



ACE19 - Finding Solutions for Small Water Systems

Benefits of Solar Energy for Small Rural Water Systems in Puerto Rico

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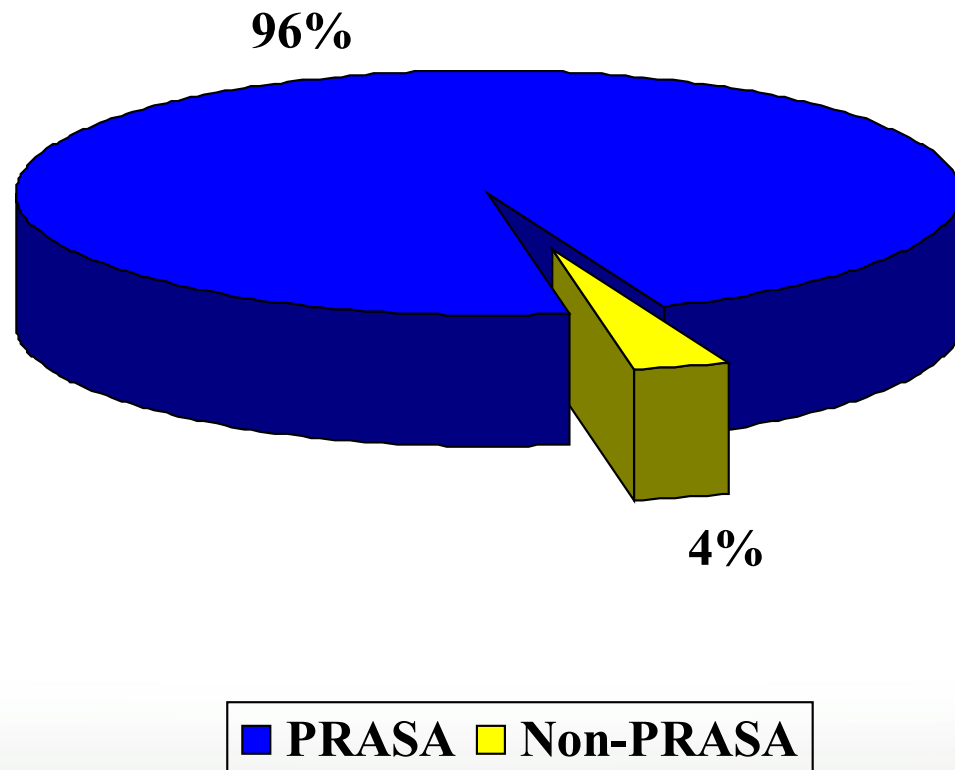




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Drinking Water Service in Puerto Rico





Non-PRASA Water Systems

- Drinking water in Puerto Rico is supplied by the Puerto Rico Aqueduct and Sewer Authority (PRASA).
- PRASA does not reach very rural areas and about 242 public water systems are outside of PRASA control.*
- Only about 185 (76%) of these 242 systems use some form of chlorination.
- 140 of these systems serve between 100 and 500 people.
- There is a clear need for a multi-barrier approach to provide safe water and improve the health of individuals living in communities served by the non-PRASA systems.

* - Survey conducted by the Departamento de Salud-Division de Agua Potable-Inventario Sistemas Non-PRASA (2017)



Non-PRASA Community





Non-PRASA Surface Water



An operator rakes leaves from a surface water pool created by damming a creek in the rainforest.



Water storage tank and screened intake pipe at the source



Non-PRASA Storage Tanks and Tablet Chlorinators



Operators replace chlorine tablets to provide a chlorine residual after contact time in water storage tanks.



Violations and Challenges

- Majority of violations are for Total Coliform Rule:
 - 1650 violations in 182 systems (FY15)
 - 136 MCL violations in 74 systems
 - Affecting a population of 39,470 people

- The most immediate challenges:
 - Filtration for surface water sources
 - Disinfection
 - Not enough water
 - No power
 - No money to pay for improvements



Communicating with the Non-PRASA Communities





Sustainable Small Systems

- Finding drinking water treatment technologies for small communities that are:
 - Easy to build - Fabricated with parts available on the Island.
 - Low cost.
 - Easy to operate and maintain.
 - Energy efficient.
 - Sustainable
 - Can be implemented in other communities in tropical regions.
- Community involvement and education (Citizen Science)



Project Location in Puerto Rico





Rugged Terrain in a Remote Hillside Location





Non-PRASA Surface Water Treatment System at Apeadero



2009



2014



Installing the Conventional Water Treatment System

As Delivered





Installing the Multimedia Filter



Installing
850 lbs of
filter media



Filter media had
to shipped from
Florida



Conventional Water Treatment (Apeadero)



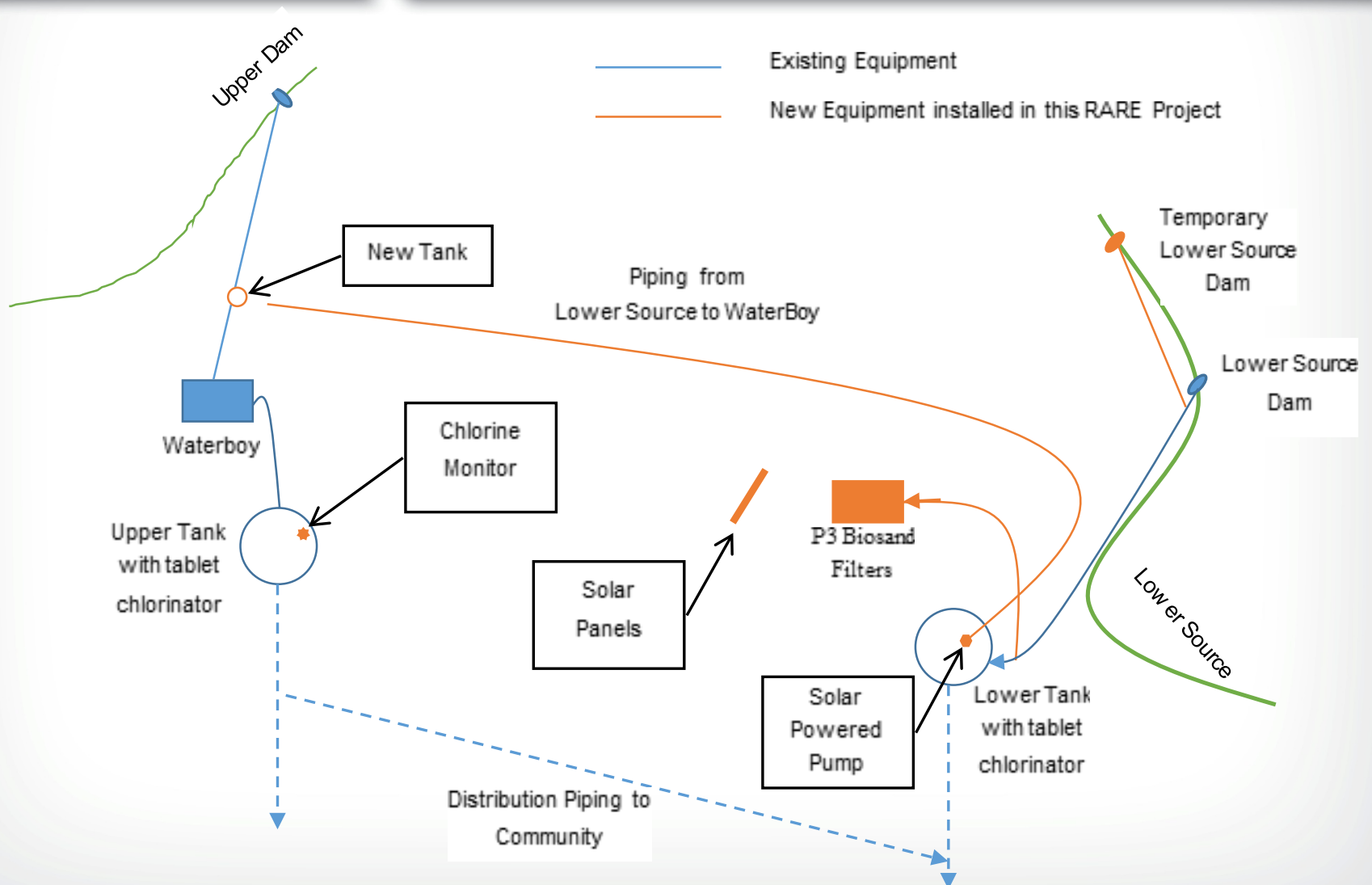


Watershed Source Water (Rain)





Apeadero Water System





Combining Watershed Sources for Water Treatment



**Conventional
Water Treatment**



**Equalization
Tank**

**Solar-Powered
Pump**



**Upper
Tank**

Steep Hill





Project Volunteers





Moving Water System Materials





Gluing Pipes for Water Lines in Steep Terrain





Installing Water Lines in Steep Terrain





Connecting Water Lines to the Pump House and Tank





Why Solar Power?

- One major cost for electricity for small communities in Puerto Rico is the transfer, treatment and distribution of drinking water.
- Non-PRASA communities are not able to afford electrical costs and many have abandoned their groundwater sources and reverted to unfiltered surface water systems, creating serious public health risks and non-compliance.
- Many Non-PRASA groundwater systems (141 out of 242) could use solar-powered pumps to extract and deliver groundwater.



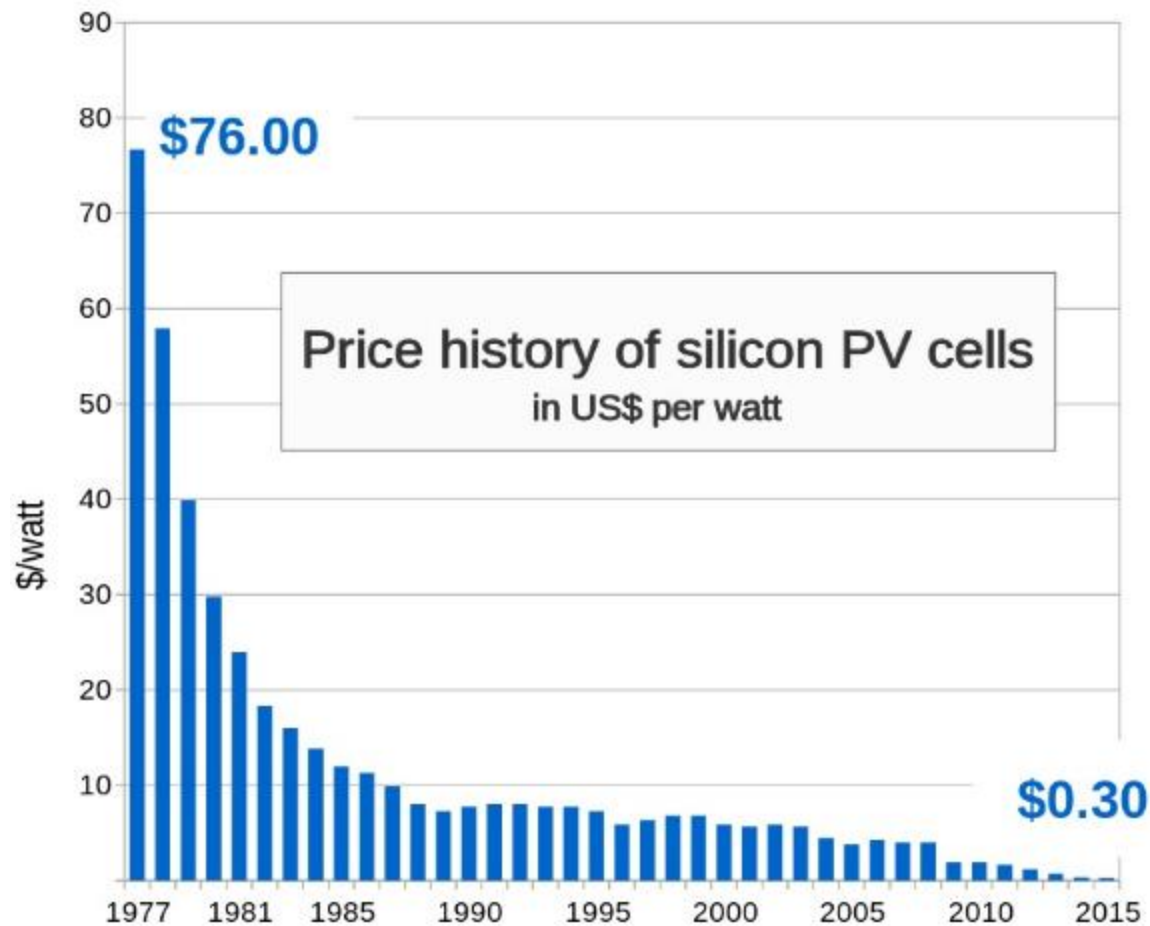
Expensive Electrical Power



Electrical power in Puerto Rico is unreliable and expensive (50% more than the U.S. average). Well water pumps in Puerto Rico are not used due to the high cost of electricity.



The Cost of Solar Cells Has Dropped Dramatically in 40 Years



Source: Bloomberg New Energy Finance & pv.energytrend.com

- High-efficiency photovoltaic cells (30-46%) are typically not commercially available and are used by NASA and others. Commercially-available solar panels are made from mono- or poly- crystalline silicon and are half as efficient (14-22%).
- The largest solar panel manufacturing companies are based in China (36%), U.S. (18%), Canada (6%), South Korea, Japan and Taiwan.
- In 2016, the U.S. added about 125 solar panels every minute.

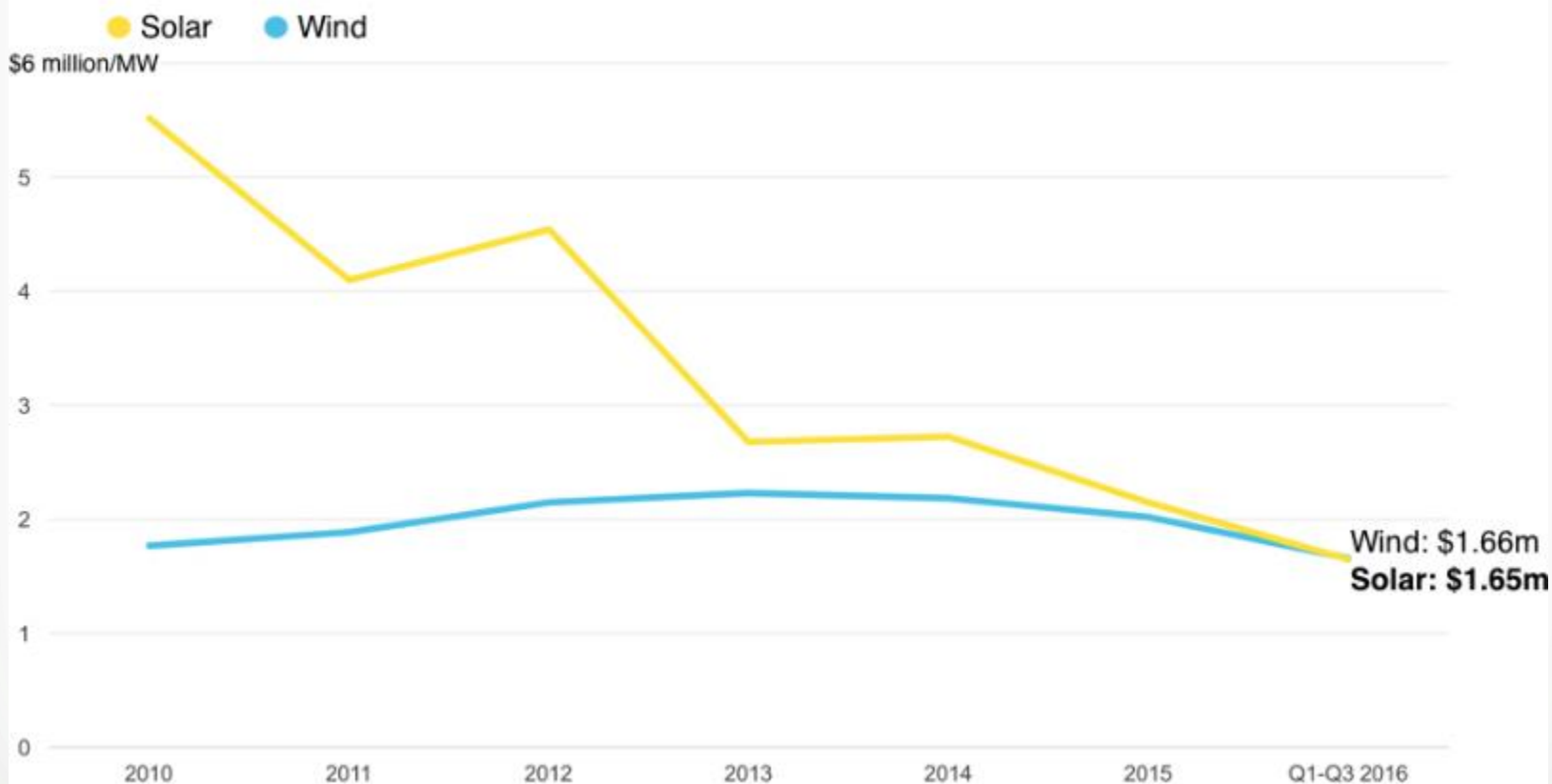
Source: news.energysage.com



In 2016, Solar Power Costs the Same as On-Shore Wind Power

Solar Surprise: Prices Fall Below Wind

A turning point for renewables in lower-income countries

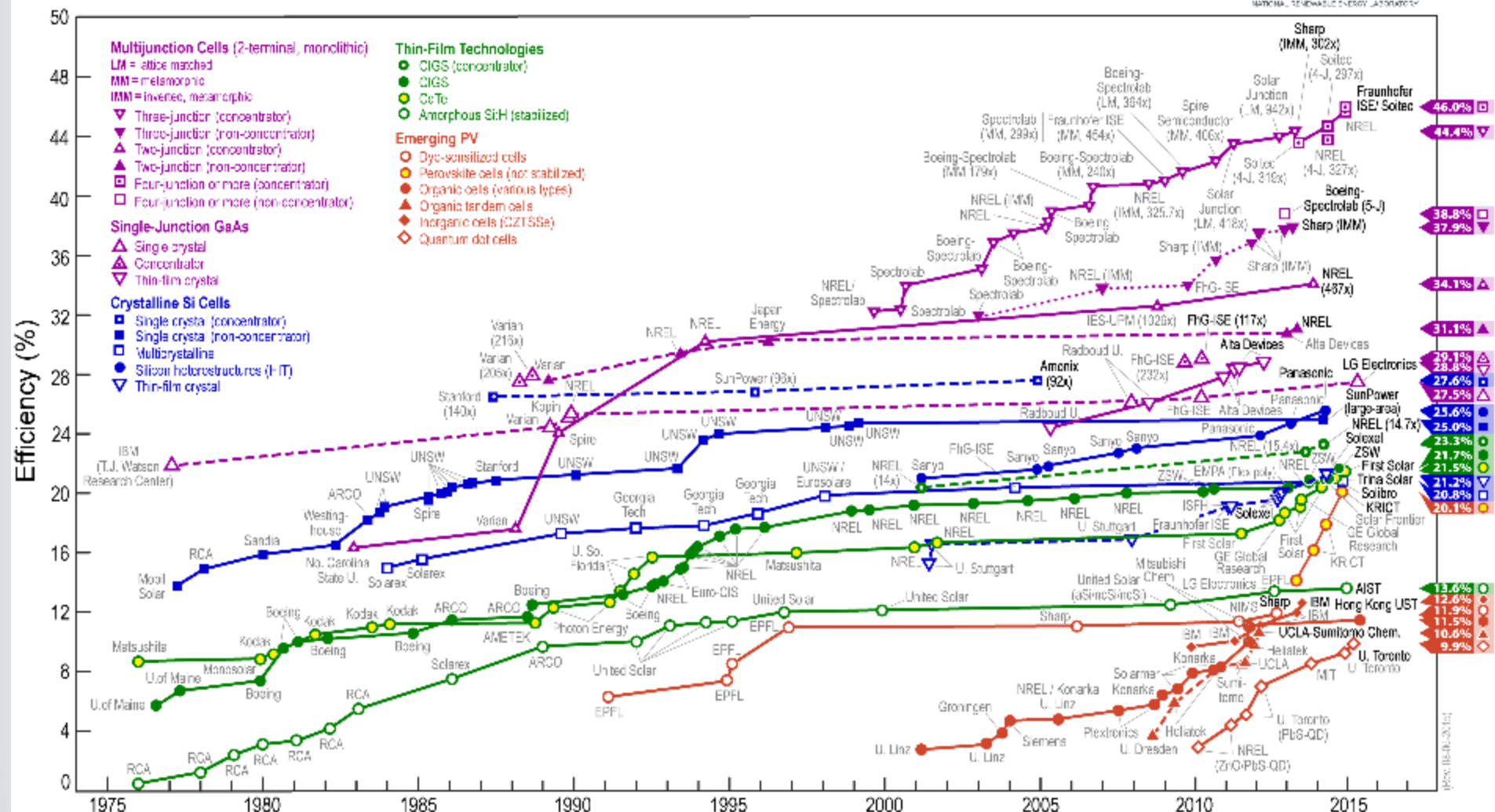


Source: Bloomberg New Energy Finance



Solar Cells Are Also Two Times More Efficient in 40 Years

Best Research-Cell Efficiencies





Energy Usage in Puerto Rico

- Electrical power in Puerto Rico is generated from Petroleum (51%), Natural Gas (31%), Coal (16%) and Renewable Energy: Wind (1.3%) and Solar (0.7%).
- From July 2012 to April 2015, distributed solar photovoltaic generating capacity in Puerto Rico increased by a factor of nine, but solar power still accounts for less than 1% of energy production.
- Puerto Rico's average electricity cost was \$0.20/Kwh compared to a U.S. average cost of \$0.13/Kwh.

Source: U.S. Energy Information Administration, 2015



Energy Cost Comparison

Energy Plant Type	Lifetime Cost (¢/Kwh)
Electrical Power in Puerto Rico*	20
Offshore Wind	20
Peaker Natural Gas	18
Coal with CCS	14.4
PV Solar	12.5
Gas Combined Cycle with CCS	10
Biomass	10
Advanced Nuclear	9.5
Conventional Coal	9.5
Hydro-electric	8.4
Natural Gas Combined Cycle	7.5
Land Based Wind	7.4
Geothermal	4.8

CCS stands for Carbon Control and Storage (Sequestration) in a remote underground location. The LCOE for Peaker Natural Gas (18.0¢) is per the California Energy Commission.

*The Guardian, Ed Morales, July 12, 2015.



Determining Elevation Differences for Pump Selection





Anchoring the Solar Panel Mounting Structure for High Winds





Installing the Solar Panels





Solar Power Work Crew





Building the Solar Power Enclosure





Solar Power Enclosure Work Crew





Batteries and Invertor System





Cost of Solar Power System

Solar Power System	Specifications	EPA Cost
Solar Panels	Hanwha Q-Cells 260 W modules (12), Area 10'x22', 10 degree tilt	\$ 2,040
Solar Panel Mounting Structure	IronRidge Ground Mounting Structure	\$ 2,395
Invertor System	Outback Flexpower One, To convert solar power to 120V	\$ 3,336
Batteries	US Battery (Deep Cycle) 12V/360Ah	\$ 2,080
Solar Enclosure	For Batteries and Invertor System	\$ 1,000
Wiring and Conduit	Miscellaneous	\$ 1,500
	Total Cost	\$ 12,351



Environmental Benefits

- The energy (6,081 kWh) produced by the 245W system in 1.5 years will offset the energy used to produce and install the system in Apeadero.
- As installed, the solar panels will eliminate as much:
 - Greenhouse gas emissions as not burning 3,004 coal lbs/yr.
 - Atmospheric carbon as is sequestered by 2.29 forested acres/yr.
 - Greenhouse gas emissions as not driving 6,657 vehicle miles/yr.

Sources: www.epa.gov/cleanenergy/energy-resources/calculator and cleantechnica.com



Keep on Trucking





Solar-Powered Pump House

Before



After





Installing the Solar-Powered Pump and Control Cabinet



- The control cabinet ensures operation of the solar-powered pump regardless of water supply conditions (no flow, empty/full equalization tank, etc).
- A timer was installed to accommodate pumping at various times during the day.



Installing the Equalization Tank





Equalization Tank as Installed





Equalization Tank Float Switch



The solar-powered pump lifts surface water up a steep hill (350 vertical feet) to this tank where it gravity feeds to treatment system.



Cost of Pump and Water System

Pump and Water System	Components	EPA Cost
Pump	Dayton High Head 5NXZ5, Flow Rate - 5 gpm, Head - 350 feet TDH, Power - 120V	\$ 692
Pump Control Panel	Control Panel Enclosure, Omron Digital Timers, Circuit Breakers, Panel Switches (3), Indicator Lights (2), Motor Starter and Miscellaneous Materials – Wiring, etc...	\$ 840
Pump Gauges	Pressure Gauges (2)	\$ 200
Equalization Tank	250 gallons	\$ 200
Water System Pipe	1-inch PVC (40)	\$ 120
Water System Pipe Fittings	Valves, etc.	\$ 250
	Total Cost	\$ 2,302



Hurricane Maria (9/20/17)



Hurricane Maria

- Hurricane María made landfall on the southeastern side of Puerto Rico on Sept. 20, 2017. Apeadero was in the direct path of the hurricane.



- Maria caused extensive damage to infrastructure, causing a complete loss of communication, energy and water services.



Non-PRASA Community Damage





Rainforest Canopy Tumbles Down



After Maria



Before Maria



After Maria



Apeadero Water System Damage





Apeadero Storage Tank Damage





Battery Enclosure Repairs after Hurricane Maria

Before



Apeadero (Maria Repairs)

Item	Cost
Surge Protector	\$125
Breaker for Batteries	\$215
Solar Voltage Inverter	\$2,419
Batteries	\$3,120
Total	\$5,879



The Good News!

Solar Panels Before and After Hurricane Maria



Solar Panels withstood 110 mph wind gusts and 35 inches of rain.



Lessons Learned



- Community involvement and education are critical. Use local assistance to keep the community involved.
- The economy is a challenge.
- Solar power is a great alternative to high-priced and unpredictable electrical power in Puerto Rico.
- Invest in a waterproof equipment enclosure and a robust solar panel mounting structure.
- It is amazing what can be constructed in difficult terrain with everyone pitching in.



Questions?

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Thank You!

