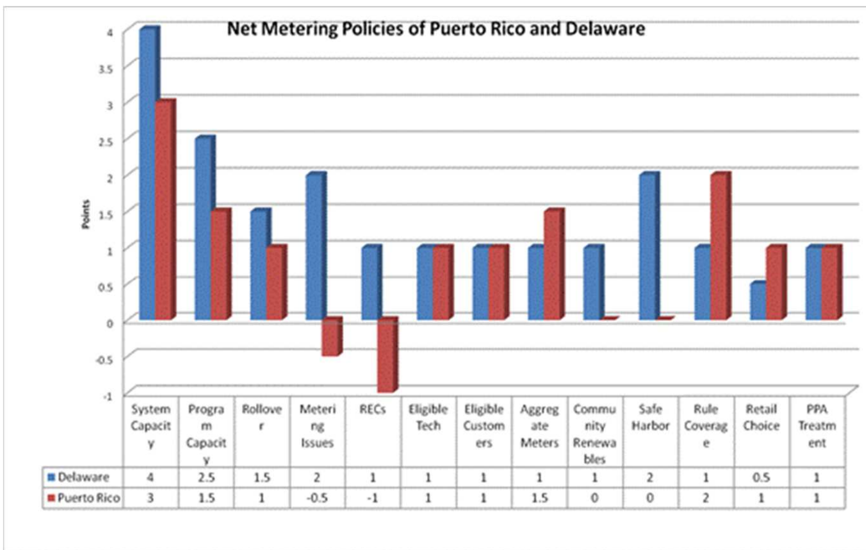


Figure 2.3: Net Metering in Puerto Rico vs. Best Practice (Delaware)

3. Hybrid. Allow RECs to be tradable, but limit or restrict the market for those RECs. Such restrictions would effectively limit the initial market for RECs to utilities, since they would be the only parties in a position to purchase and take delivery of the electricity from a generator via the grid. This utility purchaser could then make later unbundled sales of any RECs they possess in excess of their own needs. In this scenario, a generator owner may still be in a position to monetize the environmental benefits resulting from their renewable production,

but only to the extent the RECs' value can be added to the price for electricity negotiated with a utility buyer.

Conclusions for Chapter 2

All the recommendations presented in this chapter would have a great impact on Puerto Rico's PV market. One area identified by stakeholders as one with the greatest potential for market improvement and local economic development was the development of recommendations for plug and play rules for rooftop PV systems. The main philosophy is to make installing small PV systems as easy as installing solar water heaters, in which the main requirements are that the equipment and the installer are both certified. Here is the recommended streamlined process, with emphasis on plug and play cases:

1. Do not charge fees for on-line documents or processes.
2. The list of certified equipment must be made available on-line. If there are certifications from national laboratories, no additional certification is required from a local entity.
3. Begin a "plug and play" process for rooftop PV up to 25 kW (residential or commercial):
    a. If the installation uses only certified equipment, PREPA's interconnection application is the only requirement with all certifications attached (obtained on-line, for free).
    b. Once PREPA grants interconnection permit, the installation might begin.
    c. Once the installation is finished, the installer notifies PREPA the day that tests will be performed (at least five working days before the test). This is done on-line, generating a "notification receipt" as evidence that PREPA was properly notified. Tests can be performed, even if PREPA does not participate. No additional tests are required.
    d. After the test, the system is registered on-line with OGPe, to keep an inventory of PV systems in the Island.
        i. Copies of purchases of equipment and their certifications are submitted on-line, as well as photos of all the installed PV modules on the rooftop and the installed inverter, wired and already tested. PREPA's test notification receipt is also submitted.
        ii. The installer swears (or certifies) that all submitted information is correct and that the installation was made following all applicable standards and regulations. The installer confirms that all installed equipment are certified and are safely operating.
        iii. Once the registration is completed, a "registration receipt" is generated and emailed to user. There is no additional certification or process in OGPe. OGPe reserves the right to investigate and verify the submitted information within three months of the installation.
    e. Once the registration receipt is generated, PREPA is informed and the client can energize its PV system, even if PREPA did not attend the tests.

   f. Automatic application for a new meter.
   g. If client wished, the net metering application is begun.
4. Establish a strict process for evaluation and declaration of penalties to installers that violate "plug and play" rules in residential and commercial rooftops up to 25 kW. Penalties can include suspension of certification, as well as fines and other penalties. Persons that are not installers and engage in PV installations should be dealt similar to those that help a person use electric service illegaly.

This recommended streamlined process assumes that there is an on-line system for PV permitting and interconnection processes. A proof-of-concept of this on-line tool was developed and is presented in Chapter 5.

Freeing the Grid report, NNEC, 2010. *available at:* http://www.newenergychoices.org/uploads/FreeingTheGrid2010.pdf

Junta de Calidad Ambiental. (2011). *Listado de Exclusiones Categóricas* . San Juan: Oficina del Gobernador.

Oficina del Inspector General de Permisos. (2011). *OA-OIGPE 2011-11.* San Juan: Gobierno de Puerto Rico.

Oficina del Inspector General de Permisos. (2011). *OA-OIGPE 2011-24.* San Juan: Gobierno de Puerto Rico.

Renewable Energy Credits (RECs) in California (p.11) available at http://db.tt/xSO5MCxD

Sheehan, M. T. (2008). *Utility External Disconnect Switch.* Solar America Board for Codes and Standards.

Sheehan, M. T. (2008). *Utility External Disconnect Switch: Practical, Legal, and Technical Reasons to Eliminate the Requirement*, Interstate Renewable Energy Council.

Stanfiel, S., Schroeder, E., & Culley, T. (2012). *Sharing Success.* Interstate Renewable Engergy Council.

CHAPTER 3

FINANCING OPTIONS

Introduction

UPRM completed a detailed study of financing options for residential and commercial photovoltaic systems. A compilation of the most relevant PV financing structures and current developing models were studied. Comparisons among conventional financing schemes, modern community-based and third party ownership models were made. Recommended financing mechanisms are presented in this chapter to address the specific challenges in Puerto Rico. Key stakeholders in the banking industry and the financial cooperatives movement were identified. Individual stakeholders were engaged with initial information of the project (phone calls and face to face individual conversations). UPRM met with individual persons in the Financing sector. Researchers made numerous calls and exchanged emails in coordinating all the focus and small group meetings.

Mostly due to aggressive public policies and government incentives, solar photovoltaic (PV) is currently the fastest-growing renewable energy technology worldwide. According to the most recent annual report published by the International Energy Agency (IEA), it is expected that the share of renewable in power generation will grow from a 3% in 2009 to 15% in 2035. However, the high upfront cost and availability of insurance are still the main limitations for many PV systems developers.

As reported in a study performed by the National Renewable Energy Laboratory (NREL), the high upfront cost of residential and commercial PV systems are mostly due to non-technical factors. The study concluded that the cost of electricity, billing structure, government incentives and financing schemes are the main factors that determines the upfront cost of grid-connected PV systems. Furthermore, it was found that the grid-parity or break-even price (the point where the cost of PV generation equals the cost charged by the utility) of residential PV varies by more than a factor of 10 in the United States, mostly due by the differences in incentives and financing structures.

Financing: Traditional Methods and Government Incentives

Traditionally, residential and commercial photovoltaic systems have been financed through personal loans, home equity loans, mortgages and cash payments in combination with federal and state incentives. By 2010, the total cost of a residential and commercial PV system in the United States was about $5.71/Wp and $4.59/Wp, respectively. For example, a typical residential PV system with an installed capacity of 4 kW could have an upfront cost of approximately $22,840, without considering any incentives.

The upfront cost of residential and commercial PV systems can be reduced substantially by combining federal and local incentives. In Puerto Rico, for example, there is a 30% federal tax credit of gross cost at installation. Also, the "Puerto Rico Green Energy Incentives Act", through the Green Energy Fund, offers rebates of up to 40% of the cost for Tier 1 projects (0-100kW) until 2017 based on first-come, first-served scheme. In the same way, the local government offers a tax credit of $4/DC-Watt for up to $15,000 for residential PV systems and up to $100,000 for commercial PV systems. For example, assuming an installed capacity cost of $5.71/Wp, a 4kW residential PV system developer could benefit from an $8,800 total incentive amount in Puerto Rico (Refer to Tier 1 Reference Guide of the Green Energy Fund from the Puerto Rico Energy Affairs Administration for more information). When including federal and local tax credits, the total upfront cost could decrease approximately half the total initial cost ($22,480).

Despite the local and federal incentives, technological advances, declining costs of solar panels and the increasing the cost of electricity, the installed capacity of residential photovoltaic systems in Puerto Rico last year was only 4 MW. The high upfront cost of small and medium capacity PV systems is currently a barrier to the rising development of the solar photovoltaic market.

Currently, there are a variety of financing options for residential and commercial PV systems in the United States. Among the funding agencies that currently offer personal loans are Fannie Mae, Freddie Mac, HUD & FHA, VA and E.P.A. Table 3.1 shows the variety of offerings from each of these corporations. One of the disadvantages of this financing method is that the individual investment returns in a very long time, usually close to the period of complete payment of the debt.

Table 3.1: Financial Options for Residential Photovoltaic Systems (Adapted from Rich Hessler Solar Sales Training, 2009).

Entity	**Eligibility**	**Amount**	**Term**	**Note**
Fannie Mae	Power Utility Customers	$15,000	15 years	No insurance
Freddie Mac	Natural individuals	Up to $240,000	15,20 & 30 years	Collateral: First mortgage
H.U.D & F.H.A	Individual that qualifies for Title 1	$25,000	15 & 30 years	Fixed interest
V.A.	Veterans	Up to $203,000	15 & 30 years	Collateral: First mortgage
E.P.A.	Natural Individuals and Business	No limit	15 & 30 years	Collateral: First mortgage

In recent years, new models of PV systems financing have been developed in the United States and Europe. In Spain, for example, the Institute for the Diversification of

Energy Saving (IDEA) is directly involved in the process of financing solar PV projects. As they published, most projects are funded through the participation of third parties. That is, IDEA purchase PV systems to a third party and then rents it to the client. Through a three party scheme, the client pays a monthly fee to IDEA (or a third) for the rental of the photovoltaic system. Accordingly, the client pays its electric bill to the utility. Currently, this model reaches over 50% of the projects of IDEA.

Similarly, in the United States, new financing models for grid tied PV residential and commercial systems have been developed. Among the most common are third party ownership and solar leasing.

Third Party Financing and Solar Leasing

Currently, the third party financing for residential and commercial PV systems is the model with the greatest potential for development in the short term. Through this model, the client is relieved from the high upfront and maintenance responsibilities. In this case, a third party owns the system and charges the customer a monthly fee, which is usually less than the payment of electricity bill. A fixed or variable monthly payment is negotiated between the third party and the client. Accordingly, the client continues to pay the electric bill to the utility. Both the third party and the client assume the risk of energy generation variability.

For years, the leasing of capital goods has been used in the commercial sector and transportation. Recently, this model has being introduced into the residential and commercial PV market. Overall, the customer pays a fixed monthly payment for the rent of the photovoltaic system. At the end of the period, the customer has two options: to renegotiate the contract, purchase the equipment or remove the equipment. When the client has a net metering agreement with the electric company, the excess generation of solar energy can be sell back to the grid. Table 3.2 shows two examples of current leasing programs in the United States.

Table 3.2: PV Residential and Commercial Leasing Options in the U.S. (adapted from NREL, 2009)

Program	State	Investor	Description
SolarCity	California	Morgan Stanley	Zero down payment. A minimum level of electricity output is guaranteed. Pricing and deal structure vary based on local market conditions. Example: A 3.2 kW system could cost $83/month.
CT Solar Leasing	Connecticut	State	Zero down payment. Examples of current leasing options: 2kW ($49/month), 4kW ($97/month) and 6kW ($144/month).

One of the biggest drawbacks of this model is the time term of the contract. The risk that results from the variability in electricity costs can be a determining factor for a PV system developer in committing to a 15-20 years lease.

For commercial PV systems, the customer can sell the power generated by the solar system to the electric company through a purchase agreement. In this case, a price is negotiated based on solar power generated and the customer to the electric company sells solar photovoltaic system. Unlike a lease, the cost of sale depends on the solar photovoltaic generation. One of the biggest advantages of this model is again over from the high initial investment costs. This type of model is the most common commercial photovoltaic systems.

The development of new models of financing for residential and commercial photovoltaic systems is a key factor for the development of solar photovoltaic market in the short to medium term. The modern financial structures such as the leasing and purchase agreements provide the customer an innovative alternative that addresses the problem of high upfront cost. NREL published a summary of the financing options and it has been included in Table 3.3.

Table 3.3: Financing Options (Summary, adapted from DOE, 2010)

Financing Option	*Cash*	*Home Equity Loan*	*Other Loan*	*Leasing*	*PPA*
Upfront Cost	High	Low	Low	Low	Low
System's Owner	Homeowner	Homeowner	Homeowner	Homeowner	Homeowner
Ongoing payments	None	Yes	Yes	Yes	Yes
System's maintenance	Homeowner	Homeowner	Homeowner	Solar Cooperative	Solar Cooperative
Federal Credit	Yes	Yes	Yes	No	No
Tax deductions	N/A	Interest on loan	No	N/A	N/A
Term	N/A	5-30 years	Up to 20 years	Up to 20 years	10-20 years

The stakeholder meetings on Financing during 2012 proved to be vital for this project. The meetings allowed us to confirm the strong interest from the cooperative sector in financing residential and small commercial PV systems. The traditional banking sector is more interested in larger scale renewable systems. A key suggestion from these meetings is the importance of integrating appraisers and insurance companies in these financing discussions.

In Puerto Rico, several financing cooperatives across the island have started to move towards the development of financing structures for residential and commercial PV systems. One of the main concerns shared by local financing entities is the *perceived risk* associated with the investment of new PV systems. The lack of information regarding the solar PV market, the insurance related issues, the equipment's life expectancy time and the PV system's ability to uphold strong weather conditions are among the *perceived risks* associated with such technology (Findings from the DOE's Rooftop Solar Challenge Meeting with local financing cooperatives on July 18th at the University of Puerto Rico at Mayagüez facilities, 2012).

Because these *perceived risks* are obstacles to financing rooftop PV systems, the UPRM team explored the risks associated to PV systems and modeled the most common residential PV system's financing structures available nowadays. From the economical point of view, special attention was given to the cash flow and payback period (the two main financial performance metrics for small scale PV systems). Furthermore, a discussion of Renewable Energy Credits (REC's) was made in order to provide a general understanding of renewable energy incentives currently available.

Risks Associated with PV Systems

There is a general concern between PV system's investors, insurance companies and homeowners about the risks associated with the solar technology. In Chaves and Bahill (2010), several of the real risks associated with solar PV systems were organized into five categories. Table 3.4 shows the different risks including a brief description of them.

Table 3.4: Description of Risks Associated with PV Systems (Adapted from Chaves and Bahill, 2010)

Risk	Description
Grid Integration	Operational risks: blackouts, balance of electricity supply, etc.
Project Management & Development	PV project's development risks such as price variability, design/permit bureaucracy, etc.
Hardware	Reliability of PV system's components
Environmental	Weather, catastrophic events, opposition, etc.
Government	Changes in government's public policy

Probably the highest risk associated with PV systems is weather-related (the rapid changes in energy generation caused by cloudy periods). From a power utility perspective, it is a true risk. However, such risk can be diminished by spatial distributing PV systems. In

Worren (2012), it was mentioned that the uncertainty around the revenues and profitability resulted from the risks mentioned above have a strong effect on the financial viability of the project. The author concludes that most of the risks associated with solar PV systems can be, in most cases, managed through actual financial mechanisms and insurance products.

PV System's Insurance Products Requirements

The risk associated with property damage, natural disasters, theft and business interruption are among the major concerns that insurance companies share. In Starrs (2000), NREL identified four insurance products necessary for small scale PV systems. An overview of the four insurance products is presented in Table 3.5.

Table 3.5: PV systems Insurance Products (Adapted from Starrs, 2000)

Insurance Product	**Description**
General Liability	Covers policyholders for death or injury to persons or damage to property owned by third parties.
Property Risk	Covers damage to or loss of policyholder's property. Also, it can indemnify homeowners of natural catastrophic events.
Environmental Risk	Coverage indemnifies system owners of the risk of either environmental damage done by their development or pre-existing damage on the development site.
Business Interruption	Lost sales as a result of the system not being operational and loss of production-based incentives also resulting from the lack of electricity production

In the same publication, NREL discussed four main areas that must be addressed in order to develop a PV insurance structure. These are:

1. To create a large database of PV historical loss data that includes system's operation, availability and insurance loss.
2. To classify the Renewable Energy Business into different groups in order to better assess insurance claims.
3. To develop a detailed testing procedure for PV system components in order to assess the weather-related vulnerability.
4. To improve the installation process by developing a standard for PV systems installers.

Modeling Residential PV Financing Structures

The two most popular financing structures for residential PV systems are the personal loan and third party leasing. In an effort to evaluate both residential PV system financing options, both schemes were compared by using the Solar Advisor Model (SAM) and Excel software.

4 kW Single Homeowner Residential PV System

Two options for a single homeowner PV system were compared: a personal loan and a third party lease. For the *third party lease* case, a .5% of the total installed cost was included to incorporate insurance costs. As a result, the *personal loan* option produces a monthly saving of $165 ($33 for the leasing case). However, the monthly savings from the leasing case can be fixed through a period of time.

40 kW Solar Community PV System

For the solar community case, the same two options were simulated. As expected, similar results from the first case were obtained. However, in this case, the decrease in total cost (from $4 to $3) of the PV system resulted in an earlier investment's payback period as shown in Table 3.6.

Table 3.6: Comparison between Single and Multiple Home Owners Financing Models

Financing Metric	**Residential and Commercial PV System's Financing Structures**			
	Residential		**Solar Community (Per Homeowner)**	
	Personal Loan	***Third Party Lease****	***Personal Loan***	***Third Party Lease****
Payback Period	8	N/A (Down Payment=0)	6	N/A (Down Payment=0)
Approximate Monthly Electric Bill	$165	$3**	$165	$3**
Approximate Monthly Loan Payment	$114	$132	$82	$132
Approximate Monthly Savings (During Loan)	$51	$33	$83	$33
Approximate Monthly Savings (After Loan)	$165	$33	$165	$33
* Third party Leasing includes a yearly insurance fee of .5% of the total installed PV system cost ** Fixed residential customers fee in Puerto Rico				

Refer to Appendixes G and H for the simulation's assumptions and methodology

Renewable Energy Credits

The 2010 Puerto Rico's Green Energy Act defines renewable energy credits (REC's) as follows:

"A personal asset that is a tradable good or security that can be bought, sold, assigned and transferred between individuals, for any lawful purpose, which as a whole, indivisible asset, is equivalent to one (1) megawatt hour (MWh) of electricity generated by a source of sustainable or alternative renewable energy (issued and registered in accordance herewith) and, in turn, comprises the environmental and social attributes defined herein"

In general terms, a REC is a financial mechanism created to achieve a minimum renewable energy generation in a state/territory (established by a Renewable Portfolio Standard; RPS). The main purpose of the REC's is to encourage the generation of electricity via renewable resources, such as solar and wind, and to give a monetary value to the environmental benefits of such technologies. The following percentages of energy generation from renewable resources should be met in Puerto Rico:

- 12% from 2015 to 2019
- 15% from 2020 to 2027
- 20% in 2035

The funding required to meet RPS's can be supplied by local/federal incentives, taxes and private investment. According to the 38th Puerto Rico Electric Power Authority Annual Report, the public utility sell approximately 18,500 GWh of aggregated energy in 2011. The 12% (goal for 2012-2019) of this energy amount should create 2.2 billion REC's (1 MWh each). Figure 3.1 shows the most recent solar REC's prices in the United States.

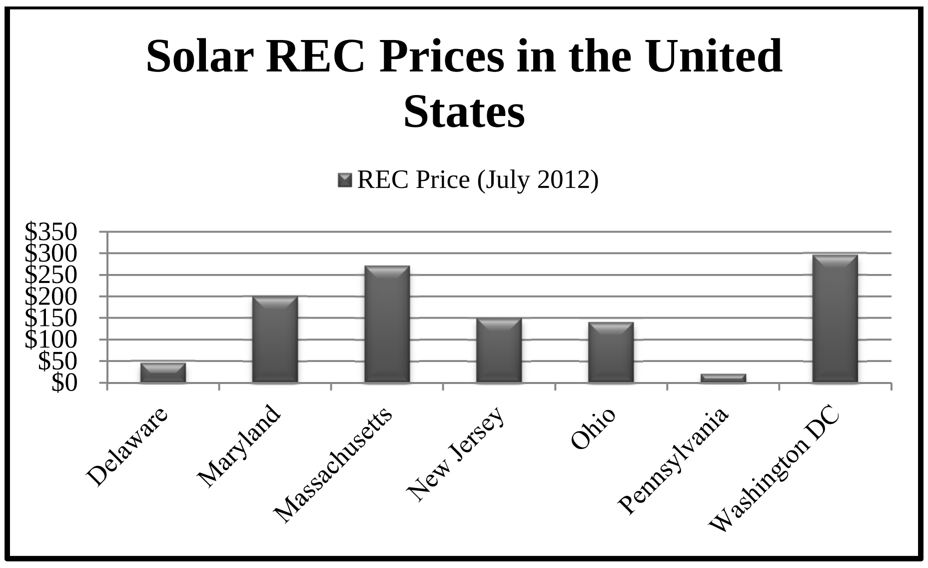


Figure 3.1: Solar REC Market Prices (from SREC Trade, 2012).

The REC's are sold separately from the electricity. This means that the homeowner will not get a credit in his monthly electricity bill. Instead, he will get paid for each REC's generated.

For example, a 4 kW residential PV system installed in Mayagüez, PR could generate approximately 6,000 kWh annually, equivalent to 6 solar REC's. In states such Washington DC a profit of $1,800 per year can be generated with a PV system with the characteristics of Mayagüez. The Department of Energy (DOE), in partnership with government and public entities, published a guide which describes the necessary steps to buy solar renewable energy certificates.

In summary, the educational process, the development of insurance products and the transparency of historical data, must be addressed in order to diminish the perceived risks associated with solar PV systems. Meanwhile, the most profitable financing option for homeowners is the solar community. From an economical point of view, this option offered a more profitable cash flow than the solar leasing.

Morris Model Description

A new solar photovoltaic (PV) financing model has emerged for governmental and municipality buildings. It is a hybrid model which requires third party ownership and government involvement. Typically known as the Morris Financing Model (developed by a municipality in New Jersey named Morris), the mechanism has been implemented successfully in schools, colleges, public agencies and municipalities all around New Jersey. Although a general concern exists regarding the time it takes from the beginning of the process until the construction phase, it is recognized as a real solution as long as public capital is cheaper than private.

The potential of generating electricity from solar PV systems installed in the rooftops of government, municipalities, schools and colleges' building, by implementing the Morris Financing Model, was assessed. The objective of the author is to explain how the 11% governmental subside can be decreased by considering the hybrid third party-PPA model. Residential and several commercial clients should be the benefited sectors.

The Morris Model is a financial mechanism used to decrease the high upfront costs associated with the installation of solar PV systems in the rooftops of government, municipalities, schools, universities and public buildings. The model requires the involvement of third parties and public entities.

The Morris model works as follows:

1. A public entity issues a request for proposals seeking a solar developer of projects on public buildings.
2. In order to finance the development costs of the PV installation, the public entity sells bonds to bondholders.

3. The public entity enters in two agreements: a third party leasing and a Power Purchase Agreement (PPA).

Implementing the Morris Model

A ten step process for the implementation of the Morris Model is shown in Figure 3.2. In order to implement such steps in Puerto Rico, several considerations must be addressed. First, local laws governing bonds should be studied in order to verify its requirements and regulations. Secondly, the process of selecting the winning bidder should be carefully planned and should not only be based on the lowest price rule. Other considerations such as zoning and public acceptance must be also incorporated. Considering the details mentioned above, does the Morris model makes sense from a common wealth perspective in Puerto Rico?

As of March 31 of 2012, public agencies and municipalities in Puerto Rico owed the Puerto Rico Electric Power Authority (PREPA) approximately $210 millions in electricity consumption bills ($189 millions from public corporations, $43 millions from public agencies and $4.3 million from municipalities). At a public hearing in Puerto Rico's House of Representatives, PREPA's executive director stated that such consumption deficit was affecting the corporation finances. Furthermore, residential and commercial electricity retail costs were absorbing such deficit, resulting in a higher kWh retail price, as both clients (which make up around 84% of PREPA's total customers base) were paying the electricity consumed by public agencies and municipalities.

Figure 3.2: Implementing Morris Model

Technical and Economic Benefits

From a utility's operational perspective, the interconnection of solar PV systems installed in governmental buildings, municipal buildings, schools and college rooftops can be very advantageous. A strong correlation exists between the solar energy resource and the daily electricity demand from public entities. Unlike residential electricity consumption profiles, were electricity generated from PV systems is thrown back to the grid (as typically, residential customers are not in their homes during the day), public entities typical consumption profile is an instant consumption/generation process.

Economic Benefits (from 84% of PREPA's customers)

As subsided government and municipality entities move towards the implementation of solar PV systems on their rooftops, the unpaid electricity will decrease resulting in a possible reduction in residential and commercial electricity costs. Although this report does not considered many factors such as public policy and political implications, it tried to provide the reader possible starting paths for the development of a sustainable governmental structure.

In order to quantify the possible decrease in unpaid electricity consumption debt from governmental corporations and agencies, as well as municipalities, an evaluation of the number of new PV systems that could be implemented using this scheme and related energy savings must be performed.

Economic and social impact of Rooftop PV Systems in Puerto Rico

The UPRM team identified and contacted managers of local commercial banks as well as regional cooperatives (financial institutions). UPRM was successful in bringing these managers, and even some Board of Directors members, to the work meetings to discuss: how the PV technology works, the solar resource in Puerto Rico and the current costs of a roof top photovoltaic system. Table 3.7 shows an estimate of the costs for a 1 kW system. Figure 3.3 shows the Levelized Cost of Energy (LCE), in $/kWh, at different sites in Puerto Rico as a function of peak sun hours.

Financial institutions managers, specially the Cooperatives, saw an extraordinary business opportunity and embrace the effort as stakeholders. UPRM researchers embarked in an effort to define, with significant input from the financial institutions, a new financial product that will make self-financing more attractive. The coops managers identified the need to bring the insurance industry into our working group, which happened in a latter meeting. The main issues raised by these managers were: insurance cost for this product, the lack of a secondary market in Puerto Rico for repossess PV systems, appraisal issues (such as how to include not just the capital value of the PV system but the monetary value of the energy it generates), limits in the Net Metering law and current incentives.

UPRM examined third party ownership options in Puerto Rico to clarify their legal status and study potential application in Puerto Rico. It is completely legal to have a third party install and operate a PV system in one's rooftop. Two contracts are needed; one contract between the consumer and the Third-party solar rooftop energy provider, and a second contract between the Utility and the consumer since Net Metering is allowed under the existing Law even if the consumer does not own the PV system.

Table 3.7: Estimate of installed cost of a 1 kW PV system

System element/task	**($/W)**
Solar panels	1.10
Inverter	0.75
Electric material	0.75
Installation	0.60
Design, permitting and certifications	0.55
Total (September 2012)	**3.75**

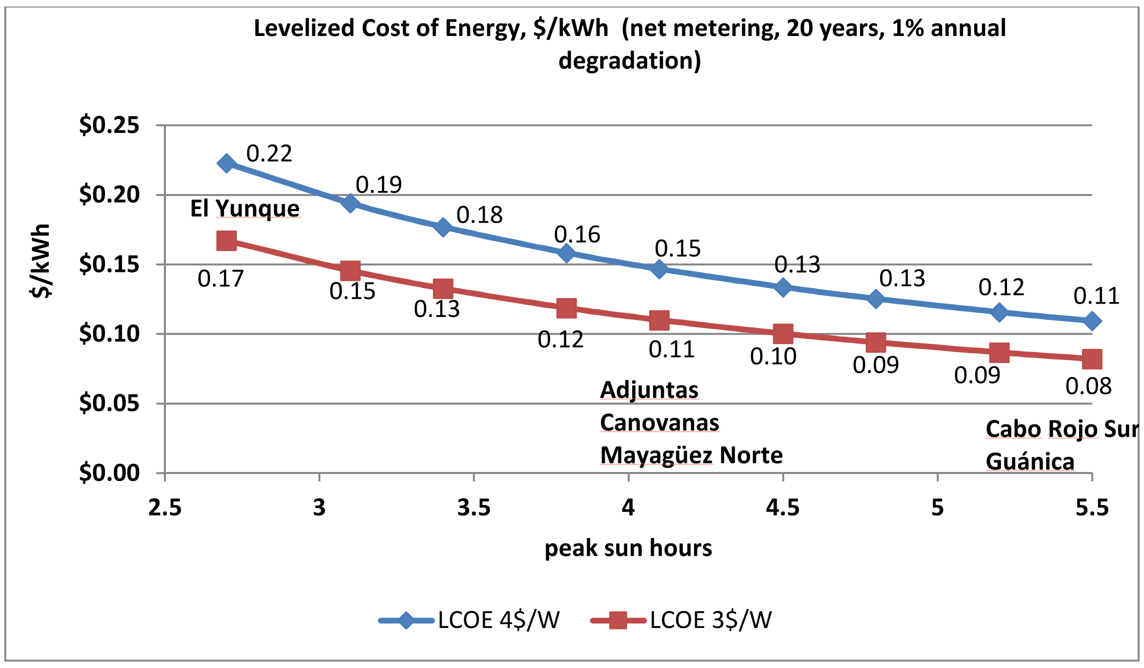


Figure 3.3: Levelized Cost of Energy (LCE), in $/kWh, at different sites in Puerto Rico as a function of peak sun hours.

There is a growing interest from large US companies in the Third-party business (e.g. Solar City) to install in Puerto Rico. A group of local businessmen and installers are also considering the development of this option. During conversations with Cooperatives officials UPRM developed the idea of developing a Solar Financing Community. Cooperatives (and Banks) know their customers and can identify possible clients (coop members, businesses) with financial resources to be used as collateral to finance a PV rooftop project. In fact, the Cooperative may decide to produce a "package" for their customers where the Cooperative writes and publish a Call for Proposals (CFP) for PV Installers where the Cooperative specifies minimum technical and financial requirements to bid for this solar systems installation project ($/W, minimum technical requirements for inverters and PV panels, minimum warranties, etc). The Cooperative may take advantage of economies of scale and sales of RECs to produce an attractive financing option for their customers.

Other Community options, such as the coordinated effort of a number of citizens to develop a process similar to the one previously described; where they will publish a Call for Proposals (CFP) for PV Installers with minimum technical and financial requirements and take advantage of economies of scale to obtain better PV prices, are indeed possible and legal in Puerto Rico.

What is currently unavailable in Puerto Rico is the use of other Solar Community schemes such as: the development of a large PV system, say 1 to 2 MW, developed by a private or public entity where citizens then buy a "solar lot" of a few kW. Local Net Metering law does not provide for the necessary "virtual net metering" (generation in one location to be credited to a customer account at a different location) that this scheme will require to take full advantage of the electricity produced by the customer "solar lot". This is an avenue worth pursuing, particularly if this is combined with a PACE program.

Programs such as the PACE program where cities, counties or other public agencies (even the public utility) issue bonds to set up a funding pool to pay for tax-assessed solar projects may be used in Puerto Rico but there are no such programs in place today. The establishment of said programs depends on the socio-economic philosophy, or vision, of elected officials. In a market-driven philosophy the PACE programs do not thrive. Wheeling (where electricity is sold from an independent generator to a customer over the transmission, or distribution, system of a third) is not available either.

Approximately 65% of residential roofs can provide the total electrical energy, not power, that was consumed in Puerto Rico in 2006, the year with the highest electricity consumption (see Figure 1.4). The highly distributed nature of this alternative, with hundreds of thousands of potential energy generators, poses integration and interconnection challenges of these systems. Nonetheless, the energy generation potential is so significant that even 10% of the households can provide close to 20% of the overall energy demand (2006 demand).

UPRM researchers strongly believe that rooftop photovoltaic generation to be the least environmentally intrusive, and the one with minimum possibility of social and community conflicts during deployment, among the renewable energy resources and technologies considered in Puerto Rico. Photovoltaic panels installed in roofs are virtually non-visible and the noise level of auxiliary equipment, such as the fan from DC/AC converter, is negligible.

What are the actual savings potential from a rooftop PV system in Puerto Rico? The following example is illustrative. First consider a residential customer which decides to supply approximately 500 kWh per month from a rooftop PV system. This may or may not be the customer's full electricity consumption. For a standard 30 days month, the customer needs to generate 16.7 kWh per day [(500 kWh/month)/(30 days/month) = 16.7 kWh/day]. Let us further assume that this customer resides in a zone with 4 solar peak hours per day. This results in a 4 kW system, [(16.7 (kWh/day)/(4 h/day) = 4.2 kW, let us say 4 kW].

The 4 kW will cost $16,000 at 4 $/W. The monthly 500 kWh cost $135 @ $0.27/kWh (from the local utility) and cost $75 @ $0.15/kWh (from the PV system). A loan with $3,000 down payment and $13,000 to be financed at 5.25%, 15 year, will pay $104.5 per month, resulting in savings of $30.5 per month. This is with no incentives. For a commercial customer the savings are greater. Let us assume the commercial customer decides to supply approximately 6,000 kWh per month from a rooftop PV system. Again, this may or may not be the customer's full electricity consumption. For a standard 30 days month, the customer needs to generate 200 kWh per day [(6,000 kWh/month)/(30 days/month) = 200 kWh/day]. In a zone with 4 solar peak hours per day the required PV system is of 50 kW, [(200(kWh/day)/(4 h/day) = 50 kW]. The 50 kW will cost $150,000 at 3 $/W (economies of scale apply). The monthly 6,000 kWh cost $1,800 @ $0.30/kWh (from the local utility, the commercial rate is more expensive than the residential rate) and cost $660 @ $0.11/kWh (from the PV system). A loan with 10% down payment and $135,000 to be financed at 5.25%, 15 year, will pay $1,085.23 per month, resulting in savings of $714.77 per month. This is with no incentives.

Table 3.8 shows the economic benefit of installing PV systems in 25% and 50% of residential rooftops in Puerto Rico. Besides the impact to the local economy of such large installations ($7.5 to $16.4 billion for a range between 2,000 to 4,375 MW), there is a large social benefit represented by decreased emissions. For example, between 7.5 to 16.4 millions of tons of CO^2 would be avoided each year. Average dollar value of that range would depend on valuation of the emissions. Table 3.8 shows values using a range of $1.4 to $6.5 per ton of CO^2. Adding other emissions would increase the social benefit besides benefits to the health of persons leaving nearby power plants which would generate less power from fossil fuels.

Table 3.8: Estimate of economic benefit from PV systems

	kWh from PV	**Emissions displaced (tons of CO^2)**	**High estimate per year**	**Low estimate per year**
25% of residential rooftops	$8x10^6$ kWh	7,531,840	$45.6M	$10.5M
50% of residential rooftops	$17.5\ x10^6$ kWh	16,476,841.48	$99.7M	$23.1M

Social Impact of Solar PV Financing Mechanisms

As distributed generation increases its participation in the Island's electric grid, the decision making process regarding the generation of electricity will be shifted from the centralized electric power utility to a group of stakeholders: communities, third party cooperatives, local authorities and also the utility. Therefore, the economic and social impact of such transformation must be addressed in order to have a broader understanding, which will be essential for the planning stage.

The following discussion identifies the social benefits and possible drawbacks of integrating a significant number of solar photovoltaic (PV) systems in Puerto Rico. Two main topics are addressed: the access of renewable energy by vulnerable communities and siting considerations.

Vulnerable Communities

In California, a pilot program named "Solar for all" was implemented with the purpose of integrating vulnerable communities into the solar PV market. It consists of three main objectives:

1. Build 375 MW of solar project specifically in disadvantaged communities through on-site distributed generation (DG).
2. Provide opportunities to building owners to be energy producers through a Feed in Tariff (FIT)
3. Create local employment opportunities through a local hire clause.

The program aims at low-income households in California. It is expected that this implementation will transform the local economy by creating new jobs, helping to boost economic opportunity and broader prosperity. A similar approach should be considered in Puerto Rico.

Siting Considerations

The siting and distributed benefits of solar PV distributed generation were discussed by the Center for Energy and Environmental Policy (2012). Among the statements made by the author, the following were the most relevant to the scope of the Puerto Rico Rooftop Solar Challenge project:

- Solar PV installations, when placed on existing rooftops, use minimal land space.
- Distributed PV generation reduces substantially the line losses.
- Distributed PV generation offsets peak demand.
- Solar PV installations tend to be less vulnerable to physical disasters, equipment failure, potential human error, or deliberate external actions.
- Power outages could be reduced.

Best Practices Applied to Local Utilities

DOE-sponsored webinars also served as sources of best practices. Of special relevance to Puerto Rico was the webinar "Ask the Utility: Working with your Local Municipality Utility".

The webinar presented two programs from two municipal utilities that have helped increase solar PV systems MW installations. Electric utilities of this type are non-profit, government-owned utilities that serve approximately 15% of U.S. customers. There are more than 2 thousand municipal utilities across the U.S. These are operated by a local government and are directly accountable to local officials that are elected or appointed. The two municipal utilities mentioned in the webinar were the Salt River Project and Austin Energy. In Puerto Rico, PREPA is a municipal utility or public power company (http://www.publicpower.org).

The Salt River Project (SRP) utility was established in 1902 and is currently the third largest public power utility in the nation, serving about 940,000 customers. As of 2013 the SRP board approved to offer a Distributed Solar Option to school districts, governmental and nonprofit entities on a pilot basis. One of its major projects is the Community Solar for Schools. This method is a good alternative for installing solar systems in rooftops. The schools can purchase a portion of the energy output of a 20 MW PV plant in the Southeast Valley area. The advantages for the school are:

- No up-front investment
- Fixed price for 10 years
- No maintenance or repair expenses
- Solar energy educational materials

This initiative sells electricity for schools at $0.099/kWh and 7.8 MW were subscribed as of early 2013. SRP is also working a similar initiative for businesses and residential customers. Businesses have the same benefits and same terms as schools except that they have to sign a 3-year commitment (schools have a 2-year commitment). Residential customers have a 5-year term, which they may cancel anytime, and pay a rate of $0.1125/kWh.

Perhaps this is not ideal for the Rooftop Solar Challenge initiative, but some of it could be taken into consideration. One way may be to let government agencies in PR generate more electricity than their demand, and since PREPA is government-owned, this policy might be aligned and coordinated with other policies that pursue less dependence on fossil fuels from the Government, participation in the PV market of individual customers or policies in support of reducing CO_2 emissions.

Austin Energy (AE) also has its own projects and plans to have 200 MW of solar energy by 2020. As of 2013 AE has a total of 8.5 MW of distributed solar energy which is divided as follows:

- Residential: 6.4 MW, which has a current rebate of $2/Watt
- Commercial: 1.36 MW, with a Performance Based Incentive of $0.14/kWh
- Installation on Municipal Buildings: 0.627MW
- Solar for School Demonstration Projects: 0.118 MW

The 2 programs that they are currently working on to reach this 2020 goal are: Equipment Leases that Qualify for Performance Based Incentives (PBI) and Community Solar. The first one is only for charitable organizations, government entities, and school districts. Other PV leases for commercial customers are not eligible for the PBI program. The other program, Community Solar, is called the Solar Choice Program which has the following objectives:

- Provide 10 MW towards AE's 2020 solar goal
- Provide solar options for homeowners that are ineligible to participate in the rebate program and have difficulties installing rooftop PV systems.
- Renters

With this program AE owns, operates and maintains the projects. Some of the possible projects for this program include retrofitting municipal buildings, integrating PV systems into new municipal constructions, cover parking at city properties, and ground mounted PV systems at locations like landfills. With this program AE expects to have 2000 subscribers, which add up the 10 MW goal.

There are 2 options for this program. In the first one, shown in Figure 3.4, the customer buys blocks (1 block=1kW) from the utility. The customer pays a monthly fee for 10 years and after that they pay a lower fee in order to cover for maintenance. The disadvantages of this program is that the cost benefit structure is difficult to understand, consumption analysis must be considered, federal tax credits are not available, and the system performance varies with weather conditions. In the second option (Figure 3.5) the Solar Choice fee remains fixed for 20 years and it is applied to 100% of the consumption. In addition the customer does not need to qualify for credit application, the locked in rate becomes less over time, and it has a proven cost structure. The only disadvantages for this option are that the system cannot be resold on a secondary market, the customer must sign up for 100% of consumption, and the customer may not have a feel of true ownership.

Despite the disadvantages in either program it is clear that both utilities are trying their best to reduce CO_2 emissions and move to solar. There will always be many different ideas on how to implement solar in communities, depending on their location and local circumstances. With this in mind these programs can still be a model for future projects or programs in Puerto Rico.

Information of the webinar: **Campbell, Becky, et al., et al.** "Ask the Utility Webinar: Working with your Local Municipal Utility" *ICLEI Local Governments for Sustainability USA.* [Online] November 16, 2012. http://www.icleiusa.org/action-center/learn-from-others/ask-the-utility-working-with-your-local-municipal-utility

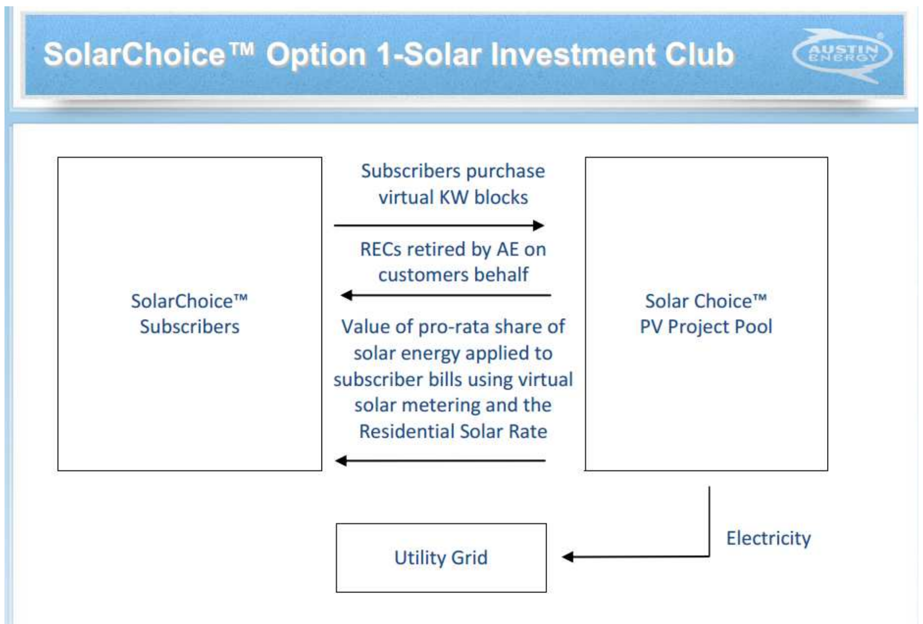


Figure 3.4: Solar Choice Option 1 from Austin Energy

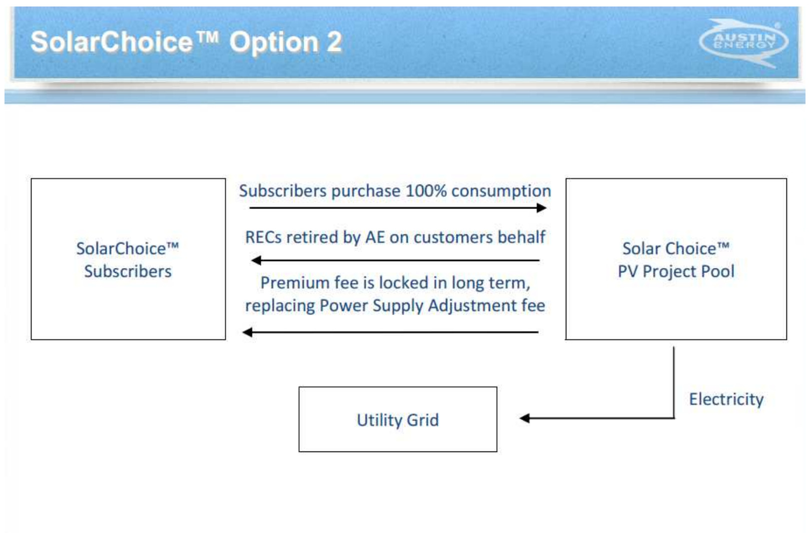


Figure 3.5: Solar Choice Option 2 from Austin Energy

Conclusions for Chapter 3

The best practices described in this chapter must be carefully studied and could be adapted in Puerto Rico. This requires a close collaboration among PREAA, PREPA, financial institutions and consumer groups, so that the financing programs established truly meet the needs and help in facing the challenges of PV deployment. A financial educational module was developed to help in this collaborative discussion effort, and is presented in Appendix I.

References for Chapter 3

L. Bernal. (2011). "Puerto Rico Energy Policy." Energy Affairs Administration. http://www.camarapr.org/SummitE3/Pres-E3/E3-Luis_Bernal.pdf

Center for Energy and Environmental Policy. (2012). "Policies to Support Community Solar Initiatives: Best Practices to Enhance Net Metering". http://www.ceep.udel.edu/energy/publications/2012_es_READY_CommunitySolar.pdf

A. Chaves and A. T. Bahill. (2010). *"Risk Analysis for Incorporating Photovoltaic Solar Panels into a Commercial Electric Power Grid"*.

J. Coughlin, K. Cory. (2009). *Solar Photovoltaic Financing: Residential Sector Deployment. NREL*. http://www.nrel.gov/docs/fy09osti/44853.pdf

P. Denholm, R. M. Margolis, S. Ong, B. Roberts. (2009). *Break-Even Cost for Residential Photovoltaics in the United States: Key Drivers and Sensitivities*. NREL. http://www.nrel.gov/docs/fy10osti/46909.pdf

DOE. (2010). *"Guide to Purchasing Green Power"*.

DOE. (2010). Homeowners *Guide to Financing a Grid-Connected Solar Electric System.* Solar Energy Technologies Program. http://www1.eere.energy.gov/solar/pdfs/48969.pdf

DSIRE. (2012). *Incentives/Policies for Renewables & Efficiency: Puerto Rico*. http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=PR

A. Goodrich, T. James, M. Woodhouse. (2012). Residential, Commercial, and Utility Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities. NREL. http://www.nrel.gov/docs/fy12osti/53347.pdf

Harvard Green Campus Initiative. *Third Party Financing Fact Sheets*. http://green.harvard.edu/sites/default/files/attachments/renewables/third-party-finance-fact-sheet.pdf

Rich Hessler Solar Sales Training. (2009). *A listing of residential solar financing*. http://articles.pvsolarsalestraining.com/articles.php?ALISTINGOFRESIDENTIALSOLARFINANCING

IDAE. *Ahorro y Eficiencia Energética: Financiación*. Ministerio de Industria, Energía y Turismo, Gobierno de España. Available at: http://www.idae.es/index.php/relcategoria.1160/id.41/relmenu.386/mod.pags/mem.detalle

International Energy Agency. (2010). *Technology Roadmap: Solar Photovoltaic Energy*. http://www.iea.org/papers/2010/pv_roadmap.pdf

International Energy Agency. (2010). *World Energy Outlook 2011: Executive Summary.* http://www.iea.org/weo/docs/weo2011/executive_summary.pdf

Green Matters (2011). "Lowering the Cost of Public-Sector Solar Power in New Jersey", http://greenmatters.csgeast.org/2011/12/23/lowering-the-cost-of-public-sector-solar-power-in-new-jersey/

NREL. (2009). Solar Leasing for Residential Photovoltaic Systems. http://www.nrel.gov/docs/fy09osti/43572.pdf

NREL (2012). "Financing Solar PV at Government Sites with PPAs and Public Depth", http://www.nrel.gov/docs/fy12osti/53622.pdf

NWSEED (2011). "Community Energy Benefits". http://nwcommunityenergy.org/community-energy-benefits#economic

PREPA (2010). "PREPA Revenue Bond Series", http://www.aeepr.com/INVESTORS/DOCS/Financial%20Information/Official%20Statement/PREPA%20Revenue%20Bonds%20Series%202012A.pdf

Puerto Rico Energy Affairs Administration (PREAA). (2010). *"PR Green Incentives Act No. 83"*.

J. Salasovich, G. Mosey. (2011). Feasibility Study of Economics and Performance of Solar Photovoltaics in the Commonwealth of Puerto Rico. NREL. http://www.nrel.gov/docs/fy11osti/49237.pdf

B. Speer, M. Mendelohn, K. Cory. (2010). Insuring Solar Photovoltaics: Challenges and Possible Solutions. NREL. http://www.nrel.gov/docs/fy10osti/46932.pdf

B. Speer, Michael Mendelsohn, and Karlynn Cory. (2010). *"Insuring Solar Photovoltaic's: Challenges and Possible Solutions"*.

T.J. Starrs, Thomas J. Starrs. (2000). *"Allocating Risks: An Analysis of Insurance Requirements for Small-Scale PV Systems"*.

SREC Trade. (2012). "State SREC Markets". http://www.srectrade.com/background.php

The Canopus Foundation & Ashoka (2012). "Solar for all", http://sfa-pv.org

URS Corporation. (2011). *Thirty-Eight Annual Report on the Electric Property of the Puerto Rico Electric Power Authority*. URS.

http://www.aeepr.com/INVESTORS/DOCS/Financial%20Information/Annual%20Reports/Annual%20Report%20URS%202011.pdf

S. Wilcox, Christian A. Gueymard. (2008). *"Spatial and Temporal Variability of the Solar Resource in the United States"*

J. Worren. (2012). *"Assessing the Risks of Solar Project Development"*. http://www.renewableenergyworld.com/rea/news/article/2012/02/assessing-the-risks-in-solar-project-development

CHAPTER 4

PLANNING AND ZONING

Solar Right Statutes and Ordinances

Best practices regarding planning and zoning standards were developed to foster a favorable environment for PV siting. Solar access is the availability of (or access to) unobstructed, direct sunlight. A property with access to sunlight means receives sunlight across property lines without obstruction from landscaping or structures from a neighboring property. This is a key issue in PV systems since electricity production is considerably reduced by sunlight obstructions. Besides manmade obstructions to sunlight natural phenomena such as clouds and weather also present challenges. It is important to identify and understand actual or potential obstructions to solar access to be able to address them. It is very important to point out that even though many solutions to this problem have worked in many other jurisdictions and/or cities, that does not mean that they will work in other contexts such as Puerto Rico's. Nevertheless, experience from elsewhere can be beneficial in dealing with local solar access issues. It is important to evaluate the many ordinances, easements, and laws that many states, cities, and jurisdictions have implemented so that the ones that fit best for Puerto Rico can be implemented. Before mentioning examples and places where these have worked it is important to first know what and why they exist.

Solar right statutes and ordinances protect the rights of property owners to install solar energy systems. Cities and counties are authorized to adopt ordinances for a variety of purposes. This typically includes the authority to prepare and enforce comprehensive plans, zoning regulations and building codes and to adopt ordinances and resolutions necessary for the exercise of its powers.

Muller and the Solar Powering Your Community report provide some recommendations and tips regarding ordinances providing for the special permit process of the local government granting easements, which can address the following:

- What constitutes an impermissible interference with the right to direct sunlight granted by a solar access permit and how to regulate growing vegetation that may interfere with such right.
- Standards for the issuance of solar access permits, balancing the need of solar energy systems for direct sunlight with the right of neighboring property owners to the reasonable use of their property within other zoning restrictions.
- A process for issuance of solar access permits including, but not limited to, notification of affected neighboring property owners, opportunity for hearing, appeal process of such permits on burdened and benefited property deeds.
- Revise local ordinances that pose unintended obstacles.

- Enforcement mechanisms, such as fees levied on parties who violate the terms of an easement.
- Require written solar easement agreements that adhere to the same recording and indexing requirements as those for other property interests.
- Conduct outreach and make an information available to educate residents, business, and homeowner's associations about solar access and solar rights.

Solar Easements

Solar easements are legal agreements that protect access to sunlight on a given property and can typically be transferred with the property title and do not terminate unless specified by the easement's conditions. They are necessary since U.S. courts have held that there is no common law right to sunlight. These are typically voluntary which means that it does not have any guarantees of an agreement with the neighbor. They require the property owner to be aware of the importance and availability of an easement, and have the time and money to work with a lawyer, neighbors, and the local government to develop and record the easement. Other limitations and advantages related to solar easements are shown in Table 4.1.

Table 4.1: Limitation and Advantages of Solar Easements

Limitations	**Advantages**
Neighbors have comparative advantage in negotiations. May need to negotiate with multiple neighbors. May add a "fuel cost" to solar collector system. Transaction costs often high. Potential windfall to "burdened" landowner. Easement not always recorded by county land office. Ineffective in protecting areas for future installation of solar systems.	Simplest and least cost to administer. Easily shaped to fit individual site requirements. May protect from tree shading.

Although these agreements are voluntary the local government can help create more proactive solar easement processes such as a solar access permit structure, which in turn may help alleviate some limitations that easements face. They can also set forth a degree of solar access protection by specifying certain setbacks in zoning ordinances (e.g., buildings are constructed far enough apart so that they would be unlikely to cast a shade on neighboring roofs). A best practice that has been implemented in Boulder, CO and Ashland, Oregon is a solar access permit scheme that involves granting easements and linking the solar permitting process to a process of creating a solar easement.

Another approach that may be used is to have a registration process which allows the solar owner to register its solar system with the local government, essentially putting their neighbors on notice that their solar system is in place. This imposes a type of solar easement on the neighbor.

Solar Right Laws

Solar Laws provide protection for residential and businesses by limiting or prohibiting private restrictions (e.g., neighborhood covenants and bylaws, local government ordinances and building codes) on the installation of solar energy systems.

These legal provisions have been implemented in many states and jurisdictions, as mentioned before. In “Solar Powering Your Community” the reader can read about states that have implemented these legal provisions. A total of 38 states and the USVI have implemented laws, statues, and/or ordinances. When implementing or creating legal provisions it is important to know that in some occasions these have led to legal actions and installation delays due to vague or absent provisions in them. At the same time it is important to revise local ordinances and zoning codes since they may inadvertently restrict installation of solar energy systems.

Each of these legal provisions is important to ensure solar access. Each of them has an implementation strategy. In general, Solar Laws are implemented in order to ensure that no ordinance or statute prohibit the installation of solar systems. This is due to the fact that many ordinances address aesthetics which in turn may obstruct the installation of a solar system. But, at the same time ordinances and statutes may be created or amended in order to ensure solar access. If none of these are available in a certain jurisdiction or state, one may turn to a solar easement. In the following section examples of these laws and ordinances are presented.

Examples of Solar Access Laws, Ordinances, Statutes, and Easement Laws

The States Advancing Solar web page presents the major solar access laws in California that include:

- California’s Government Code (65850.5) provides that subdivisions may include in their plans solar easements applicable to all plots within the subdivision.
- The Solar Shade Control Act encourages the use of trees and other natural shading except in cases where the shading may interfere with the use of active and passive solar systems. This act prohibits shading of solar collectors that result from tree growth occurring after a solar collector is installed. It states that no plant may be placed or allowed to grown such that it shades a collector more than 10% from 10 am to 2 pm. It does not apply to plants already in place or replacement of plants that die after the installation of the solar collectors. It does require that trees already in place,

but not yet obstructing the Sun, to be trimmed and maintained so that they do not impact the system in the future. A city or county may adopt an ordinance exempting its jurisdiction from the provisions of the act. Alternatively, some cities have passed ordinances that are more favorable to solar. In some cases, they require existing vegetation to be cleared to allow good solar access in at least some suitable place on a property.

- The Solar Rights Act (civil code section 714) prohibits local governments from restricting the installation of a solar energy systems based on aesthetics. It is the intent of this law that "local agencies not adopt ordinances that create unreasonable barriers to the installation of solar energy systems, including, but not limited to, design review for aesthetic purposes." Local authorities shall approve applications through permit issuance and can only restrict solar installations based on health and safety reasons. The Act is intended to encourage installations by removing obstacles and minimizing permitting costs. Additional key provisions limit aesthetic solar restrictions to those that cost less than $2,000 and limit a building official's review of solar installations to only those items that relate to specific health and safety requirements or local, state and federal law.
- The Solar Rights Act of 1978 (civil code section 714) provides that homeowner associations must not place unreasonable restrictions on homeowners wishing to install solar energy systems.
- The Solar Easement Law (civil code sections 801 & 801.5) provides the opportunity to protect future solar access via a negotiated easement with neighboring property owners.

Kettles mentions many examples of Solar Access Laws and Ordinances in different states and cities. He mentions the following:

City of Gainesville, Florida

- Allows the removal of regulated (i.e., protected) trees, where they will prevent the installation of solar energy equipment.

State of Hawaii

- Provides a very comprehensive list of instruments that are affected (covenant, declaration, bylaws, restriction, deed, lease, term, provision, condition, addition, contract, or similar binding agreement) declaring that no person shall be prevented by anyone from installing a solar energy device on any single-family residential dwelling or townhouse that the person owns, making any provision in any lease, instrument, or contract contrary to the intent of the law void and unenforceable.
- Also provides that every private entity (meaning community association) adopt rules for the placement of solar collectors: "The rules shall facilitate the placement of solar energy devices and shall not unduly or unreasonably restrict that placement so as to

render the device more than twenty-five percent less efficient or to increase the cost of the device by more than fifteen percent."

- Spells out the relative risks and responsibilities, when installing solar energy equipment on common property.

State of Massachusetts

- Provides for, among other things, a solar easement as well as a solar access permit.
- Voids restrictions against use of solar energy.
- Provides for solar access guidelines in subdivision regulation.
- Also provides for solar access in zoning ordinances, including the regulation of planting and trimming of vegetation on public property to protect solar access on public and private solar energy systems.

State of New Jersey

- While the law against deed restrictions that prohibit solar energy is fairly typical, it provides for enforcement of the law by the state's Department of Community Affairs, which aims to avoid the need for expensive litigation.

State of New Mexico

- Provides that a homeowner can record ownership of a solar energy system and allows the owner to establish a solar easement: "A solar right may be claimed by an owner of real property upon which a solar collector…has been placed. Once vested, the right shall be enforceable against any person who constructs or plans to construct any structure, in violation of the terms of the Solar Rights Act or the Solar Recordation Act (A solar right shall be considered an easement appurtenant, and a suit to enforce a solar right may be brought at law or in equity)".

City of Ashland, Oregon

- Establishes a procedure for a obtaining a solar access permit to protect a solar energy system from vegetation that would shade the collector.
- Provides for recording the easement.
- This detailed ordinance provides a level of protection that a voluntary solar easement does not. The procedures for obtaining the permit are comprehensive and protect the interests of all parties involved.

Virgin Islands

- Provides that deed restrictions (and other instruments) that prohibit the use of solar and wind energy are void and unenforceable.
- Also provides for a greater height restriction for solar and wind energy devices and provides for the dedication of solar easements as a condition of subdivision approval.

State of Wisconsin

- Provides local governments with the authority to enact an ordinance to require the trimming of vegetation that blocks solar energy equipment.
- Also, provides that restriction against the use of solar or wind energy are void.

Zoning Considerations for a Future Solar PV Generation Scenario in Puerto Rico

The development of new financing mechanisms, interconnection standards and online permitting applications may result in an evolution of the renewable energy sector in Puerto Rico. Space availability is a strong constraint for solar PV systems as mentioned in Salasovich (2011). In this publication, NREL concluded: *"The feasibility of PV systems installed on landfills is highly impacted by the available area for an array, solar resource, operating status, landfill cap status, distance to transmission lines, and distance to major roads."*

As a result, promoting the installation of solar PV systems on the rooftops of residential and commercial buildings reduce these constraints. Furthermore, from a technical perspective, the spatial distribution of solar PV systems through an area diminishes the fluctuations caused by the variability of the solar resource as shown in Figure 4.1. Moreover, a study published by Perez et al., concluded that the power outage that occurred on August 14, 2003 in US and Canada could have been prevented with dispersed PV generation available at the moment. Therefore, the reliability of the system could improve with a solar-based generation power system.

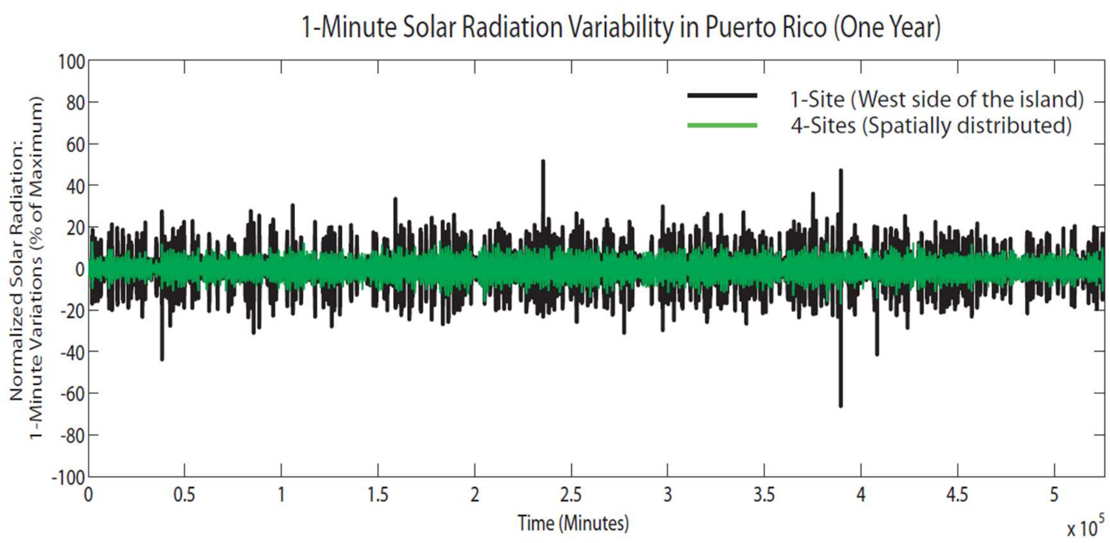


Figure 4.1: Effect of Spatially Distributing Solar PV Systems in PR

As the solar PV market grows as expected in Puerto Rico, new technical and non-technical issues will develop from a planning perspective. These can be grouped into two main topics: zoning considerations, including architectural issues and construction/structural standards and secondly, siting considerations, which include technical factors such as the operational effects that distributed generation (DG) of solar PV systems can create on a power system. Both topics will be presented in this chapter with a strong emphasis in Puerto Rico.

First, a review of solar siting ordinances in the US and PR will be described. Secondly, some aspects of the architecture and structural concepts that must be taken into account when considering a solar siting ordinance will be discussed.

Solar Siting Ordinances in the U.S.

A review of the most relevant solar siting ordinances in the US can be found in Clackamas County (2005). Most of them focus on new developments of residential and commercial buildings. Although they do not specify a strict regulation, they do set a minimum percentage of houses that will have an east-west orientation. A description of several solar siting ordinances in the US are mentioned and briefly discussed. Also, an example of a current ordinance can be found in Minnesota (2013).

1. Clackamas (Oregon), 2011. *Zoning and Development Ordinance.* Section 1017. Solar Access Ordinance for New Development.

   Summary of key points: Solar access ordinance for new developments. Divides the land with the purpose of maximizing solar access to residential and commercial structures.

2. Dixon (California), 2011. *Zoning Ordinance*. Section 12.19.21. Single Family Residential and Secondary Living Units Design Standards. Section 12.27. Energy and Water Conservation Regulations.

   Summary of key points: A single family dwelling should be designed and oriented on the lot to enhance its energy conservation features, including both passive and active solar systems.

3. Laramie (Wyoming), 2011. *Unified Development Code*. Chapter 15.14, Development Standards; Section 15.14.030.A, Solar Energy; Part 3, Solar Oriented Lots. Chapter 15.28, Definitions.

   Summary of key points: Solar energy collectors, storage tanks and equipment, roof ponds, or other solar equipment appurtenant to a solar energy system may exceed by *three feet* the maximum height limits established by this code.

4. Oakridge (Oregon), 2011. *Zoning Code.* Article 15, Sub-districts; Section 15.04(8), Planned Unit Development Sub-district.

5. San Luis Obispo (California), 2011. *Municipal Code.* Title 16. Subdivisions; Chapter 16.18, General Subdivision Design Standards; Section 16.18.160, Energy Conservation. Seattle, Wash.: Code Publishing Company, Inc.

Summary of key points: A very specific ordinance was found. It specifies that shadow patterns for shading structures such as buildings and trees between the hours of 9:30 and 2:30pm must be submitted to the City Administrator.

6. Santa Clara (California), 2011. *County Code.* Division C12, Subdivisions and Land Development; Article IV, Requirements; Part 9, Solar Access for Subdivision Development. Tallahassee, Fla.: Municipal Code Corporation.

Summary of key points: It includes a specific ordinance for sunlight access. “The provision of direct sunlight to a south wall and/or south roof of a principal structure from 9:00 a.m. to 3:00 p.m. Pacific Standard Time on December 21 sufficient for the effective use of a solar energy system.”

Solar Siting & Access Ordinances in Puerto Rico

Dr. Ana J. Navarro, a collaborating partner of UPRM researchers in the DOE project, summarized parts of several laws related to sunlight access in Puerto Rico. Dr. Navarro participated in the September 2012 focus group, and shared this important material. A review of these laws is presented below.

§ 1701. Object Legal Easements

Easements imposed by law. It concerns the public and individual interests.

History: - Civil Code, 1930, art. 485.

§ 1702. Laws governing public utility easements

Everything concerning easements established for public or communal use shall be governed by special laws and regulations.

History: - Civil Code, 1930, art. 486.

§ 1703. Laws governing easements on private interest

Easements imposed by law in the interest of individuals, or for privacy reasons, are governed by the provisions of this part, subjected to the provisions of the laws, regulations and local ordinances.

These easements may be modified by an agreement of stakeholders.

History: - Civil Code, 1930, art. 487.

§ 1773. Windows and balconies

A homeowner cannot open a window with a direct view, balcony or other similar projections on the neighbor's property… Neither can be side or oblique views on the same property, if the distance is sixty (60) inches away.

History: - Civil Code, 1930, art. 518, June 16, 1953, No. 90, p. 315, sec. 1, eff. 90 days after June 16, 1953.

§ 1775. Buildings separated by public streets

The provisions of sec. 1773 of this title do not apply to buildings separated by a public road.

History: - Civil Code, 1930, art. 520.

§ 1776. Distance that can build when purchased right

When any title with the right to have direct views, balconies or bay windows on the adjacent property, the owner of the current estate cannot build less than two meters away, taking the measure as described in the sec. 1774 of this title.

History: - Civil Code, 1930, art. 521, June 16, 1953, No. 90, p. 315, sec. 1, eff. 90 days after June 16, 1953.

§ 1803. Trees

Trees may not be planted near a property of a neighbor unless it is at a distance authorized by the ordinance.

History: - Civil Code, 1930, art. 527.

§ 1804. Branches and tree roots

If the branches of some trees go over the property, garden or yard of neighbors, the owner can cut the parts that extend over the property. If the roots of nearby trees percolate in the soil of another, the owner of the land may cut the tree into his property.

History: - Civil Code, 1930, art. 528.

§ 1805. Special Trees

Existing trees in a hedgerow mediator are also presumed mediator, and any owner has the right to demand its demolition. Except trees that serve as markers, which cannot be trimmed unless there is an agreement between the neighbors.

History: - Civil Code, 1930, art. 529.

Architectural Integration

The Spanish Industry of Energy has published a guide for solar PV system installations in residential and commercial buildings. It includes a comprehensive discussion of the architectural and structural considerations for an optimum design. In their publication, they discuss the advantages and disadvantages of the three main types of solar PV system installations in the world. These designs are shown in Figure 4.2.

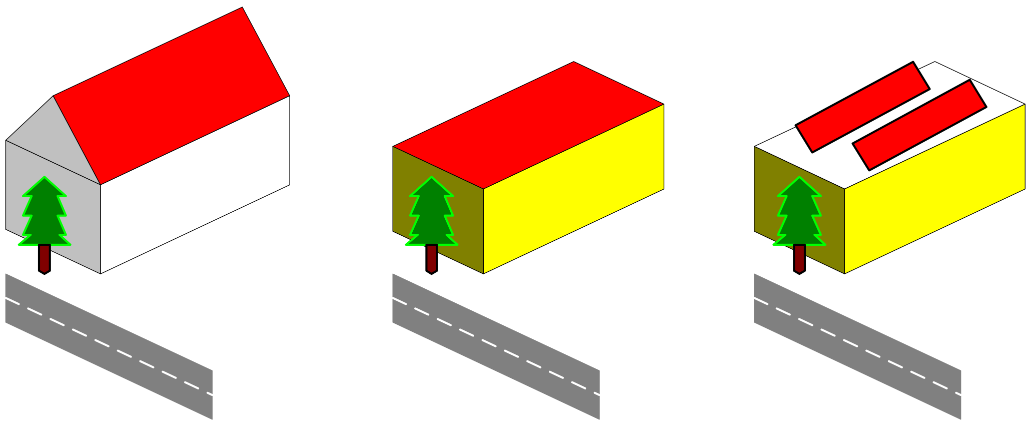


Figure 4.2: Common examples of photovoltaic integration applications.

Inclined Surfaces (First diagram of Figure 4.2)

Covers or pitched roofs are a very constructive solution to facilitate water drainage. This slope, always oriented at an angle to the south, can be used to design a PV system.

Flat Surfaces (Second diagram of Figure 4.2)

Flat roofs with minimum slope are also a very common. The photovoltaic modules are lifted by the structure, normally between 20 ° and 30°, to achieve maximum energy production. Maintenance is minimal.

Solar Energy Zones

In the path to reducing CO_2 emissions the U.S. has designated 285,000 acres of public land for solar development in Arizona, California, Colorado, Nevada, New Mexico, and Utah. The Department of the Interior has divided this area in 17 zones for utility-scale solar energy projects that combining all resources may total around 32,000 MW. An important aspect of these new zones is that they are supposed to simplify and speed up the approval process for renewable energy projects.

Besides designating these public lands, the document also excludes 79 million acres of federal land as being inappropriate for development and another 19 million acres as “variance” areas where the government would continue to decide solar projects case by case. The document responsible for assigning these zones is the culmination of two years of dialogue between regulators, environmentalists, industry advocates and the public at large.

These zones are specifically for utility-scale projects but one must pay attention to the efforts and collaborations among different groups in order to address everyone’s concerns. This should be even simpler here in Puerto Rico, since there is only one utility and the existing will to move towards solar energy.

Solar Ready Building Design and Orientation

This section is an overview of guidelines that may address specific site planning, building form, space planning, and roofing issues to be considered in the design of solar ready buildings. These guidelines were developed for the Twin Cities, Minnesota but should be viewed in order to prepare similar ones for Puerto Rico. The original document has plenty of information for all types of solar systems but only information regarding PV systems will be mentioned.

For site planning the document recommends to consider the size and orientation of the prospective building sites and the impacts of existing buildings and vegetation on solar access. To maintain solar access in developing communities, agreements or easements with neighboring property owners regarding heights of future buildings and landscaping should be developed. It is important to know that this approach should minimize or eliminate the need for additional permits or reviews.

The building's roof is an area that should be well planned and organized in order to take full advantage of it. Both flat and angled roofs can accommodate solar panels. In general, 100 – 150 sq. ft. of roof area is needed for 0.8 – 1kW of solar modules and should be arranged with solar access as a design criterion. The location should also be optimized in order to minimize the length of the electrical feeds to the inverter, electrical meter, and for the routing of the solar electric feed.

Another consideration is to design the location of the building and array in an area that neighboring building and maturing trees do not cast shadows on this area while at the same time should be oriented in a way it receives the maximum exposure to the sun (as suggested in NREL's *Solar Ready Buildings Planning Guide*). Not all shading is the same, the time of day and the time of year can have a great impact on solar shading. The area should be free of obstructions, anything that may shade the area should be installed in the northern part of the roof, and its blueprints should provide specifications for leaving the area open and unshaded. This area should be maximized in order to provide flexibility and ease of installation.

Finally the structure of the building should withstand the weight of the arrays and should account for the additional load wind can cause to the system. The mounting system of the arrays, in the case of flat roofs (most in Puerto Rico), may avoid roof penetrations, making pre-installed mounts irrelevant. There are also products that can be integrated on the roof structure, such as solar shingles, which may be desirable in certain buildings such as on historic properties.

As 2013 California requires new buildings, residential and commercial, to be solar ready opening the possibility for many more buildings to run on solar and helping California's solar industry. Besides applying to new buildings, the standards would also be in force for major renovations and additions to existing buildings. According to the California Commission estimates these standards will reduce energy demand for homeowners 25%, commercial buildings 30%, and low rise multifamily buildings 14%. It will also eliminate the need for six, 500 megawatt from new natural gas power plants.

Preferred PV Zones

UPRM originally proposed to DOE: "A strategy to be studied is establishing preferred PV zones, where massive deployment of small PV systems can occur in ideal located, vulnerable or financially challenged communities. This deployment will require a creative combination of financing, third party ownership and education in order to improve the quality of life of the residents while supporting economic activity and Puerto Rico's incipient PV industry." In Puerto Rico, the total number of individual residential units is approximately 1,181,112, and the total number of industrial establishments is close to 46, 348. Also, in 2003, there was a total of 1,552 public schools and 562 private schools. Therefore, approximately more than 1.3 million of rooftops are available for solar photovoltaic (PV) systems installations (government, universities and privately own buildings were not considered). As a result, solar PV systems can be deployed all over the island.

In Puerto Rico there is a sample of Preferred PV Zone established in Culebra and Vieques for the Green Energy Fund purposes. The Dollars per Watt allowed for proposed PV system is higher than the rest of the island. The idea of preferred zones was suggested by Mr. Gerardo Cosme, PE a long-time PV installer and energy leader in Puerto Rico. Mr. Cosme collaborated with UPRM in the DOE Rooftop project since the proposal stage. He suggested during a November 2012 planning and zoning focus group meeting the following ranking system to determine best PV suitable locations:

- Energy high demand occurs during daytime hours
- Utility infrastructure is robust
- Solar radiation resource is best
- Suitable roof space availability is high
- Expected of stable or growing load profile
- Chances or plans to change surrounding buildings heights are low or not expected for long time period
- Economically –strained communities
- Low small business density
- Entities that are high consumers (schools, hospitals, government offices, etc)
- Entities that has low or no revenues to pay electricity (public schools, government offices, etc.)

Several of these criteria are analyzed in the following sub-sections.

Energy High Demand Occurs During Daytime Hours

The electrical power system of Puerto Rico consists of approximately 5,839 MW of generation capacity. Typically, the aggregated electricity demand (including residential, commercial and industrial customers) peaks twice a day, at 12:00pm and at 8:00pm. As a stochastic process itself, electricity demand creates strong ramp events during the day, as shown in Figure 4.4.

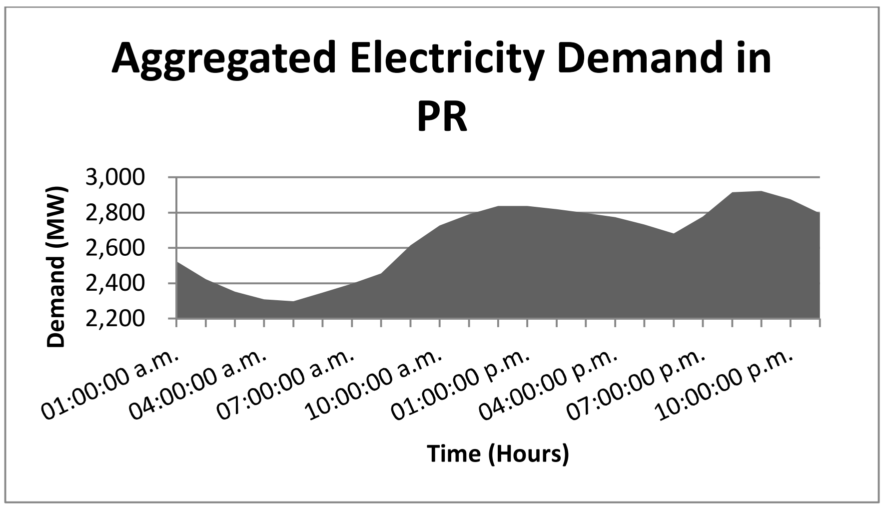


Figure 4.4: Aggregated Electricity Demand in Puerto Rico (Data provided by PREPA; 2011)

Utility Infrastructure is Robust

The robustness of a utility infrastructure can be determined, in general terms, by quantifying the ability of the electric grid to support projected and unexpected variations. Figure 4.5 and 4.6 show a comparison between Ramp Up and Ramp Down characteristics of the actual generation and at different percentages of solar PV integration.

From the figures, a maximum of 30% of solar PV installed capacity (1,200MW) produces 200-300MW hourly changes. As the black curve (no PV) shows, this percentage still falls behind PREPA's current ramp requirements.

Solar Radiation Resource is Best

Puerto Rico receives enough solar radiation to supply approximately 115% of the energy consumed in the island. In Irizarry (2009) several conclusions regarding the solar resource of the island were presented. One of these is the following quote:

"The least intrusive renewable energy resource technology considered in our study is solar photovoltaic. Contrary to other countries were photovoltaic farms are considered, in Puerto Rico photovoltaic roofs were the main focus of the study. We have selected this approach based on Puerto Rico's high population density and historic single family housing trends"

A solar radiation map was developed for Puerto Rico (Figure 1.3 in Chapter 1). Although the map is a first attempt and can be improved, it is quite obvious that Puerto Rico has an excellent solar resource, the south coast of the island having the best radiation.

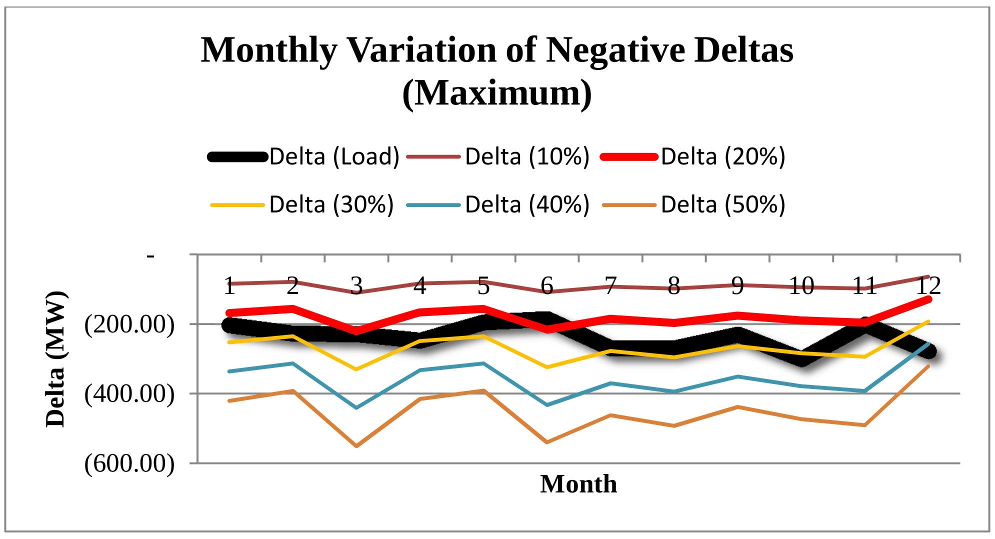


Figure 4.5: Ramp Down Hourly Load Following Requirements as a function of Installed PV Capacity

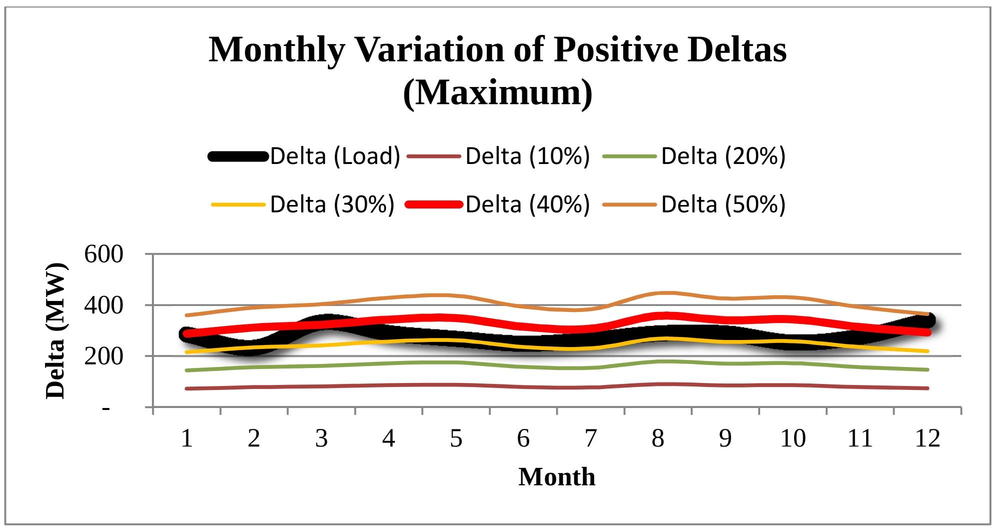


Figure 4.6: Ramp Up Hourly Load Following Requirements as a function of Installed PV Capacity

Suitable Roof Space Availability is High

In Deck (2005) the most common types of roofing systems in modern construction were discussed. However, the greatest concern for rooftop solar PV systems is the obstacle that trees around the house can create. In Junta de Planificación (1996) a table of the required area that must be covered by trees is presented. Table 4.2 shows a review of the percentage of area by zoning type.

Table 4.2: Percentage of Trees Cover

Zone	Percentage Covered
Residential (Low Density)	25%
Residential (Medium Density)	20%
Residential (High Density)	20%
Commercial (Office)	20%
Commercial (General)	15%
Industrial	20%
Commercial (Urban Zone)	10%
Institutions	25%
Touristic (Urban Zone)	20%
Touristic (Rural Zone)	30%

A Favorable Environment for PV Siting.

In order to develop best practices regarding planning and zoning standards that would create a favorable environment for PV siting in Puerto Rico, an understanding of the geography and area classification of the island is required. Moreover, estimating the seasonal trajectory of the sun on an hourly basis will be key for the development of a local solar right law. This section includes a general description of such considerations.

Puerto Rico, located in the Caribbean, is a 3,515 square miles island (approximately 100 miles E-W and 35 N-S) with a tropical climate with a nearly constant solar radiation throughout the entire year. Geographically, it consists of central mountains, hills, mountain sides, and low areas within the mountains. Typically, the land use of the island is classified into three main groups: rural, urban and suburban.

Most urban and suburban areas are located all over across the island. As a result, massive developments of solar PV communities can be achieved in residential and commercial rooftops. However, the effect of shading around the proposed solar communities must be evaluated, as it provides a better estimation of the PV system's performance and subsequently, preferable zones. Moreover, it can be used to determine minimum distances, maximum heights and orientation angles for the development of a local solar right act. The following section includes a general description of key solar geometry concepts.

Subsequently, a solar path chart for Puerto Rico will be shown. Finally, an example of shading requirements will be proposed.

Solar Radiation

The solar radiation can be defined as the radiant power emitted from the Sun that spreads out in a surface perpendicular to the direction of propagation. The World Radiation Center states that the maximum theoretical solar radiation intensity at the outer surface of the earth's atmosphere is 1,367 W/m², and it is normally refer to as the solar constant Gsc.

The intensity of solar radiation available at the earth surface is mainly influenced by five factors: weather, landscape, time of the day, geographic location and season. The seasonal variation of the solar radiation is a direct result of the Earth's elliptical orbit. Sites located close to the Northern hemisphere are exposed to stronger solar radiation during the summer as the surface is facing the sun directly. The opposite effect takes place during the winter. Figure 4.7 shows the diurnal and seasonal variations of the solar radiation for sites located in the northern hemisphere.

From a fixed reference point at the earth's surface, the sun follows a different diurnal path through the year. During the summer, the time difference between sunrise and sunset is greater than during the winter, as a result of longer exposition to solar radiation. The opposite is true through the winter, as less exposition to solar radiation results in shorter periods of sunlight.

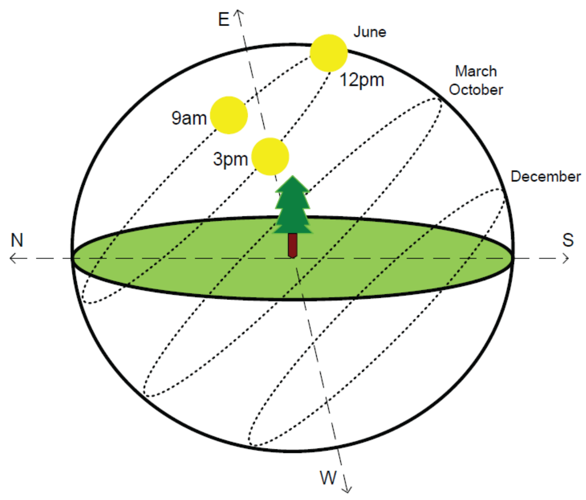


Figure 4.7: Seasonal and Diurnal Variations of the Solar Radiation

Geometrical Considerations

Solar radiation can be divided into six main components as a result of the interaction with the atmosphere. These are: beam, diffuse, scattered, absorbed and reflected solar radiation as shown in Figure 4.8. At the Earth surface, only the beam and diffuse components are useful for electricity generation as the scattered, absorbed and reflected components does not reaches the earth surface. The vectorial sum of the beam and diffuse components is known as the global horizontal radiation G0.

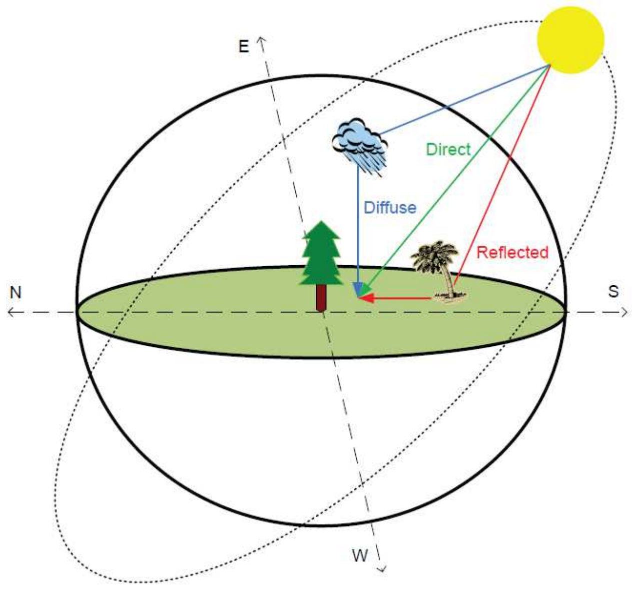


Figure 4.8: Solar Radiation Components

In order to quantify the solar radiation available at the Earth's surface, a general understanding of the solar trajectory is necessary. The location of the Sun, referenced from a fixed object on the Earth's surface, is determined by the solar altitude h_s and solar azimuth as shown in Figure 4.9. The solar altitude is defined as the angle between the horizontal plane and the sun. It varies from 0-90 degrees.

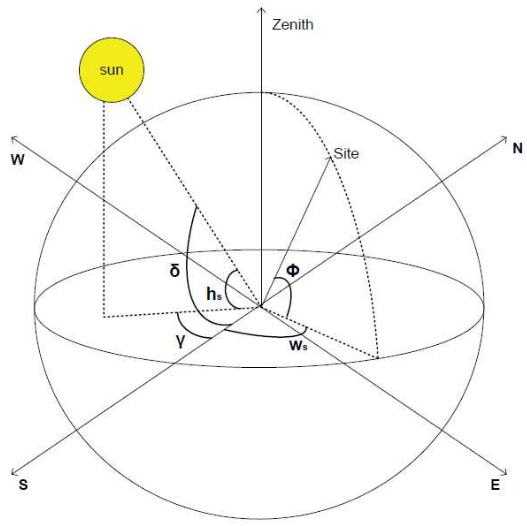


Figure 4.9: Solar Angles

Accordingly, the solar azimuth angle is defined as the angle between the projection of the horizontal plane and the south, it is typically assumed positive in the clockwise direction.

Horizontally, the position of the sun can be determined by the solar azimuth angle. The application of these concepts will be discussed in the following section.

Sun Position Chart of Puerto Rico

In order to estimate the effect of shading objects on a solar PV array, a sun position chart must be created for a specific location. A sun path chart is a graphical representation of the Sun's altitude and azimuth angles over a given period of time, for specified latitudes. These can be used to determine the Sun's position in the sky, at any time of the year. These are the basis for evaluating the effects of shadings on a PV array.

A sun path chart was developed for the island of Puerto Rico (18º latitude) and it is shown in Figure 4.10. Using an excel sheet downloaded from the NOAA website, the hourly variation of the altitude angle, on a monthly basis, was calculated.

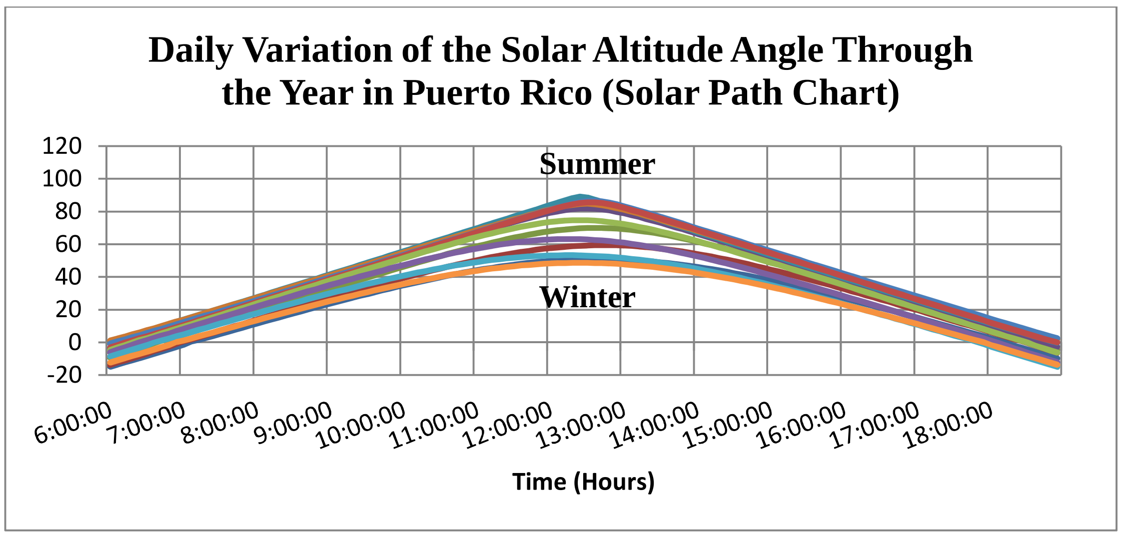


Figure 4.10: Solar Path Chart for Puerto Rico (At 18 degrees Latitude)

A more sophisticated sun chart can be created using the software developed by the University of Oregon, presented in Martinuzzi (2008). Figure 4.11 shows the specific sun chart for San Juan, Puerto Rico.

As already mentioned, two types of shading/obstructing problems that apply to PV systems exist: (1) shading of a collector by objects such as buildings and trees and (2) shading of a collector by adjacent collectors. The effect of both shading problems on the performance and economics of solar PV systems can be quantified by developing a solar position chart.

Shading Requirements in California

In Solmetric (2009) the impact of shadings on solar PV systems in California is discussed. A minimal shading factor is required as shown in Figure 4.12. Also, in this publication, the "cost of shading" was approximated and it was concluded that each 10% shading reduces solar PV production by $26/kW/yr.

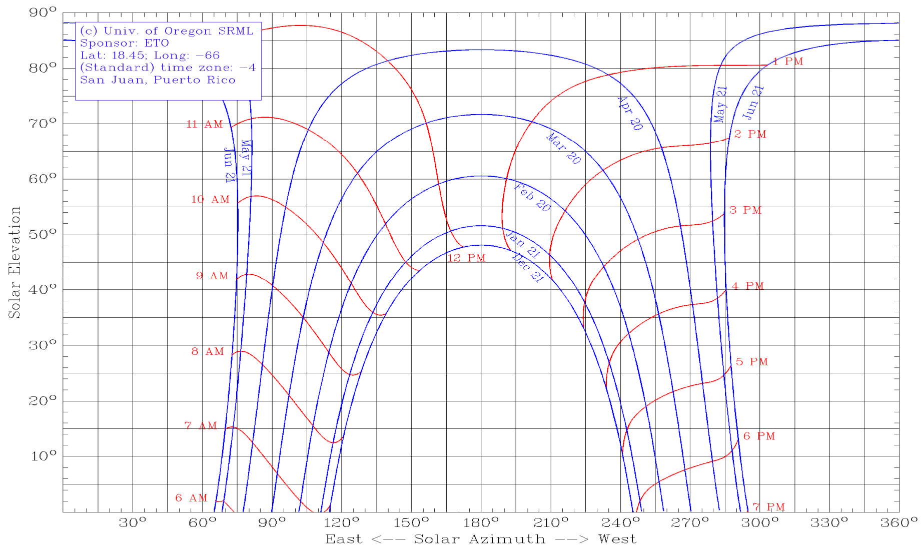


Figure 4.11: Sun Chart for San Juan, PR

In Figure 4.12 distance to closest point on the array is identified with D and H is the height above the array. They define the two parameters for determining the minimum height and orientation angle. A D/H ratio greater than 2 is required for solar PV rooftop installations. Also, a minimum elevation angle of $\Phi=\tan^{-1}$ (H/D) is also required.The "cost of shading" was approximated and is shown in Figure 4.13. The horizontal axis represents the percentage of shading on the solar PV array.

The California planning and zoning considerations for the development of solar communities could be applied in Puerto Rico. Although most of the island's land area is mountainous, the majority of the urban and suburban zones are spatially distributed across the coast, where tree shading is minimal. However, obstacles such as high buildings could be an issue when considering a massive development of solar communities. As a result, a minimum requirement such as the one from California must be calculated for urban and suburban areas in Puerto Rico. The development of solar path charts can be used for the long term planning and zoning of solar communities in Puerto Rico.

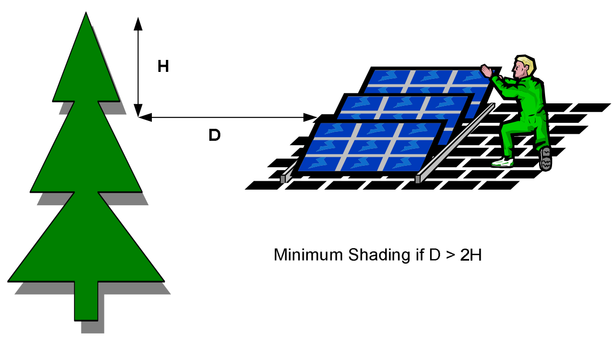


Figure 4.12: Minimal Shading Factor in California (adapted from Solmetric, 2009)

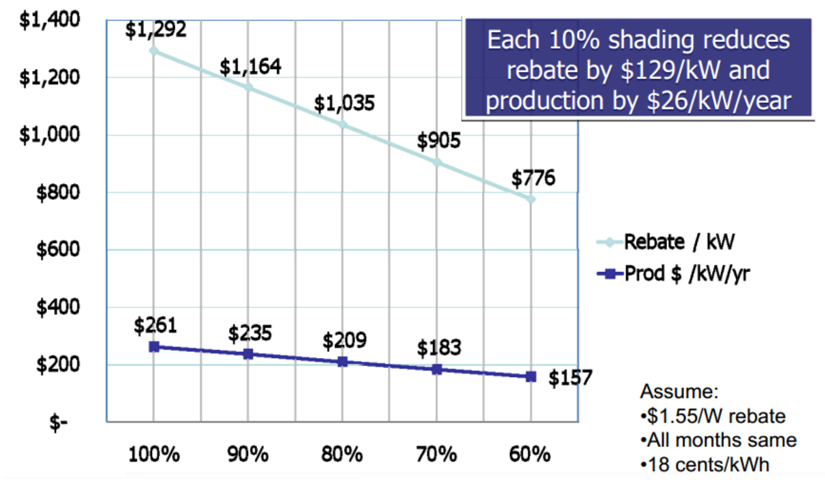


Figure 4.13: Cost of Shading in California

Construction Codes and Guidelines for PV Ready Buildings

Home designers should have in mind that a PV system could be installed in the roof of the house they are designing and constructing. Shading is likely to have the largest impact on overall PV system performance. Two evaluations should be done in order to ensure full sunlight on the system. One should be done during the design phase and the other should be during the installation of the equipment to ensure that there are no shading issues that were not considered. As a rule of thumb any potential shading structure should be twice as far away from the PV array as its height. Many products exist for these evaluations such as the Solar Pathfinder, and the Solmetric SunEye.

Other issues that should go hand in hand with PV ready constructions are the orientation and site planning of the unit. In Puerto Rico (and the Northern Hemisphere) the roof should have enough area facing south for these PV systems. The roof area should have about 100 sq. ft. for each kilowatt of system capacity for crystalline technologies and 175 sq. ft. for each kilowatt of thin film PV products. The orientation does not have to be due south (it may not be easy for a whole neighborhood to be able to have an unobstructed view due south), even at 60 degrees of due south at least 90% of energy is still available and at 90 degrees at least 80% of the energy is still available (in the contiguous US). There is also an advantage when facing due west for utilities, because the peak hours are mostly during the afternoon, when the sun is facing west. With this in mind, many new neighborhoods could be planned in coordination with PREPA to coordinate operation with the peak hours.

Windows and their orientation may also be of value when designing PV ready units since they may add energy efficiency to the building, and thus reducing thermal load and electricity bills due to room cooling. Many windows are designed to prevent heat from passing through it, to block heat caused by sunlight, and to minimize air leakage through them. Along with window overhangs should be incorporated in order to provide appropriate shedding throughout the year. Since the Sun in PR does not change angle as much as in the states the overhangs might block sunlight in winter too (which is not a big problem for PR since it is relatively warm during this time). Even though these do not have a direct impact to solar rooftop PV installation they are important to incorporate in the design in order to have a fully energy efficient building.

Below a list of best practices for builders and installers provided by Building America:

Builder Best Practices

- Conduct site assessments to ensure that solar energy will not be obstructed.
- Keep solar collectors and arrays close to the roof line. Avoid placement too close to the peak or the eaves.
- Take into account the climate and orientation in selecting windows.
- Free web-based software exists for designing overhangs. Use overhangs in the design for protection from rain and sunlight.
- Design communities and landscaping to avoid shading solar equipment.
- Save native trees to encourage cooling while avoiding shade on solar equipment.
- Consider adding the shading analysis sun chart to the homeowner's manuals.

Installer Best Practices

- Conduct site evaluations of shading to ensure that communities have viable solar exposure.
- Help builders assess the economics and performance of solar installations by using models to analyze performance.
- Ensure unobstructed solar exposure before choosing locations or installing solar collectors or arrays.
- Provide copies of site assessments to builders, including sun charts. These materials may be used for marketing or may be passed on to home purchasers.

PV Systems in Historic Sites

In many cases buildings are part of a historic district or the building itself is historic. Installation of these systems on these buildings may often be difficult since many jurisdictions have regulatory limitations and strict interpretations of historic standards which may prevent adoption of solar technologies. To prevent this from happening policies should be well articulated in order to embrace the PV systems while at the same time protect historic resources.

The following list provides guidelines to follow for the installation of PV systems in historic buildings and districts and is provided in "Implementing Solar PV Projects in Historic Buildings and in Historic Districts":

1. Locate solar panels that respect the building's historic sitting, locating the solar panel arrays in an inconspicuous location.
2. Locate solar panels in approved new constructions.

3. Locate solar panels on non-historic buildings and additions of historic buildings.
4. Place solar panels in areas that minimize their visibility.
5. Avoid solutions that would require or result in the removal or permanent alteration of historic fabric.
6. Avoid installations that would result in the permanent loss of significant, character-defining features of historic resources.
7. Solar panels should be mounted no higher than a few inches above the roofing surface and should not be visible above the roofline of a primary façade.
8. Set solar panels back from the edge.
9. Ensure that solar panels, support structures and conduits blend into the resource. This may be done by color matching the historic resource and minimizing reflectivity.

Pilot Project for Preferred PV Zone: Paseo Gautier Benítez-Caguas, Puerto Rico

The City of Caguas agreed to merge the preferred PV zones concept with their current efforts to foster economic development in the historic city center. The City of Caguas, located in the central-east part of Puerto Rico, is currently planning the redesign of a highly commercial street, known as “Paseo Gautier Benitez”. High electricity prices together with old and inefficient buildings are among the problems faced by local commercial and residential habitants. One of the objectives of the City’s Planning Committee is to convert the area into a solar community. The viability of installing 100 kW solar PV systems on the rooftops located in both sides of the street was evaluated.

Methodology

A structural description of the buildings located in the community was provided by the Planning committee of Caguas and it is shown in Figure 4.14.

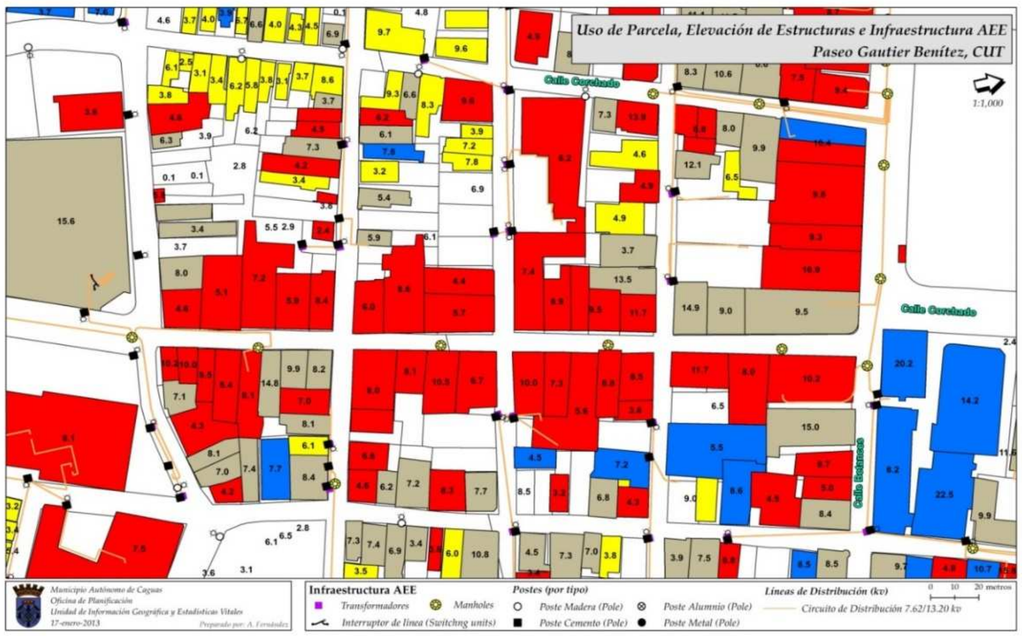


Figure 4.14: Building Heights (meters). Used with permission of the City of Caguas.

With the above information it is possible to quantify the effect of shading on the proposed solar PV systems. The software Meteonorm was used for the development of synthetic global radiation, considering the shading obstacles. Furthermore, the System Advisor Model (SAM) was used for the economic evaluation of the proposed solar PV community. In general, the methodology can be divided into three main groups as shown in Figure 4.15.

Site Evaluation

For purposes of simplifying the analysis, a reference site was selected for the shading calculations. The tallest two buildings in the nearby community were identified (for shading calculation purposes).

Shading Considerations

The topography of the site must be also considered for the shading analysis. As the solar PV system will be oriented to the south, the topographic obstacles from the East and West directions are of great interest. A rough topographic study of Caguas was done using Google Earth including the height of the terrain as a function of distance (from the East). A horizontal view from the West side of the reference point (tallest two buildings) was also used and a higher topographic elevation obstacle was observed when considering the West side (sunset hours).

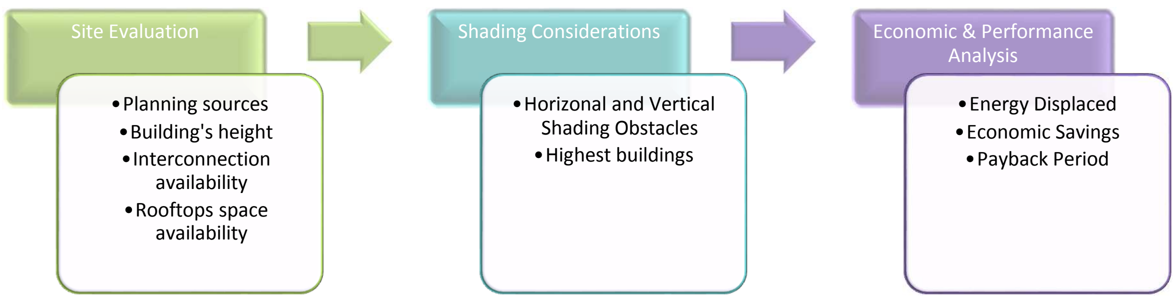


Figure 4.15: Methodology

Development of Solar Radiation Profile in Caguas, PR

The software Meteonorm was used for the development of the solar radiation time series. The software provides the option of including shading obstacles in the simulation. Figure 4.16 shows the horizontal view (due south; represented by 180 degrees) of Caguas.

After running the simulation, a new solar radiation time series was developed. From the selected point of reference, the highest building (40 degrees) will not cause any shading (not even during the winter, were the solar path is lower). However, there is one building that will create partial shading during the summer. The resulted monthly variation of the global solar radiation in Caguas, considering shadings can be seen in Figure 4.17.

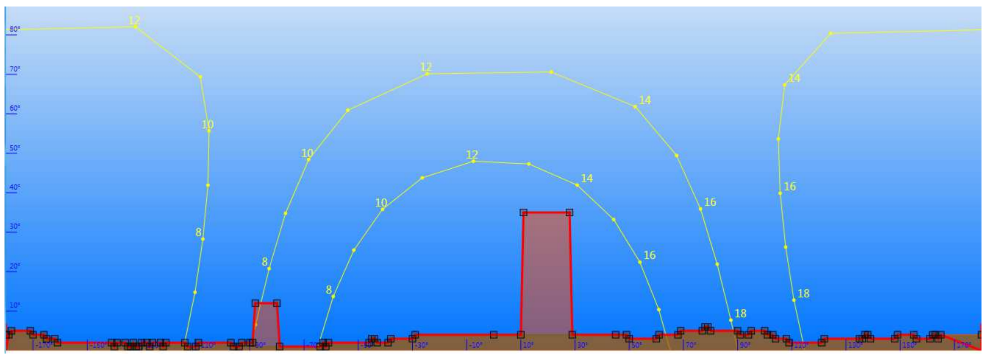


Figure 4.16: Horizon for Caguas, PR

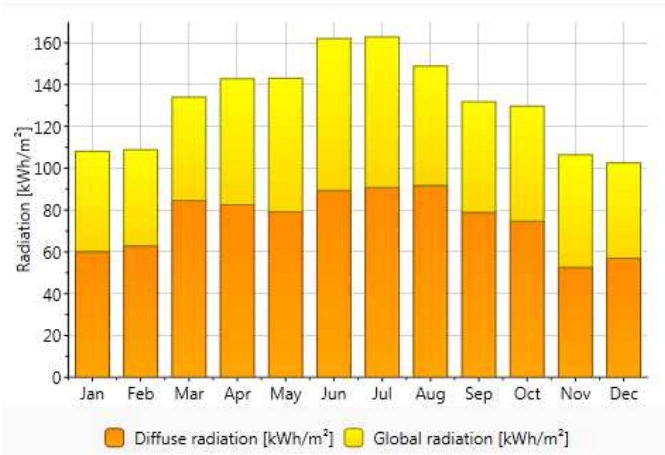


Figure 4.17: Temporal Variation of solar radiation in Caguas

Simulation Results

The Levelized Cost of Energy (LCOE) quantifies the value of the solar energy in the market. Figure 4.18 shows the resulted LCOE for Caguas as a function of installed capacity cost ($/kW). Assuming: 30% down payment, 20 years, 5.25% interest, 1% degradation.

From a siting perspective, the “Gautier Benítez” street does not have significant topographic and/or structural obstacles that will create a shading problem. Economically, the development of a solar PV community in the area will depend on the financing mechanism used. For example, when considering a solar community financing the upfront cost, the LCOE will be 0.2 $/kWh (approximately, $.07/kWh less than the actual utility average cost). As a result, developing a Solar Community in Caguas PR is feasible from a technical and economical perspective.

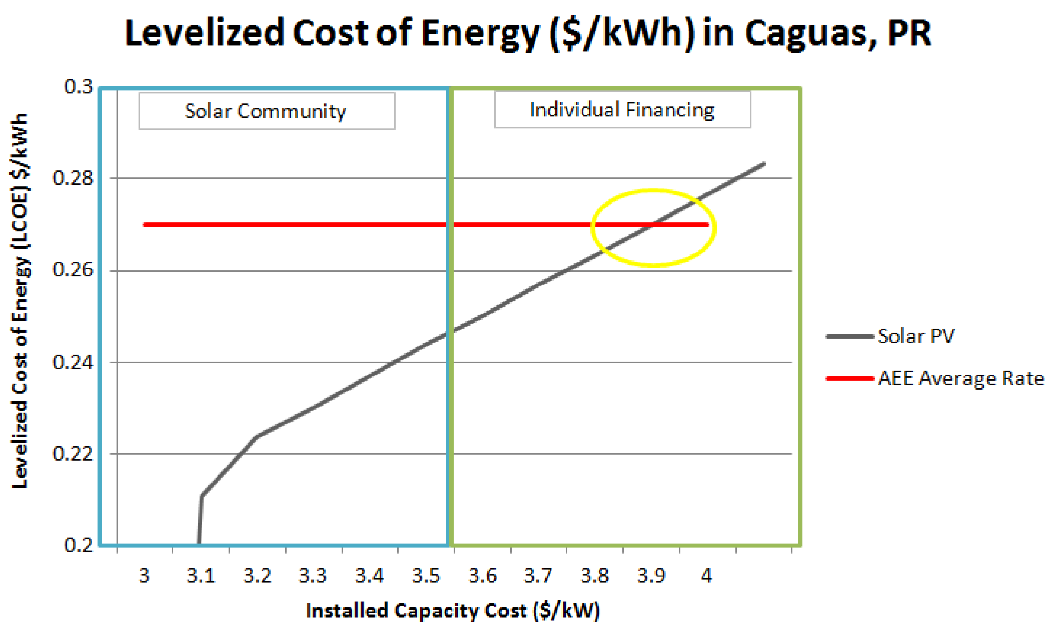


Figure 4.18: LCOE in Caguas

References for Chapter 4

Baechler, Michael C., et al., et al. *Building America Best Practices for High-Performance Home Technologies: Solar Thermal & Photovoltaic Systems.* s.l.: U.S. Department of Energy, 2007.

Belsie, Laurent. The Christian Science Monitor. [Online] October 14, 2012. http://www.csmonitor.com/Environment/Energy-Voices/2012/1014/Renewable-energy-US-takes-new-tack-with-solar-energy-zones.

Brooks, W., Dunlop, J., "Photovoltaic Installer Resource Guide", NABCEP, 2012. Online Available: http://www.nabcep.org/wp-content/uploads/2012/08/NABCEP-PV-Installer-Resource-Guide-August-2012-v.5.3.pdf

Campbell, Becky, et al., "Ask the Utility Webinar: Working with your Local Municipal Utility". *ICLEI Local Governments for Sustainability USA.* [Online] November 16, 2012. [Cited: November 16, 2012.] http://www.icleiusa.org/action-center/learn-from-others/ask-the-utility-working-with-your-local-municipal-utility.

Census of Puerto Rico. Table 1319: Selected social, demographic and housing characteristics in Puerto Rico 2009. Online Available: http://www.census.gov/compendia/statab/2012/tables/12s1320.pdf

Census of Puerto Rico. Table 1322: Puerto Rico-Economic Summary by Industry 2008. Online Available: http://www.census.gov/compendia/statab/2012/tables/12s1321.pdf

Clackamas County Zoning and Development Ordinance (2005), "Solar Siting Ordinances", http://www.planning.org/pas/infopackets/open/pdf/30part4.pdf

Clean Energy Group, "States Advancing Solar," [Online]. Available: http://www.statesadvancingsolar.org/policies/policy-and-regulations/solar-access-laws. [Accessed October 2012].

Deck, J., et. al., "Investigating and Promoting Extensively Natured, Green Urban Rooftops in Puerto Rico", 2005.

DOE (2011). "Solar Powering Your Community: A Guide for Local Governments".

Duffie J. andWilliam A. Beckman. Solar engineering of thermal processes / John A. Duffie, William A. Beckman. Wiley, New York :, 2nd ed. edition, 1991.

Ecology and Society, "Maps of Puerto Rico", Online Available: http://www.ecologyandsociety.org/vol13/iss2/art1/figure1.html

Education Bug. "Puerto Rico Public Schools Statistics". Online Available: http://puerto-rico.educationbug.org/public-schools/

Enciclopedia de Puerto Rico, Education Chronology, Online Available: http://www.enciclopediapr.org/ing/article.cfm?ref=08011801&page=3

Industria, Energía y Minas Consejería de Economía y Hacienda Comunidad de Madrid y la Fundación de la Energía de la Comunidad de Madrid (2009), "Guía de Integración Fotovoltaica", DG de Industria, Energía y Minas, M-22.465-2009.

Irizarry, A., "Electricidad Sostenible: Opciones de Aplicación Inmediata para Puerto Rico", ACEER, Available online: http://aceer.uprm.edu/pdfs/pres_airizarry_28nov07.pdf

Irizarry A., O'Neill E., Collucci J., "Achievable Renewable Energy Targets for Puerto Rico", Puerto Rico´s Energy Affairs Administration, Under contract number 2008-132009, 2009. Available online: http://www.uprm.edu/aret

Junta de Planificación y Departamento de Recursos Naturales y Ambientales, "Reglamento de Siembra, Corte y Forestación para Puerto Rico", Reglamento de Planificación Num.25, 1996.

Kandt, A., et al., et al. *Implementing Solar PV Projects on Historic Buildings and in Historic Districts.* Golden, Colorado: National Renewable Energy Laboratory, 2011.

C. M. Kettles, "A Comprehensive Review of Solar Access Law in the United States: Suggested Standards for a Model Statue and Ordinance," Solar American Board of Codes and Standards, 2008.

Kooles, Kimberly, Frey, Patrice and Miller, Julia. *Installing Solar Panels on Historic Buildings: A Survey of the Regulatroy Environment.* s.l.: U.S. Department of Energy, 2012.

Leone, Steve. Renewable Energy World. [Online] October 15, 2012. http://www.renewableenergyworld.com/rea/news/article/2012/10/western-solar-zones-to-streamline-development-on-public-lands.

Lisell, L., Tetreault, T. and Watson, A. NREL Solar Ready Buildings Planning Guide. *National Renewable Energy Laboratory.* [Online] December 2009. http://www.nrel.gov/docs/fy10osti/46078.pdf.

Lunning Wende Associates, Inc. . Solar Ready Building Design Guidelines. *Minnesota Government web site.* [Online] September 2010. http://mn.gov/commerce/energy/images/Solar-Ready-Building.pdf.

Madisun Solar Energy Program. *City of Madison.* [Online] April 2011. http://www.cityofmadison.com/Sustainability/City/madiSUN/documents/SolarPVGuide.pdf.

Martinuzzi, S.; Gould, W.A.; Ramos Gonzalez, O.M.; Quinones, M.; Jimenez, M.E. (2008). Urban and rural land use in Puerto Rico. Research Map IITF-RMAP-01.

Minnesota Pollution Control Agency, (2013). "Solar Energy Standards", Model Ordinances http://greenstep.pca.state.mn.us/modelOrdinances.cfm.

H. Muller, "Solar Access: Recomendations for the City and County of Denver," US Department of Energy Solar Energy Technologies Program, 2009.

Myers D., Steve Wilcox, Manajit Sengupta, Ray George, Craig Turchi, Tom Stoffel, Dave Renn. Concentrating solar power best practices handbook for the collection and use of solar resource data. Technical-Report NREL/TP- 550-47465, NREL, 2010. Online Available: http://www.nrel.gov/docs/fy10osti/47465.pdf.

NOAA. "Solar Position Calculator", Online Available: http://www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html

North Carolina State University, "DSIRE SOLAR," [Online]. Available: http://www.dsireusa.org/solar/solarpolicyguide/?id=19. [Accessed October 2012].

Perez, R.; Herig, C.; Letendre, S.; Hoff, T.; Williams, J. G.; Margolis, R. M. (2004), "Distributed PV Solutions for Power Outages: Case Study of the August 14th 2003 Northeast Power Blackout.", Proceedings of the World Renewable Energy Congress VIII (WREC 2004), 29 August--3 September 2004, Denver, Colorado.

K. Rappe, "Protecting Solar Energy Systems from Shading: Solar Access Policy Options for Seattle and Washington," Seattle, 2009.

Salasovich, J.; Mosey, G. (2011), "Feasibility Study of Solar Photovoltaics on Landfills in Puerto Rico (Second Study). A Study sponsored by the U.S. Department of Energy Weatherization and Intergovernmental Program Technical Assistance Project on behalf of the Puerto Rico Environmental Quality Board.", NREL, NTIS/GPO Number: 1023100

Solar-Ready Roofs Standard for New California Buildings. *Sustainable Business.* [Online] June 1, 2012. http://www.sustainablebusiness.com/index.cfm/go/news.display/id/23744.

Solmetric Corporation, (2009). "Shade Measurements for California Solar Rebates", Go Solar California, Available on line from:

http://www.californiasolarcenter.org/pdfs/forum/2009/20090129_SolarForum_SB1ShadingAnalysis_WMacDonald-SolMetric.pdf

URS Corporation. “Thirty Eight Annual Report of PREPA”, submitted to US. Bank Trust Association (Bond Trustee), 2011.

Vignola, F., “Using Sun Path Charts to Estimate the Effect of Shading on PV Arrays”, University of Oregon. Online Available: http://solardat.uoregon.edu/download/Papers/UsingSunPathChartstoEstimatetheEffectofShadingonPVArrays.pdf

CHAPTER 5

PERMITTING AND INTERCONNECTION PROCESSES

UPRM developed a “proof-of-concept”, holistic web-based framework that integrates PV information, permit and interconnection processes in order to ensure process liability and standardization while dealing with rooftop PV market barriers. It could provide a consistent starting point for the PV industry, users and government agencies if fully implemented and used by the Puerto Rico Electric Power Authority (PREPA) and the state main permitting agency (OGPe).

This task required stakeholder input, which was obtained during four meeting held during May 2012 in Mayagüez (UPRM) and San Juan (PREAA). Stakeholder comments and recommendations were used to fine-tune the PV market assessment regarding permitting and interconnection processes (previously done as part of the original proposal to DOE for the rooftop project). UPRM researchers studied the best permitting and interconnection practices from *Solar ABCS*, as well as searched and studied information from NREL, DOE and other energy-related websites on topics related to processes. IREC's 2012 report "Sharing Success Emerging Approaches to Efficient Rooftop Solar Permitting” was also a key reference. A summary of the key points from these reports follows next.

The website for *Solar ABCS* contains a wealth of resources on interconnecting rooftop PV systems. The specific resources analyzed were:

1. *Comparison of Four Leading Small Generator Interconnection Procedures*, J. B. Keyes and K. T. Fox, Interstate Renewable Energy Council, 2008.
2. FERC’s *Small Generator Interconnection Agreement* (SGIA, for Gen Facilities ≤ 20 MW), FERC, 2006.
3. FERC’s *Small Generator Interconnection Procedures* (SGIP, for Gen Facilities ≤ 20 MW), FERC, 2006.
4. *Rule 21*, California PUC.
5. Glossary and Resources Rule 21 Working Group California Public Utilities Commission, April 2011
6. *IREC Model Interconnection Procedures*, 2010.
7. *Updated Recommendations for FERC Small Generator Interconnection Procedure Screens*, M.T. Sheehan and T. Cleveland, North Carolina Solar Center, 2010.

UPRM researchers studied four interconnection procedures used by regulators to develop state and local procedures. This included review of criteria, analysis of scoring criteria, safety issues, reliability and cost. A comparative analysis was performed of the four procedures per score. The reports also include analysis of structural barriers and market issues. The main conclusion is that the IREC procedures may serve as a starting point to improve Puerto Rico’s procedures with California’s Rule 21 being superior regarding Interconnection charges. In California’s Rule 21 generators eligible for net energy metering are exempt from paying fees, including any necessary studies, and solar-powered generating facilities up to 1 MW that do not sell power to the grid are also exempt from these fees in almost all cases. The recommendations are aligned with establishing limits based on existing system parameters at the point of interconnection; such as % of transformer capacity, system voltage levels and aggregate contribution of the DG in a specified area rather than a spot.

Other references studied were:

1. "Expedited Permit Process PV Systems: Standarized Process for Review of Small-Scale PV Systems" B.Brooks, Rev. 1, 2011. This reference presented a simple, expedient, permit process suggested for systems that satisfy both structural and electrical requirements (which are easily satisfied by a majority of residential PV projects).
2. "Exploring Aggregated Net Metering (ANM) in Arizona, NARUC. A report for the Arizona Corporation Commission," Funded by U.S. DOE, 2011. This reference presents the positive and negative aspects of ANM in the context of Arizona law. A summary on ANM practices in 10 states including: eligibility, tariffs, limits (physical and administrative), credits and fees. Useful to commence a study of advantages and disadvantages of ANM for Puerto Rico.

Various key ideas from the IREC's 2012 report "Sharing Success Emerging Approaches to Efficient Rooftop Solar Permitting" were followed. Aspirational best practices must be sought but also realistic and effective ways to improve solar permitting in Puerto Rico. The responsibility for change should be shared among all stakeholders, especially Utility (processes and requirements) and the PV Industry (complete and accurate applications). Commitment is needed from a broad set of stakeholders in order to be effective in the reform process. Also, changes to permitting policy should benefit all involved. In order to steer towards that goal, PREPA's operation and services must be understood and taken into consideration as well as the PV industry's challenges in a fast-changing technological arena. The economic conditions faced by both groups are critical, but the best solutions are those that benefit the broader community.

There was a focus group on processes that helped in confirming, refining and discovering action items. For example, the current processes at the Permit Office (OGPE) and the Puerto Rico Electric Power Authority (PREPA) require various visits to these agencies, and submittal of paper forms. Unforeseen obstacles were discovered related to the transfer of responsibilities from PREAA to OGPE. OGPE was created to accelerate permitting processes in Puerto Rico. PV permitting responsibilities such as equipment and system certifications passed from PREAA to OGPE. However, the initial intent of consumer protection regarding such certifications has turned into additional time and fees for people installing PV systems on their homes. On the other hand, even though PREPA has rules and specific (steps) for interconnection, the application and interpretation varies depending on the region the system is to be installed (PREPA has 7 regions). This lack of consistency among PREPA regions is an obstacle in reducing red tape for rooftop PV systems. UPRM used the stakeholder input and the references on best practices were used to develop recommendations adapted to the PV market in Puerto Rico (already presented in Chapter 2). Those recommendations guided the development of the software blocks for the integrated system.

Through various stakeholder engagement activities (described in the next chapter) UPRM researchers were able to identify, discuss and present options to these problems. PREAA and UPRM are proposing OGPE to concentrate on the initial intent of consumer protection, not on collecting fees. PREPA was also engaged in discussions on ways to streamline their internal processes for interconnections. Furthermore, the proposed on-line framework has the potential to save time and money to all involved. There are two approaches for the on-line system:

- Best practice: An Integrated Web-based Framework for Rooftop PV Systems that integrates all relevant agencies (PREAA, OGPE and PREPA)
- Near term: PREAA-based functions to complement processes at OGPE and PREPA

On-line Rooftop PV System

An on-line framework is a key improvement strategy that could save time and money to all involved. UPRM researchers developed an initial structure for an integrated web-based framework for Rooftop PV Systems. The first level includes general information of rooftop PV in PR, access to the integrated system for permitting and deployment, the Puerto Rico Solar interface (PV Community), and document templates.

UPRM hired a graduate student, Mr. Israel Ramirez, to help in the development of the software tools needed for the integrated web-based system. Mr. Luis Lugo worked as webmaster for the project. UPRM researchers studied various references for software development. Particularly helpful was "Automated Permit Tracking Software Systems: A Guide for Massachusetts Municipalities" which gives general guidelines for the on-line system such as:

- the software should be able to produce status reports
- highlight any problems that should or would hold up the permitting process
- be able to pull data from other existing databases, allows concurrent review of application and site plans
- allows on-line application, submission of plans, and payment of permit fees
- intuitive to learn, easy to use and train new staff on; flexible and allows customization
- the software must have permit tracking capabilities.

The reference identifies more advanced features to achieve greater automation such as: automated document distribution, automated task and expiration date reminders, problem-flag tracking and online payment.

Specific recommendations when selecting or designing permitting software are:

1. Determine the features and services that are essential for all organizations involved.
2. Determine if there are existing systems that offer part of the services needed
3. Choose software applications that provide the capabilities needed to create the desired features

UPRM also consulted various IT specialists regarding software options for the development of the web-based system. Angel L. Pérez, VP & General Manager of Rock Solid Technologies, Juan L. Collado, VP xRM Group Technologies for the holistic framework, Dr. Bienvenido Vélez (Computer Science) and Dr. José Cruz (Computer Information Systems) from UPRM. They all agreed that a workflow approach seemed the best approach for this project. All of them mentioned MS Sharepoint as a potential software development platform, or its open-source counterpart, Alfresco. Sharepoint has tools of its own, but can also act as integrator of tools developed in other platforms. UPRM researchers studied available software options, and concluded that MS Sharepoint was used for the project. The Government of Puerto Rico has an umbrella license for MS products, and Sharepoint is currently used for various tasks at PREAA, OGPE and PREPA. Other Microsoft programs were used in conjunction with Sharepoint: Windows Server 2008, SharePoint Server 2010, SharePoint Designer 2010 and InfoPath 2010.

Researchers from other Rooftop Solar Challenge projects in the Southeast region were consulted about this task; UPRM obtained interesting comments from the Broward County team. They considered MS Sharepoint but did not choose it because they felt customization was harder, and it was difficult to replicate for agencies that did not have the product in their servers. These issues do not apply to the UPRM team. Broward County also offered valuable comments regarding the features of on-line permitting systems:

1. Designed to reflect the needs of the customers instead of the organization.

2. Provides a customized view for different customer types (such as residential, business, professional, etc.).

3. Customers should not need to know which part of the organization offers a service (all services for that customer type will be provided in one portal location).

4. If agencies reorganize, the changes should be transparent to customers.

5. The portal should provide a more rapid review and approval process than in-person processes.

6. Increase transparency by showing all elements of the permitting process, which will also serve as a pressure to reduce the complexity of those permitting processes.

7. On-line systems provide a transition to more green process (less paper, less travel).
8. Allow for simultaneous review of permit applications by various agencies.
9. Information will be available anywhere and at all times (not just in government offices during business hours).

The suggestions above were used in the development of the software tools for the Puerto Rico project. UPRM also followed the steps of the software/systems development life-cycle (SDLC). Many authors call the steps of the SDLC with many names, but in general these are: Requirement Analysis; Design; Program Coding; Program Testing; Installation.

The vision for the Puerto Rico on-line rooftop PV permitting functions was to have a collection of software tools that become a one-stop shop for the PV market. The user inputs all the data for the proposed rooftop PV installation in once place, which creates a profile/case or user ID for each installation. Once the data input is finished, the system checks correctness and completeness of the information, and automatically completes and electronically submits all needed forms (OGPE, PREAA, PREPA). The designated person in each agency will receive the requests, process them, and input in the system the certification or completed permits needed, and the case then moves on to the next stage. All processes that can be done simultaneously were identified. The objective was to speed up processing of rooftop PV cases to attain the recommended practice of less than a month for the whole process. UPRM researchers discussed a potential Android application so that users can access the web-based systems using their smart cellphones. This was later developed as a proof-of-concept.

The on-line system could be accessed through PREAA’s website. The workflow in Appendix D illustrates the overall structure of the integrated system. For clarity we have taken parts of the workflow in the Appendix for the following discussion. After the user enters the required data, the system checks for completeness, fill and submit all needed documents and applications. Part of the user interface includes automated features for financing mechanisms as shown in Figure 5.1. For example, is a user is interested in using the Green Energy Fund, information will be provided on the fund’s requirements. The system then checks if the equipment selected are certified. Figure 5.2 shows this process that related to OGPE functions. This check is done automatically using a database of certified equipment that should be available from PREAA’s or OGPe’s website. If everything checks, the application moves on to PREPA, with all the supporting electronic documents.

The process within PREPA has two main steps. Figure 5.3 shows part of the first step, the interconnection application. There is a simple interconnection process for single-phase systems less than 25 kW, or 200 kW for three-phase system. Else, the usual interconnection evaluation takes place. These processes can also be automated through tools developed in the project. All the steps are time-stamped to allow time tracking and status-checks of the application. The PREPA endorsement of the project signals approval to start installing the rooftop PV system.

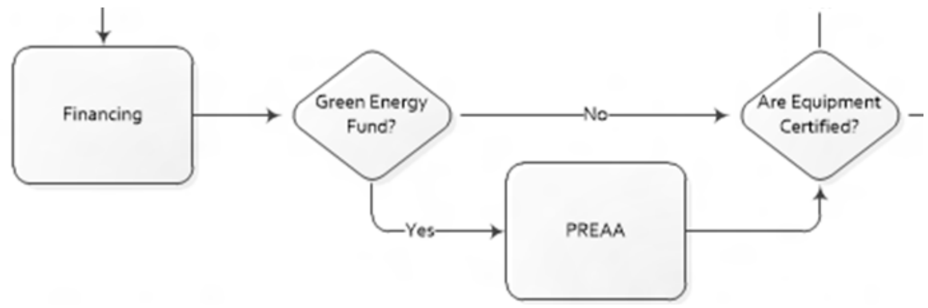


Figure 5.1: Financing functions

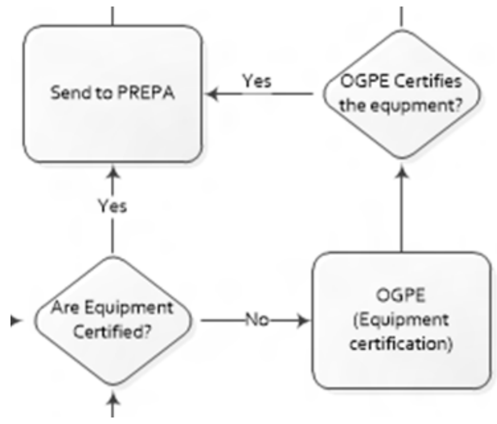


Figure 5.2: Checking for equipment certifications

In Figure 5.4, once the PV installation is completed, the on-line system is used to submit the installation certification to OGPE. The system is also used to coordinate the PV system tests with PREPA. When final interconnection approval occurs, the PV system can begin operating. If the user selects to have net metering, the application for that process automatically begins after interconnection approval is given. Figure 5.5 shows the net metering application process.

Interconnection evaluation is made by the PREPA technical region where the PV system is to be installed. The net metering evaluation is made by a PREPA commercial office. Nowadays this represents time and money invested in filling and submitting forms in person and following up on the status of the PREPA evaluations, also in person. The proposed system could reduce this time, and reduce paperwork, striving to make it transparent to the user the various steps within PREPA required to complete internal bureaucratic processes.

Appendix L shows the description of the development of a proof of concept software applying the concepts just described.

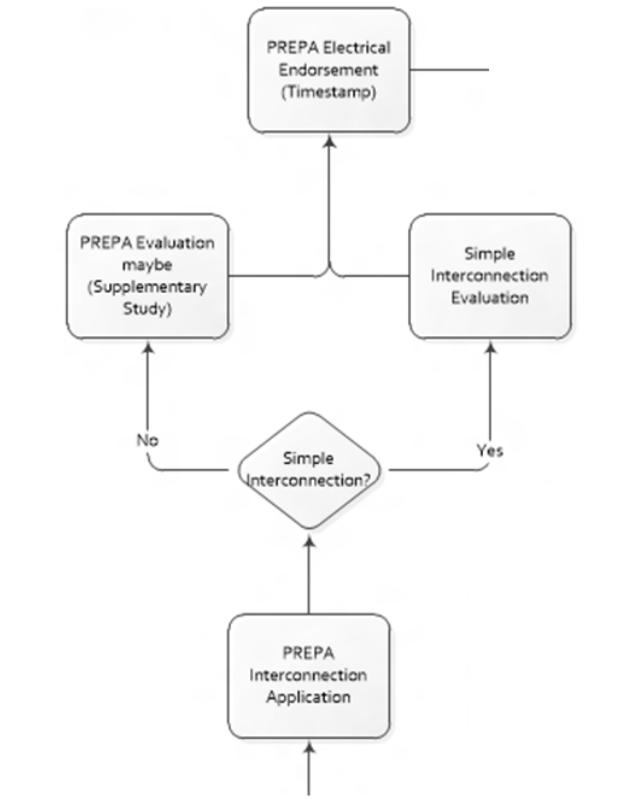


Figure 5.3: Interconnection application and evaluation

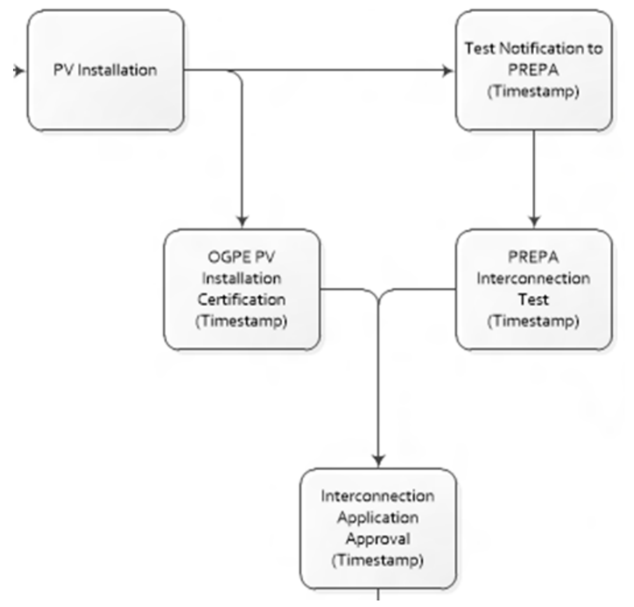


Figure 5.4: PV Installation, test and certification.

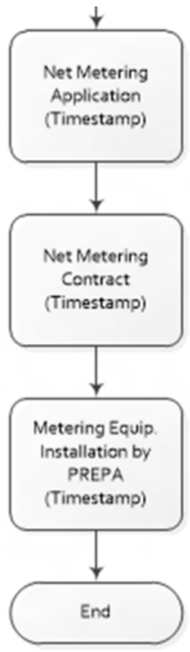


Figure 5.5: Net metering application and evaluation.

Conclusions for Chapter 5

On February 2013 UPRM completed the installation of the completed “proof of concept” web-based system to a computer server in the Puerto Rico Industrial Development Company (PRIDCO). The estimates of the savings in time if the new system were implemented at OGPe and PREPA is that within one month, all permitting and interconnection procedures for rooftop PV up to 300 KW could be completed. This would represent a savings of 50% from the current time, which on average is at least two months for residential and small commercial PV systems.

CHAPTER 6

STAKEHOLDER ENGAGEMENT

In order to ensure the success of the project's activities, key stakeholders were periodically convened and engaged in the vicinities of San Juan and Mayagüez. Stakeholders were included early in this project, so that they could actively participate in: the framework development, revisions needed for standards, the study of new financing options, discussion of new planning and zoning tools, and finally the creation of an Island-wide "PV community" that will result a more favorable environment for PV systems in Puerto Rico.

As part of this task, UPRM developed and shared rules of engagement with the PV stakeholders to guide discussions. First it was clear that developing best practices was an "aspirational" process: a vision of where the rooftop PV market should be in Puerto Rico. Nevertheless, there are practical considerations that needed to be included in discussions, issues or obstacles that limit the collective ability to get closer to the vision. The dialogues were moderated by UPRM researchers in a respectful way, emphasizing that agreement would not be reached on everything, but at least all involved should listen and understand the other sector's perspective. Finally UPRM strived to show the value-added in participating in the project's activities for each sector. These rules proved to be effective in all stakeholder activities.

The project was announced to large audiences on April 27th and April 30th of 2012 during two continuing education activities delivered by Dr. Efrain O'Neill in San Juan and Mayagüez. Over 300 persons participated in those activities and were made aware of the project's goals and given contact information if interested in collaborating. The kick-off activities of the project were also announced during those activities. The kick-off meeting was on May 2, 2012 at PREAA. Community, professional, environmental, utility, PV industry and financial groups were represented in the meeting. Dr. O'Neill (UPRM) and Eng. Damarys Gonzalez (PREAA) led the meeting, with help from Dr. Agustín Irizarry (UPRM). A second kick-off meeting occurred in Mayagüez, on May 8, 2012. Dr. O'Neill led that meeting with help from Dr. Irizarry and Dr. Eduardo Ortiz (UPRM). Those meetings officially kicked-off the project, and marked the beginning of the organizational activities geared toward the creation of an Island-wide PV community.

The main outcomes of those initial meetings were:

1 Official beginning of the project

2 Interest from the Puerto Rico Electric Power Authority, PREPA (local utility) in actively participating

3 Identification of key stakeholder for focus groups (working groups)

4 The need to balance various (and many times conflicting) interests of stakeholders

5 The need to begin the Financing work of the project earlier

6 Confirmation that the processes work can be effectively combined with the standards work to catch up with the initial timeline of the project

7 The need for a holistic vision in renewable energy, and the challenge of attaining such vision with the limited time frame the project had (less than one year).

In coordination with PREAA, UPRM developed a timeline with the objectives of complying with the proposed activities and comply with the proposed activities originally submitted to DOE. The timeline moved the work for financing earlier, and combined the work on standards and processes. UPRM had originally proposed to coordinate, convene and lead four (4) bi-monthly meetings: Small group stakeholder meetings starting on the third month of the project, and focused on specific issues. However, in order to be successful with the more aggressive timeline, besides the small group bi-monthly meetings, UPRM convened working meetings in San Juan and Mayagüez with focus groups of around 10-15 people. The focus group meetings had the participation of key PV stakeholders in each of the areas: standards, processes, financing, zoning and planning. Appendix A shows the tasks completed following the more aggressive timeline.

Engagement levels

The effort ended up with the following levels of stakeholder engagement: focus groups (approx. 10-15 persons), small group meetings (approx. 30), and PV Summits (over 100 persons). Through these levels of engagement UPRM sought to create a PV Community in Puerto Rico that could champion, in collaboration with PREAA, the recommendations developed in the DOE's Rooftop Solar Challenge project.

The focus group meetings were held on May 30th and June 19th at PREAA and May 31st and June 20th at UPRM, all in 2012. Each of the meetings was divided in two topics, standards and processes. In essence, each meeting was in fact two meetings since the stakeholders for these two topics are the same. The outcomes of those meetings were mainly recommendations to the UPRM team on areas to pay attention in the standards and processes work. Details were given in Chapter 2. The next small group meetings were on July 12th and 13th on processes and standards.

A key initial task was to fine-tune with PV stakeholders, the evaluation of the rooftop PV market submitted to DOE in the proposal on August 2011 (revised during negotiations with DOE on December 2011). The objective was to acquaint key stakeholders with the language and metrics DOE uses and to get an updated perspective of the PV market. That task started with the focus group meetings of May 30th and May 31st mentioned in this chapter.

The main references read and studied for stakeholder engagement:

1. Peter Senge, *The Necessary Revolution: How Individuals and Organizations are Working Together to Create a Sustainable World,* Doubleday, 2008.

2. Venkat Ramaswamy, *The Power of Co-Creation*, Free Press, 2010.

These references offered great advice on how to deal with diverse and seemingly contradictory perspectives when engaging groups from different sectors in sustainability topics such as PV systems. For example, Senge argues that the deep problems faced today are the result of a way of thinking whose time has passed or is near its end. A vital question to ask stakeholders is: Do we protect the ways of the past or join in creating a different future? Seeing the deeper pattern that connects many different problems is crucial if we are to move beyond piecemeal reactions and create lasting change for PV systems. Senge cautions that many collaborative initiatives can be frustrating because they produce lots of talk and little action. Building capacity to collaborate is hard work and needs to be seen as such. It takes time and a high level of commitment. Since there was a clear focus (rooftop PV under 300 kW), UPRM leveraged on the interest of each group regarding such systems in building the needed collaborative attitudes. Senge provides an example in which the groups collaborating did not have exactly the same set of objectives, but there was enough of a common ground to work together. This is what was followed in the early engagements with PV stakeholders in Puerto Rico.

Dr. Ramaswamy stresses the importance of stakeholder engagement in facing today’s challenges (including energy). He argues in favor of co-creation, the practice of developing systems, products or services through collaboration with customers, managers, employees and other stakeholders. This is exactly what UPRM researcher did during the project. Instead of developing rooftop PV best practices in a vacuum, UPRM actively engaged and collaborated with key stakeholders that later on could champion in favor of those changes. Co-creation involves democratization and decentralization of value-creation, moving it from concentration inside a few to interactions with stakeholders. Dr. Ramaswamy goes on to describe “social eco-systems” an environment with free flow of information, which engages people better and enable richer, fuller stakeholder interactions than traditional outreach strategies. In this process the development and effective use of engagement platforms is essential. For this project, the use of focus and small group meetings were key engagement platforms supported by electronic and phone conversations with key stakeholders. Those engagement platforms could be turned into a “virtual” PV Community in Puerto Rico.

There were four stakeholder meetings in July 2012. Two small group meetings related were held, one in the Western Puerto Rico (July 12th) and the other in the Eastern side (July 13th). Each meeting was included two parts, one for processes and another for standards. These meetings allowed UPRM to present to key PV stakeholders the work done in these areas to date. Researchers also received important feedback that was integrated in the recommendations. Key suggestions and comments made by stakeholders are included below:

- The need to distinguish optimum from implementable practices
- User perception of government systems
- Should include a mobile application
- Use lessons from "e-government"

- Develop a historic database of PV systems
- Establish a Service Level Agreement: Determine the time it takes to assign a permit application and determine what should be the maximum processing time. Determine time it takes to make a decision on applications (accept or reject)
- The client has no control of his/her case
- There are no consequences or accountability regarding actions or decisions made by government officials regarding PV processes.
- Revise financing process, including improvements to the Green energy fund.
- Changes are needed to PREPA's standards
- Need to model feeder load profiles
- Problems with equipment certifications from OGPE
- Problems related to the use of non-certified PV equipment such as "Do it yourself" and sale of equipment in flea markets and through the internet.

The Financing focus group meetings were held on July 18th at UPRM and July 19th of 2012 at PREAA. Various groups from the Financing sector participated: banks, cooperatives, appraisers and PV professionals. Focus group meetings were not included in the original proposal, they were a means of catching up with the original schedule proposed to DOE. During July 2012 the UPRM team caught up with stakeholder engagement activities as proposed originally to DOE.

On July 17th UPRM met at PREPA in San Juan with their Information Technology Group. UPRM Researchers presented the Rooftop Project, especially the development of the web-based tool. The UPRM team had a very revealing exchange of ideas with PREPA personnel. They made valuable suggestions such as having two layers of identity verification for users of the web-based system and allowing users to evaluate various actors in the PV installation process (PREPA, PREAA, PV installers, etc).

There was one focus group meeting held for financing during August 2012 in Mayagüez. This was the second and final focus group meeting in the Western side of the Island. The team decided not to hold the second San Juan area focus group meeting because the data collected during the second meeting in the West achieved the objectives for financing, and the little interest shown by the financial stakeholders in the San Juan area. Two small group meetings on financing were held during September 2012. These were the final stakeholder meetings for this topic. The Western region meeting was held on September 24th, 2012 in Mayagüez and on September 25th, 2012 in PREAA (San Juan). Two focus group meetings on planning and zoning were held, one on September 18th, 2012 in Mayagüez and another on September 19th, 2012 in PREAA.

In addition to the scheduled meetings, the UPRM team participated in a "Green Energy Business Conference" sponsored by PREAA through the project's City Outreach initiative. The team presented the project's findings to a diverse audience in Mayagüez. This activity entails outreach to a broader audience, and another means of engaging stakeholders.

One focus group meeting on planning and zoning was held during in the Western region on October 31st, 2012 in Mayagüez. Discussion and work on this area was previously presented in the planning and zoning chapter.

Another focus group meeting on planning and zoning was held during in the Eastern region on November 13th, 2012 at PREAA. Detailed discussion and the work on this area was also presented in the planning and zoning chapter. General ideas presented by stakeholders during that meeting included:

1. Importance of optimizing use of rooftops, and develop an ideal layout for PV-friendly rooftops.
2. A roof planning instrument was presented by Dr. Fernando Abruña. Suggestions for use of the instrument included developing a simpler version for potential people interested on PV but not knowledgeable of the field.
3. Printed material should be developed.
4. Recommendations for construction codes should include recommended areas on rooftops for PV installations (concern with potential leaks caused by drilling rooftops to anchor frames for PV panels).
5. Require one blueprint, as part of the ones already required for new construction, which shows an example of how a PV system might be installed in the rooftop. The new owner decides whether to use it or not. During the transition this requirement could be an administrative order from OGPe. From the developers' perspective, this could be a marketing tool (e.g., "PV ready home").
6. A "generic" PV education document could be required as part of the sale of new homes, with recommendations on optimizing rooftop use (A/C units, PV, antennas, water reservoirs, etc).
7. Mr. Gerardo Cosme, PE, presented a draft for "preferred PV zone" guidelines. The document was well-received by the stakeholders. It was suggested that it could be applied to a zone within a city using already available planning tools. This would allow studying the instrument's effectiveness, and correcting any problems. Caguas volunteered as a test case in collaboration with its Planning Department to identify where are the opportunities for PV in that city.
8. Regarding solar rights, a consensus was reached not to pursue new legislation, but rather to take advantage of existing codes and laws. For example, there are vegetation codes, usually within city governments, that provide guidelines on types of trees to plant near structures. This is a "low hanging fruit" since inclusion of guidelines on heights of trees could be recommended for those codes so that trees do not cast shadows in the South of buildings.
9. Solar access related to nearby constructions is a difficult topic, but the project can lay

the foundation for a serious discussion on the topic for Puerto Rico to develop a solar access policy.

10. Try to develop recommendations for PV alternatives for multi-family buildings.

A planning small group meeting originally scheduled for November was moved to January 2013. This allowed time to integrate the on-going work to present to stakeholders, and also gave the team a chance to have a transition to a new leadership at PREAA. A summary was presented in the zoning and planning chapter.

UPRM communicated with PV stakeholders almost on a daily basis through email. Communication was bi-directional, since many times stakeholders begin an email exchange by sharing an article or website relevant to the project's objectives. UPRM kept a website for the project, http://prsolar.ece.uprm.edu which served as a communication channel with stakeholders. The registration for the PV Summits was handled through the website. UPRM researchers also received periodic stakeholder communications at puertoricosolar2012@hotmail.com an email address to better manage emails from stakeholders. The new level of engagement, focus group meetings, enabled the UPRM team to maintain face to face communication and interaction with key stakeholders.

There were various activities for Outreach to general public. One was in Arecibo (Northern part of Puerto Rico), coordinated by PREAA during a Green Energy Business Conference, on November 2nd, 2012. Another activity was in Carolina (Eastern Puerto Rico) on November 13th. This activity marked the first time the ideas of this project were used by one of the PV stakeholders on one of their activities. ACONER (PV installer association) had their annual meeting and used the Summit presentation as the main education activity of the meeting. Another outreach activity was in Mayagüez on November 28th, 2012 coordinated by the Western Chamber of Commerce. These activities were opportunities to showcase the project's results and recommendations.

PV Summits

As per the proposal to DOE, two PV Summits (1 day-long each) were coordinated, convened and held, one in the Eastern half and another in the Western half of Puerto Rico to provide broad participation. These meetings served as a summative evaluation of the project, strengthened the PV Community and were an opportunity to discuss plans for the establishment of best practices. The Summits were held on October 18th (Rincon, Western) and October 30th (Caguas, Eastern). Participation was outstanding, about 140 persons in Rincón, and 151 in Caguas. The UPRM team presented best practices on processes, standards and financing. Initial work on zoning and planning was also presented. These Summits were a collaboration with one of the key stakeholders, the Puerto Rico State Society of Professional Engineers and Land Surveyors, who awarded continuing education credits to all licensed engineers that participated in the Summit. The future of the project was discussed and the formal creation of a PV Community called *Puerto Rico Solar*. The project's recommendations present an important opportunity to expand the rooftop PV market in the

Island. In order to incorporate explicit favorable provisions in state and local codes regarding use of PR's Solar Resource, the recommendations are planned to be moved through the policy process by this PV Community. The multi-sector nature of the community (government, industrial, commercial and residential) would help to envision a new power grid and a new way to design and operate it with higher penetration of rooftop PV systems. During the PV Summits UPRM also conducted an evaluation of the project, the results and comments are presented next.

Evaluation results from PV Summits

A total of 140 persons went to the Rincón PV Summit, and 151 persons attended the Caguas PV Summit. Figures 6.1 and 6.2 show a distribution of the participant background in each Summit. Both Summits were co-sponsored by the State Society of Professional Engineers, which provided continuing education credits for the activity. Thus, a large number of participants were engineers.

UPRM researchers presented project findings and recommendations to participants during the morning. UPRM students prepared posters that gave further information of the project. A discussion session in the afternoon gave participants the opportunity to ask questions and provide suggestions on next steps. Before the end of each Summit participants filled out evaluation forms that asked participants to rate these efforts and the ideas, based on what they learned from the project.

Figure 6.3 shows results on permitting and interconnection processes. A total of 198 participants answered this question (the rest did not answer or left after lunch). An overwhelming majority (87%) evaluated the project as excellent or good in terms of developing a transparent, consistent, and expedient permitting and interconnection process.

Figure 6.4 shows results from 191 responses to the question on net metering and interconnection standards. Most participants (83%) rated the work as excellent or good in terms of dealing with these tasks. Only two responses rated this task as deficient, one comment being "there is still a lot to do". UPRM researchers agree with this statement, and since this is the first ordered and multi-sector effort, more will be done, especially with the formation of the "Puerto Rico Solar" PV Community.

On Financing Options 184 responses resulted in 84% approval of the work and recommendations. There were 5 persons giving the project a deficient rating, based mostly on the experience with the current PV incentives, and the doubts about the financial sector integrating the recommendations. However, there is encouraging news from the cooperative sector: at least on cooperative institution will begin to offer PV-related financial packages. Furthermore, 99% of responses rated the financing ideas as very useful, useful or with potential (see Figure 6.6).

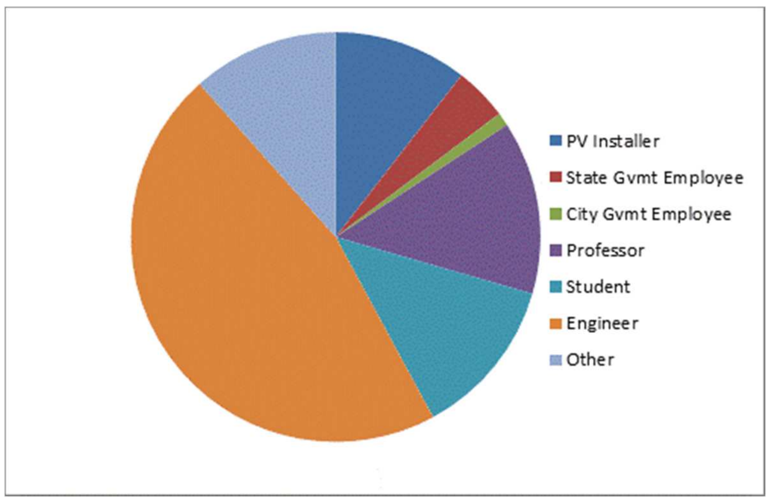


Figure 6.1: Profile of PV Summit Participants (Rincon)

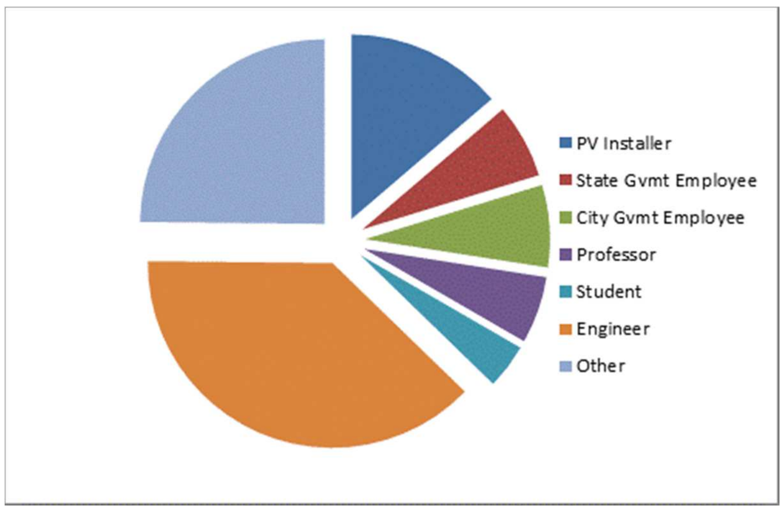


Figure 6.2: Profile of PV Summit Participants (Caguas)

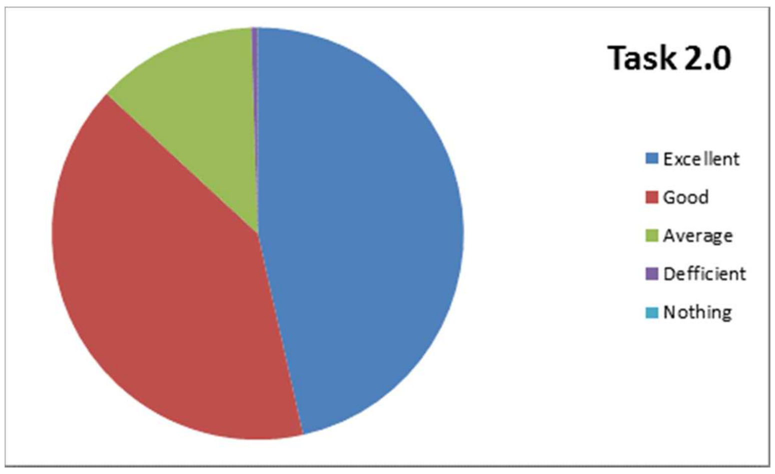


Figure 6.3: Evaluation Results for Permitting and Interconnection Processes

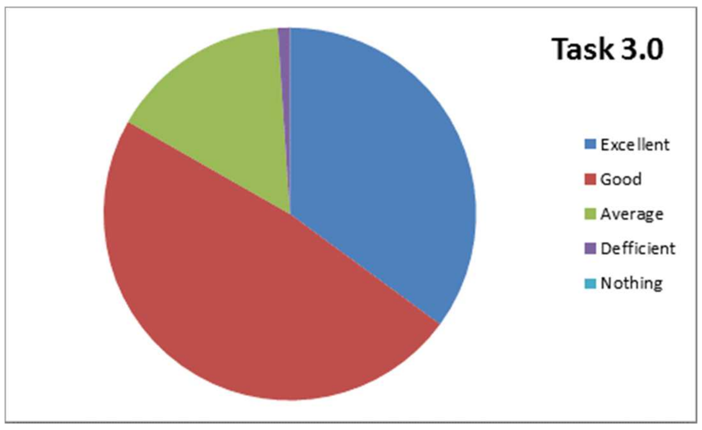


Figure 6.4: Evaluation Results for Net Metering and Interconnection Standards

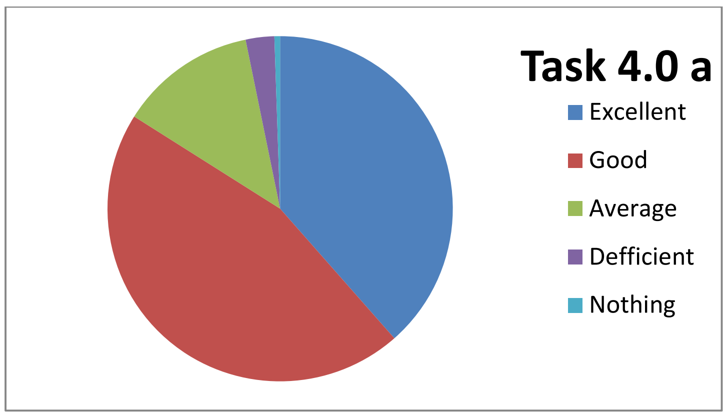


Figure 6.5: Evaluation Results for Financing Options

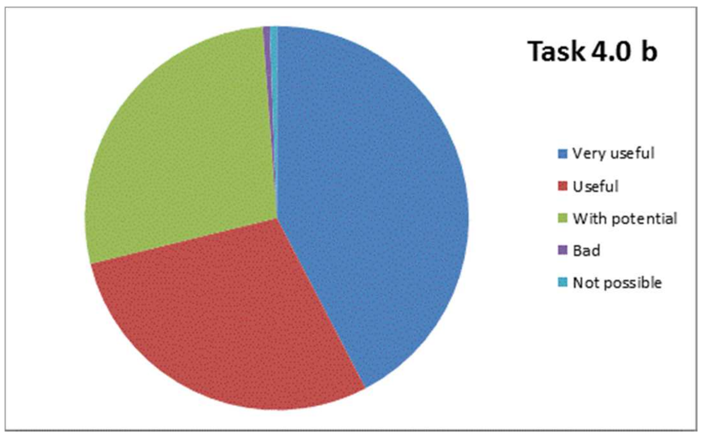


Figure 6.6: Evaluation Results for Feasibility/Practicality of Financing Options

Participants rated with 81% the work on planning and zoning (Figure 6.7). The majority (99%) positively rated the planning and zoning proposals from "very useful" to "with potential" (see Figure 6.8).

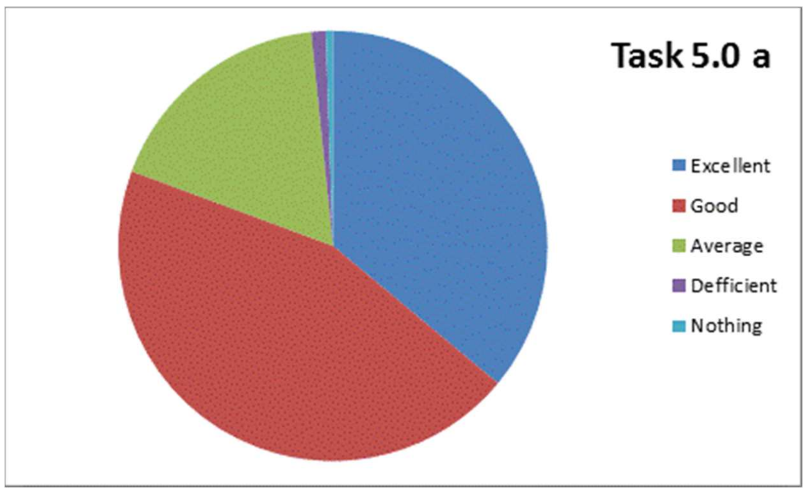


Figure 6.7: Evaluation Results for Planning and Zoning Ideas

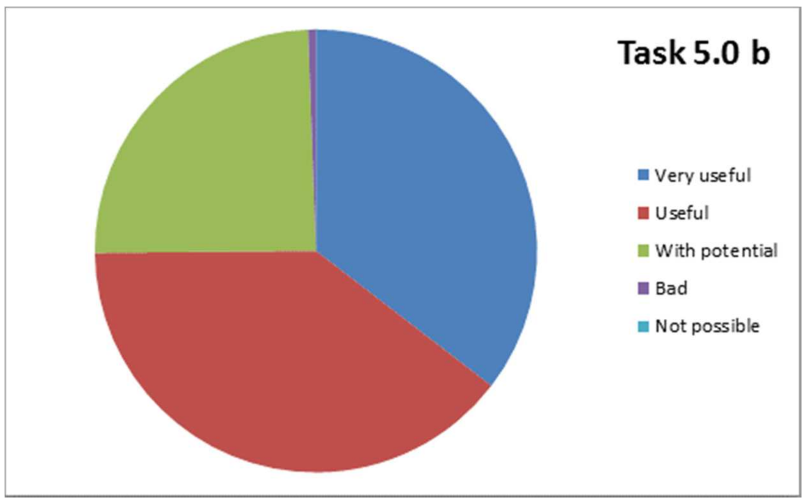


Figure 6.8: Evaluation Results for Feasibility/Practicality of Planning and Zoning Ideas

Participants also rated the focus group and small group meetings convened during the year on each of the four topics. A total of 52 responses were received from persons who had participated in those stakeholder engagement activities. All of the responses stated that the smaller group activities were very useful and helped the project.

Summit participants also gave written recommendations for improving this work. All these ideas were evaluated and integrated with other recommendations from the focus and small group meetings.

A “virtual” PV Community called *Puerto Rico Solar* was initiated during the October Summits. The stakeholder engagement activities initiated in the project will be continued and expanded through regional and island-wide effort. The plan was that *Puerto Rico Solar* would follow the project’s approach of conducting activities in two main foci. Efraín O’Neill (PI of the project, professor at UPR-Mayagüez) and Ernesto Rivera (engineer, president

ACONER-PV installer association) would be coordinators in the Western Region. Fernando Abruña (Architect, retired professor from UPR, energy expert) and José Maeso (engineer, public policy background, Business Development Director PREC) would be coordinators in the Eastern Region. These coordinators would facilitate, not control, the interaction of stakeholders and encourage concrete actions for the implementation of the recommendations. On February 6th, 2013 a final stakeholder meeting was held in Rincón, from 6 to 10pm. About 70 persons attended among them PV industry, students, engineers, professors and the general public. During the meeting the final recommendations of the project were presented.

Conclusions for Chapter 6

The stakeholder activities were a success. Key stakeholders were willing and eager to collaborate; their active participation and help allowed the UPRM team to catch up with the original schedule. UPRM also leveraged on current work on distributed generation within the utility, and the participation in the project meetings of two engineers from the utility. The project's main successes were sent to DOE, and this information was used to develop an "awardee spotlight" feature by NREL (See Appendix E for details). A general brochure was published with key information of the project (Appendix F).

CHAPTER 7

CONCLUDING REMARKS

UPRM researchers completed a final PV Market Assessment and input the data into the US DOE/NREL Solar Metrics Rooftop Solar Challenge Database (See Appendix K). The PV Market Assessment was completed by the last day of the project (February13, 2013) and reflected improvements in local market conditions.

Independent industry verification of these results was sought. This verification was in the form of a letter signed by representatives from at least 2 companies in the residential PV business and at least 2 companies in the commercial PV business representing a significant portion of PV sales in the participating jurisdictions. Although the Puerto Rico project did not achieve the 800-point mark, it is important to keep in mind that the original proposal to DOE was written following a FOA for the Rooftop Solar Challenge program that originally entailed a two-phase approach. The first phase was the development of the recommendations and initial steps for implementation (which represents the project summarized in this book). The second phase in the FOA was where the full implementation of the recommendations would have been carried out. As the second phase was eliminated, the Puerto Rico project's first phase was in disadvantage with regards to the 800-point metrics established by DOE.

Notwithstanding the proposal's original structure, the results from Puerto Rico's rooftop solar challenge project have been received with great enthusiasm by local energy stakeholders. UPRM researchers are confident of the impact of the project in Puerto Rico's rooftop PV market.

An important lesson learned was distinguishing the aspirational nature of best practices vs. the practical implementation considerations in working towards those best practices was. Establishing near term objectives was thus very important for the project. Those near term goals included the clarification of gray areas that exist in various rules and regulations related to rooftop PV processes and standards. MS Sharepoint is currently used at the three main government agencies relevant to rooftop PV systems, and thus was selected as a tool for the on-line proof-of-concept permitting and process tool. Key energy stakeholders were engaged early, which in part allowed us to successfully combine the processes and standards work of the project. Other important lessons learned include the large support that the recommendations had regarding changes to technical interconnection requirements. For example, there is a window of opportunity to drop the external disconnect requirement, at least for residential systems. There is also great interest from cooperative financial institutions in the Western side of Puerto Rico in developing new financial mechanisms for rooftop PV systems. Insurance companies already have good coverage for PV systems to support those financing instruments. One Cooperative Financial Institution began offering a product motivated in great extent by their participation in the project's stakeholder meetings.

On February 13, 2013, the UPRM team completed all technical tasks related to the Puerto Rico Rooftop PV project funded by DOE. UPRM researchers completed all the tasks for the project as described in the modified timeline, even with the leadership change that occurred at the Puerto Rico Energy Affairs Administration. UPRM researchers are confident that the project's recommendations will continue impacting the Rooftop PV Market since the new leadership at the Puerto Rico Energy Affairs Administration (PREAA) is fully committed to this work, as were the previous PREAA's Directors. PREAA's new Executive Director, Jose Maeso, PE was an active participant of the Puerto Rico Project, and co-founder of the "Puerto Rico Solar" PV Community. Furthermore, the project's PI (Dr. O'Neill) included part of the project's recommendations in his work agenda as Senior Advisor to the Governor of Puerto Rico on Energy. That gave continuity to the efforts beyond the project's end. UPRM will collaborate with Mr. Maeso from PREAA in taking all project recommendations and turning them into concrete actions to improve the Rooftop PV Market in Puerto Rico. Some of the follow-up actions that will use the project's recommendations but were beyond the scope of the funded work are:

- Coordinate required changes in PV processes with OGPe and PREPA.
- Update the net metering law.
- Simplify project results and promote its recommendations.
- Submit the project recommendations to the Planning Board, for evaluation and use by the agency.

Appendix A: Tasks completed in the Rooftop Solar Challenge project.

All tasks were completed by the end of the project as originally proposed to DOE. All goals and objectives established for the project were met. Tables A.1 thru A.5 present all the completed tasks for the modified schedule from May 2012 thru February 2013.

Table A.1: Main Milestones for Standards Work for the Project

Area	Task	Time
Standards: Evaluate and improve net metering and interconnection standards by surveying standards and establish best practices	Perform detailed analyses of best practices from NNEC.	May 2012 (*Freeing the Grid* report)
	Study and propose changes to existing standards	June 2012
	Define rational limits to net metering (not based on utility's peak demand) and increase net metering system allowed capacities from 1 MW to 2 MW.	July 2012
	Establish practices to screen applications by degree of complexity and explore plug-and-play rules for residential-scale systems including an expedited procedures for commercial systems. Prohibit requirements for extraneous devices, such as redundant disconnect switches, and do not require additional insurance.	July 2012
	Examine fees in relation to a project's size.	August 2012
	Study and justify a monthly carryover of excess electricity at the utility's full retail rate (unlimited). PREPA's economic model, economic analysis of benefit to PR.	August 2012

Table A.1 (continued): Main Milestones for Standards Work for the Project

Area	Task	Time
Standards: Evaluate and improve net metering and interconnection standards by surveying standards and establish best practices	Review renewable energy credits framework, including explicit protection against unnecessary fees or penalties. Allow customer-sited generators to retain all renewable energy credits for energy they produce. Allow all renewable technologies to net meter. Allow all customer classes to net meter.	September 2012
	Ensure that best practices are transparent, uniform, detailed and public.	October 2012
	Estimate potential impacts on PV market due to each of the proposed actions.	October 2012
	Make available best practices to relevant stakeholders including the PV industry and PV community.	October 2012

Table A.2: Main Milestones in Financing for the Project

Area	Task	Time
Financing: Develop and/or improve financing mechanisms by providing new financing options other than self-financing	Stakeholder meetings. Initial planning of tasks and potential meetings. Identification of key stakeholders.	Focus groups: June to August
	Evaluate third party ownership options, clarify legal status, and examine potential application in Puerto Rico.	July 2012
	Study financing of community solar projects, for example through a cooperative-type of operation.	July 2012
	Pursue new or improved programs and practices with the housing industry so that the installation of a PV system can be accounted in the property value.	August 2012
	Establish preferred PV zones, where massive deployment of small PV systems can occur in vulnerable or financially challenged communities.	August 2012
	Create PV financing information and application tools including corresponding user interfaces. Perform testing and validation of these tools.	August 2012

Table A.2 (continued): Main Milestones in Financing for the Project

Area	Task	Time
Financing: Develop and/or improve financing mechanisms by providing new financing options other than self-financing	Estimate the economic and social impact of each of the selected mechanisms. The economic impact that will be evaluated will include number of new PV systems that could be deployed using these schemes and related energy savings. Social impact will be measured with potential for fossil fuel displacement, access to renewable energy by vulnerable communities.	September 2012
	Make available best practices regarding the selected financing mechanisms.	October 2012

Table A.3: Main Milestones in Planning and Zoning for the Project

Area	Task	Time
Planning and Zoning: Develop and make available best practices regarding planning and zoning standards that would create a favorable environment for PV siting.	Stakeholder meetings. Initial planning of tasks and potential meetings. Identification of key stakeholders.	Focus groups: Sept-Nov. Small group: November (re-scheduled for the end of January)
	Study and present explicit favorable provisions in state and local codes regarding solar rights. Estimate the potential socio-economic impact of best practices.	November – December 2012
	A best practices guide for PV friendly construction will be developed, including a comparison of cost reductions in PV deployment through PV-friendly design and construction. Engage construction professionals, developers and organizations representing these groups.	December 2012 to January 2013

Table A.4: Main Milestones for Web-based System for the Project

Area	Task	Time
Processes: Holistic web-based framework that integrates PV information, permit and interconnection processes	Perform detailed analyses of best permitting and interconnection practices.	May 2012 (Solar ABCS)
	Recruit students	May – June 2012
	Study and propose changes to existing processes	June 2012
	Produce specifications of web-based tools	June 2012
	Create tools and corresponding user interfaces for general information solar PV. Perform testing and validation of these tools. This sub-task includes the overall web system structure and functions.	Mid-June to Mid-July 2012
	Standardized and simplified forms and mechanisms for permitting and interconnection and make available on-line. This will include examples of typical residential and commercial systems.	July-August 2012
	Creation and testing of all the functions related to permitting and interconnection process including a time-tracking mechanism, status report function, on-line applications, among other functions.	July-September 2012

Table A.4 (continued): Main Milestones for Web-based System for the Project

Area	Task	Time
Processes: Holistic web-based framework that integrates PV information, permit and interconnection processes	Estimate time savings related to the capabilities of the integrated system. The time tracking mechanism will allow estimating time savings related to the permitting and interconnection processes. The completed system will also allow estimating potential impact and costing reductions of PV systems due to standardized and simplified forms and mechanisms. Standardize and simplify forms for net metering.	Initial estimates on proof of concept, September 2012. Fine tuning October.
	Implement the completed system at UPRM site. Incorporate the completed system, in collaboration with the PREAA in their computer systems. Integrate the outcomes and improvement from Task 3 (net metering and interconnection) in the web-based system.	First version – late September 2012 at UPRM. Fine tuning in October.
	Continue working on fine-tuning the web-based tools and working on integrating the systems into a government’s computer server.	January 2013

Table A.5: Main Milestones for Stakeholder Engagement for the Project

Area	Task	Time
Stakeholder Engagement: Create best practices with active participations of PV stakeholders	First PV Stakeholder Summit (Two meetings to ensure broad participation)	Eastern side of Puerto Rico (May 2nd), Western side of Puerto Rico (May 8th).
	Processes and standards focus group meeting: Fine-tune the rooftop PV market evaluation. Discuss proposed work on processes and standards.	May 30th at RUM May 31st at PREAA
	Processes and standards focus group meeting: Discuss progress, get feedback.	June 19th at PREAA June 20th at UPRM
	Small group meeting on standards and processes	July 12th at UPRM July 13th at PREAA
	Financing: Focus group meetings	July 18th UPRM July 19th PREAA
	Financing: Focus group meetings	August 28th, 2012, Mayagüez
	Financing: Small group meeting	September 24th (Mayagüez), September 25th (San Juan).

Table A.5 (continued): Main Milestones for Stakeholder Engagement for the Project

Area	Task	Time
Stakeholder Engagement: Create best practices with active participations of PV stakeholders	Zoning and planning: Focus group meetings Second PV Stakeholder Summit: Present best practices; discuss future of the PV Community, summative evaluation.	September 18th (Mayagüez) September 19th (San Juan) October 18, Rincon (Western side of Puerto Rico), and October 30 (Eastern side of Puerto Rico).
	Zoning and planning: Focus group meetings	October 31st (Mayagüez)
	Focus groups: Sept-Nov.	November 13th, 2012. Focus group meeting at PREAA on planning and zoning.
	Outreach to general public	November 2nd, Arecibo
	Outreach to general public	November 28th, Mayagüez
	Small group meeting on planning and zoning: November	Re-scheduled January 24th (Mayagüez) and January 31st (PREAA)
	Final large group meeting (first Puerto Rico Solar meeting)	Rincon (Western side of Puerto Rico), Feb. 6th, 2013.

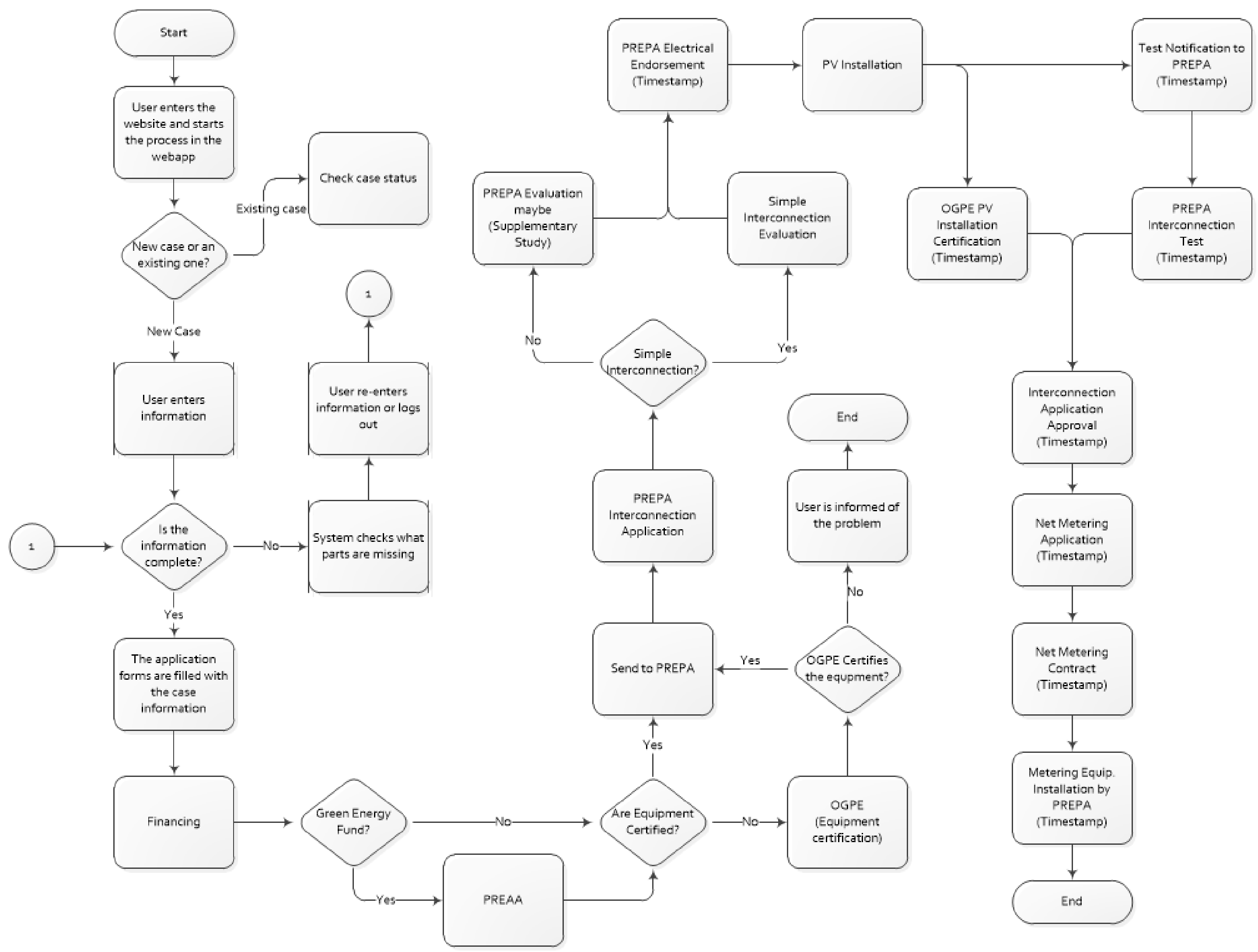
Appendix B: Comparison of Net Metering Practices in Puerto Rico, Hawaii, and Delaware

	Puerto Rico	Hawaii	Delaware
	B (_,B)	B (C,B)	A (B,A)
Eligible Renewable/ Other Technologies:	Photovoltaic, Wind, “Other Sources” of Renewable Energy	Photovoltaic, Wind, Biomass, Hydroelectric, Small Hydroelectric	Photovoltaic, Wind, Biomass, Hydroelectric, Anaerobic Digestion, Small Hydroelectric, Fuel Cells
Applicable Sectors:	Commercial, Industrial, Residential, Nonprofit, Schools, Multi-Family Residential, Agricultural, Institutional	Commercial, Residential, Local Government, State Government, Fed, Government	Commercial, Industrial, Residential, Nonprofit, Schools, Local government, State Government, Fed. Government, Agricultural, Institutional
Applicable Utilities:	PREPA	All utilities	All utilities
System Capacity Limit:	1 MW for non-residential; 25 kW for residential	100 kW for HECO, MECO, HELCO customers; 50 kW for KIUC customers	DP&L: 2 MW for non-residential DP&L customers; 500 kW non-residential DEC and municipal utility customers; 25 kW for all residential customers; 100 kW for all farm customers on residential rates
Aggregate Capacity Limit:	No limit specified	3% of utility’s peak demand for HELCO and MECO; 1% of utility’s peak demand for KIUC and HECO	5% of peak demand (utilities may increase limit)
Net Excess Generation:	Credited to customer’s next bill at utility’s retail rate (with certain limitations); excess reconciled at end of 12-month billing cycle	Credited to customer’s next bill at retail rate; granted to utility at end of 12-month billing cycle	Credited to customer’s next bill at retail rate; indefinite rollover permitted but customer may request payment at the energy supply rate at the end of an annualized period.
REC Ownership:	Not addressed	Not addressed	Customer retains ownership of RECs associated with electricity produced and consumed by the customer
Meter Aggregation:	Not addressed	Not addressed	Not addressed
Recommendations:	» Remove system size limitations to allow customers to meet all on-site energy needs. » Allow customers to retain all RECs associated with generation.	» Remove system size limitations to allow customers to meet all on-site energy needs » Increase capacity to at least 5% of a utility’s peak	» Allow net metering for third parties using the PPA model

Appendix C: Comparison of Interconnection Practices in Puerto Rico, Hawaii, and Delaware

	Puerto Rico	Hawaii	Delaware (Previous evaluations)
	F(_,F)	F(F,F)	A (D,F)
Eligible Renewable/Other Technologies:	Photovoltaic, Wind, "Other Sources" of Renewable Energy	Solar Thermal Electric, PV, Landfill Gas, Wind, Biomass, Hydro, Geothermal, Fell Cells, CHP/Cogen, Micro-turbines, Other DGs	Solar Thermal Electric, PV, Wind, Biomass, Hydroelectric, Anaerobic Digestion, Fuel Cells, Other DGs
Applicable Sectors:	Commercial, industrial, Residential, Nonprofit, Schools, Multi-Family Residential, Agricultural, Institutional	Commercial, Industrial, Residential, Nonprofit, School, State Government, Fed, Government	Commercial, Industrial, Residential, Nonprofit, Schools, Local Government, State Government, Fed, Government, Agricultural, Institutional
Applicable Utilities:	PREPA	Investor-owned utilities	All Utilities (only Delmarva Power is subject to commission rules)
System Capacity Limit:	No Limit specified	No limit specified	10 MW (2MW)
Standard Agreement:	Yes	Yes	Yes
Insurance Requirements:	Vary by system size and/or type; levels established by PREPA	Amount not specified	"Additional" liability insurance not required for systems that meet certain technical standards
External Disconnect Switch:	Required	Required	Required for systems larger than 25 kW
Net Metering Required:	No	No	No (Yes)
Recommendations:	» The territory should adopt IREC's model interconnection procedures.	»Remove requirements for redundant external disconnect switch »Prohibit requirements for additional insurance	»None (» Remove requirements for redundant external disconnect switch for larger systems » Expand interconnection to cover all utilities (i.e., munis and co-ops) » Further delineate tiers to accommodate different levels of complexity among system types and sizes)

AppendixD: Workflow for On-line System



Appendix E

NREL's Awardee Spotlight

Rooftop Solar Challenge Successes–Puerto Rico

Puerto Rico's Stakeholders Participate in the Rooftop Solar Challenge

For better communication with all the residents of the island territory, the leaders of Puerto Rico's Rooftop Solar Challenge (RSC) created a photovoltaic (PV) community managed through a Western section and an Eastern section. That way, more Puerto Ricans could take an active part in exploring ways to reduce barriers, and lower costs for residential and small commercial rooftop solar systems.

RSC organizers recognized that stakeholder engagement is a major component of the Challenge in Puerto Rico. As such, they reached out to the community at various levels, from focus groups with a dozen or more people, to larger PV summits drawing more than 100 persons apiece. Three major summits were held in Rincon (October and February) and Caguas (October), plus two Green Energy Business Conferences entitled "The Solar Challenge", were held in Arecibo (November) and Mayagüez (September), to introduce the challenge to large audiences representing industry, related professions, and the community. These large meetings were so successful that organizers now believe that even more of these conferences would be very beneficial.

The results of these engagements are already being seen through follow-up activities. The project has positively influenced the revision of interconnection requirements and overall permitting for rooftop PV projects. For example, and partially in response to the RSC project outreach, the local utility company expanded capacity of net-metered systems to 5 megawatts. Further, efforts to develop companies and partnerships to implement third-party ownership of PV systems have started.

The ripple effect is happening in financing, too. An improved PV financing mechanism is being designed by a number of cooperatives in Western Puerto Rico. For example, one cooperative expects to begin offering its financing product in March 2013, and its executives acknowledge participation in our focus and small group meetings were essential in developing the product.

Also, because of the RSC efforts new ideas are taking root on the island. The City of Caguas volunteered for a pilot project in which the "Preferred PV zones" suggested in the Puerto Rican project would be merged with the city's geographic information system (GIS) planning tool to identify rooftop PV opportunities in the historic downtown area to support economic development in the area. This could have an especially big impact among small businesses.

The solar-related awareness spreading over the territory won't stop there. Organizers believe that most of the strategies are replicable elsewhere. They used many references and adapted those to the Puerto Rican context. However the general guidelines behind the recommendations are easily exportable. The project's final report will present the project's results and recommendations. This document will have all the information and background needed to understand why the Puerto Rican group pursued specific paths, and will help readers determine if the experience is similar and helpful for their context.

Learn more about this project at the http://prsolar.ece.uprm.edu/

This project is funded by the Rooftop Solar Challenge program under the U.S. Department of Energy SunShot Initiative.

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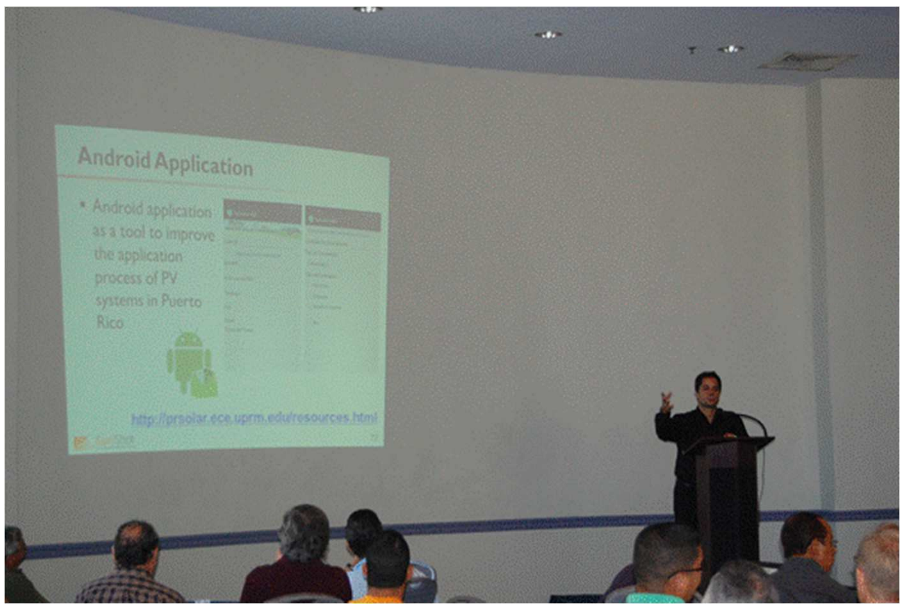

Appendix F

Project Educational Brochure for Dissemination and General Outreach (Spanish)

Appendix G: Single-Homeowner Residential PV System Simulation Assumptions and Results (Author: Armando L. Figueroa-Acevedo)

General Assumptions

Site: Mayagüez, PR

PV System Capacity: 4 kW

Monthly Electricity Consumption: Approximately 600 kWh

Electricity Cost: $0.27/kWh

Extra Energy Rate: $.07/kWh

Total System Cost (Without Incentives): $16,000 ($4/W)

Personal Loan:

- Amount: $14,000
- Down Payment: $2,000
- Interest: $5.25
- Period: $15 years

Results

1. Comparison between the monthly electricity demand and PV system output

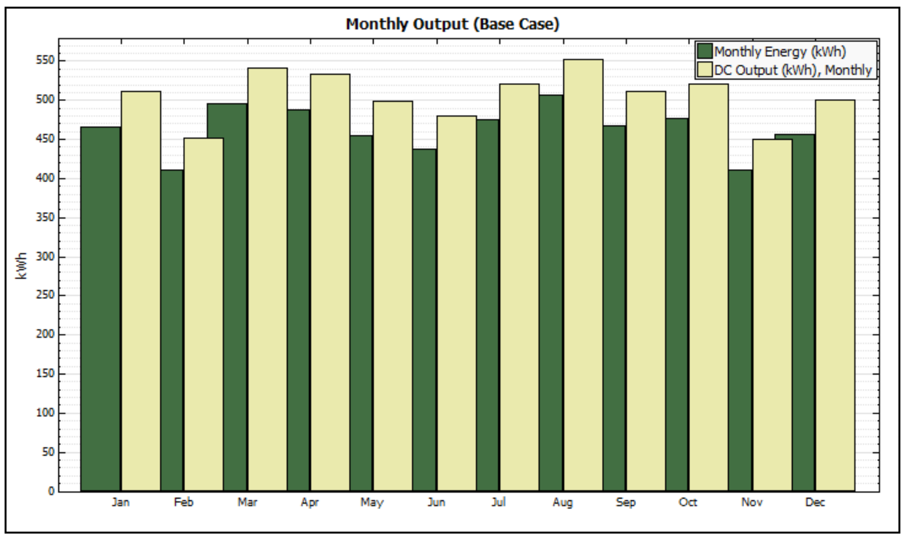

Figure G.1: Monthly Electricity Demand and PV System Generation

2. After tax cash flow

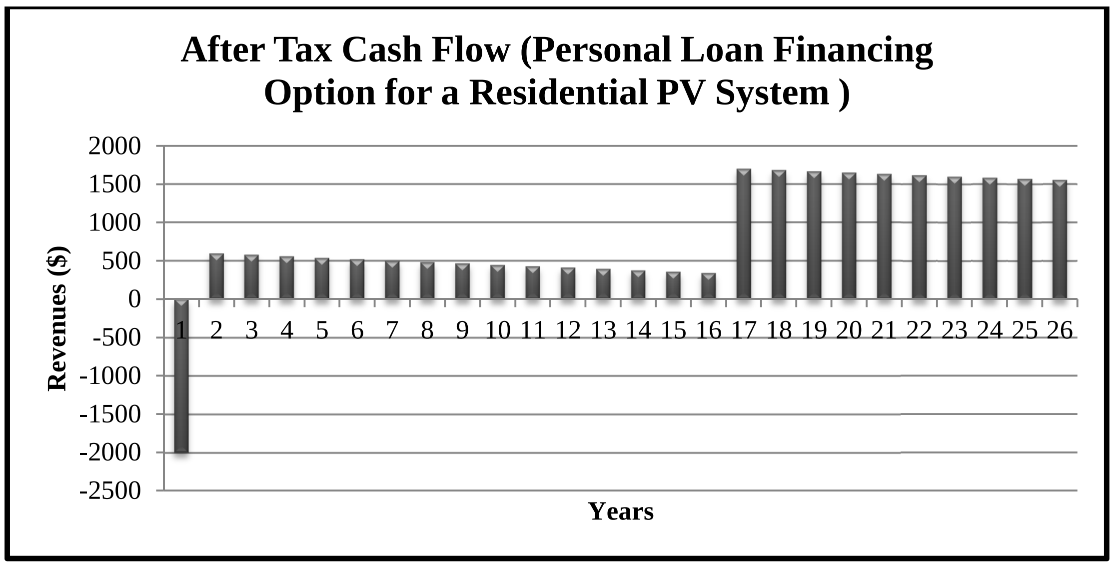

Figure G.2: After Tax Cash Flow (Personal Loan/Single Homeowner)

3. Payback Period

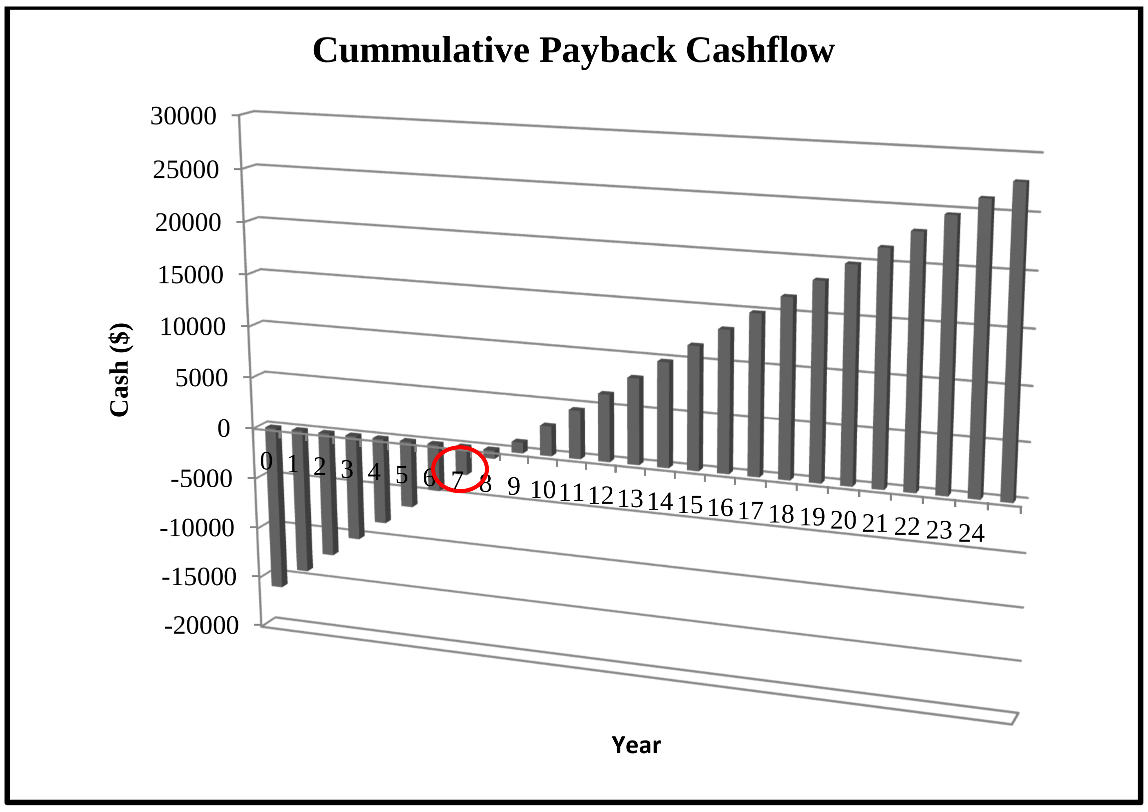

Figure G.3: Payback Period (Personal Loan/Single Homeowner)

Appendix H: Solar Community Residential PV System PV System Simulation Assumptions and Results (Author: Armando L. Figueroa-Acevedo)

General Assumptions

Site: Mayagüez, PR

PV System Capacity: 4 kW/Homeowner (40kW total)

Monthly Electricity Consumption: Approximately 600 kWh/Homeowner (7,200 kWh total)

Electricity Cost: $0.27/kWh

Extra Energy Rate: $.07/kWh

Total System Cost (Without Incentives): $120,000 ($3/W)

Personal Loan:

- Amount: $100,000
- Down Payment: $20,000
- Interest: $5.25
- Period: $15 years

Results

1. Comparison between the monthly electricity demand and PV system output

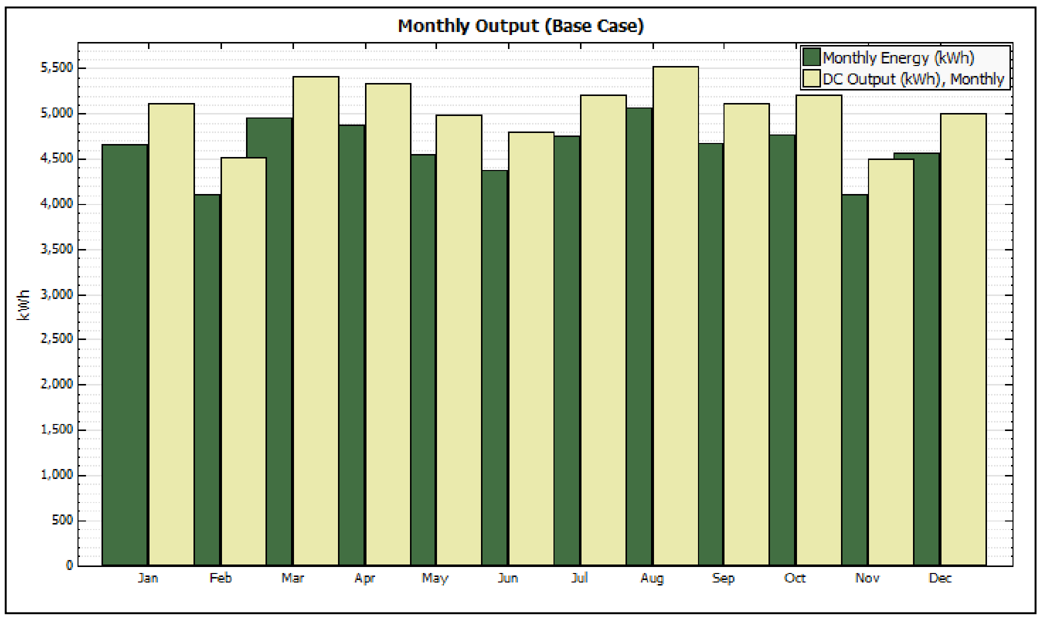

Figure H.1: Electricity Demand and PV System Energy Generation

2. After tax cash flow

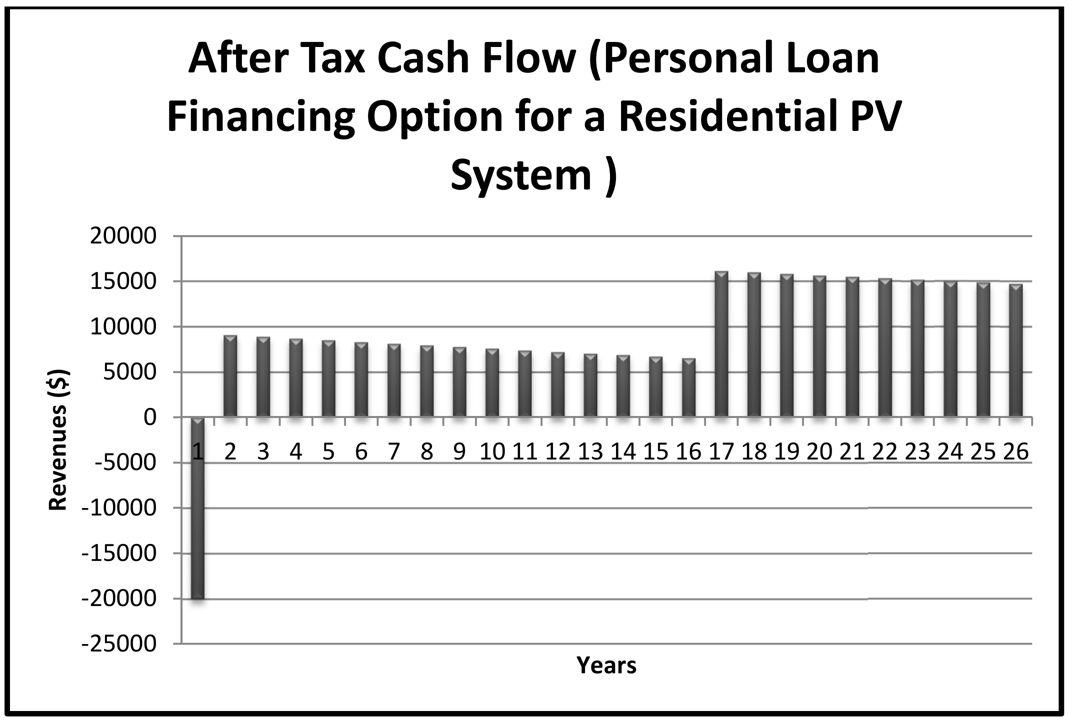

Figure H.2: After Tax Cash Flow (Personal Loan/Solar Community)

4. Payback Period

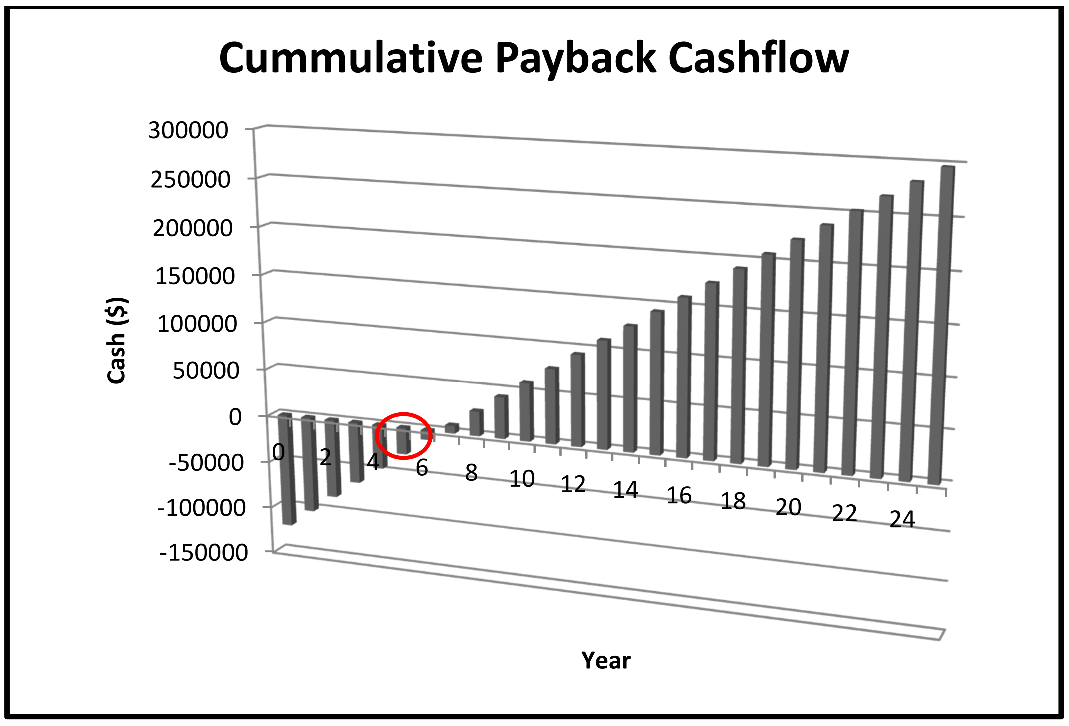

Figure H.3: Figure 3: Payback Period (Personal Loan/Solar Community)

Appendix I

Financial Educational Module

Financing Considerations for Rooftop PV in Puerto Rico

University of Puerto Rico-Mayaguez (ECE Department)

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1

Contents

- Financing Models for Residential & Commercial Solar PV Systems
- Exploring the Perceived Risks Associated with Solar PV Systems
- Modeling Financing Structures

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2

Solar PV Facts

- "The high upfront cost of residential and commercial PV systems are mostly due to non-technical factors" –NREL
- The break-even price (PV_{Rate}=$Utility_{Rate}$) of residential PV varies by more than a factor of 10 in the United States, mostly due by the differences in incentives and financing structures

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3

Traditional Financing Mechanisms

- Traditionally, residential and commercial photovoltaic systems have been financed through personal loans, home equity loans, mortgages and cash payments in combination with federal and state incentives
- By 2010, the total cost of a residential and commercial PV system in the United States was about $5.71/Wp and $4.59/Wp, respectively
- For example, a typical residential PV system with an installed capacity of 4 kW could have an upfront cost of approximately $22,840, without considering any incentives.

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Modern Financing Mechanisms

- Third party
  - The client is relieved from the high upfront and maintenance responsibilities. In this case, a third party owns the system and charges the customer a monthly fee, which is usually less than the payment of electricity bill.
- PPA
  - A price is negotiated based on solar power generated and the customer to the electric company sells solar photovoltaic system.

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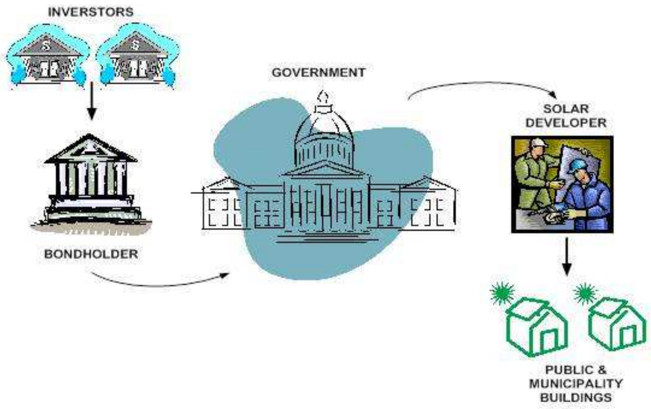
Hybrid Financing Model

- *"The hybrid (Morris) model is a financing option by which a public entity issues a government bond at a* ***low interest rate*** *and transfers that low-cost capital to a developer in exchange for a* ***lower*** *PPA price."*



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Financing Mechanisms Recap

Financing Option	Cash	Home Equity Loan	Other Loan	Leasing	PPA
Upfront Cost	High	Low	Low	Low	Low
System's Owner	Homeowner	Homeowner	Homeowner	Homeowner	Homeowner
Ongoing payments	None	Yes	Yes	Yes	Yes
System's maintenance	Homeowner	Homeowner	Homeowner	Solar Cooperative	Solar Cooperative
Federal Credit	Yes	Yes	Yes	No	No
Tax deductions	N/A	Interest on loan	No	N/A	N/A
Term	N/A	5-30 years	Up to 20 years	Up to 20 years	10-20 years

Table: Financing Options (Summary); Adapted from [1]

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PV Systems Perceived Risks

- Perceived: The lack of information regarding,
  - the solar PV market
  - the insurance related issues
  - the equipment's life expectancy time
  - The PV system's ability to uphold strong weather conditions

Real Risk	Description
Grid Integration	Operational risks: blackouts, balance of electricity supply, etc.
Project Management & Development	PV project's development risks such as price variability, design/permit bureaucracy, etc.
Hardware	Reliability of PV system's components
Environmental	Weather, catastrophic events, opposition, etc.
Government	Changes in government's public policy

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Insurance Considerations

- NREL identified four insurance products necessary for small scale PV systems

Insurance Product	Description
General Liability	Covers policyholders for death or injury to persons or damage to property owned by third parties.
Property Risk	Covers damage to or loss of policyholder's property. Also, it can indemnify homeowners of natural catastrophic events.
Environmental Risk	Coverage indemnifies system owners of the risk of either environmental damage done by their development or pre-existing damage on the development site.
Business Interruption	Lost sales as a result of the system not being operational and loss of production-based incentives also resulting from the lack of electricity production

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Modeling Financing Mechanisms

- The two most popular financing structures for residential PV systems are the personal loan and third party leasing
  - 4 kW Single Homeowner Residential PV System
  - 40 kW Solar Community PV System

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Financing Modeling: Results

Financing Metric	Residential and Commercial PV System's Financing Structures			
	Residential		Solar Community (Per Homeowner)	
	Personal Loan	*Third Party Lease**	*Personal Loan*	*Third Party Lease**
Payback Period	8	N/A (Down Payment=0)	6	N/A (Down Payment=0)
Approximate Monthly Electric Bill	$165	$3**	$165	$3**
Approximate Monthly Loan Payment	$114	$132	$82	$132
Approximate Monthly Savings (During Loan)	$51	$33	$83	$33
Approximate Monthly Savings (After Loan)	$165	$33	$165	$33

* Third party Leasing includes a yearly insurance fee of .5% of the total installed PV system cost
** Fixed residential customers fee in Puerto Rico

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Appendix J

Paper presentations evaluated during the *IEEE International Symposium on Sustainable Systems and Technology*

Participation in the *IEEE International Symposium on Sustainable Systems and Technology* (ISSST) Conference in Boston (2012) was a key activity in the project. This was an excellent opportunity to engage with professionals from all over the world in areas such as stakeholder engagement, PV systems, interconnection issues and financing issues, all related to the project. Dr. Efraín O'Neill was able to disseminate part of the project's initial work and get valuable feedback from sustainability experts. Below a description of some of the sessions and a summary of relevant topics for the project.

The following papers below address interconnection and sustainability issues. It is of utmost importance the understanding of customer requirements (demand profile, power quality) in order to achieve both effective and efficient energy strategies. In the rooftop solar challenge project these facts were included in the discussions with stakeholders, especially with the utility and the PV installers.

Domestic Load Characterization for Demand-Responsive Energy Management Systems	Ana Soares, Alvaro Gomes and Carlos Henggeler Antunes
Power Quality Monitoring in Sustainable Energy System	Shahedul Haque Laskar And Sanaullah Khan
'Environmentally conscious design of autonomous power supplies for distributed micro-systems'	Stephan Benecke, Jana Rueckschloss, Andreas Middendorf, Nils F. Nissen and Klaus-D. Lang
The water footprint of thermal power production: closing methodological gaps of regionalization and heat emissions	Stephan Pfister, Sangwon Suh, Ramkumar Karuppiah, Ian Laurenzi and Alessandro Faldi

The papers below present environmental aspects related to PV systems. An area not usually discussed is the recycling of PV panels. In Puerto Rico a serious discussion shall begin on this topic, in order to be prepared in the coming decades for the large numbers of used panels. The papers also present important economic tools to justify an increased use of PV systems. These ideas were also considered in the socio-economic analysis of the project.

Strengthening the Case for Recycling Photovoltaics: An Energy Payback Analysis	Michele Goe and Gabrielle Gaustad
Comparative Hazard Assessment of Emerging Photovoltaic Processing Methods	Daniel Eisenberg, Mengjing Yu, Carl Lam, Oladele Ogunseitan and Julie Schoenung
Recycling Potential of Photovoltaics Modules	Annick Anctil and Vasilis Fthenakis
Impact of PV Growth on CO2 emission in the world	Kotaro Kawajiri, Stanley Gershwin, Tonio Buonassisi and Timothy Gutowski
A Cost Benefit Trend Analysis of Solar Photovoltaic Supply for Greenhouse Gas Emission Mitigation of Global Automotive Manufacturing	Qiang Zhai, Xiang Zhao and Chris Yuan

The following papers provide further financing and economic tools. Of special importance to the project are life cycle analysis (LCA) and the calculation of footprint. These tools are vital for Puerto Rico because they represent strong justifications for the use of PV systems in an island with limited land.

Estimating Impacts & Benefits of Dense Energy Sensing	Derrick Carlson, H. Scott Matthews and Mario Bergés
Bounding scenario analysis: a case study of future energy demand of China’s steel sector	Eric Williams, Ramzy Kahhat and Shinji Kaneko
Beyond life cycle analysis: Using an agent-based approach to model the emerging bio-energy industry	Andrew Heairet, Sonika Choudhary, Shelie Miller and Ming Xu
Assessing the Sustainability of Renewable Energy	Reggie Caudill, Joseph Wright and

Technologies	Jaime Bustamante
Environmental Footprint Analysis of On-shore and Off-shore Wind Energy Technologies	Mehdi Noori, Murat Kucukvar and Omer Tatari

The Puerto Rico project was deeply rooted in Stakeholder Engagement. That is why it was so important to keep abreast of current issues and best practices in stakeholder communications and issues. The papers below give various perspectives that were applied to the project. Some of the papers deal with special social or environmental issues and how those affected reacted or dealt with such situations. Relating the PV project to current environmental and social issues is an important way to keep many sectors (e.g., communities, environmental NGOs) interested in the rooftop solar challenge project. Another important aspect discussed in this paper is the assessment of the effectiveness of strategies. Such assessment depends on maintaining strong communications with stakeholders. An interesting idea from the NGO "Green Alliance" is to develop a report card that can be filled out by stakeholders on various aspects of a project.

Can nanotechnology decontaminate water in a morally contested context?	Rider Foley, Arnim Wiek, Braden Kay and Richard Rushforth
Unexpected Outcome by Consumer's Behavior	Kotaro Kawajiri, Tomohiro Tabata and Tomohiko Ihara
Assessing Social Impacts: The Good, the Bad and the Ugly	Lise Laurin and Melissa Hamilton
Cultured Meat: The Systemic Implications of an Emerging Technology	Carolyn Mattick
Durban: Geoengineering as a Response to Cultural Lock-In	Brad Allenby
Resilience of Urban Water Systems	Arka Pandit and John C Crittenden
Infrastructure Ecology: An Integrative Approach towards More Sustainable Urban Systems	Arka Pandit, John C. Crittenden, Hyunju Jeong, Zhongming Lu, Elizabeth A. Minne, Jean-Ann C. James, Ming Xu, Steven P. French, Sangwoo M. Sung, Douglas Noonan, Marilyn Brown, Reginald DesRoches, Bert Bras, Miroslav Begovic, Lin-Han Chiang Hseih and Insu Kim

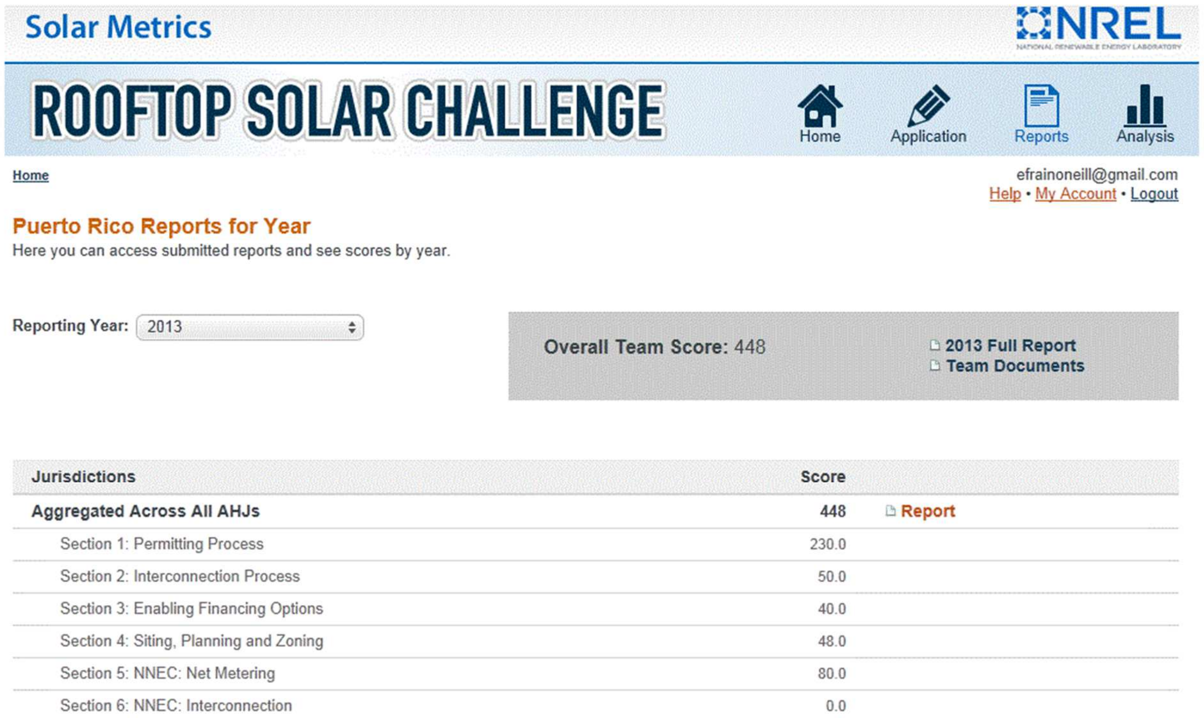
Performance of Green Infrastructure for Urban Water Management	Mallory Squier, Pavle Bujanovic, Carli Flynn, Jeremy Tamargo and Cliff Davidson
ICT Congestion Management Strategy to Promote Urban Environmental Sustainability	Yeganeh Mashayekh, Chris Hendrickson and Scott Matthews
LEED Certified Residential Brownfield Buildings to Promote Transportation Sustainability	Yeganeh Mashayekh, Chris Hendrickson and Scott Matthews
Life Cycle Dialog—what can better communication up and down the supply chain achieve for a more sustainable future? (PANEL)	Lise Laurin, Susan Landry, Ray Dawson, John Malian and Bill Flanagan

Finally, the following papers present dissemination and education experiences in sustainability. The strategies presented are important in the design of effective stakeholder engagement activities. For example, the idea of “systems thinking” is akin to “integrated planning” mentioned for utilities or the “holistic framework” proposed in the project.

Sustainable Wellbeing Education in Engineering	Marcel Castro-Sitiriche, Christopher Papadopoulos, Héctor Huyke and William Frey
A Model Transdisciplinary Design for Environment Curriculum: Blending Perspectives from Industrial and Engineering Design	Callie Babbitt, Ana Maria Leal and Alex Lobos
Engineering the Engineer: The Failure of Engineering Education and What To Do About	Braden Allenby and Thomas P. Seager
Systems Thinking for sustainability: Envisioning Trans-disciplinary Transformations in STEM Education	Fazleena Badurdeen, Robert Gregory, Gregory Luhan, Margaret Schroeder, Leslie Vincent and Dusan Sekulic
Sustainable Green Engineering System Design and Quality Educational Challenges, and Solutions	Paul Ranky and Yijun Zheng

Appendix K

PV Market Assessment



Solar Metrics

NREL

ROOFTOP SOLAR CHALLENGE

Home Application Reports Analysis

Home

efrainoneill@gmail.com

Help • My Account • Logout

Puerto Rico Reports for Year

Here you can access submitted reports and see scores by year.

Reporting Year: 2013

Overall Team Score: 448

2013 Full Report

Team Documents

Jurisdictions	Score	
Aggregated Across All AHJs	448	Report
Section 1: Permitting Process	230.0	
Section 2: Interconnection Process	50.0	
Section 3: Enabling Financing Options	40.0	
Section 4: Siting, Planning and Zoning	48.0	
Section 5: NNEC: Net Metering	80.0	
Section 6: NNEC: Interconnection	0.0	

Appendix L

Proof-of-concept software to expedite PV application processes

The UPRM team completed a proof-of-concept, integrated on-line system to ease and streamline PV permitting and interconnection processes. Figure L.1 shows the interface that a PV installer would use to enter the system. The actual client has to authorize the installer to enter the required personal information. If a client authorizes a third party this way, the client will be given access to his case to check on the status of the applications. Initial screens were created on MS Access, but later transferred to Sharepoint.

Figure L.1: PV Installer Login Window

There is an option for a user to begin a new case or enter into an existing case. For example, a user might be entering data for a new case, save it and return to finish it later. A user might also enter an existing case to check on the status of the applications. One of the main advantages of the proposed system is the capability it would give to maintain a record of all rooftop PV systems in Puerto Rico. Currently such database exists only at PREPA, but not with the detail this project's database would offer. Figure L.2 shows how the database might look. Another benefit of this effort is that for the first time, a holistic approach is taken to study and propose changes to rooftop PV processes in Puerto Rico. For example, the workflow did not exist before this project. The integrated system was based on SharePoint, as well as the PREAA functions.

SharePoint: Integrated System

A SharePoint site was created to allow users to enter the information needed to fill the various forms. The SharePoint programs are only installed in the server. Once the users get access, they only need internet service and a web browser to use the site and enter their information. Users only need Adobe PDF and MS Word to read documents. In the server the Operating System used was Windows Server 2008 R2. There are some pre-requisite steps that need to be followed but only in the server and by the persons in charge of the system (not the users). Once the SharePoint Server was installed, a Publishing Site was created. SharePoint is used in many companies as an Intranet, but in this case the site needs to be public so that it can be accessed from anywhere. The site is password protected. When anyone tries to enter the site, it asks for a username and a password. After the user enters the required data, the system checks for completeness, fill and submit all needed documents and applications. Figure L.3 shows the input screen for a new case. There is a screen for login for each of the user-agencies. Each relevant agency (PREAA, OGPe, PREPA) would have accounts that would allow them to work their part of the process.

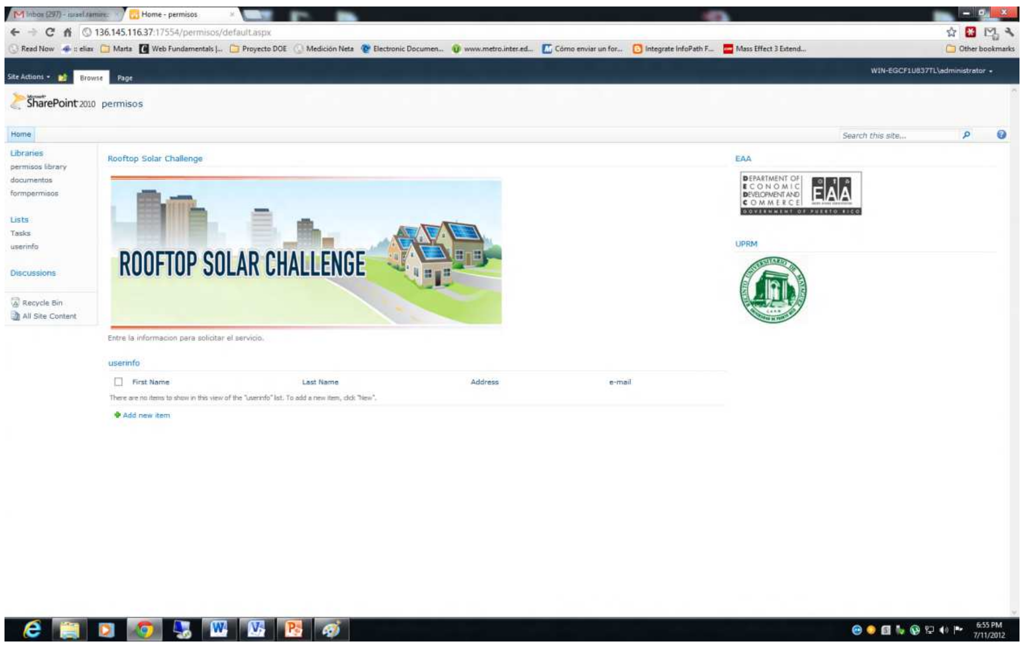


Figure L.2: Database of PV Cases

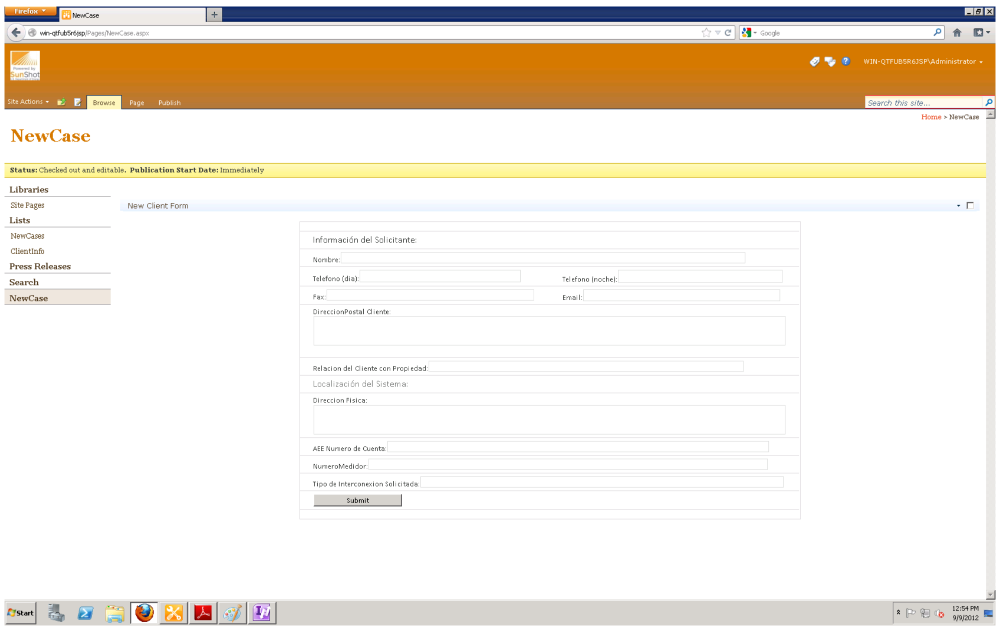


Figure L.3: Example of a SharePoint Data Entry Screen

Once information is entered, it is checked for completeness and used to fill out the PREPA forms. Standardized mechanisms and forms for permitting and interconnection were developed. This includes the creation and testing of all the functions related to permitting and interconnection process. During July 2012 emphasis was given to the development of on-line applications for PREPA procedures.

The main parts of the integrated web-based framework were completed in SharePoint. A timestamp is used to mark the end of the user input phase. This serves as the initial step in time-tracking of the PV permitting processes, a tool that currently does not exist in Puerto Rico.

The system checks for completeness of the information entered. An email is sent to PREPA informing of a new case for revision. The user from PREPA will receive the email, will be able to enter to the site and see the information (form/permits filled) and decide if approval is given, or more information is needed. Part of that process within SharePoint is shown in Figure L.4.

If PREPA approves the case, another time-stamp will save the date it was approved. The client will receive an email with the decision. Negative decisions are also sent to the client. Standardized PREPA forms are available electronically.

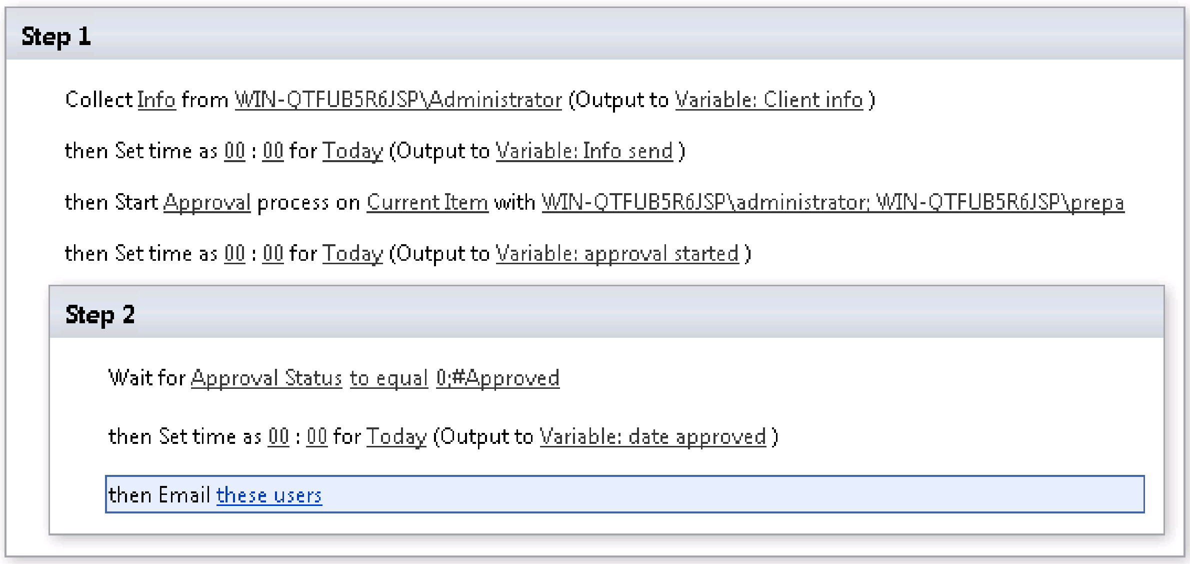


Figure L.4: SharePoint functions related to PREPA revision of a case

The timestamp instruction was revised to make sure it would work for all steps that need to be tracked (see Figure L.5). Once the information is submitted, the approval process begins. The Approver, in this case PREPA receives an email. The client also gets an email indicating that the information was received).

As the case goes through the various phases of the process, the user receives status reports via email. The Approver can write a comment and Approve, Reject or Reassign Task. If PREPA approves, the status is updated. If the Reassign function is used, the evaluator creates a request (for example, ask for a corrected document).

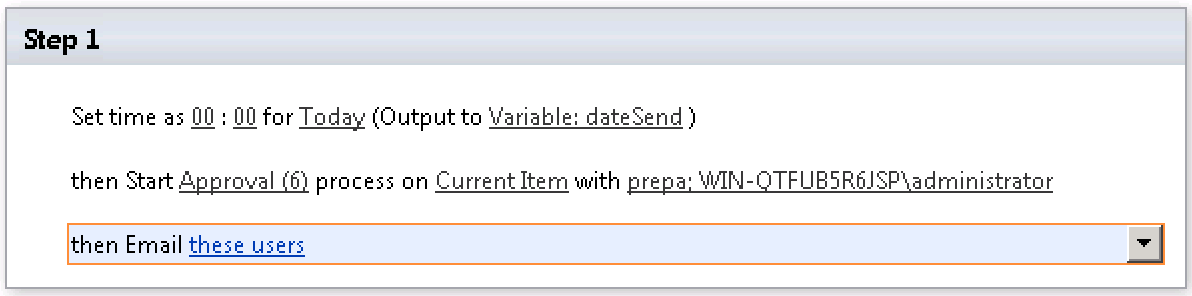


Figure L.5: Timestamp Instruction

When the interconnection is finally approved, the client receives the interconnection contract for it to be digitally signed (see Figure L.6).

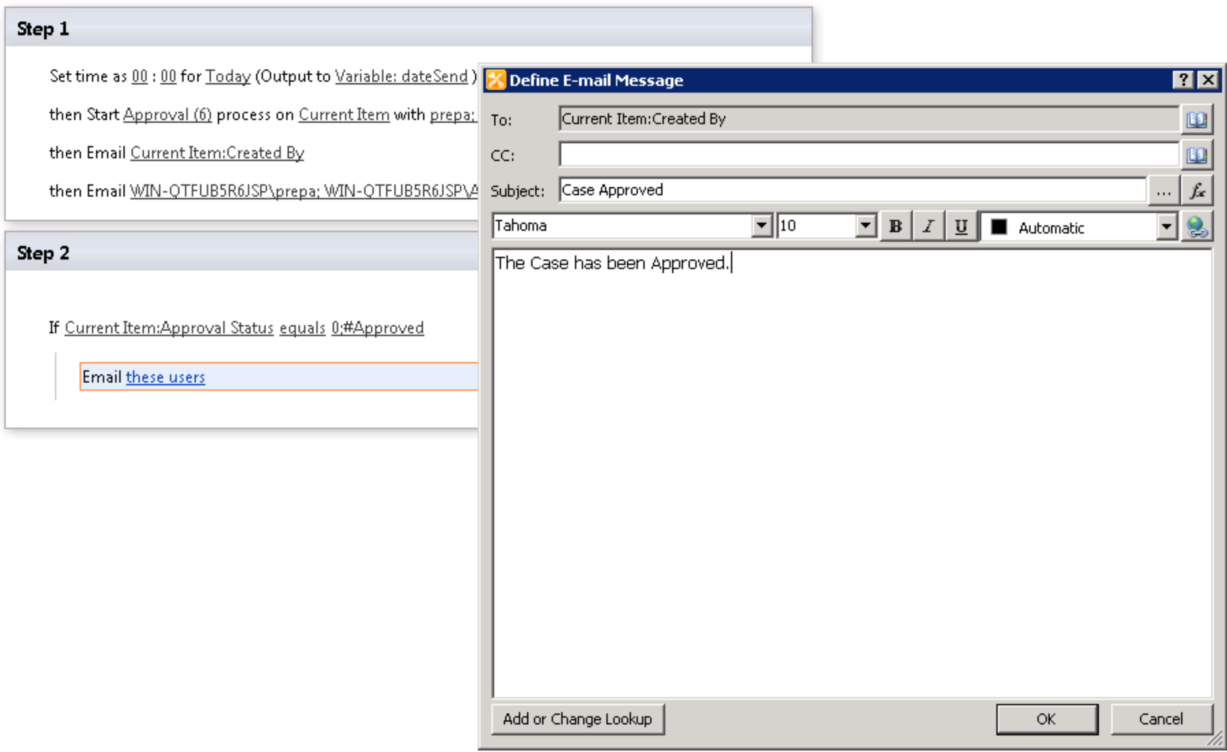


Figure L.6: Confirmation email for client approving interconnection

Figure L.7 shows an image of the completed workflow. With the Approved and Rejected options, timestamps in every step and email notification to the client after every phase is completed. This is the workflow information; the workflow history for a particular case can be seen. The “item” named “Israel Ramirez” was the name of the case created. In the “Status:” it can be seen that it is in progress. In “Tasks” it can be seen that this is an Approval Process for

PREPL. The approval tasks have not been started as seen in the status. It has no due date, because none was entered in the testing process.

In the workflow history the events of the workflow can be seen in detail. In this case, there are two errors in the workflow which are email errors. The system shows an error since the recipient did not have an email address in the system at the time of taking this image.

On November 2012 UPRM worked on integrating suggestions from the Summit into the web-based system and began preparing to for final implementation of the web-based system on a government's computer server. UPRM also evaluated what should be included in the project's website to improve its value to stakeholders:

- Should have a list of modules that qualify for the state's rebate program and a list of qualifying inverters. Should also have a feature to find installers in the area.
- Should include links to free web-based model estimators:
  - Clean Power Estimator – A PV system sizing model
  - PVWATTS – from NREL. Calculates electrical energy produced from a grid-connected PV system.
  - Find Solar – the site has energy calculators for photovoltaic systems
  - In the DOE's Building Technology web site there is a list of free and available for purchase energy models.

Figure L.8 shows an Android application created for the project. This tool is available at: **http://prsolar.ece.uprm.edu/resources.html**. This will complement the web-based system and help improving the application process of PV systems in Puerto Rico. This was not originally proposed, but undergraduate student collaborators were able to complete it for the project.

During January 2013 migration of the software system to server at the Puerto Rico Industrial Development Company (PRIDCO) began, and the upload to a PRIDCO server was completed on February 2013. PRIDCO is a "sister agency" of PREAA, both falling within the Economic Development and Commerce Department. Figures L.9-L.15 show some of the final screens of the on-line system.

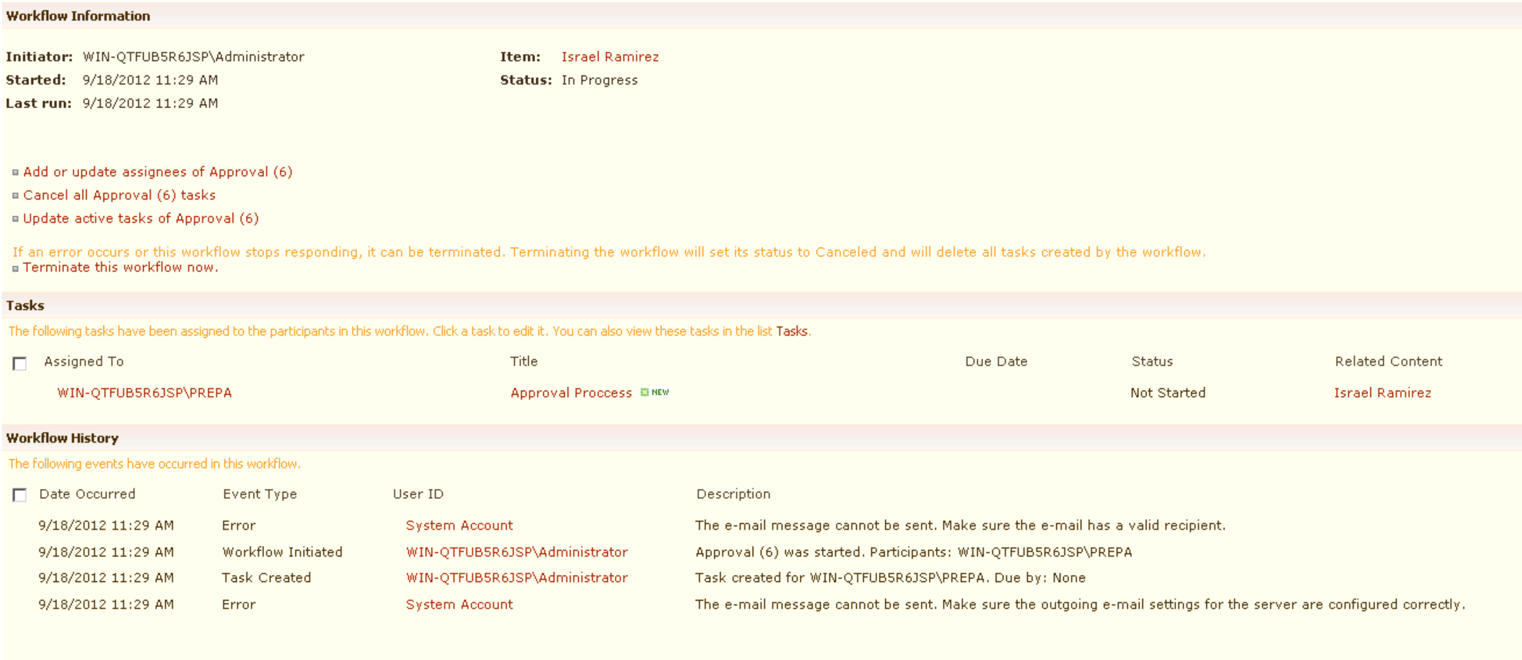


Figure L.7: Workflow implemented in SharePoint

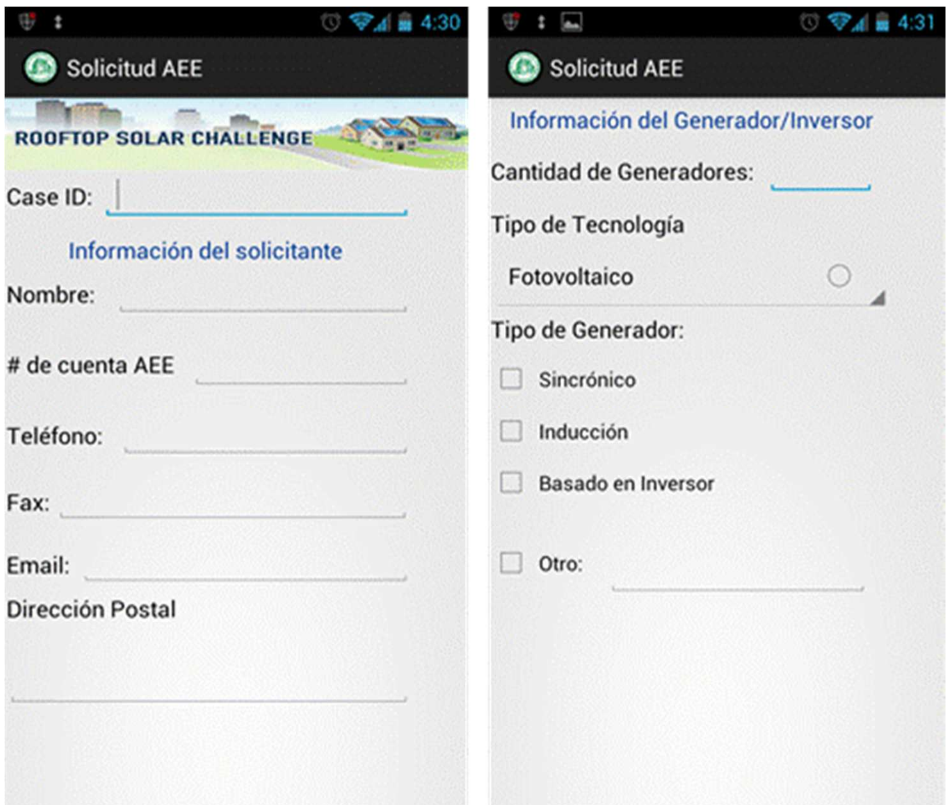


Figure L.8: User Input from an Android Application

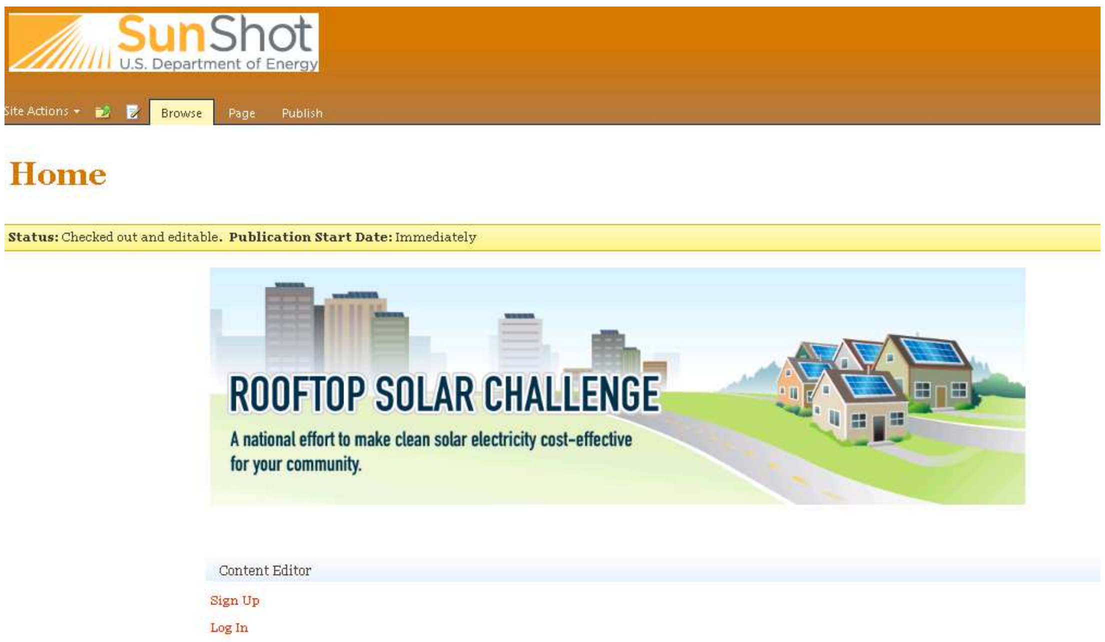


Figure L.9: Login Screen

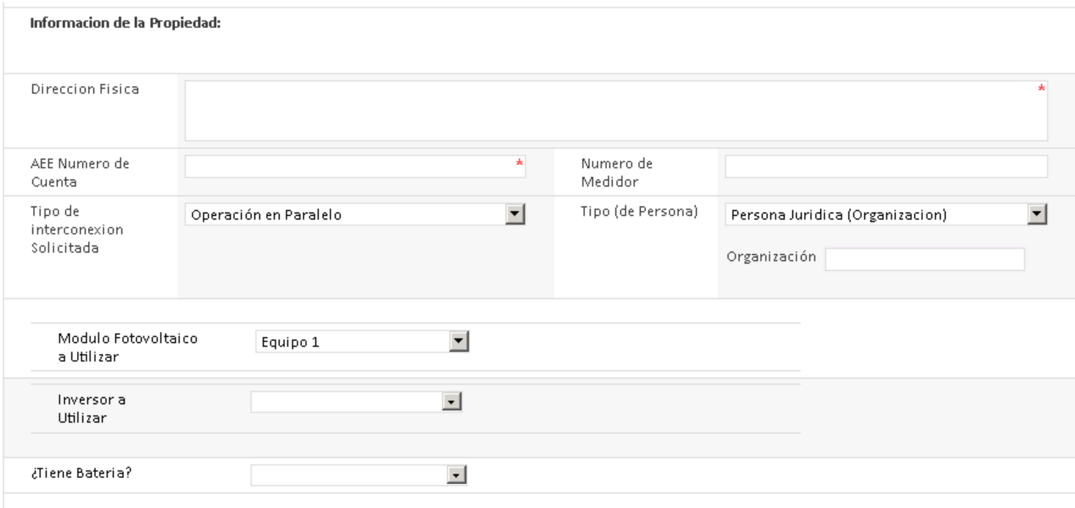


Figure L.10: User Input Screen

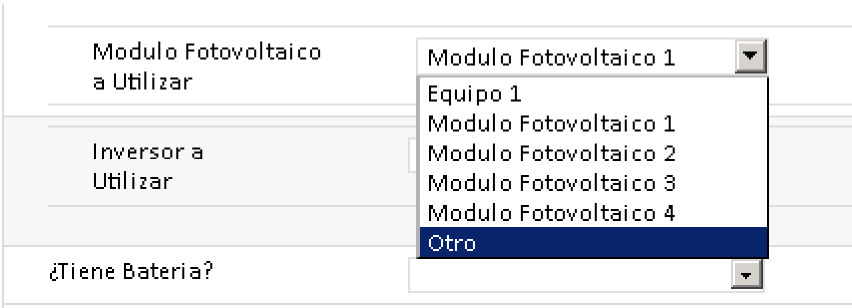


Figure L.11: Drop Down Menu to Select the Type of PV Modules to be Used

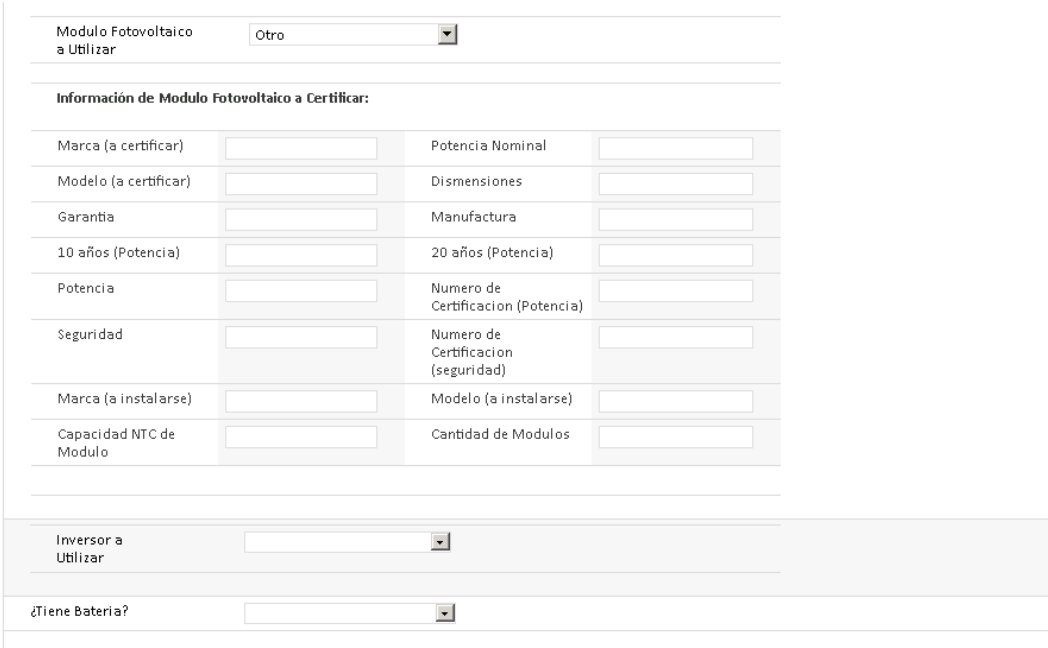


Figure L.12: User input screen for uncertified PV Modules

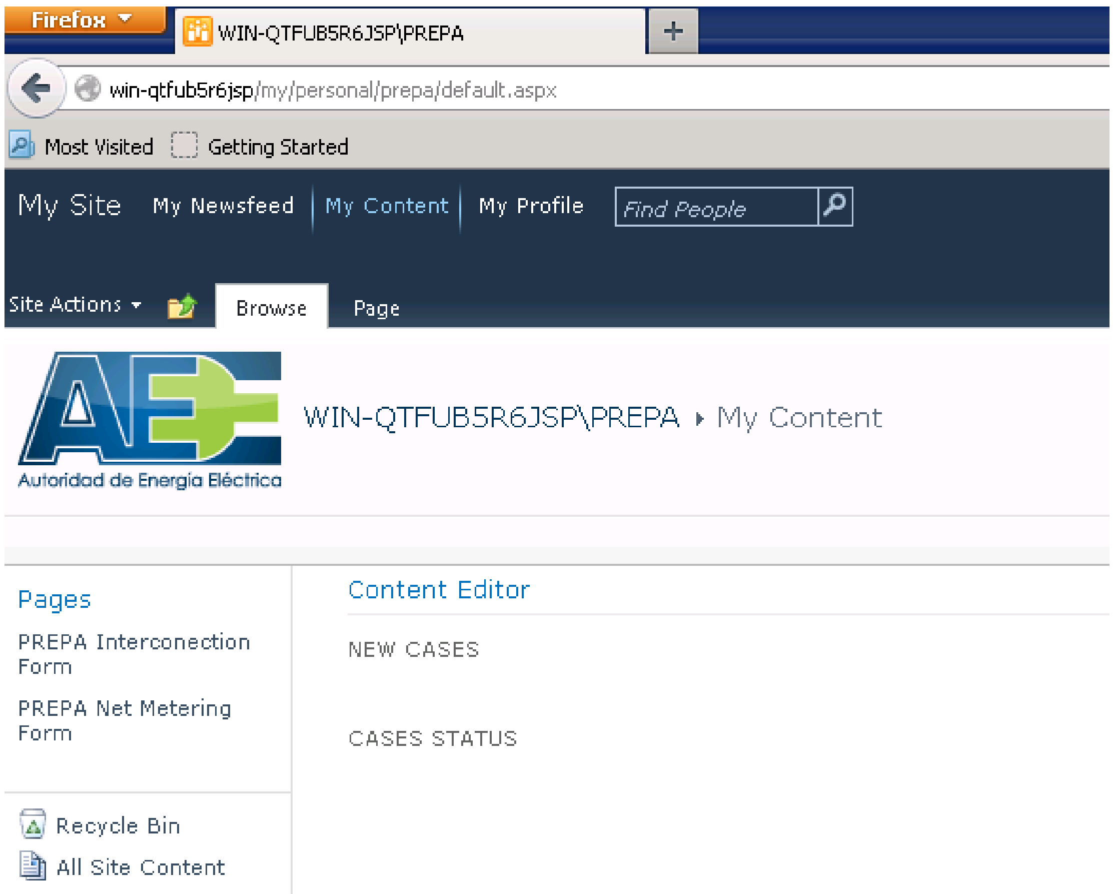


Figure L.13: Login Screen for Utility Personnel assigned to evaluate on-line applications

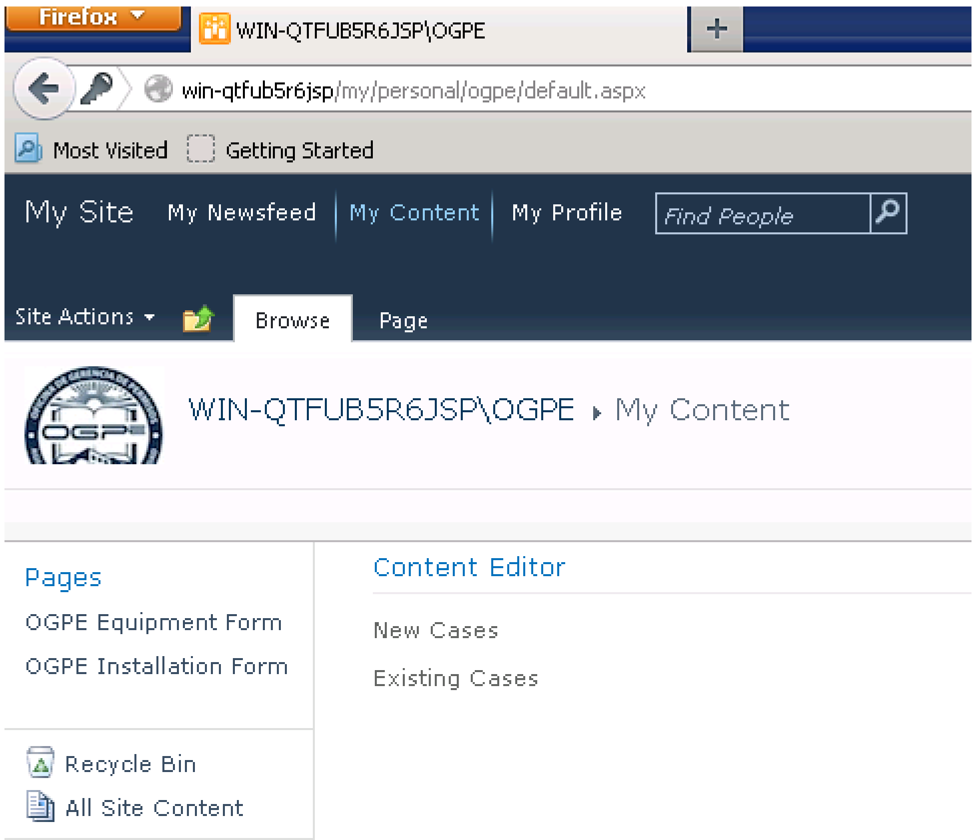


Figure L.14: Login Screen for OGPe (permitting) Personnel assigned to evaluate on-line applications

OGPe

SOLICITUD DE CERTIFICACION DE INSTALACION DE SISTEMAS FOTOVOLTAICO

Caso ID — Select...

Información del Sistema

Fecha de Instalación — *Costo de Equipo e Instalación*

Localización de instalación

Número de Catastro — *Calificación*

Nombre — *Organización*

Dirección Fisica

Telefono — *Email*

Modulos Fotovoltaicos

Marca — *Modelo*

Capacidad NTC de Modulo — *Cantidad de Modulos*

Inversores

Marca — *Modelo*

Capacidad Nominal — *Cantidad de Inversores*

Controladores de Carga

Marca — *Modelo*

Capacidad Nominal — *Cantidad*

Baterias

Marca — *Modelo*

Voltaje — *Capacidad* — *Cantidad de Baterias*

Figure L.15: Example of the OGPe Form that users fill out and submit on-line for installed system certification

Appendix M

Overview of project deliverables

A. Powerpoint Presentations during Focus Group and Small Group Meetings:

- A. Kick-off activities (May 2nd and May 8th, 2012), focus group presentations (May 30-31, June 19-20, 2012).
- Small group meetings on processes and standards
  - July 12th, 2012, Mayagüez; July 13th, 2012, PREAA
- Focus group meetings on financing
  - July 18th, 2012, August 28th, 2012, Mayagüez
  - July 19th, 2012, PREAA
- Small group meetings on financing
  - September 24th, 2012, Mayagüez; September 25th, 2012, PREAA
- Focus group meetings on planning and zoning
  - September 18th, 2012, Mayagüez; September 19th, 2012, PREAA
- Small group meetings on processes and standards
  - July 12th, 2012, Mayagüez; July 13th, 2012, PREAA
- Focus group meetings on financing
  - July 18th, 2012, August 28th, 2012, Mayagüez
  - July 19th, 2012, PREAA
- Small group meetings on financing
  - September 24th, 2012, Mayagüez; September 25th, 2012, PREAA
- Focus group meetings on planning and zoning
  - September 18th, 2012, Mayagüez; September 19th, 2012, PREAA
- PV Summits of October 18th (Rincon) and October 31st (Caguas)
- Small group meetings on planning and zoning
  - January 24th and 31st 2013, Mayagüez and PREAA
- Large group meeting presentation (Rincon), Feb. 6, 2013

- Brochure with general information (Appendix F).
- Book with general information on PV Systems and the project's recommendation (some printed copies, but available from the project's website).
- Graduate class presentation, March 2013, INEL 6025 UPRM (Dr. Agustin Irizarry)
- Radio program on PV systems and financing (Armando Irizarry), March 2013.
- Presentation to the PR State Society of Professional Engineers, March 2013.
- Presentation to the PR Electrical Contractors Association, April 2013.

Slides available in the project's website.

B. Project Website: http://prsolar.ece.uprm.edu

C. The focus group meetings allowed the UPRM team to reach out to diverse PV stakeholder groups. This was extremely helpful not only in disseminating the project ideas but also in getting active participation and collaboration in the project. Other outreach activities include:

TV Interview for UPRM's program "Foro Colegial" December 2012.

http://www.uprm.edu/portada/article.php?id=2405

http://www.youtube.com/watch?v=xWtMLjDhbfY

NREL's Spot on Awardee (Appendix E)

F. On-line system for PV permitting in Puerto Rico uploaded to a server of the Puerto Rico Industrial Development Corporation (PRIDCO).

A plan to transform the rooftop photovoltaic (PV) market in Puerto Rico through a standardized framework, based on streamlined permitting and interconnection processes, for the safe and fast deployment of residential and small commercial PV systems.

In collaboration with the Puerto Rico Energy Affairs Administration, funded by the U.S. Department of Energy (Award DE-EE0005700)

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